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Siblings, Not Triplets: Social Preferences for Risk, Inequality and Time in Discounting Climate Change

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Abstract

Arguments about the appropriate discount rate often start by assuming a Utilitarian social welfare function with isoelastic utility, in which the consumption discount rate is a function of the (constant) elasticity of marginal utility along with the (much discussed) utility discount rate. In this model, the elasticity of marginal utility simultaneously reflects preferences for intertemporal substitution, aversion to risk, and aversion to (spatial) inequality. While these three concepts are necessarily identical in the standard model, this need not be so: well-known models already enable risk to be separated from intertemporal substitution. Separating the three concepts might have important implications for the appropriate discount rate, and hence also for long-term policy. This paper investigates these issues in the context of climate-change economics, by surveying the attitudes of over 3000 people to risk, income inequality over space and income inequality over time. The results suggest that individuals do not see the three concepts as identical, and indeed that preferences over risk, inequality and time are only weakly correlated. As such, relying on empirical evidence of risk or inequality preferences may not necessarily be an appropriate guide to specifying the elasticity of intertemporal substitution.

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1 Introduction

Nowhere are the theoretical and empirical challenges of discounting more evident than in the context of public policies with very long-run consequences, such as climate change (Broome, 1992; Cline, 1992; Nordhaus, 1994). The starting point of analysis remains the canonical work of Ramsey (1928), who showed in a now standard model we describe below that the optimal consumption discount rate is given by

$$r_t = \delta + \eta g_t \quad (1)$$

where r_t is the consumption discount rate at time t , δ is the pure rate of time preference (or utility discount rate), η is the elasticity of the marginal utility of consumption, and g is the growth rate of consumption.

Much of the recent discounting debate, stimulated by the Stern Review (Stern, 2007), has focused on the ethics of δ . Yet while δ is important to the economics of climate change, so too are η and g . As Anthoff, Tol and Yohe (2008), and Stern (2007) demonstrate, the costs and benefits of mitigating climate change are very sensitive to the specific parameter choice for η . Unfortunately, the debate following the Stern Review has shown that there is little agreement on precisely what value η should take. This is in large part because, in the ‘workhorse’ model of welfare economics as applied to climate change, η simultaneously represents preferences over three significant dimensions of the policy issue, namely risk, inequality within a generation (which we shall usually call spatial inequality) and inequality in consumption between generations:

1. **Risk**: uncertainties about the impacts of climate change are large and may in part be irresolvable (as emphasised by Stern, 2007). Furthermore, the worst-case scenarios imply very large damages on a global scale (e.g. Weitzman, 2007);
2. **Time**: the marginal impact of a tonne of greenhouse gas persists long after it has been emitted;
3. **Space**: there are large spatial disparities in the relative impacts of climate change worldwide, with tropical and sub-tropical low-income regions widely expected to experience some of the greatest relative damages (IPCC, 2007).

Considering evidence on risk preferences, Gollier (2006) supports values of η in the range 2-4. By contrast, evidence from the actual distribution of income within countries might suggest a value of unity or less (Atkinson and Brandolini, 2007). Dasgupta (2007) and Weitzman (2007) take yet another approach, backing out the appropriate value of η from evidence on the appropriate consumption discount rate. This approach leads them to recommend that η be greater than unity.

This divergence suggests it would be worthwhile to examine whether public attitudes to climate change support a model in which preferences over risk, inequality and time are identical, or whether they in fact support a model in which these preferences are distinct. This is the objective of our paper, which reports the outcomes of the Climate Ethics Survey – a stated-preference survey delivered online to over 3000 respondents. The survey poses direct questions about hypothetical consumption choices under each of the three defining characteristics of climate change. The results show that the correlations between attitudes to risk, inequality and intertemporal substitution are weak. This suggests that the standard model is not well-suited to incorporating the

attitudes of the public into the analysis of climate change, and provides a rationale for disentangling the three concepts.

The next section investigates the theory and practice of economic modelling of risk, inequality and time, and shows that the approach taken to the three issues has a very strong influence on the economic analysis of climate change. Section three describes the methodology used in the empirical research. Our findings are presented in section four and discussed in section five. Section six concludes.

2 Theory

Let the elasticity of the marginal utility of consumption be denoted by $\eta = \frac{-u''c}{u'}$, where c is consumption (defined in the broadest sense) and u is a utility function. Assume that the utility of individual i , in state of nature s , at time t is a function of that individual's consumption in the same time period: $u_{its} = u(c_{its})$. In the workhorse model, the utility function takes the specific iso-elastic form:

$$u_{its} = \frac{c_{its}^{1-\eta}}{1-\eta} \quad (2)$$

Assume that social welfare, W , is Utilitarian, represented by the unweighted sum of individual utilities, and that the problem is to aggregate over individuals, states of nature and time periods. Then (expected) social welfare is given by

$$E(W) = \sum_{i=1}^I \sum_{t=0}^T \sum_p p_s(u_{its})(1+\delta)^{-t} \quad (3)$$

where p_s is the probability of state of nature s occurring and δ is the utility discount rate. With this specification, η completely determines (social) aversion to inequality in consumption between individuals (i.e. over space), (social) aversion to inequality in consumption over time, and is a coefficient of relative risk aversion. In this framework, the optimal consumption discount rate, r , for a given growth rate g , will be given by equation (1).¹

Due to the triple role that η plays, there are three distinct sources of data that have been used for calibration. Moreover, there are at least two fundamentally different approaches to the study of each of the three elements of η . Revealed-preference approaches attempt to infer preferences from observed behaviour in markets, or alternatively from the observed egalitarianism of the tax system. This is in contrast to stated-preference approaches, which ask respondents about their preferences in hypothetical choice situations. The large array of different data sources and research methods has given rise to a wide range of values for η . In an early study, Stern (1977)

¹ Under uncertainty about g , the optimal risk-free consumption discount rate r^f is given by $r^f = \delta + \eta\mu + \frac{1}{2}\eta^2\sigma^2$, where μ is the mean and σ^2 the variance of growth, which is assumed to be i.i.d. normal.

produced estimates ranging all the way from 0 to 10 based on revealed-preference studies of all three of the dimensions of η .

In the context of climate change, there is a strong ethical element to the choice of η . In addition, the outcome of numerical modelling of climate policy is very sensitive to this parameter (Anthoff, Tol and Yohe, 2008; Stern, 2007). η has often been set to unity (Fankhauser et al., 1997; Nordhaus and Boyer, 2000; Stern, 2007; Tol, 1997), which gives the particularly tractable case of equation (2) where utility is the natural logarithm of consumption. However, other economists, including Dasgupta (2007), Weitzman (2007) and Gollier (2006) have suggested this value is too low. Like the numerical estimates in the literature, these arguments are typically based on only one of the three dimensions of η , and it is not clear that they are equally valid to all three. It therefore appears that disentangling the three may reduce the domain for disagreement (Beckerman and Hepburn, 2007; Dietz et al., 2008).

