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Discounting Disentangled:

An Expert Survey on the Determinants of the Long-Term Social Discount Rate

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Not for general distribution.

Abstract: We present evidence from a survey of 197 experts on the determinants of the long-term social discount rate (SDR). Besides eliciting expert's recommended SDR, the survey disentangles central components of discounting: the risk-free interest rate, rate of pure time preference, elasticity of marginal utility, and a prediction of long-term per capita consumption growth. We find a mean (median) recommended long-term SDR of 2.25% (2%). While there is considerable disagreement on point SDRs, 92% of experts are comfortable with SDRs somewhere in the interval of 1% to 3%. Our results point towards key deviations from standard policy guidance. In particular, only a minority of experts recommends a SDR in line with the Ramsey Rule. Instead, many experts suggest more comprehensive approaches to discounting and intergenerational decision-making, addressing issues such as uncertainty, heterogeneity, relative prices, and alternative ethical approaches.

JEL-Classification: H43, D61

Keywords: Social discount rate, expert advice, project evaluation, disagreement

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1 Introduction

We report survey evidence on the appropriate long-term social discount rate (SDR) according to a sample of 197 academics who can be defined as experts on social discounting by virtue of their publications. A key innovation of our survey is that we elicit responses on the disentangled, individual components of the Ramsey Rule's social rate of time preference: the rate of pure time preference, the elasticity of marginal utility, and a prediction of long-term per capita consumption growth. We also elicit predictions of the long-term average real risk-free rate of interest, and ask experts to recommend a point value and an acceptable range for the SDR. Our findings lead us to the conclusion that current policy guidance concerning social discounting and the evaluation of long-term public projects needs to be updated.

Discounting the distant future has been described as *"one of the most critical problems in all of economics"* (Weitzman 2001: 260). Views differ substantially on the issue and over the past decades economists have found themselves either stumbling around in the *"dark jungles of the second best"* in pursuit of an answer or accused of *"stoking the dying embers of the British Empire"* if they claim to find one (Baumol 1968: 789; Nordhaus 2007: 691). From both an academic and policy perspective, the Ramsey Rule has been a constant presence as the workhorse representation of the SDR. This approach has lead to the recommendation that the social rate of time preference or the rate of return to capital should be used as the SDR. It is widely accepted that the Ramsey Rule serves as a *"useful conceptual framework for examining intergenerational discounting issues"* (Arrow et al. 2012: 3), and policy guidelines on cost-benefit analysis across the world are testament to this view (Arrow et al. 2013; HMT 2003; IPCC 2014; Lebegue 2005). The prevalence of the Ramsey Rule has also meant that prominent disagreements on social discounting have been articulated in relation to its components and the ethical concepts they embody (Dasgupta 2008; Nordhaus 2007; Stern 2007; Weitzman 2007). What has been missing so far is a more representative account of expert opinions on the matter to place the debate on firmer empirical ground.

Eliciting responses on the individual components of the Ramsey Rule allows us to disentangle expert opinions on the SDR into their fundamental constituent parts. Given the aforementioned prevalence of the Ramsey Rule in policy guidance, our data thus provide vital raw inputs into the discounting policy debate currently underway in many countries (including the US, UK, The Netherlands, Sweden and Norway).

Our survey data also inform ongoing discussions on improving conceptual approaches to intergenerational decision-making. For instance, recent work has shown that the appropriate way of aggregating expert responses and the resulting term structure of SDRs depends on the distribution of the parameters that our survey disentangles (Freeman and Groom 2014; Gollier and Zeckhauser 2005; Heal and Millner 2014a,b; Jouini et al. 2010; Weitzman and Gollier 2010). This is important because discounting guidelines in several countries already recommend declining term structures of SDRs (Cropper et al. 2014), a policy change that has been influenced by the seminal survey of Weitzman (2001: 271). He asked a general audience of economists for the appropriate *"real discount rate"* or *"rate of interest"* with which to discount projects aimed at mitigating climate change. While this sounds like an innocuous question with a clearly interpretable answer, in the context of intergenerational public investment, it is not. One key difficulty with the Weitzman (2001) survey is that the responses were almost certainly composed of 'normative' positions that emphasize ethics and justice, and 'positive' positions that emphasize observable rates of return, a dichotomy that goes back at least to Arrow et al. (1996). This dichotomy remains important since, as argued by Freeman and Groom (2014), we ought not to use the same aggregation mechanism for both normative and positive responses. Doing so would conflate heterogeneity of subjective values with uncertainty over facts, with important implications for the term structure of SDRs (see also Heal and Millner 2014a,b). One of the advantages of our survey is that we are able to distinguish between experts' recommendations concerning subjective values as well as their forecasts, and further determine their normative-positive position. This will allow future work to provide clearer guidance on the term structure of SDRs.

The 197 expert responses make for interesting reading.[1] The mean (median) recommended SDR of our experts is 2.25% (2%). This is substantially lower than the mean (median) values 4% (3%) reported in Weitzman (2001). The modal value of 2% is identical. On the rate of pure time preference we are able to show that expert opinion is very heterogeneous. The modal value is zero, in line with many previously reported opinions, including Ramsey (1928) himself. But with a mean (median) of 1.1% (0.5%), the results do not confirm the IPCC's (2014: 229) conclusion that *"a broad consensus for a zero or near-zero pure rate of time*

[1]The pool of potential experts we identified, based on their pertinent published papers in the leading 103 economics journals, is 627 (cf. Section 2.2). We obtained a response rate between 30% and 42%, depending on which responses are counted (cf. Section 3).

preference" exists among experts. We further characterise the empirical distributions of all other discounting determinants elicited.

A closer inspection of the data reveals some striking results which go beyond the direct utility of these data as inputs to current policy and applied theory. First, the survey reveals that there remains a great deal of disagreement between experts on the appropriate SDR, who recommend point values ranging between 0 and 10%. Despite substantial disagreement on point SDRs, the responses show that there is more space for agreement than one might have expected. Specifically, based on the reported acceptable ranges for the SDR, 92% of experts are comfortable with recommending SDRs somewhere in the interval of 1% to 3%. Nevertheless, there remains considerable disagreement on the relative importance of normative and positive approaches to discounting, which are elicited on a sliding scale. The responses show that these previously accepted categories overly polarise the more nuanced expert views on social discounting. Indeed, most experts report that recommendations on the SDR should reflect both normative and positive considerations, with normative justifications given more weight (62% versus 38%). This highlights that distinguishing between disagreement about subjective values and uncertainty over forecasts is an essential task for informing decision-making on long-term public projects.

Second, we find that only a minority of experts recommends a SDR that coincides with their forecasted risk-free interest rate or the Ramsey Rule's social rate of time preference. In fact there are wide discrepancies between their recommended SDR and the imputed social rate of time preference or the interest rate. Both the average social rate of time preference (3.48%) and the forecasted risk-free interest rate (2.38%) are higher than the average recommended SDR. The root cause of these discrepancies varies among experts for reasons often found in their qualitative responses. An unambiguous result of our survey therefore is that the prominence of the simple Ramsey Rule needs to be revisited.

Finally, and relatedly, the rich body of qualitative responses underscores that policy on long-term public decision-making needs to engage with many issues that transcend the confines of the simple Ramsey Rule. Numerous comments highlight that social discounting must account for a more comprehensive set of technical issues, such as uncertainty, limited substitutability and heterogeneities. The responses also highlight that decision-making on long-term public policies should consider participatory and procedural approaches, as well as other societal criteria such as notions of intergenerational equity and sustainability.

In the following sections we present our survey instrument and sampling procedures, our results and analysis. We also report several robustness checks on potential selection and response bias. These checks are reassuring in that overall they do not suggest systematic biases in terms of SDR recommendations. Of course, it is perfectly reasonable to question whether experts per se represent a suitable source of information on matters of social discounting and the parameters of the Ramsey Rule. This in itself has been a source of disagreement in the past (Dasgupta 2001, 2008; Weitzman 2001). We devote considerable space to this important question in our discussion. We therefore close by briefly noting that governmental guidance on social discounting has been and will continue to be influenced by experts. For this reason, it is imperative to obtain a more representative account of expert advice to place governmental guidance on a more robust footing.

2 Survey Design and Expert Selection

2.1 Survey Context and Set-Up

Guidance on the SDR for cost-benefit analysis is commonly organised around the Ramsey Rule, which can be found in government guidelines across the world and in most academic discussions on intergenerational discounting (Arrow et al. 1996, 2014). Yet, there remains disagreement on the exact role of the Ramsey Rule. Its determinants as well as single components have been the subject of great controversy (Dasgupta 2008; Nordhaus 2007; Stern 2007; Weitzman 2007). One reason for this is that the Ramsey Rule comes in different representations. Following Arrow et al. (1996) one can distinguish three forms of the Ramsey Rule: First, the Ramsey Rule's social rate of time preference (SRTP), which is composed of the rate of pure time preference or utility discount rate (δ), and an interaction term of the growth rate of per-capita consumption (g) with the elasticity of marginal utility of consumption (η). This is typically considered to be the normative or prescriptive approach to determining the SDR. Among others, the UK Treasury recommends the use of the SRTP in its Green Book (HMT 2003). Second, the opportunity cost of capital approach to the Ramsey Rule, relating to some rate of return in the market place, typically the risk-free rate of return on government bonds. In contrast to the SRTP approach, this is viewed as the positive, or descriptive approach. Among others, the US-EPA follows this approach by recommending to use returns to

government-backed securities for determining the SDR (USEPA 2010). Finally, the Ramsey Rule in its strict optimality form (Ramsey 1928), where the marginal productivity of capital equals the SRTP.[2] Accordingly, the simple Ramsey Rule approach to social discounting is captured in the following formula, containing all three approaches:

$$r \;=\; SDR \;= \underbrace{\delta \;+ \eta \; g}_{SRTP}. \tag{1}$$

Despite the prominent debates on the Ramsey Rule, there is no clear understanding of a representative expert view on these discounting determinants. For this reason, we designed the survey to elicit the components of the Ramsey Rule to keep the survey relevant for the policy community and parsimonious in order to have as high a response rate as possible. As a comprehensive discussion of social discounting needs to engage with numerous complexities, we review limitations of the Ramsey Rule and thus the survey design in Sections 4 and 5.

In the survey, we followed an agnostic approach and asked respondents about all determinants of social discounting in this Ramsey setting, without including any specific reference to the Ramsey Rule itself. The questionnaire began with the following contextual preamble:

> *Imagine that you are asked for advice by an international governmental organization that needs to determine the appropriate real social discount rate for calculating the present value of certainty-equivalent cash flows of public projects with intergenerational consequences.*
>
> *For its calculations, the organization needs single values for the components of the real social discount rate. While this does not capture all of the important complexities of social discounting, it does reflect most existing policy guidance on the matter. Your answers will therefore help to improve the current state of decision-making for public investments.*
>
> *Specifically, you are asked to provide your recommendations on the single number, global average and long-term (>100 years) values of the following determinants of the social discount rate: [Appendix A contains the full survey text].*

[2]Considering a social planner's problem with a standard utilitarian social welfare function and imposing some further restrictions, such as isoelastic utility, one obtains the strict optimality form version of the Ramsey Rule that forms the basis of our analysis (for further elaboration, see Arrow et al. 1996). We abstract from an explicit time dependency of the single determinants and thus omit time subscripts.

Following this introduction, we asked experts on their advice on central components and single determinants of social discounting. Besides the real risk-free interest rate (Question 4), we asked for the three individual parameter values that underlie the right-hand-side of Equation 1, i.e. the SRTP (Q1–3). Further, we asked for the actual point-value of the SDR that they would recommend for evaluating the certainty-equivalent cash flows of a generic global public project with intergenerational consequences (Q6).[3] This allowed respondents to deviate from both the real risk-free interest rate as well as the SRTP if they so wished, to account for more complex issues of social discounting. Examples may include distortions and market failures, questions of uncertainty and prudence effects or alternative frameworks for intergenerational decision-making. The survey does not include a direct mechanism to extract the rationales for deviating from the Ramsey Rule, as we abstained from mentioning it to avoid triggering respondents into conforming with the expectation that it must hold. However, we offered an open comment section (Q8) for feedback on the survey, where respondents could and often did provide rationales pointing towards various extensions of the Ramsey Rule.

