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Personal Carbon Emissions Trading: An Experimental Analysis

Abstract

Personal Carbon Trading (PCT) is a newly proposed policy option for mitigating greenhouse gas (GHG) emissions. Research into the potential role of PCT has focused on developed country applications. This study was designed to assess the potential role of PCT, and to better understand the public's response to mitigation policy, within the context of South Africa. An experiment was conducted that simulated a personal emissions trading scheme. Fifty six student volunteers participated in the experiment over the course of six and a half weeks. Participants measured their baseline emissions associated with personal transport, committed to reducing their emissions over a four week commitment period, and were able to trade emission credits through an online auction platform. The experiment consisted of two treatments. The first treatment assessed the role of cheating by comparing outcomes of a group that signed an honesty declaration when reporting emissions data to a group that did not sign any honesty declarations. The second treatment tested the impact of different allocation methods by comparing outcomes when applying a group target versus individual targets. Differences in reported emissions, levels of cheating, involvement in the auctions and perceived acceptability of the scheme design were assessed. The experiment proved successful at achieving a reduction in the transport related emissions of the sample. The majority of individuals participated in the auction but the benefits of trading were not evenly distributed. Cheating was found to have a significant impact on reported baselines. Different allocation methods had no significant impact on achieved reductions but did influence the perceived acceptability of the scheme design. Concern regarding personal financial risk contributed to less ambitious targets and resulted in over-allocation in the market. The experiment provided useful insights into the reaction of the South African public to potential mitigation policy but, due to potentially high implementation costs, PCT was not found to be a feasible policy option in the South African context.

1 Introduction

Personal Carbon Trading (PCT) has been proposed as a radical policy option for mitigating greenhouse gas emissions. Most of the research on this particular policy instrument comes from researchers in the environmental and energy domain, who argue that some form of individual rationing of greenhouse gas (GHG) emissions is necessary. Economists have tended to prefer upstream schemes because of their lower transactions costs (Brohe 2010). Thus, there is a need to interrogate the value of PCT as a policy option from an economic perspective.

Proponents of Personal carbon trading (PCT) suggest it could be a potentially powerful instrument with which to achieve GHG emission reductions. It has, as yet, only been implemented in a small number of pilot programmes, mostly in the UK. Most research on PCT has been undertaken in the United Kingdom. The PCT literature focuses on the technology for implementation and costs of operation, interactions with existing policy landscape, the public's ability to deal with a parallel currency, social acceptability, impacts on individual psychology and distributional effects. Social acceptability has been the most widely researched aspect of the policy. The literature suggests that PCT has great potential, but that more detailed aspects of the policy need to be debated and developed. PCT as a policy option has not yet attracted much attention in the developing country context.

At this stage a mandatory scheme is not likely in South Africa. However, as highlighted by Fawcett and Parag (2010), studying PCT is useful in that it raises important issues, the recognition of which may be vital in developing future policies regardless of the actual implementation of PCT.

This experiment aimed to simulate an emissions trading scheme for individuals and to shed light on design implications that would need to be considered, should a voluntary scheme be implemented. These results can contribute to understanding better the potential role of emissions trading in contributing to climate change mitigation, particularly at an individual level.

Laboratory experiments can create real, simplified and controlled markets to help answer questions such as these (Cason 2010). This experiment initiated a trading scheme for the personal transport emissions of individuals (students at the University of Cape Town). The experiment had the following objectives:

- To assess the potential of conducting an auction to contribute towards reducing GHG emissions associated with personal transport (is auctioning an efficient way of motivating a reduction in individual carbon footprints?);
- To gain an improved understanding of some of the complexities in designing an emissions trading scheme for individuals;
- To test the potential role of dishonesty in affecting the outcomes of the scheme;
- To determine the price of carbon associated with personal transport emissions for a sample of individuals; and
- To test perceptions around the social acceptability of PCT as a policy option.

Experimental modelling can provide insight into complex design problems faced by regulators implementing emission trading systems (Cason 2010). Experiments allow researchers to test theory, as well as unimagined factors that affect outcomes. They can be used to investigate the outcomes when certain features are varied and, therefore, test the effectiveness of those different features; or they can be used as a test-bed to try new rules and institutions, even those not guided by specific theoretical predictions, but rather by the designer's intuition (Cason 2010).

