Climate Change Disaster Management: Mitigation and Adaptation in a Public Goods Framework

Reviva Hasson, Åsa Löfgren and Martine Visser

Working Paper Number 178

Climate Change Disaster Management: Mitigation and Adaptation in a Public Goods Framework [*]

Reviva Hassan[†], Åsa Löfgren[‡]and Martine Visser [§]

May 4, 2010

Abstract

This paper explores the collective action problem as it relates to climate change and develops two models that capture the mitigation/adaptation trade-off. The first model presents climate change as a certain disaster, while the second models climate change as a stochastic event. A one-shot public goods experiment with students reveals a relatively low rate of mitigation for both models. The effect of vulnerability towards climate change is also examined by varying the magnitude of the disaster across treatments. Our results find no significant difference between the high and low-vulnerability environments. This research contributes to the literature concerning public goods experiments as well as the analysis of climate change policy.

Keywords: Public good; climate change; mitigation; adaptation; experiment; risk;

1 Introduction

Over the past two decades, mitigation has been the primary focus of international climate change conferences, with the United Nations Framework Convention on Climate Change and all subsequent documents repeatedly calling on countries to cooperate in reducing greenhouse gas emissions (UN-FCCC, 1992). This 'narrow' focus on mitigation has been criticised by some for failing to integrate adaptation sufficiently into policy (Burton *et al,* 2007). However, the role of adaptation in addressing climate change is becoming more important. This is partly because of the cumulative effect of past emissions, such that there is a certain amount of climatic change to which we are committed, and partly because the global conventions are not bringing about the necessary degree of mitigation. Thus mitigation and adaptation are both essential in addressing climate change effectively. However, financial constraints apply and even when funds have been allocated towards fighting climate change, a decision on how best to allocate these resources must be made.

In this paper we use behavioural and experimental economics to study a particular aspect of the economics of climate change: the potential trade-off between mitigation and adaptation. The Earth's atmosphere is a prime example of a global public good. By extension, mitigation efforts in reducing the concentration of greenhouse gases can be characterised as an investment in the public good, since emissions from any location spread uniformly through the atmosphere. Investing in

---

[†]Reviva Hasson is a Junior Research Fellow at EPRU at the School of Economics at the University of Cape Town, (email) R.Hasson@uct.ac.za.

[‡]Dr. Åsa Löfgren is an Enviornment for Development (EfD) Research Fellow. Department of Economics, Box 640, SE 405 30 Gothenburg, Sweden, (email) asa.lofgren@economics.gu.se;

[§]Dr. Martine Visser is the Director and Research Fellow at EPRU at the School of Economics UCT, (email) Martine.Visser@uct.ac.za. University of Cape Town, Private Bag, Rondebosch 7701, South Africa, (tel) 27 21 650-2723, (fax) 27 21 650-2854

adaptation measures, on the other hand, constitute a 'private good' investment, benefiting only the country or the individual that invests in adaptation.

The social dilemma that societies face when dealing with public goods is that an action that is rational for an individual country is not globally optimal. This is because each country faces the private costs of abatement whilst the benefits of such efforts are shared by all, regardless of their level contribution. There is thus a strong incentive to free-ride.

We use a one-shot public goods game framework with two adjustments. First, our experiment is framed in terms of climate change, which implies that the public good does not generate a potential gain, but rather that subjects face a loss in earnings[1]. The size of that loss is determined by the types of investments made in preparing for climate change, i.e. mitigation or adaptation. Second, the effects of climate change are highly uncertain and there is therefore a risk of a climate disaster independent of mitigation effort. Our stochastic model reflects this risk by incorporating probabilistic destruction into the design.

The paper is structured as follows: Section 2 provides a background in understanding the terms used in the context of climate change. In section 3 a review of the public good literature is given, followed by a discussion of the core papers that influenced the design of our models. Section 4 analyses the theoretical models. Section 5 describes the design of the experiment and analyses the results. Finally, section 6 concludes the paper.

2 Background

2.1 *Climate Change*

Climate change is a complex science and its effect on the human environment will be experienced in multiple ways, from gradual changes to sudden disasters[2]. For the purpose of simplicity and clarity, this paper models climate change as an event, namely a climate change-induced natural disaster. This is justified since extreme weather events, such as floods, hurricanes, heat waves and droughts, constitute some of the most direct and threatening risks of global warming (Stern, 2007).

2.2 *Mitigation*

The term 'mitigation' in the climate change vernacular refers specifically to approaches that reduce the concentration of greenhouse gases in the atmosphere. Mitigation can be achieved by using cleaner technology or by reducing the demand for fossil fuels. It can also refer to enhancing greenhouse gas sinks[3]. Quantifying the effectiveness of mitigation schemes is relatively straightforward, as there is a comparable unit of measurement, namely carbon dioxide equivalent (CO_2e)[4].

The effect of mitigation on climate change can be understood in two ways and each is explored separately in this paper. Firstly, by decreasing the concentration of greenhouse gases in the atmosphere, mitigation has the effect of reducing the *severity* of a climate change disaster. This understanding frames climate change as a deterministic event where mitigation affects the degree of climate change but not the likelihood. This can be understood in general terms as well as in relation to a specific event. For example, hurricanes are classified on a scale from 1 to 5, with 1 representing a minor storm. Climate change is likely to increase the intensity of such weather events so that a

---

[1]This illustrates the finding in the IPCC fourth Assessment Report (2007) that the majority of countries are likely to experience a loss in wealth due to climate change and not a gain. Additionally, beyond certain increases in temperature, global agricultural productivity is projected to decline.

[2]See the IPCC Fourth Assessment Report (2007) for a review of the implications of a warmer climate.

[3]Such as preventing deforestation as well as employing carbon capture and sequestration techniques.