With Question 5, we aimed at eliciting respondents' rationales by asking what relative weight the governmental body should place on normative versus positive issues for determining the SDR, measured on a sliding scale from 0 to 100%. This question intends not only to highlight potential heterogeneity in responses, but also to explore disagreement in rationales that has been evident at least since Arrow et al. (1996): whether normative issues, involving justice towards future generations, or descriptive issues, involving forecasted average future returns to financial assets, or a mix of both should determine the SDR. In addition to this suggested dichotomy between normative and descriptive approaches, a further distinction concerns the individual components of the SRTP, where r and g are forecasts, whereas δ and η may represent value judgements. The fundamental reasons for this distinction between forecasts and value judgements is that in 100 years from now we will have some known realization of r and g, yet there may still remain disagreement about δ and η. Accordingly, the latter have been termed the *"two central normative parameters"* (Nordhaus 2008: 33) or plainly *"policy parameters"* (Pindyck 2013: 221).[4]

[3]For reasons of parsimony, the survey was not designed to elicit opinions on the treatment of risk in intergenerational cost-benefit analysis. We therefore explicitly asked about certainty-equivalent cash flows and did not ask experts for their risk-premium estimates.

[4]There are good reasons that may blur this dichotomy between value judgements and forecasts: First, δ and η may be attached purely descriptive content and estimated accordingly. Second, both r and g might

Finally, as there are no single correct values for the discounting determinants elicited, we would have preferred to include confidence intervals for each. For the sake of parsimony, we only asked for the minimum and maximum values of the SDR (Q7) that respondents would still be comfortable with recommending in order to elicit an 'agreeable range' for the SDR.

2.2 Expert Selection and Survey Dissemination

Our definition and selection of experts is based on demonstrated expertise in the form of pertinent journal publications in the field of (social) discounting. A simple full-text Google scholar search in March 2014 for 'discount rate' yielded approximately 600 000 hits. We have narrowed down the pool of potential experts by only selecting contributions made in leading economics journals. For this, we have drawn on the economics journal ranking by Combes and Linnenmer (2010, Table 15) that ranks 600 journals and have used all journals rated A or higher.[5] This amounts to 103 peer-reviewed journals. Relying on full-text analysis in the Google scholar engine, we searched these journals for publications since the year 2000 including the terms 'social discounting', 'social discount rate' or 'social discount factor'. As not all pertinent contributions to the field use the term 'social discount rate', but often 'real discount rate' or simply 'discount rate', we further performed an EconLit abstract-based search for the term 'discount rate' within the same journals. Correcting for scholars with multiple publications, and also discarding a number of papers that did not pass a weak relevancy test (see Appendix B), our sample of potential experts includes 627 scholars.[6]

There are five potential limitations to this selection strategy. First, we restricted the search to publications since the year 2000 to only capture scholars active in the current debate on social discounting, thus missing some relevant earlier contributors. Second, by selecting experts based on their publications, we necessarily include co-authors of relevant papers that are not themselves experts on discounting. Third, we do not pick up all relevant publications in the field that may have used other terms to discuss discounting. Restricting

itself depend on value judgements: If g is thought of as a growth rate of inclusive consumption equivalents that includes non-marketed goods, it may not only depend on descriptive information but also on the societal objective on how to capture such missing values. As a result, no single correct revealed value of g would exist.

[5] In addition to the 102 A-rated journals, we included the *Review of Environmental Economics and Policy*.

[6] Although potential experts have published in leading economics journals, a small number of them do not have a PhD in economics but come from diverse fields, including law and the natural sciences.

the search to the above-mentioned keywords was again a pragmatic choice to avoid having to deal with and manually discard a large number of non-relevant publications. Fourth, due to the keyword-based selection and a rather generous weak relevancy test of the selected papers, we include a number of scholars who might not regard themselves as true experts on the issue. This possibly leads to a lower response rate compared to surveying a stricter sample of potential experts. Finally, we miss potentially relevant articles in lower-ranked journals.

Starting in May 2014, we sent out a link to the online survey (implemented in SurveyMonkey) via e-mail to all potential experts, and used three general rounds of reminders, each time slightly varying the subject line and motivation for answering the survey.[7] The online survey required respondents to provide numerical answers to Q1-7, while Q8 was optional. Therefore, if respondents did not want to provide an answer for individual questions, they had to indicate so in the comment section. We manually coded such instances as missing values. In later rounds, we offered the option of completing the survey in a Word document or the e-mail itself to increase flexibility. Until November 2014, this yielded responses from 197 experts, and replies by 27 scholars explaining their missing response. From December 2014 to April 3^{rd} 2015, we carried out a robustness check by randomly selecting 60 potential experts that did not respond previously. We contacted them again with the survey via e-mail as well as, where possible, via phone. We received 38 responses from this bias-check sample.

3 Survey Results

3.1 Introduction to the Survey Responses

This section presents both quantitative and qualitative results of the survey questionnaire. These contain evidence on expert recommendations and forecasts on the determinants of the SDR to be used for the analysis of global, long-term public projects. Table 1 provides an overview of answers for each question in the survey, reporting mean, standard deviation, median, mode, minimum, maximum as well as number of respondents for each question in our survey. Since not all respondents answered all questions, we also report the aggregate number of quantitative and qualitative responses.

[7] In spring 2014, we piloted different versions of the survey to find the best trade-off between completeness and parsimony with selected discounting experts, economists from other fields as well as students.

Table 1: Descriptive Statistics on Survey Results

Variable	Mean	StdDev	Median	Mode	Min	Max	N
Real growth rate per capita	1.70	0.91	1.60	2.00	-2.00	5.00	181
Rate of societal pure time preference	1.10	1.47	0.50	0.00	0.00	8.00	180
Elasticity of marginal utility	1.35	0.85	1.00	1.00	0.00	5.00	173
Real risk-free interest rate	2.38	1.32	2.00	2.00	0.00	6.00	176
Normative weight	61.53	28.56	70.00	50.00	0.00	100.00	182
Positive weight	38.47	28.56	30.00	50.00	0.00	100.00	182
Social discount rate (SDR)	2.25	1.63	2.00	2.00	0.00	10.00	181
SDR lower bound	1.15	1.38	1.00	0.00	-3.00	8.00	182
SDR upper bound	4.14	2.80	3.50	3.00	0.00	20.00	183
Number of quantitative responses							185
Number of qualitative responses							99
Number of responses used for analysis							197
Number of explained non-responses							27
Number of bias-check responses							38
Total number of responses							262

We closed the survey in November 2014, by which time we had received quantitative and qualitative responses from 197 experts, including 12 expert that solely provided qualitative feedback containing important insights. We also received replies by 27 scholars explaining why they did not answer the survey and whose answer did not warrant inclusion as a qualitative response. The most common reason for such simple non-response was self-reported insufficient expertise, but it also included simply not having enough time or being unable to respond due to other reasons, such as central bank confidentiality.

Table 1 also reports the number of responses to a subsequent robustness-check on internal validity carried out via e-mail and telephone on 60 randomly selected non-respondents in December 2014. By April 3^{rd} 2015, 38 previous non-respondents provided responses as well as comments explaining their previous non-response. Their quantitative responses are only used as a robustness check (cf. Section 5) and not included in the calculation of the individual discounting determinants reported in Table 1. Overall, this adds up to a total of 262 responses out of a pool of 627 potential experts. The response rate depends on which type of response

we consider. If we only consider the 185 quantitative responses the response rate is 30%. If, in addition, we include qualitative responses, robustness checks and explained non-responses, the response rate rises to 42%. This is well in line with response rates to comparable surveys (Alston et al. 1992; Necker 2014). Our subjective assessment is that our sampling strategy was very successful in obtaining responses from almost all international thought leaders on social discounting.

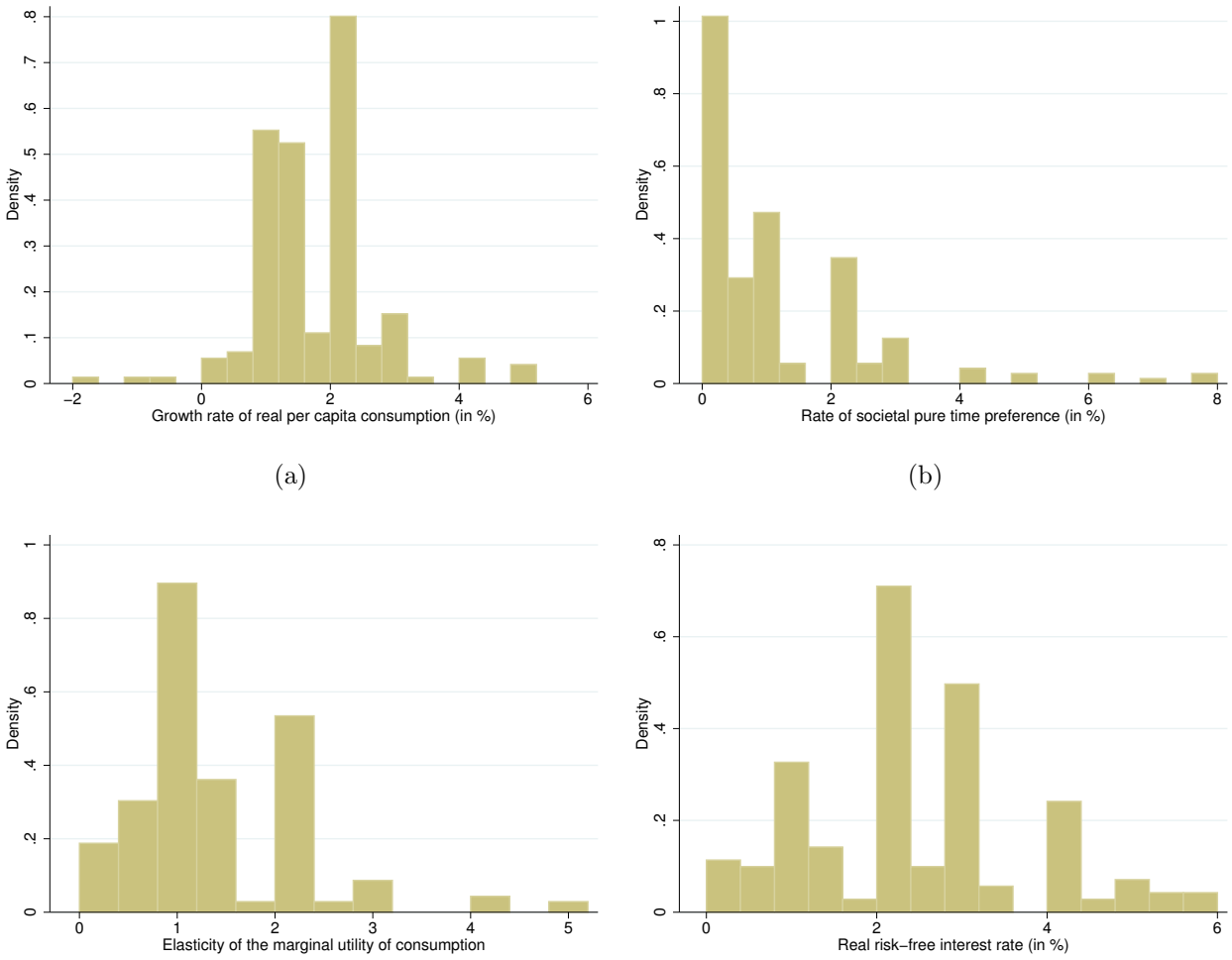
3.2 Quantitative Responses

This subsection presents and discusses the individual quantitative results to survey questions Q1-Q7 based on the summary statistics presented in Table 1 and the corresponding histograms contained in Figures 1 and 2.

Growth Rate of Real Per-Capita Consumption

According to the IPCC (2000), the world average growth rate of income per-capita was 2.2% from 1950 to 1990 and is projected to be on average between 1.3% and 2.8% for the time period up to 2100. The growth rate of consumption per-capita has been around 2% in the western world for the last two centuries (Gollier 2012). For non-OECD countries, the growth rate in GDP per-capita over the period 1900 to 2000 was 1.6% (Boltho and Toniolo 1999). While estimates of the real long-term growth rate of consumption per-capita are scarce, Hänsel and Quaas (2014) employ the DICE model of Nordhaus and Sztorc (2013) to estimate that the maximal constant growth rate of per-capita consumption that can be sustained over a 300 year time-horizon is 1.22% per year. This provides the background against which to evaluate the expert responses on the growth rate of per-capita consumption.