The relationship between η and the optimal rate of greenhouse gas emissions control is a priori unclear, because increasing η has three possibly divergent effects (Anthoff, Tol and Yohe, 2008; Dietz et al., 2007). In the context of estimates of climate-change damage, higher aversion to intertemporal inequality might well lower present-value estimates of long-run damage, because it increases the discount rate as long as expected future growth rates are positive. Higher risk aversion, on the other hand, might well increase damage estimates, as more weight is placed on outcomes with a low probability and very low consumption. This would be reinforced by higher aversion to spatial inequality, because relative impacts are on the whole higher in countries with lower incomes.

A handful of theoretical models exist that can disentangle risk aversion from intertemporal substitution. The first were developed simultaneously but independently by Kreps and Porteus (1978) and Selden (1978), and represent generalizations of the expected-utility model (von Neumann and Morgenstern, 1944), which emerges as one particular case. Epstein and Zin (1989) and Weil (1990) extended the two-period Kreps-Porteus-Selden model to a multi-period context. These are the richest models to date, and have preserved the expected-utility model's desirable feature of dynamic consistency. Kreps-Porteus preferences have been used in an analytical model of climate-change impacts by Ha-Duong and Treich (2004), but to our knowledge none of these preference structures have been incorporated into a numerical analysis of climate change. Using a non-Utilitarian social welfare function would also disentangle risk aversion from inequality aversion and intertemporal substitution. Such functions have been applied to climate change by Fankhauser et al. (1997), but only in an a-temporal setting. An important theoretical lacuna still exists because no model to date enables all three concepts to be disentangled simultaneously.

It is important to note that a rationale has been given for why preferences over risk, spatial inequality and intertemporal substitution should be identical. Harsanyi (1955, 1976) argued that if people were to choose between different income distributions from behind a 'veil of ignorance', aversion to spatial inequality would be identical to risk aversion. Broome (1991) further proved formal theorems showing that if certain conditions are fulfilled, consistency may require that risk aversion, aversion to spatial inequality and aversion to temporal inequality must all be equal.

However, the veil of ignorance does not exist in reality, which places some limitations on its relevance for actual moral judgements. Furthermore, evidence from

hypothetical choice experiments and subjective measures of well-being suggest that Broome's conditions for the distribution of consumption in the three dimensions are systematically violated.²

3 Methodology

3.1 Relevant Existing Studies

In the context of climate change and many other policy questions, η is essentially an ethical parameter. This makes it problematic to use observed behaviour in markets to estimate its value, as explained by Beckerman and Hepburn (2007) and Dietz et al. (2008). Hence there are weaknesses in using revealed-preference methods to address our question. Theoretical and philosophical arguments have a bearing, given the ethical nature of the parameter. However, this does not imply that public preferences can be ignored, since in functioning democracies these arguments will ultimately have to be justified in public debate (Miller, 1992). This study therefore takes an intermediate approach, by conducting a stated-preference survey of the general public.

Our research is related to Carlsson et al. (2005), who investigate stated preferences over risk and inequality among undergraduate students in Sweden. Respondents are asked to make choices on behalf of their imaginary grandchildren. One experiment measures risk aversion with the level of inequality fixed, while another experiment measures inequality aversion in a setting with no risk. The results suggest that relative risk aversion is between 2 and 3 and that relative inequality aversion is between unity and 2. The results indicate a correlation between the two parameters of 0.46.³ Note the standard welfare model implicitly assumes a perfect correlation.

Barsky et al. (1997) elicit estimates of risk aversion and intertemporal substitution in the context of personal income. Their questions are delivered to a subsample of the large Health and Retirement Survey in the United States. Two thirds of respondents display a coefficient of relative risk aversion greater than 3.76, while 72 per cent of respondents display aversion to intertemporal income inequality greater than 3.45. Nevertheless there is no significant correlation between individual risk aversion and preferences over intertemporal substitution.⁴ Cameron and Gerdes (2007) also investigate stated preferences over risk and time. Taking a large convenience sample of college students in the United States, respondents on time preference are asked to choose between taking lottery winnings as a lump sum or in instalments, while

² The critical condition is what Broome refers to as *separability*. It requires that what happens in one location of a dimension can be evaluated independently of what happens in other locations in the same dimension. The dimensions in question are time, people, and states of nature. Evidence suggests that this does not hold for evaluations of income across the dimensions of time and people, as we compare our current income with our previous income, and with that of our peers (see e.g. Di Tella and McCulloch, 2006; Layard, 2005). The Allais paradox (1953) describes systematic violations of separability across states of the world.

³ Another study by the same authors (Johansson-Stenman *et al.*, 2002) contains a similar experiment on risk, except that inequality is not fixed. Consequently the results can be interpreted as measures of either risk aversion or inequality aversion, the median of which is between 2 and 3.

⁴ Although the test had limited statistical power because the number of useful observations was only 116.

respondents on risk preferences are asked to choose between a certain and risky investment. They too find a relatively weak correlation between their measures of risk aversion and time preference. However, their measures do not correspond to η in the standard welfare model above. Rather, the measure of time preference is the consumption discount rate, while they specify an ad hoc measure of risk aversion.

The Climate Ethics Survey builds on these previous studies. The original contribution is two-fold. Firstly, all three elements of η are incorporated in the same questionnaire, allowing within-sample and within-subject comparisons, in particular permitting an analysis of the correlation between individual preferences over the three domains. Secondly, the survey explores the justification for disentangling η specifically in the analysis of climate change. Previous studies have tended to abstract from real policy questions to ask individuals about, for example, personal investment choices. Here we ask respondents to express preferences for choices that affect the whole of society, not just themselves, and that offer returns over very long time-scales.

3.2 The Experiments

The survey consisted of five parts: 1) questions on general attitudes; 2) the inequality-aversion experiment; 3) the risk-aversion experiment; 4) the intertemporal-substitution experiment; and 5) demographic questions. It was created in six different versions in order to accommodate different currencies and different levels of purchasing power. Individual versions were targeted at the UK, the United States, Canada, Australia and Mexico, while respondents from other countries were offered a general version, with figures in US dollars. The general questionnaire version is available in Appendix III of the following document:

[http://www.economics.ox.ac.uk/members/cameron.hepburn/Helgeson\(2007\).pdf](http://www.economics.ox.ac.uk/members/cameron.hepburn/Helgeson(2007).pdf) .

Graphs were used to help illustrate the questions on inequality and intertemporal substitution. This is in line with recent research on stated-preference surveys, which suggests that visual illustrations may increase the ‘evaluability’ of numeric questions (Bateman et al., 2006). Each of the three experiments contained a short introduction, which explained the questions in simple terms and listed some assumptions that respondents needed to make. Not all the assumptions are reproduced here, but they can be found in the online survey. To reduce problems with learning and order effects, respondents were made aware that they could go back and change responses in previous sections if they so wished.

The survey was distributed through a number of different e-mail lists, which are given in Appendix I. It was also advertised on the social networking website Facebook. The resulting sample is purely a convenience sample. Sample biases will be discussed in section five.