[4]This measure expresses how much global warming a given type of greenhouse gas may cause, with carbon dioxide as the reference gas.

region that historically experienced 'category 1' hurricanes is likely to experience more severe 'category 4' hurricanes. Mitigation effort will thus lower the severity of such storms, for example to a 'category 2' level hurricane.

Alternatively, the effect of mitigation can be understood to decrease the *probability* of experiencing an extreme event. This approach analyses climate change as an endogenous event where humans play a role in determining the likelihood of experiencing a climate change disaster. For example a region may have historically experienced a flood once in a hundred years but, with climate change and no mitigation effort, it could occur more frequently at a rate of one in ten years. Therefore, mitigation will reduce the probability of such events.

In reality, it is most likely that mitigation measures will decrease both the severity as well as the likelihood of a climate change disaster. However, this paper models these effects separately, since the purpose of this research is to understand and analyse the trade-off between mitigation and adaptation as a social dilemma, and this is best achieved when mitigation has only one influence.

2.3 *Adaptation*

In contrast to mitigation, adaptation is complex to define and measure. In essence it denotes any action taken to reduce the vulnerability of a human or natural system from the negative effects of climate change. Adaptation schemes can be pre-emptive, such as crop diversification and infrastructure developments[5]. Alternatively, adaptation can refer to the improvement of emergency services and insurance funds to deal with a disaster once it has happened (Midgley, 2008).

There is no uniform way to measure an investment in adaptation, nor is it clear how to quantify a return to that investment that is comparable across schemes (Ziervogel, 2008). Finding a suitable adaptation solution for a region is specific to a particular economy and ecosystem. It is thus difficult to quantify how effective a particular strategy is in general terms. Furthermore, some types of climate change impacts can be compensated for by means of adaptation, but many present challenges that are too drastic to surmount. Thus, the effectiveness of an adaptation technique is limited. Another significant problem in undertaking adaptation strategies is that there is a large degree of scientific uncertainty regarding future weather patterns[6]. While certain adaptation strategies are indeed effective, when compared with mitigation, the return to an investment in adaptation is limited to a specific area or interest group and weakened by inherent uncertainty.

2.4 *Vulnerability*

Vulnerability defines how severely a region will be impacted by climate change. It represents factors such as the political and economic environment as well as the susceptibility to natural disasters. The vulnerability factor can be used to express inequalities across countries since different regions will experience the effects of global warming in diverse ways. It can also be used, as in this paper, to indicate various scientific projections regarding the degree of severity of climate change. For example, it has recently been shown that the growth rate in actual emissions has exceeded the worst-case scenario forecast by earlier IPCC reports (UNEP, 2009). This has significant implications for all countries.

---

[5] Such as improving storm water drainage systems and building wave breakers.

[6] For example, although the temperature in the Western Cape is predicted to rise due to climate change, there is no clear expectation regarding rainfall. This could result in either higher rainfall or a drought. The appropriate adaptation strategy would not be the same in both of these cases (Midgley, 2008).

3 Literature Review

3.1 *Public Good Experiments*

Although climate change analysis is a growing area of economic research, it has been surprisingly under-investigated within the sub-discipline of experimental economics. The notable exception is in the area of permit trading[7]. There is, however, a vast experimental literature that aims to understand the conditions that facilitate cooperation despite the rational incentive to free-ride, and these studies offer insights that are relevant in the context of climate change[8].

The classic collective action experiment is the linear public goods game described as follows (Ledyard, 1995; Sturm and Weimann, 2003; Ostrom, 2000): Each agent is endowed with a fixed asset and must choose how much to contribute towards the public good. All contributions are then pooled together, multiplied by some factor and then divided equally amongst the group. The payoff structure reflects a prisoner dilemma trade-off, such that the dominant strategy for each agent is to invest nothing in the public good since the marginal per capita return[9] of investing in the public good is always less than 1. However, a larger payoff can be earned by everyone if all players contribute their entire endowment to the public good.

Numerous lab experiments have established the importance of conditional cooperation, reciprocity, communication, trust and the concern for one's reputation in explaining the positive cooperation levels found in field and laboratory experiments[10]. On the other hand, lab experiments have also revealed that there are a variety of individual types, for example strict free-riders and strict cooperators, and that many individuals play a particular strategy that is largely independent of the experimental circumstances (Sturm and Weimann, 2003).

When the public good experiment is conducted in a discrete choice framework (as in this paper), cooperation levels are generally found to be between 40% and 60% in the first round of a repeated game. (Maier-Rigaud and Apesteguia, 2003:5; Beckenkamp, Hennig-Schmidt and Maier-Rigaud, 2007:7). When the experiment is carried out as a one-shot game, cooperation rates tend to be lower, for example, Dawes, McTavish and Shaklee (1977:5) report average cooperation at 30% and Cooper *et al* (1996:200) find cooperation averaging 38%.

Only a few public goods experiments have been conducted in South Africa. Contribution levels have ranged from about 47% in the first round of a repeated game, carried out with rural communities (Visser and Burns 2007:12), to approximately 33% in experiments with urban high-school students (Hofmeyr, Burns and Visser, (2007:513) and Kocher, Martinsson and Visser, (2008:510). The latter authors also found that stake size did not have any significant effect on contribution levels (*ibid*: 511). Unfortunately our results cannot be compared directly with these South African studies, since they were conducted in a continuous-choice framework.

3.2 *The Design of our Model*

The models presented in this paper are based on the public goods game as outlined above. They differ from the standard design in order to capture specific dynamics relevant to the climate change context. Firstly, we explicitly express our model in terms of a loss environment which reflects the circumstances of a climate change disaster. Furthermore, uncertainty and risk, which are pervasive

---

[7]See for example, Bohm and Carlen (2002); Cason (2003); Cramton and Kerr (2000) and Wråke *et al.*(2008).