Similarly to Benz and Ehrhart (2007), the purpose of this experiment was to study an emissions trading scheme as a whole, with an assessment of the interaction of all of its components: determining baseline data, deciding on the initial allocation based on the agreed targets, agreeing an appropriate penalty or enforcement mechanism, trading and, finally, abatement decisions. The results provide an initial view on the potential value of PCT compared to alternative measures for addressing individuals' emissions, and also provide a better understanding of the issues surrounding the concept.

Few experiments have been conducted on carbon emissions trading and very few have been conducted on emissions trading for individuals. The literature suggests that no experiments have been conducted to examine the implications of implementing a PCT scheme in a developing country context. "Given the very small amount of work that has been carried out to support or refute the range of behavioural influences which have been suggested may arise from PCT, and with no actual PCT schemes in existence, it is argued that the use of simulations offers an opportunity to test for behavioural effects within a controlled environment and over a relatively short time-scale" (Capstick & Lewis 2010: 381).

1.1 The climate change challenge

Climate change is a significant challenge facing the world today. It is now accepted that greenhouse gas emissions (GHGs), as a result of human activities, contribute to this change. Reducing GHGs, referred to as climate change mitigation, is an important part of managing the potential risks of climate change. In addition to adapting to the physical changes, countries are looking at ways to reduce the concentration of GHG emissions in the atmosphere.

The current focus on setting mandatory emission reduction targets will mean that countries and organizations will be forced to assess all possible mitigation opportunities. Personal carbon trading represents one possible policy option to be included in a suite of options (Fawcett & Parag 2010). This project does not assess the practical feasibility of implementing a PCT scheme in South Africa, but rather focuses on providing some understanding of the dynamics and challenges in implementing potential mitigation policies.

Proponents of PCT suggest that it might provide a framework for delivering long-term, sustainable cuts in carbon emissions in a way that other policies cannot. PCT has the advantage of targeting individuals responsible for emissions directly and, through the widespread distribution of environmental property rights, could involve the entire population (Fawcett & Parag 2010). Most existing market-based instruments do not engage the public directly. For example, the EU Emissions Trading Scheme (EU ETS) does not currently cover most emissions by individuals and is invisible to energy end-users.

1.2 Design

The experimental design was intended to simulate both elements of the Kyoto Protocol (and subsequent emissions trading schemes such as the EU ETS) and also incorporated many of the elements of the proposed PCT schemes. The study drew on volunteers from the University of Cape Town in South Africa. During a six-and-a-half week process, participants were introduced to emissions trading and were able to experience some of the elements of a personal emissions trading scheme.

The experiment consisted of two treatments:

1. Honesty declaration versus none: cheating effect
2. Targets: group versus individual targets

The first treatment aims to provide insight into the importance of verifiable data and the efforts that will need to go into ensuring accurate data, based on the tendency of participants to cheat. Treatment 2 addresses issues around allocation, which has important implications in terms of, among other things, the acceptability of the scheme.

Students calculated their personal carbon emissions associated with transport. They then committed to reducing their emissions over a period of four weeks (the commitment period). Their commitment translated into an emission allowance for the commitment period. Participants who exceeded their allowance (failed to meet their commitment) were subject to a penalty.

To assist participants reduce their emissions at the lowest cost, an emissions trading scheme was set up. Participants able to reduce their emissions at relatively low costs were able to trade, via an auction, with those who could only reduce their emissions at relatively higher costs. To assist students in making informed decisions regarding their target commitments and at what price to buy or sell carbon credits, information on mitigation options was provided with associated costs per kilometre travelled and per kilogram of CO_2e emitted.

The experiment provided information on the reductions achieved, prices paid for units of CO_2e, as well as participants' behaviour. Additionally, through the use of a post-experiment questionnaire, this study obtained information regarding participants' perceptions around PCT as a potential policy option for reducing GHG emissions.

2 Literature review

With the pressure to reduce GHG emissions, but within a context of the need to become / remain internationally competitive, grow economies, create jobs, reduce poverty and achieve other socio-economic development goals, policy makers are caught in a dilemma. They need to find the balance between applying sufficiently high price signals to uncover economically beneficial efficiency measures and to change individual behaviour without causing severe regressive economic impacts downstream. Furthermore these policies need to be socially and politically acceptable.