3.2.1 Risk Aversion

Our risk experiment has two characteristics that together distinguish it from typical studies in economics and psychology: the stakes are high and the risks apply to the

whole national economy⁵. This makes the results particularly relevant for the analysis of climate change. The structure of the questions borrows from Barsky et al. (1997), but the framing is modified to measure aversion to societal rather than individual risk.

The experiment uses a triple-bounded dichotomous choice format. Respondents are grouped into eight categories based on their answers to three questions each. In the first question, respondents are asked whether they would be willing to have their government adopt a policy that gives a 50% chance of doubling the national average income and a 50% chance of cutting it by one third. Those who answer ‘Yes’ (‘No’) are presented with a second question that is identical, except that the amount by which income is cut is now increased to 50% (15%). Similarly, those answering ‘Yes’ (‘No’) to the second question are then given a third question, in which the policy is more (less) risky still.

In the standard economic framework, the responses to these questions can be used to derive a measure of aversion to risk to society. An expected-utility maximiser whose income changes proportionally to national average income will accept a policy that gives a 50% chance of income doubling and a 50% chance of income falling by a fraction of θ , if and only if

$$\left[\frac{1}{2}u(2\bar{y}) + \frac{1}{2}u(1-\theta)\bar{y} \right] \geq u(\bar{y}) \quad (4)$$

where \bar{y} denotes national average income. Assuming an isoelastic utility function, this becomes

$$\left[\frac{\frac{1}{2}(2\bar{y})^{1-\eta^s}}{1-\eta^s} + \frac{\frac{1}{2}((1-\theta)\bar{y})^{1-\eta^s}}{1-\eta^s} \right] \geq \frac{\bar{y}^{1-\eta^s}}{1-\eta^s} \quad (5)$$

which simplifies to⁶

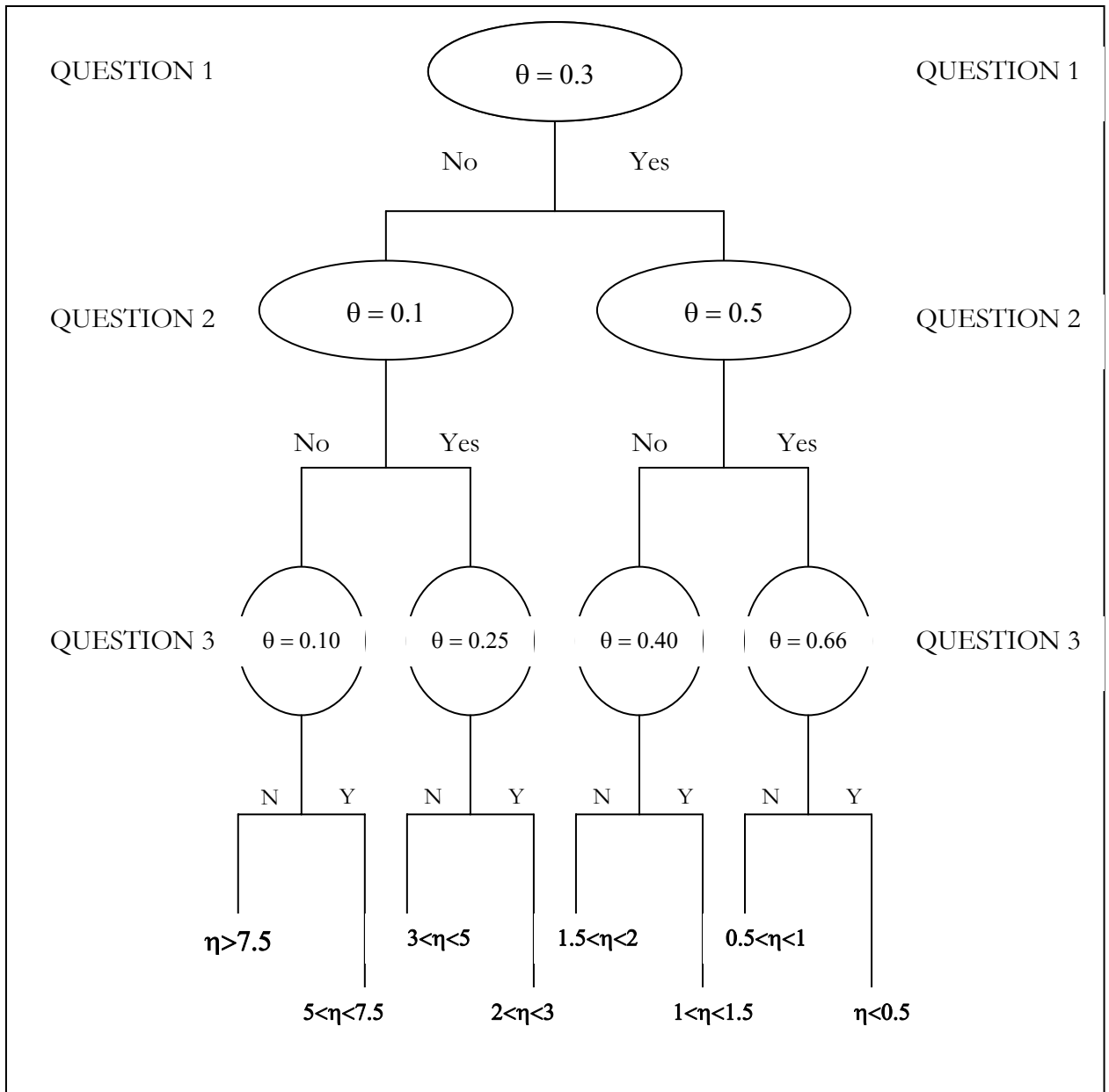
$$\left[\frac{\frac{1}{2}(2)^{1-\eta^s}}{1-\eta^s} + \frac{\frac{1}{2}(1-\theta)^{1-\eta^s}}{1-\eta^s} \right] \geq \frac{1}{1-\eta^s} \quad (6)$$

where η^s is the coefficient of relative risk aversion (s denoting a state of nature as before). These equations can be used to find intervals of η^s corresponding to each of the eight combinations of answers. Figure 1 illustrates the structure of the questions in this section. It gives the value of θ in each question, and shows what questions respondents will be asked based on their previous answer. Furthermore, it lists intervals of η^s , into which respondents are categorised.

⁵ The survey also contained an experiment on risks to individuals but, for the sake of brevity, the results are not reported in this paper. Further data can be obtained from the corresponding author.

⁶ For $\eta^s=1$, the equation is: $\left[\frac{1}{2}\ln(2) + \frac{1}{2}\ln(1-\theta) \right] \geq 0$

Figure 1. Triple-bounded dichotomous choice format for risk-aversion experiment.



3.2.2 Inequality Aversion

To investigate aversion to spatial inequality in income, respondents are presented with a pair of hypothetical income distributions and are asked to choose the one they prefer. The options are described in terms of maximum (y_{max}), average, and minimum income (y_{min}). Option A always offers the highest total income, while option B always provides the more equal distribution. Figure 2 gives an example of our graphical presentation of the choice.