[8]Brekke and Johansson-Stenman, (2008) provide a well-researched overview of the contribution of behavioural economics to the economics of climate change.

[9]The MPCR is measured by the ratio of the return to the public good relative to the private return, divided by the number of participants.

[10]See for example Lave (1962); Dawes, McTavish and Shaklee (1977); Selton and Stoeker (1986); and Cooper *et al* (1996), Ostrom, (2000); Fehr and Gächter (2000); Bowles and Gintis, (2000). Gächter 2007; Fischbacher, Gächter, and Fehr (2001) and Falk and Fischbacher (2006).

in the study of climate change, are dominant features in our models[11]. Uncertainty is present in both the deterministic and stochastic models, since there is no way of assigning probabilities to the strategy to be chosen by group members. In the stochastic model there is the added risk of a climate change disaster.

Berger and Hershey (1994) address several issues that are pertinent to our study: They investigate the effect of loss avoidance and risk in a discrete choice public goods experiment by comparing the rates of cooperation from a stochastic and a deterministic model respectively[12]. The cooperation rate in the deterministic case averages 50% (1994:183), which is in line with other public good experiments, suggesting that the loss environment does not significantly affect contributions. In the stochastic experiment, however, the cooperation rate is significantly lower at 15%. The stochastic environment increases the prevalence of free-riding behaviour.

The climate change environment differs in many ways from Berger and Hershey's insurance market. One important distinction is that in the context of climate change the loss is not shared equally by all, but is experienced by individual countries and indeed by individual persons. Another important difference is that in our stochastic model contributions to the public good lower the risk of disaster for all players but do not eliminate the possibility of disaster altogether. Furthermore, if a disaster occurs, the size of the loss is dependent on individual factors including the amount privately invested in adaptation.

In our stochastic experiment we model an environment characterised by probabilistic destruction, meaning that contributions towards mitigation lower the probability that a disaster will occur. The stochastic model presented in this paper is very similar to that of Walker and Gardner (1992), who investigated the consumption of common-pool resources. In their first treatment, where any level of consumption increased the probability of destruction, they found typical free-riding behaviour and the resource was destroyed. In their second treatment they introduced a safe zone where low levels of consumption would not threaten the resource. They found some evidence that consumption behaviour was retained within the interval; however, in general the resource still tended towards destruction. We do not incorporate a safe zone into our models which implies that even with total mitigation by all group members there will still be some possibility for a disaster to occur. The lack of a safe zone in our design is motivated by inherent environmental uncertainty. Furthermore, there is already evidence that many of the Earth's natural systems have been affected by climate changes (IPCC, 2007), thus humanity's 'safe zone' has in fact elapsed.

The trade-off between mitigation and adaptation is well expressed in terms of the endogenous-risk literature. An endogenous risk implies that an individual or policy maker can 'influence the likelihood that a state of nature will occur' (Shogren, 1991:241). In a seminal paper by Ehrlich and Becker (1972), the authors distinguish between two types of investments that can be undertaken by an individual in preparation for some adverse event. 'Self-insurance' is an investment that reduces the size of the loss if the event were to occur. In the deterministic model both adaptation and mitigation are self-insurance measures. 'Self-protection' on the other hand is defined as the effort taken to reduce the probability of an unwanted event, but does not affect the magnitude of the loss if the event occurs. This characterises the role of mitigation in the stochastic model since it reduces the probability of a climate change disaster. The stochastic model in this paper can be viewed as an extension of Ehrlich and Becker's work, since climate change is portrayed as an endogenous risk and the trade-off between self-insurance and self-protection is evident.

---

[11]Uncertainty refers to situations in which various outcomes of a particular choice are possible, but one does not have the knowledge to assess the probability of each outcome. Risk applies to circumstances where the decision maker knows all the possible outcomes and can assign a probability value to each outcome (Griffiths and Wall, 2000).

[12]The context is the insurance market where loss control measures undertaken by the insured individuals can be considered public goods.

4 Theoretical Analysis

This section presents two models that reflect the trade-off between mitigation and adaptation, and analyses them using expected utility theory. While there are shortcomings to such normative theories of choice[13], expected utility theory provides the standard framework for analysing decisions involving risk. Alternative decision strategies are then discussed at the end of this section.

The experimental paradigm is as follows: Individuals are randomly placed into groups of four and are each given a sum of money, their 'initial endowment', as well as a budget to invest in addressing climate change. Participants must choose whether to spend their budget on either mitigation or adaptation. The experiment is designed so that the private rational incentive is to contribute nothing to mitigation[14].

Parameters:
$E = Initial\ Endowment$
$B = Budget\ towards\ addressing\ climate\ change$
$n = group\ size$
$x_i = Investment\ in\ Mitigation,\ x_i \leq B$
$a_i = Investment\ in\ Adaption,\ a_i = B - x_i$
$B = x_i + a_i$
$m = Return\ to\ Mitigation$
$d = Return\ to\ adaptation$
$S = Severity\ of\ Disaster$
$P = Probability\ of\ Disaster$

4.1 *Design of the Deterministic Model*

In the deterministic model the agents face a climate change disaster with certainty and both investment strategies will decrease the vulnerability of the country to a climate change disaster. Mitigation lowers the impact of a disaster for everyone, whilst adaptation lowers the severity for that individual alone. The payoff for each agent is given by equation 1, which shows that the individual's final payoff is a function of their private investment in adaptation $d\left(\frac{B-x_i}{B}\right)$ as well as the group's collective investment in mitigation.$m\left(\frac{\Sigma x_i}{nB}\right)$ It is also influenced by the exogenous severity term (S) which specifies the vulnerability of a particular environment. A higher S denotes greater vulnerability and a lower final payoff.

$$\pi_i = E - SE\left[1 - d\left(\frac{B - x_i}{B}\right) - m\left(\frac{\Sigma x_i}{nB}\right)\right] \tag{1}$$