Figure 1(a) presents the results of our respondents' forecasts of the growth rate of real per-capita consumption as a histogram. We observe that the overriding majority of respondents forecast a positive growth rate, with a mean of 1.7% and a median of 1.6% (cf. Table 1). Three experts project a negative growth rate of real per-capita consumption, and as many as 55 experts forecast a lower growth rate of real per-capita consumption than the IPCC's (2000) lower bound projection of 1.3% for the period from 1990 to 2100. 28 experts forecast a growth rate larger than the 2% prevalent in the western world over the two last centuries.



(a) (b) (c) (d)

Figure 1: Histograms of expert recommendations and forecasts on discounting parameters. Figure (a) shows real growth rate of per capita consumption (in %), (b) rate of societal pure time preference (in %), (c) elasticity of marginal utility of consumption, and (d) real risk-free interest rate (in %).

Rate of Societal Pure Time Preference

Historically, positions on the rate of societal pure time preference have been the subject of strong and opposing opinions. For instance, the views of luminaries of economics such as Pigou (1920), Ramsey (1928) and Harrod (1948) are well documented on this matter. Their belief was that the rate of societal pure time preference should be equal to zero because we ought not to weigh the well-being of one generation differently from another. This normative view stems from their classical impartial Utilitarian philosophy. Alternative arguments exist for the use of a positive rate of societal pure time preference. For example, Arrow (1999)

provides agent relative ethical arguments for this position, Nordhaus (2007) a more positive revealed preference position and Koopmans (1960) an axiomatic argument. Finally, one popular argument for a non-zero rate of societal pure time preference is that it should reflect the hazard of societal collapse (Stern 2007). One would expect experts' responses to reflect different distillations of these concepts and beliefs. In short, one would expect a great deal of disagreement. Indeed, this is precisely how the responses turn out.

The histogram in Figure 1(b) highlights substantial disagreement among experts concerning recommendations on the rate of societal pure time preference. The results show that a rate of pure time preference of zero is a focal point among the experts: it is the modal value. If we include those responses in the range of 0 to 0.1%, almost half the responses (specifically 38% of experts) take what might be called the Ramsey-Stern view on the rate of societal pure time preference. Nevertheless, the distribution of responses is substantially right skewed with a median of 0.50% and a mean 1.10%. The dispersion of responses is considerable, with a standard deviation of 1.47%-points. The skewness and spread are driven in part by the vast range of positions on this parameter: the maximum recommendation is 8%. Based on these results, we cannot confirm the IPCC's (2014: 229) conclusion that *"a broad consensus for a zero or near-zero pure rate of time preference"* exists among experts.

Elasticity of the Marginal Utility of Consumption

The (absolute value of the) elasticity of the marginal utility of consumption represents the second *"central normative parameter"* (Nordhaus 2008: 33) of the Ramsey Rule's SRTP approach. Even though most of the heated discussion following the publication of the Stern Review (2007) centered on the rate of societal pure time preference, settling on a value of the elasticity of the marginal utility of consumption is also an intricate affair. The reason for this is that the elasticity of the marginal utility of consumption might capture vastly different concepts and thus lend itself to different interpretations that are not only divided along the lines of normative (e.g., issues of distribution) and positive determinants (e.g., preferences for consumption smoothing), but might capture (societal) preferences for the aversion of consumption inequalities across space, time and also states of nature (i.e., risk aversion). Needless to say that these different rationales may lead to vastly different values for the elasticity of the marginal utility of consumption. Previous discussions in the literature point towards a range of 0.5 to 4 (Cowell and Gardiner 1999; Dasgupta 2008). As official government

guidelines often leave open which specific concept of the elasticity of the marginal utility of consumption to use (e.g. HMT 2003), we have also decided to leave this open to several interpretations. All these rationales could be used to inform the parameterization of elasticity of the marginal utility of consumption, although the survey question might reasonably have led respondents to primarily consider interpretations relating to an intertemporal context. The resulting expert recommendations for elasticity of the marginal utility of consumption as presented in Figure 1(c) are indeed widely dispersed, with a mean (median) of 1.35 (1.00) and a standard deviation of 0.85. The smallest recommended value is 0, the largest one is 5.

Real Risk-Free Interest Rate

The risk-free rate of interest, commonly interpreted to be the yield on government bonds, has played a central role in positivist approaches to social discounting. Historically, the average real risk-free rate for the time period of 1900-2010 has been about 1% for bills and 2% for bonds globally (Dimson et al. 2011).[8] The corresponding rates are 1.1% for bills and 1.9% for bonds for the US, 0.8% and 2.0% for the UK and -0.5% and -0.6% for Japan (Dimson et al. 2011; see also Gollier 2012 for similar figures). The average response to our survey was 2.38%, with a standard deviation of 1.32%-points and a median value of 2%. The maximum forecast is 6%, the minimum value, forecasted by three experts, is 0%. The forecasted long-term global real risk-free interest rate according to our sample of experts is thus slightly higher than the estimated World average real risk-free rate of return on bonds.

Normative versus Positive Determinants of the Social Discount Rate

A central point of previous discussion on the SDR has concerned the question whether whether normative issues, involving justice towards future generations, or descriptive issues, involving forecasted average future returns to financial assets, or a mix of both should determine the SDR (Arrow et al. 1996, 2014). A clear finding from our data is that the vast majority of experts (80%) thinks that both dimensions are relevant (see Figure 2(a)). However, experts recommend that governmental institutions should place greater weight on normative issues in determining the SDR (both the mean, 61.53%, and median, 70%, weight point towards a more important role for normative issues). 15% of experts recommend to only consider normative issues, while 5% recommend to solely consider positive issues when determining the SDR. As

[8]Based on Dimson et al. (2011), we estimate the world (arithmetic) average real risk-free rate on bills and bonds by subtracting the equity premia (cf. Tables 2 and 3 in ibid.) from the return on equity (cf. Table 1).

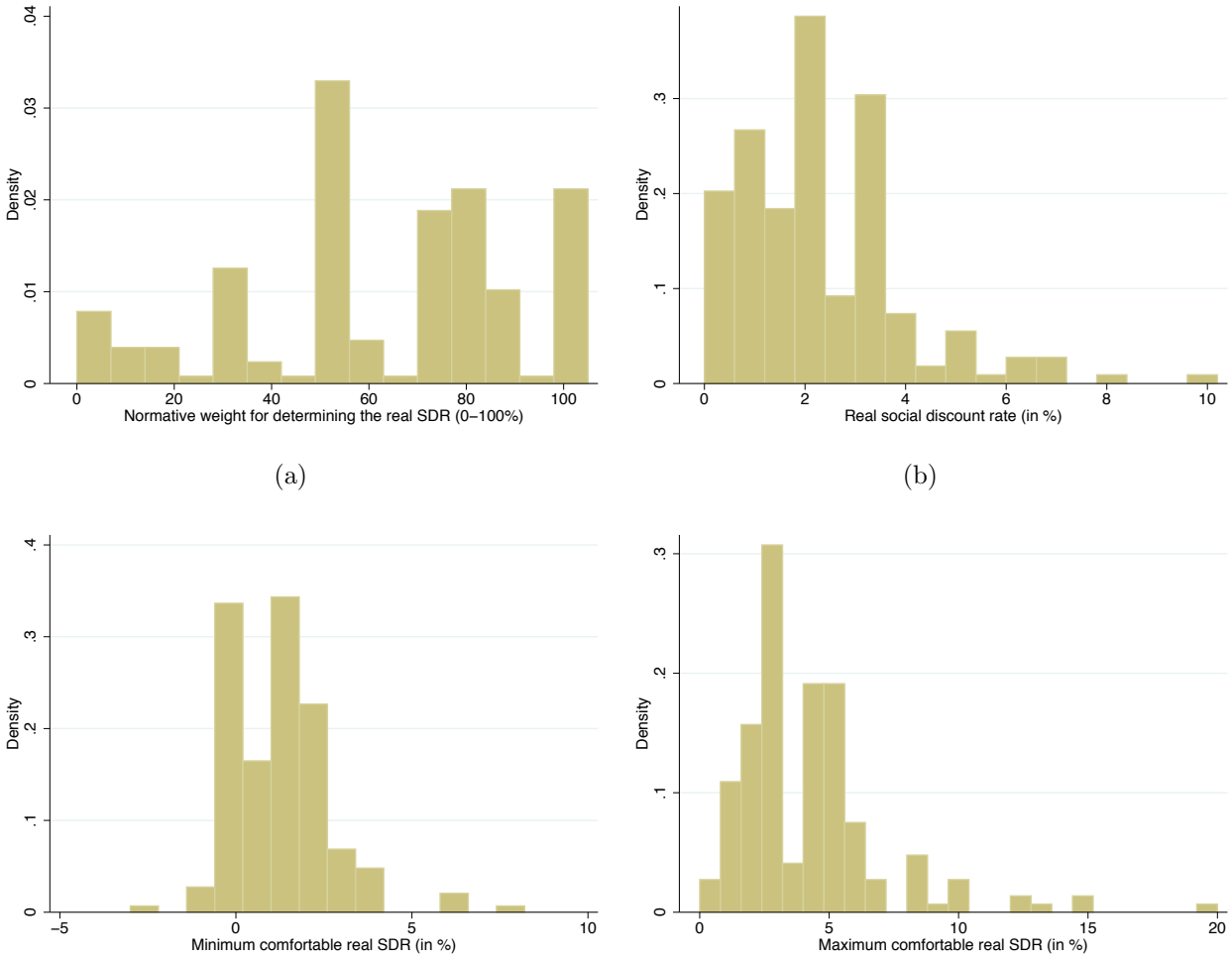


Figure 2: Histograms of expert recommendations on and determinants of social discount rates. Figure (a) shows normative weight for determining the real SDR (in %), (b) real SDR (in %), (c) minimum comfortable real SDR (in %), and (d) maximum comfortable real SDR (in %).

many as 42 experts are divided equally between the two rationales.

These findings highlight that disentangling normative and positive determinants of the SDR is not straightforward and suggest that setting the SDR requires both facts and values.

Recommended Long-Term Social Discount Rate

In recent years, prominent experts such as Gollier (2012), Nordhaus (2008), Stern (2007) and Weitzman (2007) have proposed a wide range of real SDRs. Accordingly, we would expect disagreement between the experts we survey. Figure 2(b) highlights that there is considerable disagreement on the recommendable real social discount rate for evaluating the certainty-

equivalent cash flows of a global public project with intergenerational consequences. The smallest recommendation is 0% and the highest 10%. However, a vast majority of experts provide point-recommendations in the range of 0 to 4%. We find that the interval of 1% to 3% encompasses the point SDR recommendations of 67% of experts. The mean (median) of the SDRs recommended by our discounting experts is 2.25% (2%), substantially smaller than the corresponding values from Weitzman's (2001) survey of economists of 4% (3%). Yet the most common single value recommended in these two different surveys is 2%. We discuss the acceptable ranges of the SDR in more detail in Section 4.

Our aggregated results on the SDR deviate substantially from discount rates proposed by some prominent experts (see IPCC 2014: 230). They are closer to recent findings by Giglio et al. (2014) on revealed evidence on long-term discount rates from the housing market in Singapore and the UK, which imply discount rates below 2.6% for 100-year claims on leaseholds.

3.3 Qualitative Responses

More than half of our respondents provided comments ranging from short remarks, such as *"risk matters"*, to explanations over multiple pages.[9] The qualitative evidence provides a rich body of evidence which sheds light on various complexities of the theory and practice of social discounting, much of which has been developed over the past decade. It also confirms that no simple survey could have addressed all of these concerns and considerations. We group these individual comments in four main categories that address (i) individual survey questions Q1-Q5, (ii) technical issues, (iii) methodological issues, and (iv) concerns about limited expertise. Each category has multiple subcategories. Table 2 provides an overview of the most common issues raised, including the number of experts that have commented upon the respective issue and an exemplary quote, sometimes edited for brevity.[10] We make use of these comments for the analysis and discussion in Sections 4 and 5.

[9] Appendix C contains an example for such a long response and further details on the qualitative comments.

[10] Two of the authors have classified comments into subcategories, while a third has performed random robustness checks. Where appropriate, a single comment has been counted towards multiple subcategories.