Each respondent is asked three such questions, giving the same triple-bounded format as before. Thus option A remains the same in each choice, but the income levels in option B change each time. This makes it possible to see how much total income the respondent is willing to trade off for a more equal distribution. The income figures in option A were chosen to reflect the 90th percentile and the 10th percentile of the world distribution of real income as reported by Dikhanov (2005)⁷.

Figure 2. Graphic illustration of income distributions.



Under the assumptions of the standard model, this information can be used to estimate the coefficient of relative inequality aversion. The mathematical structure is based on Carlsson et al. (2005) and Johansson-Stenman et al. (2002), but the question-framing is different.

Respondents are told that people are distributed uniformly between the two income extremes, since this distribution is particularly easy to interpret. With this uniform distribution, the social welfare arising from each income distribution is given by

$$W = \int_{y_{\min}}^{y_{\max}} \left(\frac{\bar{y}^{1-\eta^i}}{1-\eta^i} \right) \left(\frac{1}{y_{\max} - y_{\min}} \right) dy = \left(\frac{1}{(1-\eta^i)(2-\eta^i)} \right) \left(\frac{y_{\max}^{2-\eta^i} - y_{\min}^{2-\eta^i}}{y_{\max} - y_{\min}} \right) \quad (7)$$

⁷ The survey also contained an experiment on the distribution of income within a country, which is not reported in this paper but is available from the corresponding author. Future work could try to differentiate between aversion to spatial inequality on a global scale and aversion to spatial inequality on a national scale.

where η^i refers to relative aversion to spatial income inequality⁸. If a respondent is indifferent between distributions A and B, we have $W(A)=W(B)$ and hence from equation (7) we have

$$\left(\frac{y_{\max,A}^{2-\eta^i} - y_{\min,A}^{2-\eta^i}}{y_{\max,A} - y_{\min,A}} \right) = \left(\frac{y_{\max,B}^{2-\eta^i} - y_{\min,B}^{2-\eta^i}}{y_{\max,B} - y_{\min,B}} \right) \quad (8)$$

Solving this equation for η^i gives the minimum inequality aversion for someone choosing option B, or the maximum for someone choosing option A. For consistency, we use the same intervals of η as in the risk-aversion experiment (see figure 1).

Respondents are asked to make several assumptions to ensure that the questions are interpreted in the intended manner. Specifically, they are told that prices are consistent across the two options, that there is no welfare state, and that economic growth rates would not be affected by the choice. Respondents are further told to assume that their own position in the income distribution would be approximately the same as in reality. If respondents were choosing from behind a ‘veil of ignorance’, choices would be influenced by risk aversion, as stressed by Rawls (1971) and Harsanyi (1955). To keep risk aversion and inequality aversion separate, uncertainty about the respondent’s personal position needs to be eliminated. Finally, respondents are told that the very poorest and the very richest live outside the stated range, in order to reduce problems with lexicographic responses stemming from a sole focus on, for example, the poorest individuals in a society.

3.2.3 Intertemporal Substitution

The structure of the questions on intertemporal substitution is also taken from Barsky et al. (1997), who asked respondents to choose between different options for allocating consumption before and after retirement. We applied their structure to national borrowing and saving and lengthened the timeframe to 200 years to make the choice situation similar to climate-change policy decisions.

Respondents are given the following information:

Some of the policies adopted by governments affect how the standard of living will change in the future. Many of these policies can be thought of in a way similar to your own decisions on how much to spend and how much to save.

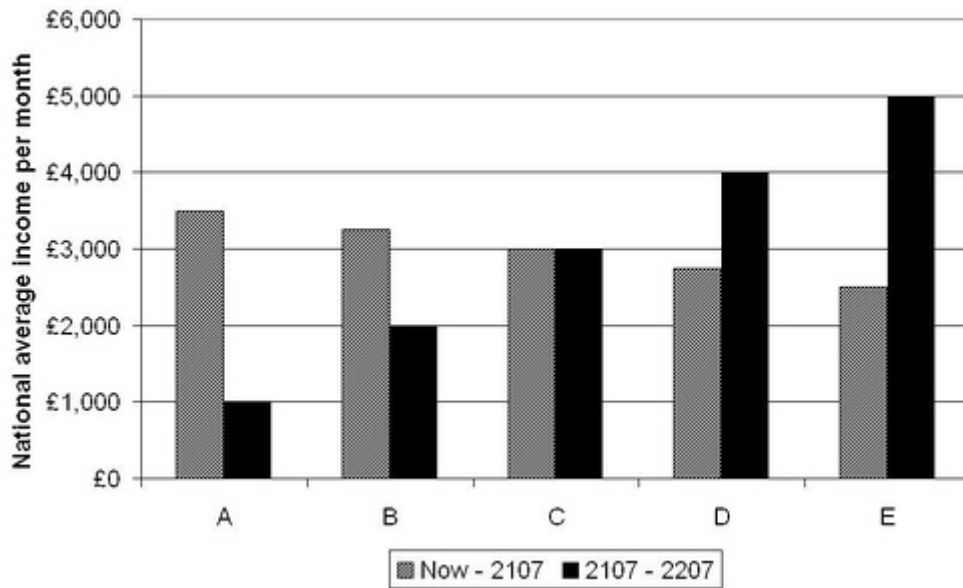
They are then asked to choose between different government plans for spending and saving, each with different implications for living standards in two time periods: 2007-2107 and 2107-2207. The measure of living standard used is national average real income.

⁸ For the special case of $\eta^i=1$ we have: $W = \left(\frac{y_{\max} \ln y_{\max} - y_{\min} \ln y_{\min}}{y_{\max} - y_{\min}} \right) - 1$

and for $\eta^i=2$ we have : $W = \left(\frac{\ln y_{\max} - \ln y_{\min}}{y_{\max} - y_{\min}} \right)$

The first question contains only three alternative spending plans, and serves as a warm-up for respondents to familiarise themselves with the format. They are then presented with three further questions, each with five alternative spending plans (A-E in figure 3). In each question, the present discounted value of each option is the same for a given interest rate. This interest rate is zero in the warm-up question and the first of three full questions, then in the two subsequent full questions it is 1.39% and -1.39% respectively. Figure 3 gives an example choice card.

Figure 3. Graphic illustration of income paths.



To interpret the responses, we observe that Ramsey's formula for the optimum consumption discount rate (equation 1) can be rearranged to find the optimum growth rate of consumption for a given market interest rate:

$$g_t = \frac{1}{\eta^t} (r_t - \delta) \quad (9)$$

where $1/\eta^t$ is the elasticity of intertemporal substitution. Equation (9) contains two known parameters, the growth rate g and the market interest rate r , and two unknown parameters, η^t and δ . From each of the questions, we observe a respondent's preferred g at a given r . Comparing choices in two questions makes it possible to solve for η^t and δ . However, since each question offers only five choices of g , it is likely that the respondent's most preferred g lies somewhere in between two choices. Their preferences can therefore only be estimated to within a range, the breadth of which is limited by the number of questions we can ask.