4.2 Design of the Stochastic Model

In the stochastic model climate change is depicted as an endogenous risk. An investment in mitigation by any agent lowers the probability of a disaster for all, while adaptation lowers the severity of disaster only for that individual. Whether a disaster occurs or not depends on two factors:

1. Mitigation effort: If more people mitigate, the probability of a disaster is reduced.

2. Chance: Since there is always a possibility that a natural disaster can occur independent of human involvement.

The public good character of mitigation is apparent, since the return from mitigation is largest only if all players mitigate. Moreover the probability of a disaster is the same for all members of the

---

[13]See Shaw and Woodward (2007) for a discussion on the limitations of expected utility theory.
[14]The instructions for the experiments can be obtained on request from the authors.

group regardless of their individual contributions, as shown in equation 2. The total investment in mitigation by the group is divided by the total budget available to all players such that the more people that invest in mitigation, the lower the probability of disaster[15].

$$P = 1 - m \left(\frac{\Sigma x_i}{nB} \right) \tag{2}$$

$$E(\pi_i) = P \left[E - SE \left(1 - d \left(\frac{B - x_i}{B} \right) \right) \right] + [1 - P] E \tag{3}$$

Equation 3 above shows the expected payoff for each individual[16]. The first term shows the expected payoff if there is a disaster and the second term shows the expected payoff if there is no disaster. If no disaster occurs then players keep their full initial endowment. If there is a disaster the actual payoff is similar to that for the deterministic model, where the size of the loss is a function of the amount invested in adaptation as well as the severity level.

4.3 *Choice of Parameters*

While the models can be analysed in both a continuous and a discrete-choice framework, in the experiment the participants are faced with a binary choice between mitigation and adaptation[17]. We thus analyse the models using a discrete prisoner dilemma framework.

Simple data trials using Excel show the sensitivity of the model to some of the parameters. The initial endowment (E=100), budget (B=10), and severity term influence the absolute payoff, but do not affect the relative structure of the game[18]. In our experiments the vulnerability term is homogenous, affecting the stake size without introducing inequality. In the low-vulnerability environment S=0.8, thus subjects face a potential loss of 80% of their initial endowment. In the high-vulnerability environment S=1.2, implying a more significant loss that would have to be financed from the participation fee.

For a social dilemma to exist, the return to mitigation (m) and adaptation (d) must be such that the constraint, as expressed in equation 4 below, is upheld[19]: The marginal per capita return to mitigation with full cooperation ($n*MPCR_m$) must be greater than the marginal per capita return for one unit of adaptation ($MPCR_a$), which in turn must be greater than the marginal per capita return for one unit of mitigation ($MPCR_m$)[20].

$$n * MPCR_m \quad > MPCR_a \quad > MPCR_m \tag{4}$$

By constraining $m \leq 1$ we ensure that even with total mitigation there will still be some chance of a disaster. The parameters chosen for the experiment are m=0.7 and d=0.475 which fulfil the public good constraint in equation 4, i.e.: $0.07 > 0.0475 > 0.0175$.

Table 1 shows the payoff charts for the abovementioned parameters[21]. In each of the tables the payoffs are shown for the column player as combination of their decision and the number of other people in the group that choose to mitigate. 'Adapt' is the dominant strategy in all cases and since it is a symmetrical game the resulting Nash equilibrium will be for all players to adapt.

---

[15] This setup is based on Walker and Gardner's (1992) probabilistic destruction model. The structure is necessary in order to get a probability value between 0 and 1, and also shows that the mitigation effort is dissipated amongst all players.

[16] Because it is uncertain whether a disaster occurs or not, it is necessary to express an individual's earnings in terms of their expected payoff.

[17] The reason for this is explained in section 5 on the Experiment Design.

[18] The amount of the budget is actually inconsequential to the final payoffs.

[19] Unfortunately, there is no data in the literature that provides quantitative figures for the return of an investment to either mitigation or adaptation.

[20] Where $MPCR_m$=$m/(n*B)$ and the $MPCR_a = d/B$.

[21] Actual payoffs are shown for the deterministic model and expected payoffs are shown for the stochastic model.

Consequently society lands up at a Pareto-inferior outcome. The 'social optimum' position is that of full mitigation, which has a larger expected payoff than the Nash equilibrium.

The risk/return ratio calculates the potential loss from free-riding compared with the potential gain from free-riding[22]. The risk/return ratios are 0.75 and 4.44, for the deterministic and stochastic model respectively, and are constant across vulnerability levels. The ratios suggest that there is more to lose by free-riding (i.e. adapting) in the circumstances of the stochastic model than in the deterministic model. This could imply that more people would cooperate given the stochastic setup.

5 *Sensitivity Analysis*

It should be noted that the prisoner's-dilemma framework does not hold for all values of m and d(where m is the return to mitigation and d the return to adaptation). Table 2 below shows the results of a rudimentary sensitivity test where m is held constant at 0.7 and d is varied. For the stochastic model, the table shows that when the difference between m and$d$is roughly less than 30% there is a strict prisoner's-dilemma conflict. When the difference is greater than 50% there is no social dilemma and it is in everyone's best interest to mitigate. A weak social dilemma environment exists between the two extremes such that if a certain number of players mitigate, one should also mitigate. In the deterministic model the social dilemma holds over a much wider range of parameters.

5.1 *Alternative Decision Strategies*

Using the expected payoff is a suitable means to solve the stochastic model as it accounts for the likelihood of a disaster and the relevant payoffs thereof. The weakness of this method is that it assumes individuals to be risk neutral in that they treat expected payoffs the same as certain payoffs. In practice this assumption may not hold and individuals may use other decision rules. This subsection highlights alternative decision-making criteria that are likely to be used by individuals facing this dilemma.