Table 2: Overview of Qualitative Responses

Issue	N	Exemplary quote
Q1: Growth rate	14	I foresee a very bright economic future with a continued 2% growth rate for the coming century.
Q2: Pure time preference	10	I see no reason to treat generations not equally.
Q3: Elasticity of marginal utility	12	The elasticity of MU of consumption is heterogeneous, and using a single value is — it seems to me — a crude simplification.
Q4: Real risk-free interest rate	8	There is no interest rate for 100 year horizon (to my knowledge).
Q5: Normative vs. positive	16	The components of the SDR are overwhelmingly normative in nature.
DDRs and time horizon	20	I am more comfortable with declining discount rates (DDRs) [...] due both to declining time preference rates and to uncertainty about future consumption growth.
Heterogeneity & aggregation	19	Ideally, the input for our SWF would be a utility function that allows for heterogeneous preferences.
Opportunity cost of funds	8	SDRs should reflect the social opportunity cost of borrowed funds.
Project risk	6	We would have to consider very carefully the risk structure of the investment to get a correct discount rate.
Substitutability & environmental scarcity	20	If future costs/benefits accrue e.g. to environmental amenities, I would argue for a very low discount rate, based on an expectation of increasing relative prices for these goods.
Uncertainty	20	We need to admit that the current state of the world is full of uncertainties. [Yet] most uncertainties are neglected, and sometimes few remain when these are considered most important, [...] or easiest to accommodate.
Alternatives to discounting	15	Instead of imposing a SWF and calculate the corresponding optimum, it is 'better' to depict a set of feasible paths of consumption, production, temperature, income distribution, etc. and let the policy maker make a choice.
Comments on the survey	14	The search for THE discount rate, if that is your project, is deeply flawed.
Confidence intervals	8	I would also insist on providing confidence intervals.
Ramsey Rule	17	My discount rate is less than implied by the Ramsey rule because I use the extended rule, incorporating uncertainty.
Role of experts	7	I really think economists have very little special expertise in knowing the 'right' number. These parameters should be chosen in an open, iterative way with an eye toward understanding the consequences of different choices.
Limited confidence	13	Please ignore my response to Q4: I don't have the knowledge to make a meaningful forecast.
Limited expertise	5	I am not a real expert on these issues.

4 Analysis

This section reports further analysis and interpretation of our survey data. First, we examine our quantitative data in light of the corresponding qualitative feedback as well as observable characteristics of our respondents. Second, we address to what extent experts disagree on point recommendations and agreeable ranges for the SDR. Finally, we scrutinise in how far expert's recommended SDRs are in line with the simple Ramsey Rule.

4.1 The Determinants of Expert Responses

We now provide a detailed analysis of the data reported in Table 1. We first consider correlations among the quantitative results to look for general patterns of responses. We then undertake a similar analysis with the qualitative responses. Finally, we analyse the relationship between these responses and the experts' personal characteristics. Our overall interest in this subsection is to determine factors that may predict an expert's recommended SDR.

Quantitative Responses

In Table 3 we report the Pearson correlations coefficients statistically significant (at the 5% significance level) among the quantitative responses to our survey, together with the imputed Ramsey Rule's SRTP. Also displayed in Table 3 are the significant correlations between the observable characteristics of our expert sample. As expected, the recommended SDR is positively associated with each respondent's rate of pure time preference, per-capita growth rate, and imputed SRTP. However, in absolute terms, the correlation with the SRTP is surprisingly low at 34%, and lower than the 40% correlation between the SDR and the risk-free interest rate response. There is very low and statistically insignificant correlation between the recommended SDR and the elasticity of marginal utility of consumption (7%).

Personal data are obtained, where possible, from the respondents' personal web pages. These variables include their current continental location, gender, whether of not they have a professorial title, and year of PhD graduation. The latter can be interpreted as a proxy for age, which was not as frequently disclosed on personal websites. We are able to identify 89 respondents from Europe, 80 from the Americas and 16 from the Rest of the World (RoW). The last group work exclusively from Asia and Australasia, giving a sample that is devoid of African representation. We have 167 male respondents, while only 16 women gave quantitative

Table 3: Correlations among Quantitative Responses and Personal Characteristics

[a]	g	δ	η	SRTP	r	Normative	SDR	European	RoW	Male	Prof
δ	36%										
η											
SRTP	69%	59%	57%								
r	40%	21%		31%							
Normative	-20%	-21%		-16%	-17%						
SDR	39%	31%		34%	40%	-41%					
Europe		-17%		-17%		17%	-23%				
RoW			29%	29%				-28%			
Male											
Prof			17%								
PhD year			-19%				-19%				-37%

[a]For values that are statistically significant at the 5% two-sided level, this table provides pairwise correlation coefficients for a number of variables of interest. These include the components of the Ramsey Rule, the risk-free interest rate, the weight placed on normative arguments, the recommended SDR, and personal characteristics of the respondent. The last category includes unitary dummy variables if the expert is currently based either in Europe or the Rest of the World (RoW), if they are male, and if they currently hold a professorial position.

answers to our questionnaire. Approximately half our sample are professors and the mean year of PhD graduation is 1994. We use a unitary dummy variable for European and Rest of the World (RoW) locations, being male, and for professorial status.

In terms of the relationship between the recommended SDR and the personal characteristics of the respondent, there is a clear negative correlation with the weight given to normative considerations, whether the expert is currently located in Europe, and the year of PhD completion. There may, though, be some interplay between these effects. Europeans are more heavily normative and the correlation between the European dummy variable and the year of PhD graduation is 16%, which is close to being significant at the 5% level.

While the number of female respondents is low, there is only limited evidence that gender affects the response, with the correlation between the male dummy variable and the recommended SDR being insignificant and small in absolute terms at -7%. Gender reveals no statistically significant correlation with any of the other explanatory variables considered here. Academic seniority, as opposed to academic age, also appears to have little influence on the recommended SDR, with the professorial dummy variable having a correlation of only 2% with the SDR.

A number of other interesting features emerge from Table 3. Consistent with the extended Ramsey Rule, the risk-free interest rate is highly positively correlated with forecasts of future growth and, to a slightly lesser extent, the rate of pure time preference. The correlation between the SRTP and both the risk-free interest rate and the SDR is very similar at just over 30%. Those who place greater weight on normative considerations are, perhaps unsurprisingly, associated with lower rates of pure time preference. Slightly more surprising is that these experts are also more likely to be pessimistic about our economic future and forecast lower future interest rates. This may help explain the strongly positive relationship between forecasts of per-capita growth rates and rates of pure time preference. While the elasticity of marginal utility of consumption has little explanatory power for the SDR, this variable is positively associated with academic seniority and location in Asia and Oceania, and negatively associated with academic age.

There is clearly some interplay between the variables that determine the recommended SDR. Before we disentangle the relative importance of these determinants more systematically, we now analyse the relationship between quantitative and qualitative responses.

Qualitative Responses

Table 4 shows how quantitative responses are correlated with different types of qualitative response. Column 1 shows how responses differ among experts that raised comments and those that did not. Overall, experts that provided comments responded with a lower pure rate of time preference (-0.54), forecast a lower per-capita growth rate (-0.54) and risk-free interest rate (-0.48), and recommended a lower SDR (-0.49) and minimum value of the SDR (-0.38). The implied SRTP is lower as a consequence (-1.39).[11]

When qualitative comments are categorised more specifically into the five most frequent issues raised, we obtain a clearer picture of the association between these concerns and the quantitative responses. The five most common responses are: 'DDR and time-horizon', 'uncertainty', 'substitutability and environmental scarcity', 'heterogeneity and aggregation', and 'comparison to the Ramsey Rule'. Raising a comment on the 'Ramsey Rule' is not significantly associated with different forecasts and recommendations (at the 10% level), and so this

[11]These results are qualitatively similar if the subsample of experts raising issues of limited expertise is excluded from the analysis. Although not shown in Table 4 only the forecasted per-capita growth rate differ significantly between the subsample of experts stating limited expertise and the subsample of experts that did not raise this issue.

Table 4: How Raising Issues Predict Responses

	(1) Made comments	(2) DDR	(3) Uncertainty	(4) Substitutability	(5) Heterogeneity
Pure time preference (δ)	-0.54**			-0.82**	-0.76***
Per-capita growth rate (g)	-0.54***	-0.43*		-0.70***	
Elasticity of MU (η)					
Risk-free interest rate (r)	-0.48**			-1.07**	
Normative weight (%)		12.43**		20.26***	13.10*
SDR	-0.49**			-0.96**	
SDR minimum	-0.38*	-0.68*	-0.94*	-1.23***	
SDR maximum				-1.76***	
Ramsey Rule's SRTP	-1.39***			-1.64*	

As usual, * refers to significance at the 10% level, ** to the 5% level, and *** to the 1% level.

issue is excluded from Table 4. This is not the case for the remaining four issues. Column 2 shows that experts raising the issue of 'DDRs or time-horizon' forecast a lower growth rate per-capita (-0.43), recommend a more normative foundation of the SDR (12.43) and a would be comfortable with a lower minimum value of the SDR (-0.68). That experts raising this issue recommend lower SDRs for the long-term is consistent with arguments provided in the literature (Arrow et al. 2013; Cropper et al. 2014). Experts that raised the importance of 'uncertainty' tend to recommend lower values of the minimum acceptable value of the SDR (-0.94). This finding is in line with many arguments in the literature that uncertainty tends to lower the appropriate SDR (Gollier 2008; Traeger 2009; Weitzman 1998; Weitzman and Gollier 2010). Experts raising the issue of 'substitutability and environmental scarcity' recommended lower rates of pure time preference (-0.82) and forecast lower per-capita growth rates (-0.70) and risk-free interest rates (-1.07). These experts also recommended that normative considerations should receive more weight (20.96), while recommending a lower SDR (-0.96) and lower minimum (-1.23) and maximum (-1.76) values of the SDR. Their implied SRTP is also lower (-1.63). These associations have a strong theoretical underpinning in the literature on dual discounting and the relative price effects of environmental goods due to limited substitutability and environmental scarcities (Gollier 2010; Sterner and Persson 2008; Traeger 2011). Finally, experts commenting on the importance of 'heterogeneity and aggre-

gation' recommended a lower rate of pure time preference (-0.76) and that the SDR should have a more normative foundation (13.10).[12]

Taken as a whole, these results suggest a negative relationship between responses from experts that provided qualitative comments, the components of the SRTP and the SDR itself. This is driven mainly by those who mention DDRs and those who are concerned about sustainability and environmental scarcity. Both the normative and the positive parameters are lower for the latter group, indicating preferences for a normative approach coupled with pessimism about future per-capita growth and risk-free rates of return. This association is less apparent for those mentioning DDRs, with only per-capita growth rates and the minimum SDR receiving lower responses. This is probably because the theoretical basis for DDRs focuses on the time series processes associated with growth and the interest rate instead of being concerned with the normative parameters per se (e.g. Weitzman 1998, Gollier 2008).

Personal Characteristics as Determinants of the SDR

Having examined the correlations among quantitative responses, and between quantitative and qualitative responses, we now try to disentangle the relative importance of experts' personal characteristics in determining the SDR response. By 'personal characteristics' we mean attitudinal data obtained from the survey, such as their positive–normative position and their qualitative responses as categorized in the previous section, as well as the data collected from experts' personal web pages. We have seen from the previous analysis that there is likely to be some interplay between these SDR determinants, so our objective here is to understand the relative magnitude of the marginal effects of the determinants discussed above.

Table 5 shows the outcome of this analysis. We present a number of models to check for robustness, from which several conclusions can be drawn. Firstly, the most robust determinants of the SDR among the personal characteristics are the normative weight, the year in which the expert received their PhD and whether or not the expert resides in Europe. Recall that the normative views are recorded on a sliding scale from 0 to 100%. The models all show that each additional normative percentage-point reduces the recommended SDR by 0.02 percentage-points. This implies that a pure 'positivist' (normative scale = 0%) would

[12]In light of the variety of heterogeneities mentioned by experts, there is not straightforward expectation on how heterogeneities impact SDR recommendations. While some respondents simply state that one must take the distributional effect for those *"affected by the project"* into account, other respondents are more specific in stating that *"the discount rate should be negative if rich people pay today for poor people in the future"*.