4 Results

4.1 Sample Size and Demographics

In total, we received 3645 responses. Of those, 505 responses were considered anomalous due to reasons that will be described in section 4.4. These were discarded altogether, leaving 3140 responses in total. Since all the questions were optional, the total number of responses varies slightly across the three experiments. The demographics of the sample are summarised in table 1 and discussed in section 4.6.

Table 1. Sample demographics.

Region of residence	Mean Age	Median Household Income Bracket	Percent Female	Members of Env. Groups	Sample Frequency
Canada	27.5	£40000-£50000	55.9 %	19.1 %	31.1 %
UK	30.2	£40000-£50000	44.4 %	30.8 %	29.1 %
USA	32.3	£50000-£60000	40.8 %	41.4 %	12.3 %
Oceania	31.4	£50000-£60000	49.5 %	30.4 %	6.0 %
Scandinavia	29.1	£30000-£40000	45.4 %	23.7 %	4.8 %
Rest of Europe	31.2	£30000-£40000	44.3 %	40.3 %	5.3 %
Rest of World	30.2	£30000-£40000	42.2 %	31.3 %	11.4 %
Sample	29.7	£40000-£50000	47.2 %	27.8 %	100.0 %

n=3140

4.2 Risk Aversion

The results from the questions on risk aversion are reported in table 2. The median η^s is in the interval 3-5, and this is also the modal group. People in this group rejected a policy that gives equal chances of doubling national income and of reducing it by one quarter, while accepting a policy where the reduction amounts to 15%.

These results are comparable to results of surveys that have estimated aversion to personal risk. Carlsson et al. (2005) obtain a median estimate of between 2 and 3, while in Barsky et al.'s (1997) study the median respondent displays a coefficient of relative risk aversion greater than 3.76. The median range also overlaps with what is typically found in revealed-preference studies of risk aversion (see Gollier, 2006). Taken together, this suggests that the logarithmic utility function underestimates people's actual aversion to risk.

Table 2. Frequency distribution for relative risk aversion.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<0.5	80	2.5	2.9	2.9
	0.5-1.0	114	3.6	4.1	7.0
	1.0-1.5	114	3.6	4.1	11.2
	1.5-2.0	467	14.9	17.0	28.2
	2.0-3.0	136	4.3	4.9	33.1
	3.0-5.0	890	28.3	32.3	65.4
	5.0-7.5	387	12.3	14.1	79.5
	>7.5	565	18.0	20.5	100.0
Missing		387	12.3		
Total		3140	100.0		

4.3 Inequality Aversion

Table 3 presents the results from the experiment on spatial inequality aversion. The median value of η^i is one category below η^s , at between 2 and 3, but the modal group is the upper extreme, above 7.5. There is also a higher frequency in the lowest category than there is for risk. Possible reasons for this distribution are discussed in section five. The median estimate is the same as that of Johansson-Stenman et al. (2002), while higher than that of Carlsson et al. (2005). However, our choice context is different to Carlsson et al. (2005), where respondents are asked to evaluate different distributions from the perspective of someone who is guaranteed to receive the median income of whichever distribution is chosen. In our survey, respondents are asked to evaluate different income distributions given their current position in society (which may be above or below the median). Hence it is not surprising that the respondents in Carlsson et al.'s (2005) study put less weight on equality. In our survey there is always a trade-off between equality and the median income.

Table 3. Frequency distribution for relative aversion to inequality.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0.5-1.0	151	4.8	5.4	19.7
	1.0-1.5	168	5.4	6.0	25.8
	1.5-2.0	197	6.3	7.1	32.9
	2.0-3.0	509	16.2	18.3	51.2
	3.0-5.0	343	10.9	12.3	63.5
	5.0-7.5	162	5.2	5.8	69.3
		>7.5	852	27.1	30.7
Missing		361	11.5		
Total		3140	100.0		

4.4 Intertemporal Substitution

Most respondents displayed a very low elasticity of inter-temporal substitution, or in other words, a very high aversion to inequality in income across time, η^t . Because of the large number of answer combinations possible, the respondents cannot be grouped into a few non-overlapping categories. For each valid response, we calculated the range of values for the elasticity of inter-temporal substitution ($1/\eta^t$) consistent with the choices made. For the median respondent, the midpoint of this range is 0.11, which corresponds to a value of η^t of 8.8. This seems to be broadly in line with the results of Barsky et al. (1997). They do not report the preferences of the median respondent, but instead report the modal response, which gives a midpoint corresponding to $\eta^t=8.7$.

These low elasticities arise because respondents changed their preferred consumption path very little in response to changes in the implicit market interest rate. The most common response (24%) was always to choose a flat path. The second most common response (20%) was always to prefer a moderately upward sloping path. This tendency was also found by Barsky et al. (1997). In their experiment, over 70% of respondents chose one of these two paths. In a follow-up study to Barsky et al. (1997), Kapteyn and Teppa (2003) find that in three out of four consecutive choices the most frequent response is a flat consumption path. Only in the first question in the series is the slightly upward-sloping consumption path more frequently chosen, and this can potentially be attributed to learning effects.

While not the main focus of this paper, the questions about time preference also provide information about δ . The results indicate that on average respondents have a negative δ . This tendency is often found in psychological experiments (see e.g. Loewenstein and Prelec, 1993), but is not evident in market behaviour (see e.g. Nordhaus 2007). For a discussion of why market behaviour may not reveal people's true utility discount rate see Dietz et al. (2008).

The time-preference experiment contained a check on the rationality of respondents. The first two questions were identical, except that the second contained two additional options. Out of the total of 3645 respondents, 141 (4%) answered these questions in an inconsistent manner. In addition, a further 363 (10%) reacted perversely to changes in the market interest rate (r), implying a negative η^t , which is unlikely to represent their true preference. The rate of anomalous responses is lower than in Barsky et al.'s (1997) experiment, where 29% were dropped due to the same inconsistencies. Failure in the rationality check could be interpreted as an indicator of lack of attention. As a precautionary measure, these respondents were therefore dropped from the analysis of the other experiments as well, even though there were no large differences between this subsample and the rest of the sample in the frequency distributions for η^s and η^i .

4.5 Correlations

To investigate whether preferences over risk, inequality and time are linked, the correlations between responses to the three different experiments were measured. The data are categorical, so Kendall's tau-b is used instead of the ordinary Pearson's r .

As table 4 shows, the correlation between each pair of variables is significant but weak. All the correlation coefficients are around 0.1. For the analyses involving intertemporal substitution, the weak correlations arise because a relatively large number

of respondents display high aversion to inequality over time but low aversion to risk and/or inequality over space. The correlation between risk aversion and inequality aversion is weakened by respondents who display high risk aversion coupled with low spatial inequality aversion. Low risk aversion coupled with high spatial inequality aversion is less common.