Policy makers are increasingly turning to market-based mechanisms to put a price on carbon and induce a behavioural change. Carbon tax and cap-and-trade (a form of emissions trading) are market-based mechanisms for reducing GHG emissions that are currently receiving the most attention. As this experiment does not look to compare a cap-and-trade system to a carbon tax, the literature focuses on emissions trading.

2.1 Theoretical Model/Hypothesis

Experiments are often motivated and structured according to specific theoretical models and predictions. However, this experiment, as aligned to an alternative motivator described by Cason (2010), is intended to model a market and regulatory environment for transport emissions. As such, the university environment is an experiment or laboratory market for individual carbon trading in a larger market. The experiment is intended as a "test-bed" to evaluate intuitions, even though they are not formally modelled (Cason 2010: 152)

This experiment deals with market adjustments over a series of iterations and is comparable to the approach taken in auctioning allowances as part of the first commitment period of the Kyoto Protocol (Klaassen et al. 2005). Individuals have two possibilities: they can meet their target or they can trade. In other words, individuals can either reduce their own emissions (domestic reductions), buy emission rights or sell emission rights in the allowance/credit market (Assaud & Maxnes 2006, Klaassen et al. 2005).

2.1.1 Economic theory behind the use of an auction in an emissions trading scheme

Putting a price on carbon can be done via taxes, trading and imposing standards or regulations. In theory, trading and taxes will have the same outcome (Ahlberg 2010).

Taxes are attractive in that they impose a relatively stable price but suffer from limitations with regard to knowing where to pitch that tax to achieve the desired level of emissions reductions. Trading can ensure that desired emission reductions are met (Ahlberg 2010). Standards require that regulators know the cost of each individual's or firm's emission reduction (Ahlberg 2010). When the true value of allowances is unknown, as in the case in this experiment, trading is the more appealing and cost-effective option (Ahlberg 2010).

Emission permits or allowances convey rights that can be exchanged between countries, firms or individuals, subject to certain constraints or rules imposed by the regulator (Cason 2010). According to theory, trading of these allowances lowers the overall costs of abatement (Benz & Ehrhart 2007; Cason 2010). Where the Marginal Abatement Cost (MAC) (the cost associated with reducing one unit of emissions) differs between participants, then trading will allow for the participants with low MACs to sell emissions allowances to participants with relatively high MACs. The participants will sell if the market price is higher than their MAC, and participants will buy if the market price is lower than their MAC; making it cheaper for them to meet their target commitments (Benz & Ehrhart 2007). It is assumed that participants will try to reach their target commitments at as low a cost as possible (Assuad & Moxnes 2006; Klaassen et al. 2005). In auctions for a single unit, Vickrey (1961) showed that, in theory, the bids will reveal bidders' true values and will produce an efficient outcome, with allocation of the allowances going to the bidder with the highest value.

Participants will typically have different MACs. This could be due to the fact that some participants can more readily substitute their mode of transportation for one that produces less CO_2e per distance travelled. For example, some individuals may live close to a train station, bus route or be able to share lifts with colleagues and friends. Others might not have access to public transportation and rely on cutting down unnecessary excursions.

However, Benz and Ehrhart (2007) suggest that an individual's willingness to pay (WTP) in the auction may depend more on their expectations of the trading price and less on their MAC. Furthermore, emission allowances become a common good with the same uncertain value for everyone. If all participants are risk-neutral and have common beliefs, then each individual's WTP is equal to the trading price and, therefore, independent of their individual MAC (Benz & Ehrhart 2007).

Weitzman (1974), when comparing price instruments (e.g. a carbon tax) to quantity instruments (e.g. a cap) suggests that, under uncertainty about the marginal costs of supplying a good (in this case reductions in carbon emissions), using a price instrument is more effective than a quantity instrument when the marginal benefit schedule is relatively flat compared with the marginal cost curve, and vice versa when the marginal benefit schedule is relatively steep. However Lockwood (2010) argues that this framework is less relevant in the context of climate change. "The persistence of carbon dioxide in the atmosphere (and thus the time lag between emission and effect), together with the potentially catastrophic (i.e. non-marginal) impacts of high global temperatures, mean that it is effectively impossible to make judgments about the relative slopes of marginal cost and damage functions" (Lockwood 2010: 451).