Table 3 and 4 portray the decision environment in an alternative way to that of Table 1[23]. Table 3 shows the probability of disaster based on one's chosen strategy[24]. Tables 4a and 4b show the *actual* outcomes dependent on whether a disaster occurs or not and the strategy adopted.

A conservative decision-making criterion is the maxi-min principle where the individual selects the best strategy given the worst-case scenario, i.e. in the event of a disaster (Griffiths and Wall, 2000:125). Choosing to adapt is then the clear strategy of choice. In contrast, the maxi-max rule is a more 'adventurous' approach (Perman *et al* 2003:460), where the individual identifies the best payoff for each strategy and selects the option with the maximum payoff. In this case the individual would be indifferent between mitigating and adapting, as both have a best-scenario payoff of R100.

The above discussion demonstrates that the strategy to adapt is weakly dominant across a range of decision-making criteria.

6 The Experiments

6.1 *Guiding Questions*

The models analysed in the previous section offer a theoretical foundation that can be tested using controlled lab experiments. While there are many interesting scenarios worth investigating, this initial study is limited to three main questions:

---

[22]

[23] These tables essentially feed into the expected payoff charts as shown in Table 1.

[24] It is worth noting that the probability values utilised in the experiment are large enough not to be subject to the irregularities in behaviour often observed for low-probability hazards (McClelland, Schulze and Coursey, 1993).

1. Game theory predicts that the number of people choosing to mitigate will be zero. Do the subjects in the experiments behave according to this expectation? If not, are the results in accordance with other public good experiments?

2. The stochastic model differs from the deterministic model in a number of ways, most notably because of the added risk. This difference is expressed in the risk/return ratio from free-riding, which is larger in the stochastic model (4.44, compared with 0.75 for the deterministic model). This ratio suggests that the potential loss from adapting is substantially greater in the stochastic setup. On the basis of this statistic we could expect more people to mitigate in the stochastic model than in the deterministic model[25]. Do the results from the experiments support this hypothesis? Moreover, do the experiments reveal any difference in behaviour between the two models?

3. In a low-vulnerability environment the payoffs are larger than in the high-vulnerability environment[26]. Because the relative payoffs are constant, the vulnerability factor should not make a difference to the decision process. Do subjects in the experiment conform to theory or do they act differently based on the vulnerability of their environment?

Four experimental treatments were conducted to address these questions[27]: two with the stochastic model and two with the deterministic model, each with a high and low-vulnerability treatment.

6.2 *Experiment Design*

We decided to use a discrete-choice environment where participants could choose to either mitigate or adapt. In this way it was easier to gauge preferences, as the participants did not have the option of indecisiveness in splitting their budget between the two options. Furthermore, the binary setup allowed the necessary information to be presented in a straightforward manner.

An important factor in analysing climate change is that decision making is to a large extent characterised by irreversibility[28]. Such a decision-making context is depicted well in a one-shot game, since global leaders make a decision today and the long-term outcome will be determined by that decision[29]. Furthermore, we are foremost interested in understanding preferences which can best be elicited through a one-shot game (Fischbacher, Gächter, and Fehr, 2001).

When running the stochastic model, the decision was taken to present the participants with actual payoff tables instead of the expected payoff tables[30]. This is because the expected payoffs could be misleading, since such payoffs best represent a game with multiple rounds, where the average payoff is the expected payoff. Moreover, the expected payoff table was deemed too confusing. This was because students would not actually earn the amounts indicated, and secondly its use required a more detailed explanation[31].

By providing an external budget that needed to be entirely spent we were able to assess with some precision the decision between mitigation and adaptation. This meant that the results could be more clearly understood than in an environment where participants could choose to spend any amount of their endowment on mitigation, adaptation or doing nothing. Importantly, both mitigation and adaptation are decisions that reflect an understanding of the gravity of climate change and the will to take action. 'Doing nothing' on the other hand cannot be interpreted in the same light and such

---

[25] This hypothesis opposes expected utility theory, which predicts no one will mitigate in either model.

[26] See Table 1 in section 4.

[27] The instructions and experiment protocol can be obtained from the authors.

[28] This is unlike some other environmental commons where there are multiple rounds and the stakeholders are able to observe, learn and act based on the results of their previous decisions.

[29] Thanks to Prof G. Harrison for his insights on this matter.

[30] That is, Tables 3 and 4 were presented as opposed to Tables 1c and 1d.

[31] These concerns were validated in the focus groups.

a strategy could be motivated by disbelief in the science, apathy, a high discount rate or free-riding sentiments.

All the experiments were conducted as homogenous, symmetrical games, both in terms of the initial endowment and vulnerability level. The instructions were first explained in person with the use of a white board. Following this, the z-tree software programme was utilised to run the experiments (Fischbacher, 2007).

6.3   Subjects

The experiments were conducted with 144 students recruited from the University of Cape Town's general student body. The median age of the participants was 20 and 43% were female. Racially, 57% of the subjects classified themselves as 'African', 15% 'White', 12% 'Coloured', 8% 'Indian', and 8% 'Other'. Approximately 70% were South African citizens. The majority of participants had taken at least one course in economics. The participants were given a show-up fee of R30[32].

6.4   Experiment Results and Analysis

Table 7 summarises the results for each experiment and shows that the mitigation rate is statistically significant for each model and treatment. The null hypothesis of zero contribution to the public good is thus rejected.

The two-sample Wilcoxon rank-sum (Mann-Whitney) test assesses whether there is a difference between the various treatments: firstly between the deterministic and stochastic models and secondly between the low and high-vulnerability treatments. The results, summarised in Table 8, indicate that there is no statistically significant difference in the mitigation rates between any of the treatments.

The questions posed at the beginning of this section can now be answered:

1. Subjects deviated from the game-theoretic prediction in all the experiments. On average 27% of participants chose to mitigate. This result is in accordance with most collective action experiments that find positive cooperation rates. When compared with other one-shot prisoner dilemma games our results are similar, but less than the 30% found by Dawes, McTavish and Shaklee (1977:5) and the 38% reported by Cooper *et al* (1996:200).