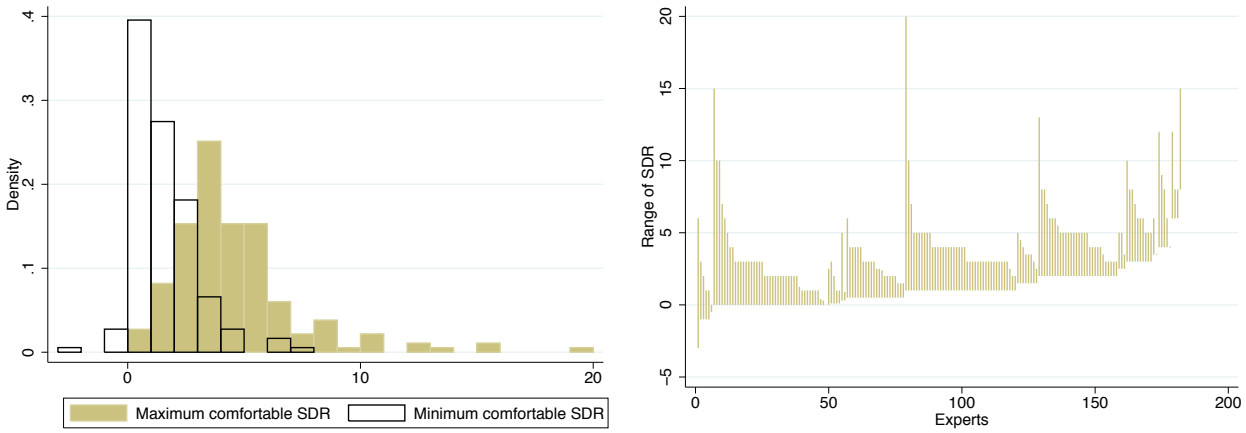
Table 5: OLS Analysis of Characteristics that Determine SDR Responses

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5
Normative (%)	-0.019***	-0.022***	-0.019***	-0.021**	-0.018***
PhD year	-0.018*		-0.016*		-0.017*
European		-0.49**	-0.23	-0.46**	-0.21
Substitutability				-0.32	-0.55
Heterogeneity				0.078	0.21
Uncertainty				-0.277	-0.30
DDRs				-0.045	0.021
Constant	39.09**	3.78***	36.10**	3.76***	37.02**
Adjusted R-squared	0.18	0.18	0.18	0.17	0.17
N	137	178	137	178	137

As usual, * refers to significance at the 10% level, ** to the 5% level, and *** to the 1% level. All standard errors are robust.

have a SDR 2 percentage-points higher than a pure 'normativist' (normative scale = 100%). This is highly statistically significant. When controlling for normative views, being located in Europe still reduces the recommended SDR by about 0.5 percentage-points. However, this result appears to be confounded by the interplay with year of PhD graduation. Once one controls for the latter, location is no longer important. Treating PhD year as a rough proxy for age, the results suggest that, other things equal, older experts recommend higher SDRs. An additional 30 years of (academic) age increases the recommended SDR by approximately 0.5 percentage-points. One can only assume that younger academics have been influenced more by the emerging literature on social discounting, which has been through something of a revival this century.

In sum, Models 3–5 suggest that the determinants of the recommended SDR lie in expert's normative stance and age. This remains true irrespective of the nature of the qualitative remarks on how long-term decision-making should be augmented. The 'European effect' seems to be an artifact of a European tendency to be normative, and the fact that the European respondents were academically younger. With adjusted R-squared never more than 0.18 in each model, it is clear that we have only captured some of the determinants of the SDR.



(a) (b)

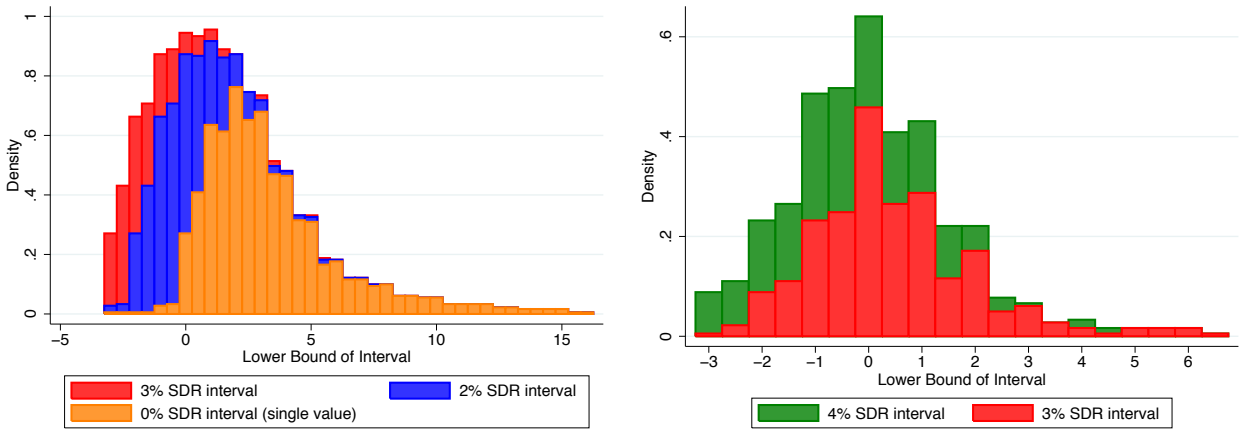
Figure 3: Figure (a) depicts the minimum and maximum values of the SDR, and (b) the corresponding range of the SDR (ordered by minimum then maximum value), that individual experts are still comfortable with recommending.

4.2 Disagreement on Social Discount Rates

We now examine the extent of disagreement and agreement among experts on the appropriate value of the SDR. As the evaluation of long-term public projects is very sensitive to the applied SDR, obtaining a more representative expert view here is crucial in light of previous wide discrepancies over the SDR recommended by prominent experts (Nordhaus 2008; Stern 2007). Recalling that point recommendations on the SDR from our data, ranging from 0 to 10%, exhibit even wider disagreement as compared to the above cited experts, we find that even the acceptable ranges of SDRs recommended by each expert often do not fully overlap from one expert to another (cf. Figures 3(a) and 3(b)).

Yet, a closer inspection of experts' acceptable ranges shows that there is also considerable agreement on the SDR. We examine this through two routes: (a) partial and (b) complete overlap of a certain SDR interval with the acceptable ranges suggested by our experts (Figures 4(a) and (b)).

Figure 4(a) depicts the lower bound of an interval of given size (e.g. 3%) on the x-axis and the proportion of experts whose acceptable SDR range has 'partial' overlap with an interval of a particular size starting at that point on the y-axis. The orange histogram depicts the 0% interval and thus shows the proportion of experts whose acceptable SDR range includes the respective single values only. For example, the single SDR value of 0% is contained in



(a) (b)

Figure 4: The x-axis shows the lower bound of an interval of given size (e.g. 3%) and the y axis shows the proportion of experts whose acceptable SDR range has *partial* overlap (Figure a) or *full* overlap (Figure b) with an interval of a particular size starting at that point.

the acceptable ranges of 23% of experts. From this we can also conclude that, besides being the median and mode recommendation point SDR recommendation (cf. Table 1), a SDR of 2% is contained in the acceptable range of 76% of experts. Furthermore, our data show that the interval 1% to 3% (1 to 4%) is overlapped by the acceptable range of the SDR for 92% (96%) of experts, as depicted by the blue (red) histograms in Figure 4(a). This interval of the SDR of 1% to 3% (1% to 4%) also contains the point SDR recommendations of 68% (76%) of experts. Figure 4(b) concerns the location and width of the proposed ranges. It shows that the SDR interval of 0 to 3% (0 to 4%) fully contains the acceptable ranges of 46% (64%) of experts. The majority of experts would thus not be comfortable with SDRs that exceed 4%.

Based on these acceptable ranges, we can also shed light on which of the prominent positions voiced in the academic and public debate – the long-term SDR of 4.5% in Nordhaus (2008), or Stern's (2007) central SDR value of 1.4% – is more representative of the expert community. Based on the point SDR recommendations, we find that 30% of experts recommend Stern's SDR of 1.4% or lower, only 9% of experts recommend Nordhaus' value of 4.5% or higher and the majority of 61% of experts form the middle ground between these two point SDR positions. Our analysis of acceptable ranges shows that the SDRs employed by Nordhaus (2008) and Stern (2007) SDR are included in the acceptable range of 39% and 57% of experts, respectively. While Stern's employed value is thus judged acceptable by more experts,

acceptability by only 57% of experts may not be deemed robust enough by policy-makers. Our results thus suggest that the public debate on SDRs has been influenced by positions that are not in the centre of opinion on the matter and that public policy should consider the middle ground of these positions. In particular, Figure 4(a) shows that the highest share of experts (76%) considers the single point SDR of 2% to be acceptable.

Overall this shows that, despite considerable disagreement on point SDR recommendations, common ground exists over narrower intervals when experts' acceptable ranges for the SDR are considered. While lower and higher SDRs may be reasonable from different ethical and practical standpoints, an interval for the SDR of 1% to 3% contains SDR values judged acceptable by 92% of experts and should thus be considered carefully in future analyses.

4.3 Expert's SDR Recommendations and the Ramsey Rule

An important question for improving governmental guidance on social discounting is whether expert's recommendation of the SDR is determined by the Ramsey Rule. We examine all three possible representation of the Ramsey Rule as outlined in Section 3.2, the opportunity cost of capital approach to the Ramsey Rule, captured by the forecasted real risk-free interest rate, the Ramsey Rule's social rate of time preference (SRTP), as well as the Ramsey Rule in its strict optimality form ($r = SDR = \delta + \eta\, g$).

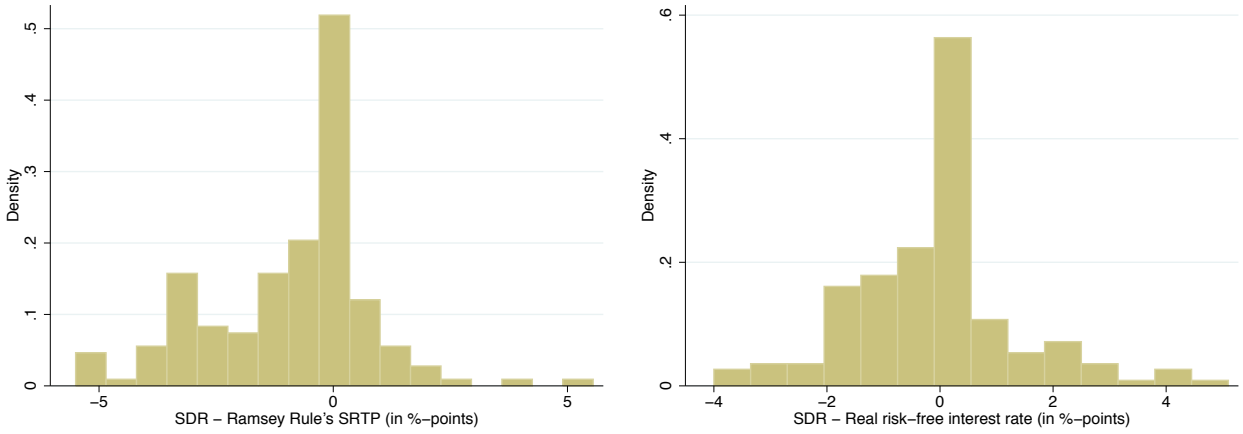
To address this issue, we impute the Ramsey Rule's SRTP via its individual components. This yields a mean value of the SRTP of 3.48% and a median of 3.00% (see Table 6). The mean SRTP is 1.23 (1.10) percentage points higher compared to the SDR (interest rate). This difference between the SDR and the imputed SRTP on the one hand, and the real risk-free interest rate on the other, is depicted in more detail in Figure 5 (a) and (b) respectively.[13]

These Figures indicate that many experts recommend a SDR that is incompatible with the Ramsey Rule's SRTP and the real risk-free interest rate. Specifically, our survey data show that the recommend SDR coincides with the SRTP for only 35 experts. For 47 experts the recommended SDR coincides with the real risk-free interest rate. For 18 of these experts, all three components match and the Ramsey Rule holds in its strict optimality form. Conversely this implies that for 90% of experts providing quantitative results the Ramsey Rule in its strict

[13]To facilitate a clearer exposition, we illustrate the respective differences for the interval [-5.5, 5,5] only. This results in dropping five extreme observations in Figure 5 (a) and two observations in Figure 5 (b).