By intertwining the three concepts, the standard model implies a perfect correlation of 1. Our results suggest that this underspecifies the structure of public attitudes. These results corroborate Barsky et al.'s (1997) finding that risk and time preferences are essentially uncorrelated, indicating that their failure to detect a relationship between the two was not only due to limited statistical power. Together the two studies suggest that the low correlation is robust to differences in the question context, since Barsky et al. (1997) looked at preferences over personal income changes, which could be different from attitudes to how society should allocate income over a much longer time-frame.

It is notable that the correlation between risk aversion and inequality aversion is substantially weaker than Carlsson et al. (2005) found. The fact that their sample consisted entirely of students cannot explain much of the difference, as the correlation coefficient among students in our sample is only slightly higher than for the whole sample, at 0.149. A more important difference may be that the two surveys are not measuring exactly the same parameters. While our survey pertains to global income distributions and risks to the entire economy, Carlsson et al. (2005) looked at national income distributions and risks to individuals. Another difference arises in the framing of the questions. In Carlsson et al.'s (2005) survey the two questions look graphically exactly the same. This is not the case in our survey, although the structure of the two are very similar. What format is best suited to elicit true preferences is not easy to determine.

Table 4. Correlations

		Relative Risk Aversion	Elasticity of Intertemporal Substitution (Midpoint)
Relative Inequality Aversion	Correlation Coefficient	0.133(***)	-0.123(***)
	N	2546	2269
Relative Risk Aversion	Correlation Coefficient		-0.069(***)
	N		2249

*** Correlation is significant at the 0.001 level (1-tailed).

4.6 Determinants of Preferences, and Selection Bias

Recruiting the sample through electronic media has both benefits and drawbacks. We obtained a large and heterogeneous sample from around the world. This provides a good opportunity to investigate how preferences differ based on respondent characteristics. On the other hand, the sample was not drawn randomly, which limits our ability to draw inferences and could introduce sample biases.

To investigate these issues, we estimated an ordered probit model for each of the three experiments. The explanatory variables are the responses given to the

demographic and attitudinal questions. The dependent variable is η . As η has eight intervals or categories, and thus we could present an overwhelming amount of information on marginal effects, we restricted ourselves to estimating marginal effects for the highest and lowest intervals on each dimension of η .⁹ Consequently we assume that an explanatory variable with a positive marginal effect on the highest interval and a negative marginal effect on the lowest interval has an overall positive effect on the dependent variable. Appendix II reports these marginal effects in full. Here we summarise.

There appear to be surprisingly small regional differences in the responses when other differences are controlled for. The only significant effects are that respondents from Africa are less averse to inequality, while those from the United States are more so, compared with the reference group, which is set to the UK.

Gender is the only variable that has a significant effect on all three dimensions of η . Women exhibit larger values for all the dimensions of η . Higher risk aversion among women is consistent with the findings of Carlsson et al. (2005), Barsky et al. (1997), Hartog et al. (2002) and Jianakoplos and Bernasek (1998). Carlsson et al. (2005) also report the same result for inequality aversion. Fortunately, the number of men and women in the sample is almost equal, accounting for 52% and 48% respectively, so the problem of bias is minimal.

Education is positively linked with inequality aversion but has no significant relationship with the results in the other two experiments. Because the sample was recruited largely through academic channels, highly educated people are over-represented. However we weighted the sample by educational attainment following De Vaus (2002) and did not find any increase in correlation between preferences over risk, inequality and time. On the contrary, the three correlation coefficients were each lower than before.

High-income respondents display somewhat lower aversion to inequality. This is as expected, given that respondents were told to assume that their position in the hypothetical income distribution would be the same as in reality. Preferences over intertemporal substitution also appear to be weakly associated with income, with respondents in the bottom income group displaying higher values of η . The sample median household income is in the range of £40,000-£50,000, which is substantially higher than the median for the UK population, for example, of just over £20,000 (Office of National Statistics, 2004). This suggests that a sample with a more representative income distribution would actually have produced larger estimates for η^i and η^t . For inequality aversion, age has a comparable effect. According to our results, age has a small but significant positive effect on inequality aversion and no significant effect on the other two parameters. Young people would also appear to be overrepresented in the sample, as indicated by comparing the sample median of 27 years with, for instance, the median in the UK population of 39 (Office of National Statistics, 2005).

Self-selection is likely to have led to an over-representation of people who take a particular interest in climate change, since the term 'climate' was used in the presentation of the survey. In addition, some of the networks through which the survey was distributed had an environmental theme. One indicator of bias in terms of interest in

⁹ To do this, responses to the questions on intertemporal substitution were grouped into the same intervals as those used for risk and spatial inequality, based on the midpoint of the estimated range for the elasticity of intertemporal substitution.

climate change is that 28% of respondents were members of environmental organisations or conservation groups. Appendix II shows that members of such groups are more averse to income inequality. This indicates that the large proportion of members in our sample may have led to higher estimates of inequality aversion than for the general population. However, the effect is not very large. Moreover membership of an environmental or conservation group did not have any significant effect on attitudes towards risk or inter-temporal substitution.

5 Discussion

Our results provide some support for the proposition that the three components of η should be disentangled when analysing climate change. The result that risk aversion, spatial inequality aversion and temporal inequality aversion are not tightly linked in the sample suggests the standard model is not well-suited to incorporating the structure of public preferences over these issues.

The responses show two further, interesting patterns. Firstly, in each of the three experiments there is a high proportion of responses indicating very large values of η . In itself, this suggests that low values of η , from unity or below to at least two, may be too low to be applied to analyses of climate change. Secondly, our estimates of spatial inequality aversion are highly polarised, with a high number of respondents in both of the extreme categories. Here we discuss whether these findings are reflections of people's true preferences or are artefacts of the survey, and to what extent it affects the core result that preferences are only weakly correlated across the three dimensions.

5.1 Hypothetical Bias

The validity of the results, including the correlations, rests upon the assumption that respondents answered the questions in a truthful and accurate way. This is not a trivial assumption in any survey-based research. Miller (1992, p557) warns of the "danger of picking up 'Sunday-best' beliefs, that is, the views that people think they ought to hold according to some imbibed theory as opposed to the operational beliefs that would guide them in a practical situation." Kahneman and Knetsch (1992) refer to this as the 'purchase of moral satisfaction'. It may have led to an inflated number of responses in the high categories to the extent that such attitudes are seen as more responsible or ethical, but it is worth noting that online distribution likely reduces this bias relative to personal interviews.