The relatively lower rate of cooperation could reflect a framing effect, that adaptation was sometimes selected as the strategy of choice and not as the non-cooperative alternative to mitigation. This would suggest that while most people selected adaptation because of the game-theoretic incentives, others chose to adapt because they deemed it the best way of addressing climate change. This notion is supported by some of the reasons given by students for making the selection they did[33]. Overall, however, the framing of the game is likely to have had a balanced effect, since some students probably chose mitigation because of a framing effect too[34].

It is difficult to isolate the effect of risk aversion from that of uncertainty aversion. However, it appears that these attitudes influenced participants towards adaptation. Students repeatedly expressed variations on the following sentiments: 'I chose to adapt because it is less risky' and 'I chose to adapt because it gives the best worst-case scenario outcome between the two options'. These types of comments suggest that many participants used a maxi-min criterion in decision making. The relatively low level of cooperation in our experiments thus reveals a tendency for caution in decision making.

---

[32]This was necessarily high because in the deterministic model with high vulnerability, students could experience a loss in earnings which needed to be funded from their show-up fee. The participation fee is comparable to the amount students earn by tutoring at the University.

[33]For example: '(I chose to adapt because) I believe that a country should look after the needs of its citizens, and undertake programmes that will benefit them first before any other population'.

[34]For example; 'mitigation will start solving the problem whereas adaptation will keep us in the same predicament each round' and 'Mitigation, I believe, is the most appropriate answer to climate change'.

2 While more people mitigated in the deterministic model compared with the stochastic model, the results are not significantly different from each other and do not support the premise that people behave differently in the respective circumstances (see Table 8). The hypothesis that more people may mitigate in the stochastic model because of the greater risk/return ratio from free-riding, is also rejected.

It is not clear why the mitigation levels are so similar between the models. It may be that there are multiple influences impacting on the decision-making process. For example in the stochastic model, risk-aversion sentiments could have swayed participants in favour of adaptation, whilst the risk/return ratio may have encouraged participants to mitigate. Alternatively, it may be that the participants played according to their 'personality types' i.e. people who had a natural tendency to cooperate would be more likely to contribute to the mitigation in both the deterministic and stochastic environment.

3 There is no evidence that people behave differently given the level of vulnerability in their environment. This supports the theoretical expectation that homogenous stake size has no effect on the level of contribution[35]. It also provides a basis for understanding the surprising reality that the increasingly dire projections by scientists about the consequences of global warming fail to influence policy makers towards greater action.

6.5 *Caveat on the methodology of student lab experiments in studying climate change*

The premise for this research paper was to understand the collective action problem as it manifests itself in the global context of climate change. The results from the experiments, however, portray the decisions made by individuals and not countries. It is thus important to assess, firstly, whether the macro-level collective action problem can be scaled down to an individual-level problem; and conversely whether one can extrapolate from the experimental results for individuals to comment on international climate change involving countries.

The macro framing of the climate change problem is clear since countries (as opposed to firms or individuals) constitute the primary unit of decision making at global conferences. However, individuals can also face a similar decision. To illustrate this point, consider the options available to a farmer in addressing climate change. This individual could invest in technology that would reduce his greenhouse gas emissions and would constitute a form of mitigation. Alternatively he could invest in research and development to find drought-resistant crops that would better prepare him for a climate with lower rainfall, which would be a means of adaptation. Thus, while many aspects of decision making certainly pertain to countries; there are areas where similar choices are relevant to individuals.

Vulnerability can also be understood on both the macro and micro level. On the macro scale, a country like Bangladesh, due to its geography, climate and economy, is more vulnerable to a climate change disaster than a country like Canada. Similarly, on an individual level people face varying degrees of vulnerability for different reasons. For instance, an academic or a professional is likely to be impacted significantly less, or less directly, by climate change than a farmer would be.

The results of the experiments portray the decisions made by individuals acting in their own interest. Just as an individual chooses a strategy they believe to be best, so too it is reasonable to expect a country's policymakers to decide on a course of action in the best interest of their constituency. It is similarly reasonable to expect that policymakers are part of the group which they represent and will therefore also be affected by the implications of their decision. While recognising the limitations of lab experiments, the behaviour of individuals that is revealed in the lab context can be used as a basis for understanding and analysing certain dynamics on the global scale.

---

[35] This finding lends support to the study by Kocher, Martinsson and Visser (2008).

7 Discussion and Conclusion

By examining the trade-off between mitigation and adaptation, this paper has questioned why the global collective action problem pertaining to climate change is so difficult to overcome. The analysis was restricted to mitigation and adaptation since both strategies indicate a willingness to take action in addressing climate change. The theoretical analysis demonstrates that an important factor contributing to the poor level of international cooperation is due to the public good nature of mitigation. The results from the student experiments, while challenging the theoretical outcome, still reveal lower rates of cooperation than would be expected. On average 27% of subjects chose to mitigate and this rate of cooperation is relatively constant for both the stochastic and deterministic models, as well as when the vulnerability level is adjusted. This suggests that the choice to invest in adaptation is influenced by multiple forces. Firstly, there is non-cooperative behaviour typical of public goods games that incentivise the individual to free-ride. Secondly mitigation is characterised by risk and uncertainty and an aversion to support adaptation. Finally, adaptation is chosen by some for its own merits as being the preferred means to address climate change.

The parameters chosen for this analysis capture the social dilemma clearly. However, as the sensitivity analysis shows, with different parameters the collective action problem may become weaker or fall away entirely. Establishing the return to mitigation and adaptation with greater accuracy may in fact demonstrate that it is in everyone's public as well as private interest to mitigate. This is an area for further investigation.