The underlying driver behind the effectiveness of market-based mechanisms is that putting a price on carbon will reduce demand. Eyre (2010) highlights that even if pricing carbon might be effective, in the short term, inelasticity of energy demand implies that very high carbon prices will be needed. However, it may not be in the political interests of governments to allow energy prices to rise unbounded and so, some safety valves on prices may be required.

Prescott (2008), referring to experiences in the UK, suggests that policymakers have found that the short-term impact of marginal price changes upstream is not sufficiently effective at changing individual behaviour downstream. Personal Carbon Trading, through targeting individuals directly, may, therefore, be more efficient with regard to this particular aspect.

Furthermore, proponents of PCT argue that it is environmentally effective in that it virtually guarantees that an emissions target or ration will be met (Lockwood 2010). However, in reality, pollution trading schemes have always included a mechanism that limits their environmental effectiveness; the most common of which is creating a safety valve by setting a ceiling on the permit price (Lockwood 2010). This safety valve is usually in the form of a penalty charge paid if the actor does not have sufficient permits to cover his emissions. In the EU ETS, for example, the Phase II penalty is €100/tCO_2 (Lockwood 2010).

2.2 Markets for trading carbon emissions

2.2.1 International markets for the trading of CO2 emissions

Carbon markets are gaining entry throughout the world. The European Union (EU) and United States have functioning markets (Ahlberg 2010). The European Union Emissions Trading Scheme (EU ETS) is the largest market in the world, covering about 50 percent of the EU's CO_2 emissions (Ahlberg 2010). Entered into operation in January 2005, the EU ETS requires a cap-and-trade programme whereby the right to emit a particular quantity of CO_2 becomes a tradable commodity (Benz & Ehrhart 2007). The price of an allowance to emit one tonne of CO_2 was approximately € 25 per tonne in 2008 (Wrake et al. 2008).

The EU ETS was launched on 1 January 2005. Phase I lasted three years and was presented as a 'learning-by-doing' phase designed to prepare for the second trading period. Phase II is scheduled for five years until the end of 2012. This coincides with the first commitment period of the Kyoto Protocol, during which the EU Member States and other industrialized countries must meet GHG emissions targets (Brohe 2010).

2.2.2 Personal Carbon Trading (PCT)

Personal carbon trading (PCT) has been suggested by some as a potentially powerful instrument with which to achieve GHG emission reductions (Prescott 2008; Fawcett & Parag 2010; Lockwood 2010). The British government, as well as a variety of other organisations and researchers, has investigated the potential and feasibility of PCT in various forms. The idea first became well known in July 2006, when the British Environment Secretary, David Miliband, announced that his government would look more radically into the option of 'tradable carbon allowances' (Jagers et al. 2010). However, no nation state is seriously considering PCT (Jagers et al. 2010).

The Department of Environment, Food and Rural Affairs in Britain provides a good summary of PCT. "Personal carbon trading requires individuals to manage their own carbon emissions; a national emissions cap would be set, and emissions rights (in the form of carbon credits) would be allocated across the population as a whole. Individuals would surrender their carbon credits upon the purchase of, for example, electricity, gas or transport fuel. Those who need or want to emit more than their allowance, would have to buy allowances from those who emit less. Over time, the overall emissions cap (and hence individual allocations) could be reduced in line with international or nationally adopted agreements" (Defra 2008: 1).

There are different versions of PCT; including cap and share (FEASTA 2008); tradable energy quotas (TEQs) (Fleming 2007); tradable consumption quota (Ayres 1997); personal carbon allowances (PCA) (Hillman & Fawcett 2004); household carbon trading (Niemeier et al. 2008); and tradable transport carbon permits (Raux & Marlot 2005). The policy research community has focused on TEQs and PCAs. These schemes differ in that TEQs have an economy-wide cap and involve auctioning off remaining permits to business, whereas PCAs focus only on the personal sector (Lockwood 2010). The common feature is that each individual is given a free tradable carbon allowance, which covers the direct emissions from household energy use and / or personal transport (these schemes do not cover embodied carbon) (Fawcett 2010; Fawcett & Parag 2010).