Table 6: Descriptive Statistics on the SRTP, SDR and Risk-Free Interest Rate

Variable	Mean	StdDev	Median	Mode	Min	Max	N
Social rate of time preference (SRTP)	3.48	3.52	3.00	4.00	-2.00	26.00	172
Social discount rate (SDR)	2.25	1.63	2.00	2.00	0.00	10.00	181
Real risk-free interest rate	2.38	1.32	2.00	2.00	0.00	6.00	176



(a) (b)

Figure 5: Histogram of the difference between the recommended SDR and (a) the imputed Ramsey Rule's SRTP, as well as (b) the real risk-free interest rate, in the interval [-5.5, 5.5].

form does not hold. Overall, the responses of only 35% of respondents can be reconciled with any of the approaches to the Ramsey Rule either via the SRTP or the interest rate.

We further examine whether expert's may have used a mixed interest rate-SRTP approach weighted by their recommended positive and normative weight to determine the SDR: $SDR = wr + (1-w)(\delta + \eta\, g)$, where $w \in [0,1]$ is the weight to be put on positive issues in determining the SDR. We find that this approach cannot explain the considerable differences between the SDR and the imputed SRTP or the interest rate, as the SDR of only 10 experts coincides with this mixed interest rate-SRTP approach in addition to the 18 experts for whom the Ramsey Rule holds in its strict form irrespective of their positive-normative weight.

The root cause of the substantial discrepancies between the Ramsey Rule and the SDR evident in Figure 5 thus cannot be explained by simple reference to positive or normative determinants of SDR. They rather vary from one expert to another for reasons often related to

their qualitative responses.[14] While one expert explicitly stated that *"the real social discount rate should be the risk-free interest rate"*, others remarked that, for example, *"incomplete futures markets justify social discount rates lower than real market rates"*. Furthermore, a number of experts explicitly stated why their recommended SDR is not in line with the Ramsey Rule's SRTP: *"my discount rate is less than implied by the Ramsey rule because I use the extended rule, incorporating uncertainty about long term growth"* or *"if the future costs/benefits accrue to non-monetary goods (e.g. environmental amenities) I would argue for a very low discount rate [...], based on an expectation of increasing relative prices for these goods (so my recommended RSDR of 3% above is adjusted downwards [...])"*. In total, we have received 17 comments relating to some form of the Ramsey Rule. Furthermore, many other expert's comments point towards extensions of the Ramsey Rule's SRTP, for example relating to uncertainty or relative price effects concerning environmental goods. We engage with these and other limitations of the simple Ramsey Rule in Section 5.3.

Overall, our findings highlight that in making policy recommendations on long-term public projects, we not only have to deal with problems of the *"second-best"* (Baumol 1968) but have to consider more advanced models of social discounting and intergenerational decision-making.

5 Discussion

This section puts our survey into context and discusses potential limitations of our study design. First, we address the issue of sample selection and potential response bias. Second, we compare our survey with that of Weitzman (2001). Third, we discuss the role of experts in informing decision-making on long-term public projects in the context of determining SDRs. Finally, we review limitations of the simple Ramsey Rule approach to social discounting.

5.1 Sample Selection and Robustness Checks

We carry out a series of robustness checks to test for potential response bias. First, we compare our 185 quantitative responses with a random sample of 60 potential experts who had not replied by November 2014. Second, we compare respondents and non-respondents

[14] An analysis of the response time in the online survey does not suggest that these discrepancies are the result of mere specification errors by our respondents. According to standard t-tests of similar means, average time of response is not different for experts giving responses consistent with the Ramsey Rule.

based on observable characteristics, such as gender and location. Last, we compare early and late respondents to obtain a further indirect measure of potentially biasing self-selection.

Respondents versus Random Non-Respondents Check

From December 2014 to April 3^{rd} 2015 we carried out a robustness-check via e-mail and telephone with 60 randomly selected non-respondents. Of these, 9 are located in Asia/Oceania, 18 in Europe and 33 in North America. We obtained responses from 38 initial non-respondents, 24 of them only provided reasons for their non-responses.[15] 14 previous non-respondents provided quantitative data. We report the results of this exercise in Table 7 .

Table 7: Robustness Check with Randomly Selected Non-Respondents

	g	δ	η	**r**	**Normative**	**SDR**	**SDRmin**	**SDRmax**
Results from the 10 bias-check responses								
Mean	1.63	1.46	1.23	1.96	71.36	2.02	1.01	3.09
Median	1.50	1.00	1.00	1.75	75.00	2.00	0.63	3.00
N	12	12	8	12	12	13	14	13
Difference to the 185 original responses (bias-check minus original survey results)								
Mean	-0.08	0.36	-0.12	-0.42	9.83	-0.23	-0.14	-1.05
Median	-0.10	0.50	0.00	-0.25	25.0	0.00	-0.38	-0.5

Overall, the mean responses in this bias-check sample tend to be lower compared to our large sample of experts (see the lower part of Table 7). The bias-check sample respondents would only recommend a higher rate of societal pure time preference δ (with a mean of 1.46% compared to the 1.10% from our original experts), and a higher weight to be put on normative vs. positive determinants. The mean SDR is 0.23 percentage points lower compared to the mean of our original expert sample, while the median is the same. However, both lower and upper bound SDRs for the bias-check respondents are considerably lower. This is also the case for the forecasted real risk-free interest rate, where bias-check respondents forecast substantially lower rates. The samples are roughly balanced in terms of forecasting consumption growth rates as well as their recommendation concerning the elasticity of marginal utility of consumption. We further find that only one respondent each recommended a SDR in line with the Ramsey Rule's SRTP or forecasts interest rates. While the small number of quantitative

[15]Reasons include having insufficient time (11) or expertise (10). The high proportion of respondents stating to be no expert suggests that we observed self-selection of experts into responding to the initial survey.

bias-check responses do not allow us to draw robust conclusions, they tend to suggest that experts forecasting higher real risk-free interest rates and recommending higher SDRs and but lower rates of pure time preference selected into responding to our original survey.

Comparing Observable Characteristics of Respondents and Non-Respondents

A common measure for potential response bias is to consider groups by gender and location (Necker 2014). We make use of expert characteristics collected after the survey to test for an indication of selection bias. We find that male experts selected into responding to our survey relative to the non-response group (91% versus 80%). The proportions of respondents and non-respondents are balanced in terms of the characteristics such as currently being Professor (49% versus 48%) and average year of PhD completion (1993.60 versus 1993.64). Relative to the respondents, non-respondents are comprised of a lower share of experts currently based at European institutions (49% versus 33%). Experts currently based in Europe selected into responding, which provides some indicative evidence for a potential selection bias impacting our results. Based on our analysis of the driving factors of responses (Section 4), we do not find an effect on recommendations or forecasts on gender (at the 10% level), but experts based at a European institution forecast a lower growth rate (-0.24*), and recommended a lower SDR (-0.76***), minimum (-0.51**) and maximum (-1.57***) SDR, pure rate of time preference (-0.50**), and place a larger weight on normative determinants (9.94**) than experts based at non-European institutions. Note that the European effect on the SDR is driven entirely by outliers, as there is no geographical pattern when examining medians. Most of the European effect is driven by the normative preference of these experts and that they are academically younger researchers. A related concern related to the discussion of biasing self-selection might be selection of environmental economists into responding.[16] Indeed, we observe that environmental economists self-select into responding. 48% of respondents are environmental economists, while only 32% of the non-respondents are environmental economists. Surprisingly, we find that environmental economists do not on average tend to provide different recommendations and forecasts than the rest of our experts.[17]

[16]We regard an expert to be an environmental economist if the publication that led us to select her or him as a potential expert is in either American Journal of Agricultural Economics, Ecological Economics, Energy Journal, Environmental and Resource Economics, Journal of Environmental Economics and Management, Land Economics, Resource and Energy Economics, or Review of Environmental Economics and Policy.

[17]Only the growth rate and pure rate of time preference differ among groups at the 10% significance level.

Table 8: Comparison of Early and Late Responses

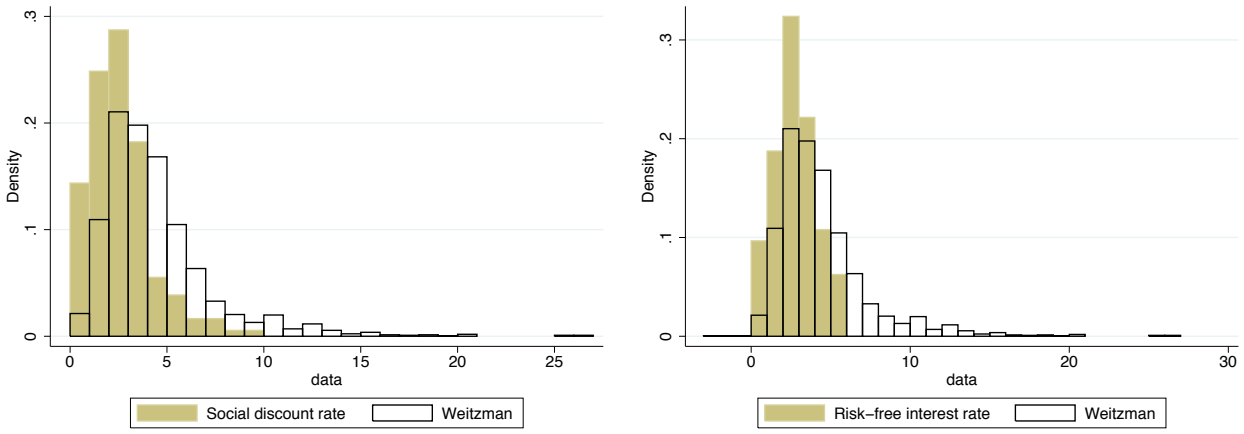
	g	δ	η	r	**Normative**	**SDR**	**SDRmin**	**SDRmax**
First half (i.e. respondents that responded early)								
Mean	1.63	0.93	1.44	2.42	61.72	2.15	1.10	3.89
Median	1.50	0.50	1.25	1.55	70.00	2.00	1.00	3.25
N	88	88	85	88	88	87	88	88
Second half (i.e. respondents that responded late)								
Mean	1.81	1.26	1.27	2.38	61.00	2.34	1.20	4.38
Median	2.00	1.00	1.00	2.00	68.50	2.00	1.00	3.50
N	85	85	83	81	88	87	87	87
Two-sided hypothesis test for difference in means								
P-value	0.19	0.13	0.19	0.86	0.87	0.43	0.65	0.25

Comparing Early and Late Respondents

Another test of potential self-selection is to compare results of experts responding early to those responding late (cf. Galecki et al. 1993). Table 8 shows our respondent sample providing quantitative results split into early and late respondents. Two-sided hypothesis tests cannot reject the hypothesis that the mean responses of the two subsamples are the same. Median values for the recommended SDR are the same in both groups.

Related robustness checks compare mean recommendations and forecasts of the subsample of 56 experts that directly responded to the first e-mail to the experts that answered a reminder e-mail. According to the two-sided hypothesis tests, mean responses on the per-capita growth rate, social rate of pure time preference and SDR are larger for experts that required a reminder. Another test splits the sample of experts that needed a reminder before answering again into two subsamples of equal size: those that responded early and those that responded late. Only for the forecasted risk-free interest rate, the two-sided hypothesis test rejects the null that mean values are the same across the two subsamples.

Overall, the series of robustness checks on potential selection and response bias do not suggest substantial and systematic unidirectional biases in terms of SDR recommendations.



(a) (b)

Figure 6: Histogram comparing results of Weitzman's (2001) survey to (a) recommended SDR and (b) forecasted risk-free interest rate.

5.2 Comparison to the Survey of Weitzman (2001)

A natural reference comparison for our results is the seminal survey of Weitzman (2001), who asked more than 2000 PhD-level economists to report a single appropriate *"real discount rate"* or *"rate of interest"* with which to discount projects aimed at mitigating climate change.

The key difference between the data of Weitzman (2001) and our results is that we find a smaller mean, median and standard deviation. The mean (median) SDR recommendation of our respondents is with 2.25% (2%) substantially lower than the corresponding value from Weitzman's (2001) data of 4% (3%). We also find a much more condensed range of point recommendations on the SDR (0 to 10%) compared to Weitzman (-3% to 27%). The modal recommended value for the SDR of 2%, however, is the same in both surveys.[18] One irresistible comparison with the Weitzman (2001) data is to see whether or not our data are in any sense Gamma distributed. Figures 6(a) and (b) depict the comparison between the distribution of expert's recommended SDR and forecasted real risk-free interest rate and the survey data of Weitzman (2001). They show that neither distribution matches Weitzman's data. It is interesting to note that only the data on the imputed Ramsey Rule SRTP comes close to approximating the distribution of Weitzman's (2001) data (Figure 7 in Appendix D).