In addressing climate change effectively, both mitigation and adaptation strategies need to be considered and the correct combination will depend on the particular socio-economic and geographic circumstances. While this paper has highlighted the public good nature of the trade-off, it has also stressed that the decision to adapt should not be considered typical free-riding behaviour. Rather, adaptation is an important component in tackling climate change, especially given the vulnerability of certain regions and the uncertainty prevalent in the climate system.
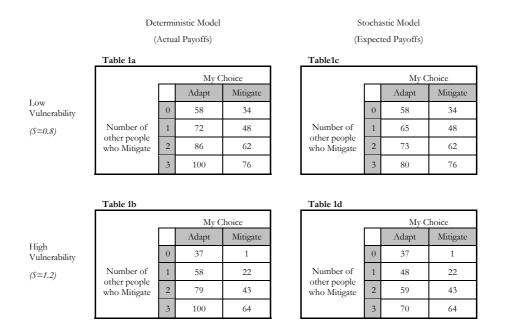
With regards to policy, this analysis suggests that global funding initiatives towards addressing climate change should take into consideration the collective action problem associated with mitigation. If countries take climate change seriously then they will be privately inclined to invest in adaptation. In contrast, a country will need more encouragement to invest in mitigation, since the benefits are shared whilst the costs are borne by the individual country. Global funding can thus play a role in addressing the imbalance in incentives.

References

[1] BECKENKAMP, M., HENNIG-SCHMIDT, H., AND MAIER-RIGAUD, F. P. (2007). 'Cooperation in Symmetric and Asymmetric Prisoner's Dilemma Games' *Preprints of the Max Planck Institute for Research on Collective Goods.* Bonn 2006/25.

[2] BERGER, L. AND HERSHEY, J. (1994). 'Moral Hazard, Risk Seeking and Free Riding' *Journal of Risk and Uncertainty.* Vol. 9:1 73-186.

[3] BOHM, P., AND CARLEN, B. (2002). 'A Cost-Effective Approach to Attracting Low-Income Countries to International Emissions Trading: Theory and Experiments'. *Environmental and Resource Economics.* 23(2):187-211.

[4] BOWLES, S. AND GINTIS, H. (2000). 'Walrasian Economics in Retrospect'. *The Quarterly Journal of Economics.* Vol. 115, No. 4: 1411-1439

[5] BREKKE, K.A. AND JOHANSSON-STENMAN, O. (2008) 'The Behavioural Economics of Climate Change'. *Oxford Review of Economic Policy.* 24(2): 280-97.

[6] BURTON, I., BIZIKOVA, L., DICKENSON, T. AND HOWARD, Y. (2007). 'Integrating Adaptation into policy: Upscaling Evidence from Local to Global.' *Climate Policy.* Vol 7: 371- 376.

[7] CASON, T. (2003). 'Buyer Liability and Voluntary Inspections in International Greenhouse Gas Emissions Trading: A Laboratory Study'. *Environmental and Resource Economics* 23(2):187–211.

[8] COOPER, R., DEJONG, D.V., FORSYTHE, R., AND ROSS, T.W. (1996). 'Cooperation without Reputation: Experimental Evidence from Prisoner's Dilemma Games'. *Games and Economic Behavior,* 12(2):187-218.

[9] CRAMTOM, P., AND S. KERR. (2002). 'Tradable Carbon Permit Auctions: How and Why to Auction, Not Grandfather'. *Energy Policy* 30(4): 333–45.

[10] DAWES, R., MCTAVISH, J. AND SHAKLEE, H. (1977) 'Behavior, Communication and Assumptions about Other People's Behavior in a Commons Dilemma Situation'. *Journal of Personality and Social Psychology.* 35(1).

[11] DAWES, R. AND THALER, R. (1988). 'Cooperation'. *Journal of Economic Perspectives*, 2(3):187-197.

[12] EHRLICH, I. AND BECKER, G. (1972). 'Market insurance, Self-insurance and Self-Protection'. *The Journal of Political Economy.* 80(4):623-248.

[13] FALK, A AND FISCHBACHER, U. (2006). 'A theory of Reciprocity'. *Games and Economic Behavior.* 54:293-315.

[14] FEHR, E. AND GACHTER, S (2000) 'Fairness and Retaliation: The Economics of Reciprocity'. *IEER Working Paper* No. 40.

[15] FISCHBACHER, U, GÄCHTER, S. FEHR, E. (2001), 'Are people conditionally cooperative? Evidence from a Public Goods Experiment'. *Economics Letters..* 71(3):397-404.

[16] FISCHBACHER, U. (2007). 'z-Tree: Zurich Toolbox for Ready-made Economic Experiments', *Experimental Economics* 10(2), 171-178.

[17] GÄCHTER, S. (2007). 'Conditional Cooperation: Behavioral Regularities from the Lab and the Field and their Policy Implications'. *Economics and Psychology: A Promising New Cross-disciplinary Field*, CESifo Seminar Series, edited by B. S. Frey and A. Stutzer.Cambridge, MA, USA: MIT Press.

[18] GRIFFITHS, A. AND WALL, S. (2000). *Intermediate Microeconomics.* (2nd Edition). Pearson Education Limited.

[19] HOFMEYR, A., BURNS, J. AND VISSER, M., (2007). 'Income Inequality, Reciprocity And Public Good Provision: An Experimental Analysis' *South African Journal of Economics.* 75(3).

[20] IPCC, (2007). 'Fourth Assessment Report. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability'. Summary for Policymakers.

[21] KOCHER, M. G., MARTINSSON, P. AND VISSER, M (2008), 'Does stake size matter for cooperation and punishment?.' *Economics Letters,* Vol. 99: 508–511.

[22] LAVE, L.B., (1962). 'An Empirical Approach to the Prisoners' Dilemma Game' *The Quarterly Journal of Economics.* 76(3) 424-436.