Most research on PCT has been undertaken in the United Kingdom (Fawcett 2010). The UK government showed considerable interest and sponsored a "pre-feasibility" study. The study focused on the following key areas: potential effectiveness and strategic fit; equity and distributional impacts; public acceptability; technical feasibility and potential cost. Costs were found to be large and outweigh, by many times, the estimated potential benefits. The study found that some low-income households may lose out from PCT and that rural areas are worse off than urban populations. The study noted potential concerns around fairness, equity and distributional impacts associated with such a scheme. Concerns of possible vulnerable groups were some of the key challenges raised, along with fears of over complexity of the system. Importantly, the scheme found that there was little evidence that people would be likely to trade, which is a crucial element of the scheme (Defra 2008).

The key finding was that, "while personal carbon trading remains a potentially important way to engage individuals, and there are no insurmountable technical obstacles to its introduction, it would nonetheless seem that it is an idea currently ahead of its time in terms of its public acceptability and the technology to bring down the costs" (Defra 2008: 3). Thus PCT is in the development stage – with full details of its design, implementation, likely effects, costs and enforcement still to be researched and calculated (Fawcett 2010).

Fawcett and Parag (2010) provide a good summary of the current literature on PCT. Their summary focuses on the technology for implementation and costs of operation, interactions with existing policy landscape, the public's ability to deal with a parallel currency, social acceptability, impacts on individual psychology and distributional effects. Social acceptability has been the most widely researched aspect of the policy. They conclude that PCT shows great potential, but that more detailed aspects of the policy need to be debated and developed. PCT as a policy option has not yet attracted much attention in the developing country context.

2.2.3 The potential benefits of PCT

Proponents of PCT claim it could cover a significant portion of national carbon emissions (be environmentally effective), be cost effective and not worsen equity (Fawcett & Parag 2010; Lockwood 2010). The main benefits are seen as fairness and effectiveness (Fawcett & Parag 2010). Equity is seen to be achieved by allocating emissions on an equal per capita basis (the preferred allocation approach adopted in most proposals).

Capstick and Lewis (2010) suggest that PCT could prove to be personalized, socially diffuse and interactive, thereby contributing to the establishment of new norms of carbon reduction and a new sense of collective efficacy. There is also the possibility that people may become more aware of their personal emissions and be more inclined to reduce their emissions (Capstick & Lewis 2010).

A review of behavioural economics and social psychology literature by Capstick & Lewis (2010) suggests that PCT may offer wider benefits; including increased visibility of carbon emissions but also the price of carbon. They suggest that this visibility may drive greater levels of abatement. They suggest that "visibility" and "cognitive availability" may operate as a form of feedback, influencing future behaviour through the heightened recognition of consequences and knowledge about energy use. This is further supported by Brohe (2010), who highlights the potential benefits associated with energy savings due to the effects of feedback.

2.2.4 The feasibility of implementing a PCT scheme

Proponents of PCT, such as Flemming and Hillman, argue that such a system could be simple and cost-effective to administer through the use of existing banking transaction technologies; for example, through debit systems and credit cards (Lockwood 2010). However, Defra (2008) found the costs to be significant. "No insurmountable technical barriers were identified to the introduction of a personal carbon trading scheme, however, the costs identified are very significant. Estimates of the likely set-up costs of the type of scheme explored ranged between £700 million and £2 billion, and the running costs £1-2 billion per annum" (Defra 2008: 3).

Concerns have been raised regarding the interaction with other schemes or other policies aimed at putting a price on carbon (such as a carbon tax). One of the key areas on concern in this regard relates to double-counting: charging for carbon emissions twice (Brohe 2010; Eyre 2010). Eyre (2010) suggests that double counting, while economically inefficient, is not an insuperable problem provided the two carbon markets are separate and the currencies are not interchangeable. This is no doubt an issue that will require considerable additional research. In addition to issues of double counting and costs of implementation the potential inefficiency of having millions of individuals participating rather than a few big industry players has been raised as a concern (Prescott 2008).