[18] Another related survey is Almansa and Martinez-Paz (2011), who focus on 'environmental discounting'. For a time-horizon of 76-125 years, they find a mean (median) 'intergenerational discount rate' of 1.88% (2%).

There are several possible reasons for the difference between our responses and those of Weitzman (2001). First, while Weitzman's (2001) pool of potential respondents is a general economics audience, we rely on an objective criterion to select as potential experts only those scholars who have published on the issue in high-ranked economics journals. One may conjecture that experts on social discounting would recommend lower SDRs. While we have no direct means of testing this due to lack of response data by non-experts,[19] we note that a general economics audience does not form a self-evident benchmark for informing governmental guidance. One unambiguous effect of selecting respondents based on their publications that is in line with the above conjecture is that we do not pick up responses that seem to be of questionable relevance to the issue of long-term discounting. If, for example, we ignore the 82 responses in Weitzman's (2001) survey that report a SDR of more than 10% (the highest single SDR recommended in our data), the mean in Weitzman's data reduces to 3.54%.

Second, our survey is considerably longer and more complex, as we ask for eight different numbers instead of a single one. Crucially, besides eliciting recommendations on the SDR, our data disentangles a broader set of discounting concepts and determinants. We are therefore able to distinguish normative and positive determinants of the SDR, which will inevitably be contained in some mixed form in Weitzman's (2001) data. However, this more comprehensive survey comes at the cost of a lower response rate of 30-42% compared to Weitzman's (2001) 75% response rate (Weitzman 2014, personal communication). Despite the sheer length and complexity effect that may have deterred potential experts from responding, the lower response rate is in part also due to the more widespread use of spam filters.[20] One further issue is that we suffered from what can only be described as a "gravitas deficit" compared to Professor Weitzman. As the issue of how selection into responding could have biased our results is important for drawing conclusions regarding their representativeness, we devote a whole section to testing potential response and selection biases (Section 5.1).

Third, while our framing concerns the evaluation of generic public projects, the focus of Weitzman (2001) was on climate change mitigation. We hypothesise that our more neutral

[19]We do perform three related indicative tests (see Section 5.1 for details): First, we find that respondents raising a comment also report lower SDRs; Second, we find no significant effect of experts stating to have limited expertise on SDR recommendations; Third, we compare responses by scholars who have published in environmental economists journals to the rest of respondents and do not find significant differences.

[20]We have received several comments by original respondents as well as the randomly selected bias-check respondents that our survey e-mails were intercepted by their spam programs.

framing would not appeal as much to emotional triggers associated with responsibility towards future generations, and may thus have led experts to recommend rather higher than lower SDRs compared to Weitzman's survey. Furthermore, our survey text is more specific about the long time horizon (">100 years"), something which is more implicit in Weitzman's (2001) survey. Pointing experts to consider an explicitly long time horizon may have led them to recommend lower SDRs, especially in light of the discussions on declining discount rates that have occurred in the intervening period since Weitzman (2001).

Fourth, there might be knowledge effects influencing reported SDRs. Views on social discounting may have been affected by the results of Weitzman's (2001) survey itself. Further, respondents may have converged over time towards lower SDRs due to the prominent discussions on discounting the future following the publication of the Stern Review (2007). Indeed, there is some evidence for such time or knowledge effects: the 50 experts we identified with a PhD competition date after 2001 had a mean (median) SDR recommendation of 1.85% (1.75%), compared with 2.23% (2.00%) for the 46 experts who graduated between 1991 and 2001 and 2.28% (2.00%) for the 42 finishing their studies before 1991.

Lastly, one might think that experts' lower SDR recommendations are driven by a downward bias in forecasts of economic fundamentals due to today's lower real growth and interest rates. While we cannot directly test for such an influence, our data do not suggest this to be a major driving factor, as the responses on the real risk-free interest rate do not closely correspond to the very low rates currently prevailing in countries such as Germany. In fact, our results on the mean SDR of 2.25% and mean real risk-free interest rate of 2.38% are very close to recent empirical evidence on long-term discount rates estimated to below 2.6% (Giglio et al. 2014). A further indication that lower SDR recommendations are not simply due to current economic fundamentals is that for the 37 experts who suggest a normative weight of less than 33.33%, and thus are mainly driven by market-based considerations, the mean (median) SDR recommendation is 3.18% (3.00%), which is even higher than their mean (median) forecasted real risk-free interest rate of 2.66% (2.50%). Moreover, the forecasted mean growth rate of real per-capita consumption of 1.7% is only slightly lower than the historical global average of GDP growth per-capita (cf. Section 3.2).[21]

[21]That five of the eleven experts that provided comments on the growth rate state that they forecast growth rates of per-capita consumption to decline over time also provides some indication that expert's forecasts are not simply downward-biased projections of current or historical growth rates.

5.3 The Role of Experts in Guidance on Social Discounting

There are some obvious caveats to using expert opinions to inform intergenerational decision-making and social discounting by governmental bodies. One typical criticism is that guidance on social discounting should be informed via more *"democratic"* means (Dasgupta 2008: 158), such as stated and revealed preferences of members of the public.[22] Indeed, economists certainly do not command any special expertise when it comes to matters of ethics. It is therefore important for future work to determine whether experts are representative of the general population on the matter of social discounting, particularly as economists' opinions have been shown to be different from ordinary Americans in recent surveys (Sapienza and Zingales 2013). When discussing the role of experts in providing guidance on the SDR, we should bear in mind that the SDR affecting the outcome of a cost-benefit analysis is only one part of the otherwise more political and potentially participatory decision-making process regarding investments in public projects (Hahn and Dudley 2007). Thus even if the determination of the SDR were solely based on expert judgements, this would not directly translate into experts determining the specific public projects to be implemented. With this context in mind, we recognize that decison-makers are informed by experts in a variety of issues, sometimes even delegating decision-making power, such as to a monetary policy committee.

Some discussants explicitly advocate such an active role of *"genuine specialists"* to steer the process of setting SDRs (Sunstein 2014: 550), and indeed existing governmental guidance on social discounting has been influenced by experts (as in The Netherlands or France; see also Arrow et al. 2012). This comes of no surprise, as the questions raised by intergenerational discounting are highly complex. Compared to other members of the general population, experts will have spent considerably more time considering the intricate issues that arise. Experts are therefore in the unique position to not only consider their informed 'gut feeling', but also draw on a broad range of empirical evidence as well as theoretical and philosophical reasoning, each single one of which may fall short of being the 'holy grail' to determining the SDR. As such, expert advice may at least serve as a complement to other stated and revealed preferences that could be used to inform governmental guidance on social discounting.

[22] This is highlighted, for example, in the following comment we received from one of the experts: *"I really think economists have very little special expertise in knowing the 'right' number. These are parameters that should be chosen in an open, iterative way with an eye toward understanding the consequences of different choices. [...] Just to be clear, I definitely think economists have an important role at the table in the public discourse over these matters – just no special normative expertise!"*

One might however argue that such influence by experts might be prone to hidden agendas and it is not possible to rule out strategic behavior (Battaglini 2004) and group-thinking. This would make it even more important to consider a broad range of opinions, and by taking such a large sample of experts, contamination by these issues should be very limited in our survey data. Against this background, it is imperative to obtain a more representative account of expert advice on the determinants of the long-term SDR, with the end of putting governmental guidance and academic understanding on a more robust basis.

5.4 Limitations of the Simple Ramsey Rule Approach

As highlighted in the qualitative responses, there is now a very nuanced view of discounting to be found among our sample of experts (cf. Table 2). We have already demonstrated that most experts do not follow the Ramsey Rule in making their recommendations. Criticisms vary considerably from the fact that it omits uncertainty and project risk, DDRs, or that substitutability and environmental scarcity should be reflected.[23] Beyond these technical arguments, which largely require extensions to the Ramsey Rule, further criticism focussed on the need for alternative approaches to inform intergenerational decision-making. In particular, many experts recorded doubts about whether, for example, *"a representative agent model with a standard Ramsey social welfare function is adequate in either descriptive or normative terms"*.[24] Experts also point towards *"richer ways of framing questions of intergenerational justice than simply tweaking the discount rate"*, such as the use of a 'tolerable windows'-approach (as can be found in recent suggestions by Rockström et al. 2009). Such an approach in the spirit of strong sustainability might, according to one respondent, *"set limits in physical terms to the future development that must not be exceeded for reasons of intra- and intergenerational justice [...]. Then, use a discounted utilitarian approach to opti-*

[23]As we cannot discuss every technical extension here, the reader is referred to the following overview articles (Arrow et al. 1996, 2014; Gollier and Hammitt 2014; Heal 2009) as well as the respective literature for a selection of existing Ramsey Rule extensions: uncertainty (Gollier 2002, 2008; Traeger 2009, 2013; Weitzman 1998; Weitzman and Gollier 2010), declining discount rates (Cropper et al. 2014; Gollier et al. 2008; Groom et al. 2005, 2007; Newell and Pizer 2003; Weitzman 2001) and limited substitutability between environmental services and manufactured goods (Baumgärtner et al. 2014; Drupp 2015; Gollier 2010; Hoel and Sterner 2007; Sterner and Persson 2008; Tol 2003; Traeger 2011; Weikard and Zhu 2005).

[24]One strand of the literature therefore contrasts Ramsey's infinitely lived agent with an overlapping-generations framework (Schneider et al. 2012). Two experts explicitly commented on this distinction.

mize development only within these limits".[25] Other experts refer to alternative criteria for intergeneration decision-making. An overview of this ongoing discussion on developing more nuanced criteria can be found in, among others, Asheim (2010), Botzen and van den Bergh (2014) and Fleurbaey and Zuber (2014).

6 Conclusions

We have presented evidence from a survey of 197 experts on the determinants of the long-term social discount rate (SDR). Obtaining such data on the SDR and its disentangled determinants is necessary for several reasons: First, the SDR might be the single most important driver of any cost-benefit analysis evaluating long-term public projects. Second, recent research has shown that the appropriate guidance on the long-term SDR depends on how heterogenous recommendations and forecasts on the SDR's determinants are combined (Freeman and Groom 2014; Heal and Millner 2014a,b; Weitzman 2001).

A key innovation of our survey is therefore that we not only elicit responses on the appropriate SDR but on individual discounting determinants: recommendations on the rate of pure time preference and the elasticity of marginal utility of consumption, as well as predictions of long-term per-capita consumption growth and the average real risk-free rate of interest. We find that mean (median) recommended SDR of our experts is 2.25% (2%). The modal value of the pure rate of time preference is zero, but with a mean (median) of 1.1% (0.5%), our results cannot confirm the IPCC's (2014: 229) conclusion that *"a broad consensus for a zero or near-zero pure rate of time preference"* exists among experts. We further characterise the empirical distributions of all other parameters elicited. Their relevance may transcend their role as an input for informing the discounting policy debate currently underway in many countries (including the US and the UK). The data on long-term forecasts of growth and interest rates may, in light of recent discussions on these two variables spurred by Piketty (2014), also prove to be of relevance in other fields, such as macroeconomics. Relatedly, our data suggest that the IPCC should consider lower growth scenarios in future assessments.

Beyond this more representative account of raw data for informing intergenerational decision-making, our results yield several findings that are relevant to both ongoing academic

[25] See, e.g., Baumgärtner et al. (2015), Drupp (2015) and Heal (2009) for discussions of such limits.

discussions as well as policy-making on long-term public projects.

First, despite substantial disagreement among experts on appropriate points SDRs, which range from 0 to 10%, there is agreement on relatively narrow "acceptable" ranges: 92% of experts are comfortable with SDRs somewhere in the interval of 1% to 3%. This interval furthermore includes the point SDR recommendations of 68% of experts. Nevertheless, there also remains considerable disagreement on the relative importance of normative and positive approaches to discounting. Most experts report that recommendations on the SDR should reflect both normative and positive considerations, thus highlighting that these previously accepted categories overly polarise the more nuanced expert views on social discounting. This also highlights that engaging with both disagreement about values and uncertainty over forecasts is an essential task for informing decision-making on long-term public projects.