[23] LEDYARD, J. (1995). 'Public Goods: A survey of Experimental Research' in Kagel, J.H. and Roth, A.E., (eds) 1995. *The Handbook of Experimental Economics.* Princeton University Press. United Kingdom. Ch. 2.

[24] MAIER-RIGAUD, F.P., AND APESTEGUIA, J. (2003). 'The Role of Choice in Social Dilemma Experiments'. *Bonn Econ Discussion Papers.* Discussion Paper 22/2003. Bonn Graduate School of Economics.

[25] MCCLELLAND, G.H., SCHULZE, W.D. AND COURSEY, D.L. (1993). 'Insurance for Low Probability Hazards: A Bimodal Response to Unlikely Events'. *Journal of Risk and Uncertainty.* Vol. 7: 95-116.

[26] MIDGLEY, G. (2008). *Understanding the Climate Change Challenge: Introducing the Science and Reviewing the Impacts.* [Lecture at the UCT GSB Climate Change Course 12-14 May 2008]

[27] OSTROM, E. (2000) 'Collective Action and the Evolution of Social Norms', *Journal of Economic Perspectives.* 14(3).

[28] PERMAN, R., MA, Y., MCGILVRAY, J. AND COMMON, M. (2003) *Natural Resource and Environmental Economics.* (3rd Third Edition). Pearson Education Limited.

[29] SELTON, R. AND STOECKER, R. (1986). 'End Behavior in Sequences of Finite Prisoner's Dilemma Supergames'. *Journal of Economic Behavior and Organization.* 7:47-70

[30] SHAW, W.D., AND WOODWARD, R.T. (2007) 'Why Environmental and Resource Economists should care about non-expected utility models'. *Resource and Energy Economics.* 30(1):66-89.

[31] SHOGREN, J. (1991). 'Endogenous Risk and Protection Premiums'. *Theory and Decision.* Vol. 31: 241-256.

[32] STERN, N. (2007). 'The Economics of Climate Change. The Stern Review' Cambridge University Press.

[33] STURM, B. AND WEIMANN, J. (2003) 'Experiments in Environmental Economics – a Survey'. *FEMM Working Paper Series 03010*, Magdeburg.

[34] UNEP, (2009). 'Climate Change Science Compendium' .Chapter 1.

[35] UNFCCC, 1992. 'United Nations Framework Convention on Climate Change'. United Nations, New York

[36] VISSER, M. AND BURNS, J. (2007). 'Bridging the Great Divide in South Africa: Inequality and Punishment in the Provision of Public Goods'. *Working Papers in Economics,* No. 219. Göteborg University, Department of Economics.

[37] WALKER, J. AND GARDNER, R. (1992). 'Probabilistic Destruction of Common-Pool Resources: Experimental Evidence'. *The Economic Journal.* 102(414) (Sep 1992).

[38] WRÅKE, M., E. MYERS, SVANTE MANDELL, C. HOLT, AND D. BURTRAW. (2008). 'Pricing Strategies under Emissions Trading: An Experimental Analysis'. *RFF Discussion Paper* 08-49.Washington, DC: Resources for the Future.

[39] ZIERVOGEL, G. (2008), (Personal Communication, June 2008).

Table 1. Payoff Tables by Model and Vulnerability Status.

Deterministic Model
(Actual Payoffs)

Stochastic Model
(Expected Payoffs)

Table 1a

Low
Vulnerability

(S=0.8)

		My Choice	
		Adapt	Mitigate
Number of other people who Mitigate	0	58	34
	1	72	48
	2	86	62
	3	100	76

Table1c

		My Choice	
		Adapt	Mitigate
Number of other people who Mitigate	0	58	34
	1	65	48
	2	73	62
	3	80	76

Table 1b

High
Vulnerability

(S=1.2)

		My Choice	
		Adapt	Mitigate
Number of other people who Mitigate	0	37	1
	1	58	22
	2	79	43
	3	100	64

Table 1d

		My Choice	
		Adapt	Mitigate
Number of other people who Mitigate	0	37	1
	1	48	22
	2	59	43
	3	70	64

Table 2: Sensitivity of the model to the parameters when m is held constant at 0.7.

Deterministic model	Stochastic model	Comment
$0.18 < d < 0.7$	$0.37 < d < 0.7$	Strict Prisoner Dilemma game
-	$0.2 < d < 0.37$	Weak Prisoner Dilemma game
$d < 0.18$	$d < 0.2$	No Prisoner dilemma game.

Table 3: Probability of Disaster

		My Choice	
		Adapt	Mitigate
Number of other people who Mitigate	0	100%	83%
	1	83%	65%
	2	65%	48%
	3	48%	30%

Table 4: Summary of Possible Outcomes

Table 4a: Low Vulnerability *S=0.8*

	Adapt	Mitigate
No Disaster	100	100
Disaster	58	20

Table 4b: High Vulnerability *S=1.2*

	Adapt	Mitigate
No Disaster	100	100
Disaster	40	-20

Table 5: Summary of Mitigation Rates by Experiment

Model	Vulnerability	Sample Size	% of Participants Mitigating	Average by Model	Overall Average
Deterministic model	Low	*n=48*	25%*		
	High	*n=32*	31%*	28%*	
					27%*
Stochastic Model	Low	*n=32*	28%*		
	High	*n=32*	25%*	26.5%*	

* Significant at the 1% level of significance using the Wilcoxon signed-rank test. Ho: % of people mitigating=0

Table 6: Results from the equality tests on unmatched data

Between-subjects effects		z	Pr > z
Model[a]		-0.125	0.9002
Vulnerability[b]	Within deterministic model	-0.609	0.5422
	Within stochastic model	0.281	0.7789

[a] Model is deterministic or stochastic
[b] Vulnerability is low or high