Another possibility is that the responses of people who are not used to thinking systematically about questions of this type will be ill thought-out and therefore not reflect their true attitudes. A general concern about stated-preference studies is whether they give respondents sufficient incentive to undertake the mental effort to answer in a way that accurately reflects their preferences (Freeman, 1979). Some respondents may have found the experiments cognitively quite demanding, and therefore relied on simplifying heuristics to aid their choices. One such heuristic would be to rank the options solely with reference to one of the attributes, for example total income or minimum income. For the risk and inequality experiments, such a strategy would place

the respondent in one of the extreme categories. In the time experiment it appears that many respondents made their choices only with reference to the sign of the slope of the consumption path, sticking to the same option even when this meant giving up a large amount of total income. Such respondents would display a very high aversion to temporal income inequality. To find out whether lack of comprehension and/or effort has produced a bias, it would be desirable to compare our extensive survey method, which generated a large sample, with a more intensive survey environment (Brown et al., 1995; Kenyon et al., 2001) that might be better suited to guaranteeing comprehension.

5.2 Alternative Mental Models

As explained in section three, the parameter values reported are based on a simple model of how people make the choices in question. As we cannot observe people's decision-making processes, we cannot verify the model. This section discusses more sophisticated theories of choice, which may be better at explaining the responses given. According to these theories, it is plausible that the results reflect true preferences, but that people were applying a rationality that the standard model does not fully capture. Since the correlation analysis does not presuppose a specific structure of preferences, this means that the low correlations are plausible even though some of the responses give rise to unconventional parameter values, when one tries to square them with the preference structure described in section three.

5.2.1 Risk

There is evidence that the expected-utility model performs poorly at explaining actual choices under uncertainty. According to a review by Starmer (2000), the cumulative Prospect Theory of Kahneman and Tversky (1992) is the theory that best predicts the empirical data. Its key insight is that people give more weight to losses than gains of equal size, even when these changes are so small that they should not command a risk premium according to expected-utility theory. People are in a sense attached to the status quo. This might help to explain our result that respondents appeared to show relatively high levels of risk aversion to policies involving potentially substantial losses.

5.2.2 Time

A robust finding from the literature on subjective measures of well-being is that the level of life satisfaction derived from a given level of consumption depends negatively on the level one is accustomed to (for a review see Di Tella and MaCoulloch, 2006 or Layard, 2005). This could help explain the strong focus on the slope of the consumption path that we observed. It implies that people would be unlikely to accept a downward sloping consumption path even if this could give them a large increase in total consumption. This is supported by empirical research (Loewenstein and Prelec, 1993).

5.2.3 Inequality

One interesting finding from the inequality experiment was the high degree of polarisation, with high scores for both the top and the bottom category. Under the assumptions of the workhorse model, this is hard to explain, since one would not expect the valuations of the elasticity of marginal utility to vary between people to such a large extent. But the reality is likely to be that views on income inequality depend on much more than how quickly one thinks marginal utility falls. Miller (1992) shows that there is a complex interplay between the two different criteria of needs and deserts in how people judge different distributions.

Those who focus on needs are quite likely to display very high aversion to inequality. A good case can be made for putting more weight on the utility of the most miserable society, hence rejecting the Utilitarian social welfare function. The maxi-min strategy advocated by Rawls (1971) would imply that η^i is infinity. From this, the high estimates we have made could indeed reflect true preferences. In addition, inequality may give rise to externalities such as more crime, another reason why inequality aversion may exceed the elasticity of marginal utility. At the other extreme we may have people who emphasise the criterion of deserts. There is evidence that many people reject equalising transfers even if they come at no cost to the total size of the pie (Bukhszar and Knetsch, 1997 and Miller, 1992). They may believe that, as a matter of justice, people should be rewarded proportionately to their efforts.

6 Conclusions

Consumption discount rates, critical to any long-term policy such as climate change, are strongly affected by the choice of the elasticity of the marginal utility of consumption, η . Unfortunately, there is little agreement on the value of η , partly because, in the standard model of welfare economics, it simultaneously represents preferences over risk, spatial inequality and intertemporal substitution. Our survey of over 3000 people shows that the correlations between preferences over these three dimensions are weak in the context of climate change.

The survey also reveals large heterogeneity in preferences within each of the three dimensions of η , particularly for inequality aversion. This means that using a single value for each would conceal important ethical disagreement. However, it does not mean that formal economic modelling of climate change is futile. On the contrary, these models are useful precisely for exploring the roles of preferences over risk, inequality and intertemporal substitution in modelling optimal climate policy. Because these are issues over which reasonable minds may disagree, modellers should present policy-makers with a range of optimal policies corresponding to different degrees of risk aversion, spatial inequality aversion and temporal inequality aversion. However, the current specification of the model puts constraints on this type of sensitivity analysis, because one cannot for example change the degree of risk aversion without simultaneously changing the temporal inequality aversion, and these two changes have opposing effects on the damage cost estimates. Therefore, the heterogeneity observed reinforces the need to disentangle η .

The conclusion is that employing a model that can disentangle attitudes to risk, inequality and time would have important advantages when analysing climate change. An area for future research would therefore be to incorporate Epstein-Zin preferences into an integrated assessment model. This would make it possible to investigate separately the role of risk aversion and aversion to intertemporal substitution. Disentangling all three dimensions requires more work, both in developing a new welfare economic model, and improving the spatial resolution of integrated assessment models. In addition, there is a need for further empirical research, with the aim of understanding how people form the preferences expressed in this survey.

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Appendix I: E-mail lists through which the survey was distributed

Environment & Ethics List, University of Oxford
Green College students & staff, University of Oxford
Linacre College students & staff, University of Oxford
Physics Department, University of Oxford.
MSc Environmental Change and Management Alumni List, University of Oxford
Fulbright Academy of Science & Technology, July 2007 On-Line Newsletter
US National Institute of Standards and Technology, Office of Applied Economics
SPIRE, Norwegian University of Life Sciences
RESECON (Land & Resource Economics Network)
EARTHNOTES, Brandeis University
Parent Heart Watch, USA
Climate Change Information Mailing List, IISD

Appendix II: Regressions

Table A1. Explanation of variables.

For categorical variables, the reference category is indicated. For regions, the reference category is the UK. For dummy variables, marginal effects are calculated for a discrete change from 0 to 1. Age is set at the sample mean value.

Demographic Indicator/Dummy Variable	Response Code
Gender	
female	Female
reference	Male
genderMiss	Failure to respond
Income Band	
Income0	<£10000
Income1	£10000-£19999
Income2	£20000-£29999
Income3	£30000-£39999
reference	£40000-£49999
Income5	£50000-£59999
Income6	£60000-£69999
Income7	£70000-£79999
Income8	£80000-£139999
Income9	>£140000
IncomeMiss	Failure to respond
Level of Education	
ed0	Some High School or Less
ed1	High School Graduate
reference	College/University Undergraduate Degree
ed3	Post-Graduate Degrees (Master or PhD)
ed4	Medical (doctor) Degree
ed5	Law Degree
edMiss	Failure to respond
“It is the role of the government to reduce differences in income between those with high incomes and those with low incomes.”	
pol0	Strongly agree
pol1	Agree
reference	Neither Agree nor Disagree
pol3	Disagree
pol4	Strongly Disagree
polMiss	Failure to respond
“The effects of climate change will pose serious risks to you and your family during the remainder of your lifetime”	
CCYou0	Strongly Disagree
CCYou1	Disagree
reference	Neither Agree nor Disagree
CCYou3	Agree
CCYou4	Strongly Agree
CCYouMiss	Failure to respond

“The effects of climate change will pose serious risks to global society during the remainder of your lifetime”

CCWorld0	Strongly Disagree
CCWorld1	Disagree
reference	Neither Agree nor Disagree
CCWorld3	Agree
CCWorld4	Strongly Agree
CCWorldMiss	Failure to respond

Conservation Group

reference	Does NOT belong to an environmental or conservation group
conserve	Does belong to an environmental or conservation group
conserveMiss	Failure to respond

Table A2. Determinants of preferences over risk.