Second, we find that the simple Ramsey Rule, which is widely accepted as a *"useful conceptual framework for examining intergenerational discounting issues"* (Arrow et al. 2012: 3) and can be found in governmental guidelines on cost-benefit analysis across the world, cannot predict the responses of the majority of our experts. In fact, 81% of experts do not recommend a SDR that is in line with the Ramsey Rule's social rate of time preference. These often substantial differences between experts' recommended SDR and the imputed social rate of time preference, as well as their forecasted real risk-free interest rate, reveal general disagreement on the role of the Ramsey Rule and suggests that there may not be a single appropriate SDR or even approach to determining the SDR.

Finally, the more complex nature of social discounting is supported by the rich body of qualitative responses we received. Many of our respondents provided comments relating to a number of extension and alternatives to the simple Ramsey Rule approach. Among others, they point to issues such as uncertainty, heterogeneity, substitutability as well as other societal evaluation approaches that policy guidance on social discounting should consider to ensure efficient and equitable decisions on long-term public projects.

Overall, our findings lead us to the conclusion that the prominence of the Ramsey Rule should be revisited and that current policy guidance concerning social discounting and the evaluation of long-term public projects needs to be updated.

Appendix

A Survey Text

A.1 E-mail Text

Dear X,

We are targeting a select group of academics with expertise in social discounting. The objective is to elicit recommendations on fundamental issues of discounting to inform long-term public investment decision-making.

We would be most grateful if you could find the time to complete the very short survey appended below.

https://www.surveymonkey.com/s/discounting-survey

Your individual response will be held in the strictest confidence.

Many thanks for your time and cooperation,

Ben Groom (LSE), Moritz Drupp (Kiel, LSE),
Frikk Nesje (Oslo, LSE), Mark Freeman (Loughborough)

A.2 Online Survey Text

Imagine that you are asked for your advice by an international governmental organization that needs to determine the appropriate social discount rate for calculating the present value of risk-free cash flows of public projects with intergenerational consequences.

For its calculations, the organization needs single values for the components of the social discount rate. While this does not capture all of the important complexities of social discounting, including time horizon-dependent individual discount rates, it does reflect most existing policy guidance on the matter. Your answers will therefore help to improve the current state of decision-making for public investments.

Specifically, you are asked to provide your recommendations on the single number, global average and long-term (>100 years) values of the following determinants of the social discount rate:

1. Growth rate of real per-capita consumption [X% per year];

2. Rate of societal pure time preference (or utility discount rate) [X%];

3. Elasticity of the marginal utility of consumption [X];

4. Real risk-free interest rate [X% per year]; Remember that this should be a global average and long-term forecast.

5. What relative weight (summing up to 100%) should the governmental body place on the following rationales for determining the social discount rate:,

   (a) Normative issues, involving justice towards future generations [X%], and

   (b) Descriptive issues, involving forecasted average future returns to financial assets [X%].

6. What is your recommended real social discount rate for evaluating the certainty-equivalent cash flows of a global public project with intergenerational consequences [X% per year];

7. What minimum and maximum real social discount rate would you be comfortable with recommending [X% to X% per year]?

8. Do you have any additional comments? [X]

B Further Detail on the Selection of Experts

Based on full-text analysis in the Google scholar engine, we searched the 102 leading economics journals (according to the ranking of Combes and Linnenmer 2010) plus the Review of Environmental Economics and Policy for publications since the year 2000 including the terms 'social discounting', 'social discount rate' or 'social discount factor' (in March/April 2014). As a result, we identified 778 potential experts. Because not all pertinent contributions to the field use the term 'social discount rate', but often 'real discount rate' or simply 'discount rate', we further performed an EconLit search for the term 'discount rate' (in April 2014). To avoid picking up a large number of papers that only mention a 'discount rate' in passing somewhere in the paper, we limited the scope to a within-abstract search. This search yielded an addition of 241 potential experts. We thus identified a total of 1019 unique potential experts. Some of these scholars should, however, not be classified as experts because their publications are not pertinent to social discounting. Two of the authors therefore manually discarded – using a weak relevancy test – publications that are clearly not relevant. When both authors were in doubt, the paper was included. The criteria used to judge whether a publication is not relevant are listed below:

- If the search phrases do not appear in the article itself, but only in the reference list.
- If the publication is a book review or another non-original contribution.
- If a parameter for the SDR is included without any explicit discussions or references to the literature.
- If a value for the SDR is simply applied in an analysis without reference to the literature.
- If one of the phrases is mentioned but not elaborated on.
- If the publication relies on a discount rate that is clearly not relevant to long-term social discounting by governmental bodies, such as discounting of profits or university fees.

A publication is labeled irrelevant if it meets at least one of the listed criteria. If at least one of the publications of a scholar is regarded to be relevant (i.e. passes this weak relevancy test), she is considered to be a potential expert. As a result of the above relevancy test, we exclude 365 scholars from the pool of potential experts, thus being left with 654 potential experts. For 27 of these scholars we could not obtain an e-mail address. Reasons include that such scholars have left academia or are deceased. Our final population of potential experts thus contains 627 scholars.

C Further Detail on Qualitative Feedback

This Appendix provides further details on the qualitative feedback received. While we cannot print every comment received, we report the preamble of one answer that shall serve to illustrate the time and thought many of our respondents put into answering the survey. Furthermore, we report in Table 9 an overview of all subcategory issues mentioned, thus including those with less than 5 mentions.

Dear members of the panel. I am asked to provide you with some information that can help you deciding on the public projects with very long-term consequences. Before I present my answers, I feel that I need to provide you some background information, as you may otherwise easily misunderstand my replies. When we assess projects, we need to admit that the current state of the world is full of uncertainties – does anyone know the precise size of the informal sector, or the increase in happiness with income and employment and its variety between individuals – and that these multiply when we look further away in time. We necessarily abstract from most uncertainties and develop a model that helps us to bring all information together into one denominator. In such a model, most uncertainties are neglected, and sometimes a few remain when these are considered most important, most interesting, or easiest to accommodate. Almost a century ago, a great mathematician analyzed the rules for optimal investment. He set up a model with an infinite living agent that maximizes some cumulative measure of welfare, and derived mathematically a rule for optimal investment, which is named after him, the Ramsey rule. The rule has gained enormous popularity in economics; it is elegant and easy to understand. The rule states that the marginal productivity of investments should be positive for two reasons. First, the marginal utility of consumption tends to go down when consumption levels increase. Thus, if future consumption is higher, then present consumption is worth more, and if I have to invest one consumption good in present, I want more than one consumption good in return in the future. The strength of this mechanism depends on the growth rate of consumption, and the so-called elasticity of marginal utility. Then, Ramsey noted that people may also dislike to give up current consumption for the benefit of the future purely on the basis of the time-line: we give more weight to the present vis-a-vis to the future. In the literature, this is called pure discounting. I have been asked to provide you with my estimate of the elements of the Ramsey rule, so that you can decide on the return that you will require from investments in long-term projects, such as investments in

clean energy that may limit climate change. I object. I have sympathy for the play with models, in which I also engage. But from my experience I conclude that the Ramsey rule cannot be applied to long-term social questions, without information on the context. My objection stems from the very first paragraph written by the committee that invited me. It is assumed that the public project can be interpreted as a stream of certainty-equivalent cash flows. Such projects may exist, but more importantly, if I answer these questions, my responses will undoubtedly be applied to projects where this assumption is fundamentally flawed. For climate change, for rainforest, coral reef and biodiversity protection, for nuclear safety, there is no certainty equivalent cash flow. How much are we willing to pay to preserve a climate that warms 2 degrees versus one that warms 3 degrees? How much are we willing to pay to preserve the blue whale, or the Amazon? Only if we assume that such questions have reasonable answers, can we start thinking about the Ramsey rule for related projects. Economists have tried to provide approximations for the costs of climate change, and then typically assume that all costs not evaluated in the market-place are zero, but some earth citizen may object that they believe they have some rights to let their grandchildren inherit a naturally rich world, and that these rights should be balanced against the rights by others to destroy part of the world richness. The question is about rights for the future, not about costs. How much do you believe society should be willing to pay for children's rights for education, or women's rights for voting, or freedom of slavery? If you consider such questions out of place, you may consider the typical long-term public project assessment equally out of place. Now that I have given you all my objections, I am happy to share with you some of my thoughts on the parameters of the Ramsey rule.

Table 9: Comprehensive Overview of Qualitative Responses

Issue	N	Exemplary quote
Q1: Growth rate	14	I foresee a very bright economic future with a continued 2% growth rate for the coming century.
Q2: Pure time preference	10	I see no reason to treat generations not equally.
Q3: Elasticity of marginal utility	12	The elasticity of MU of consumption is heterogeneous, and using a single value is — it seems to me — a crude simplification.
Q4: Real risk-free interest rate	8	There is no interest rate for 100 year horizon (to my knowledge).
Q5: Normative vs. positive	16	The components of the SDR are overwhelmingly normative in nature.
Q7: Range for the SDR	4	I contemplated a negative minimum number, but this made me uneasy. But I think economists should take negative rates more seriously.
DDRs and time horizon	20	I am more comfortable with declining discount rates (DDRs) [...] due both to declining time preference rates and to uncertainty about future consumption growth.
General equilibrium effects	3	When the real return on investments is endogenous to market regulation [etc], we better ask ourselves what we would consider a proper mechanism to determine the social costs of carbon.
Heterogeneity & aggregation	19	Ideally, the input for our SWF would be a utility function that allows for heterogeneous preferences.
Marked distortions & failures	3	Incomplete futures markets justify social discount rates lower than real market rates.
Opportunity cost of funds	8	SDRs should reflect the social opportunity cost of borrowed funds.
OLG framework	2	Thinking in an overlapping generations framework may lead to different conclusions about discounting and interest rates.
Project risk	6	We would have to consider very carefully the risk structure of the investment to get a correct discount rate.
Substitutability & environmental scarcity	20	If future costs/benefits accrue e.g. to environmental amenities, I would argue for a very low discount rate, based on an expectation of increasing relative prices for these goods.
Tax issues	4	Returns on financial assets underestimate real rates of return due to corporate.
Uncertainty	20	We need to admit that the current state of the world is full of uncertainties. [Yet] most uncertainties are neglected, and sometimes few remain when these are considered most important, [...] or easiest to accommodate.
Alternatives to discounting	15	Instead of imposing a SWF and calculate the corresponding optimum, it is 'better' to depict a set of feasible paths of consumption, production, temperature, income distribution, etc. and let the policy maker make a choice.
Comments on the survey	14	The search for THE discount rate, if that is your project, is deeply flawed.
Confidence intervals	8	I would also insist on providing confidence intervals.
Ramsey Rule	17	My discount rate is less than implied by the Ramsey rule because I use the extended rule, incorporating uncertainty.
Role of experts	7	I really think economists have very little special expertise in knowing the 'right' number. These parameters should be chosen in an open, iterative way with an eye toward understanding the consequences of different choices.
Anonymity	4	I assume that individual responses will be kept confidential.
Limited confidence	13	Please ignore my response to Q4: I don't have the knowledge to make a meaningful forecast.
Limited expertise	5	I am not a real expert on these issues.

D Further Details on Analysis of Responses

This Appendix reports on a comparison of Weitzman's (2001) data with the imputed Ramsey Rule's social rate of time preference (SRTP) of our survey results depicted in Figure 7.

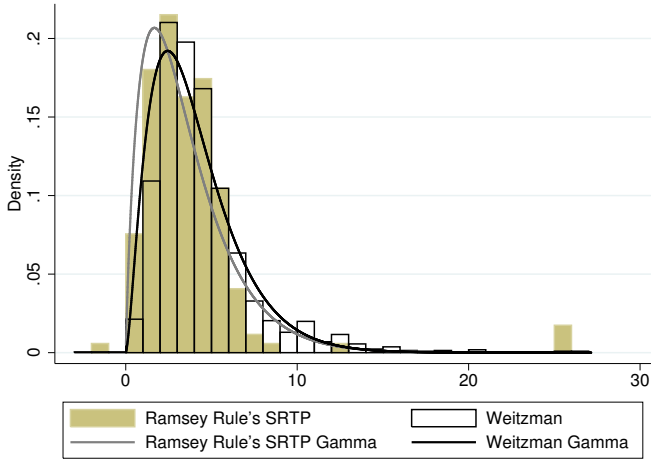


Figure 7: Comparing results of Weitzman's (2001) data to the imputed Ramsey Rule's SRTP.

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