Marginal effect on the probability of being in top and bottom categories		
	$\eta < 0.5$	$\eta > 7.5$
Africa	.0002417	.0007061
Pacific	.005005	-.0134281
LatinAm	.0475103**	-.07774***
WestEur	-.0018509	.0055618
SouthEur	.050153	-.080148***
USA	.0062323	-.0164098
Canada	.0017283	-.0048857
EastAsia	.0061283	-.0161614
Scan	-.0037116	.0115336
MidEast	.0292504	-.0573752
EastEur	.0281026**	-.055825
pol0	-.0145184	.0566886***
pol1	-.0074833	.0250033*
pol3	-.0032434	.0099926
pol4	.0030945	-.008556
polMiss	.0038015	-.0103931
CCYou0	.006478	-.0169934
CCYou1	-.0039296	.0122601
CCYou3	-.006271	.0204551
CCYou4	-.0097563	.034169
CCYouMiss	-.0321632***	.2464237
CCWorld0	.0086113	-.0218868
CCWorld1	.0151561	-.0351905
CCWorld3	.0148275*	-.0345769*
CCWorld4	.0167848*	-.0381563*
female	-.0182247***	.0783924***
genderMiss	-.0276862**	.1657568*
age	-.0003237*	.0009419**
Income0	-.0138174*	.0530421
Income1	-.0096477	.0337104
Income2	-.0096993	.0339278
Income3	-.0069501	.0229756
Income5	-.0052049	.0166322
Income6	-.0127321*	.0476407*
Income7	.0010442	-.0029855
Income8	.0079699	-.0204475
Income9	-.0040395	.0126286
IncomeMiss	-.0145924*	.0570812*
ed0	-.0069349	.0229183
ed1	-.0060227	.0195504
ed3	.0011096	-.0031691
ed4	-.0175732	.0742455**
ed5	.0315405	-.0603565
edMiss	-.003523	.0109097
conserve	.0021383	-.0060043
conserMiss	.0231644	-.0486867

(*) Significant at 10% level

(**) Significant at 5% level

(***) Significant at 1% level

Table A3. Determinants of spatial inequality aversion.

Marginal effect on the probability of being in top and bottom categories		
	$\eta < 0.5$	$\eta > 7.5$
Africa	.0746822**	-.0909152***
Pacific	.0226456	-.0331594
LatinAm	.0376078	-.0520179
WestEur	.0121726	-.018592
SouthEur	.0393239	-.0540493
USA	.0394935**	-.0542488**
Canada	.0182532	-.0271981
EastAsia	.0572173	-.0738145
Scan	-.0073228	.0121715
MidEast	.08927	-.1037933
EastEur	-.0056151	.0092609
pol0	-.0696778**	.1655091***
pol1	-.0262346***	.047776**
pol3	.0425472***	-.0577973***
pol4	.2033551***	-.1745896***
polMiss	.0070472	-.0109968
CCYou0	.0186373	-.0277277
CCYou1	.0278945	-.0400202
CCYou3	-.0130437	.0222636
CCYou4	-.0256739*	.0466211
CCYouMiss	.0387575	-.0533818
CCWorld0	.0680829	-.0846839
CCWorld1	.0579709*	-.0745942**
CCWorld3	.0070662	-.0110256
CCWorld4	-.0202825	.0358484
female	-.0411717***	.0812754***
genderMiss	-.0704703*	.1683915
age	-.0008147*	.0013106*
Income0	.0077186	-.0120102
Income1	-.01322	.0225833
Income2	-.0014212	.0023005
Income3	.0178945	-.026702
Income5	.028301	-.0405401
Income6	-.0254469	.0461556
Income7	.040258*	-.0551445*
Income8	.0822749***	-.0977653***
Income9	.0330524	-.0464995
IncomeMiss	.0033156	-.0052569
ed0	.1373407***	-.1390665***
ed1	.0078979	-.01228
ed3	.0000401	-.0000644
ed4	.0255133	-.0369422
ed5	.0053987	-.0084836
edMiss	.0301019	-.042824
conserve	-.0361506***	.0693868***
conserMiss	-.0144795	.0248829

(*) Significant at 10% level

(**) Significant at 5% level

(***) Significant at 1% level

Table A4. Determinants of preferences over intertemporal substitution.

Marginal effect on the probability of being in top and bottom categories

	$\eta < 0.5$	$\eta > 7.5$
Africa	.0069192	-.0278462
Pacific	-.0044357	.0194357
LatinAm	-.0187506*	.094487**
WestEur	-.0027899	.0120621
SouthEur	-.0232974	.124433*
USA	.017432*	-.0656186**
Canada	.002815	-.0116611
EastAsia	-.0149787	.072377
Scan	-.0124184	.0584631
MidEast	.0065512	-.026432
EastEur	-.0228957	.1216095
pol0	-.0001215	.0005145
pol1	-.0017803	.0076355
pol3	-.0061771	.027465
pol4	.0010169	-.0042687
polMiss	-.0270308**	.1528277**
CCYou0	.0220863	-.080931
CCYou1	.0285998**	-.101151***
CCYou3	.0062161	-.0251378
CCYou4	-.0041282	.0180425
CCYouMiss	.0092188	-.0365327
CCWorld0	-.0190683	.0964503
CCWorld1	-.0141477	.0677733
CCWorld3	-.0032981	.0143174
CCWorld4	-.0023012	.0099104
female	-.0130524**	.0618355***
genderMiss	-.029372**	.1732072*
age	-.0008614**	.0036438***
Income0	.0320044**	-.1112173**
Income1	.0060872	-.0246382
Income2	.0020385	-.0084927
Income3	.0031392	-.0129738
Income5	.0236272*	-.0858357**
Income6	.018033	-.0676399
Income7	.0164855	-.0624077
Income8	.0192649*	-.0717413*
Income9	.0227929*	-.0831899*
IncomeMiss	.0095219	-.0376585**
ed0	-.0033736	.014654
ed1	-.0018491	.0079348
ed3	.0096537	-.0381465
ed4	-.0158957	.0775626
ed5	.0264921	-.0947518
edMiss	-.0264007**	.147726*
conserve	.0031439	-.0129927
conserMiss	.0047786	-.0195194

(*) Significant at 10% level

(**) Significant at 5% level

(***) Significant at 1% level

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