2.2.5 The importance of accurate data

Accurate data is crucial to the success of a PCT scheme and has been raised as one of the critical concerns. Should such a scheme become mandatory, then the accuracy of the data becomes even more important (Prescott 2008).

Acquiring good quality data is difficult. The process of completing a detailed footprint can be onerous. Prescott (2008) believes that, unless carbon footprint calculators are linked to some form of incentive, it is unlikely that such a process will be widely accepted. Smart metering and the use of credit card systems for purchasing fuel, linked to data management systems, have been proposed as ways to automate the process and overcome many of the challenges (Prescott 2008; Lockwood 2010).

The potential contribution of PCT in the suite of options to mitigate GHG emissions remains highly uncertain. Much will depend on the outcomes of international negotiations aimed at setting legally binding agreements to reduce GHG emissions. However, further research is necessary.

2.3 Emissions trading in experimental settings

2.3.1 Auctions in experimental settings

Economics experiments are increasingly used for analyzing public policy, economic theories and institutions (Holt et al. 2007). Auctions are well-suited to experimental investigation due to their compact institutional form (Holt et al. 2007). Benefits of testing auctions in an experimental setting extend beyond identifying strategic relationships and market outcomes, to also allow the planner an opportunity to anticipate potential problems with institutional design (Holt et al. 2007).

Klaassen et al. (2005) assess the effectiveness of three different auction types (single bid, Walrasian and a bilateral sequential trading auction) in capturing the potential cost savings of emission trading. They find that in all three auctions, the market price converges to the market equilibrium price but, in contrast to the theory, they show that not every country gains from trading. A distortion in the gains from the competitive market outcome is due to speculative behaviour, imperfect foresight and market power. This, the authors found, could be influenced by the choice of auction. Additionally, Benz and Ehrhart (2007) found that participants' bidding behaviour depends on the auction or auction format. Hence, the choice of auction type is critical to the effectiveness of the auction in efficiently allocating allowances.

The purpose of this experiment was not to test and compare the effectiveness of different auctions within the laboratory setting, but rather to assess the implications of setting up a personal emissions trading scheme within a university environment and to determine the price of a unit of personal transport-related carbon within a university setting. Therefore, the most appropriate auction was chosen based on experiments in the literature that had conditions similar to those in this experiment.

According to the findings of Holt et al. (2007) and Ahlberg (2010), a sealed-bid auction is less conducive to collusion. Additionally, they found that Clock (or ascending bid) auctions performed no better in terms of price discovery than single-round auctions. A sealed-bid auction is also easy to implement (Ahlberg 2010).

A uniform price auction is recommended by Cason and Plott (1996). They suggest that the uniform price auction is more efficient, induces more truthful revelation of traders' costs and values, generates more accurate price information, and is more responsive to changing market conditions (Cason & Plott 1996). Other benefits include: simplicity, transparency, and the observed tendency for bidders to ensure purchases of needed allowances by bidding closer to use values (Holt et al. 2007).

The uniform price sealed bid was used in Ireland for auctioning EU ETS CO_2 allowances (Holt et al. 2007) and was one of the methods employed by Klaassen et al. (2005) in assessing whether emission trading converges to equilibrium within the context of the Kyoto Protocol's international commitments. However, Benz and Ehrhart (2007) warn that a one-sided uniform auction, combined with grandfathering, is expected to generate too high market price signals.

2.3.2 PCT in experimental settings

Simulated PCT schemes have focused on improving regulators understanding of the feasibility of implementing such a scheme and also to understand the implications of alternative design attributes. Most of the research has focused on public acceptability.

Capstick and Lewis (2010) used a computer-based simulation to examine the effects of participants' decisions on their personal carbon allowances within the context of a PCT scheme. They took into account the environmental concern, attitudes and personal carbon footprint of participants. They used software that allowed participants to respond to information related to their own disaggregated carbon footprint, as well as the cumulative consequences of their decisions on their personal carbon allowance. The aim was to assess whether participants would make more carbon conserving decisions as their allowance decreased over time and whether people would budget more carefully in a second simulated year when the allowance was cut further.

Capstick and Lewis (2010) note doctoral work by Wallace (2009), which examined peoples' responses to the idea of personal carbon allowances using both qualitative and quantitative methods. The research was based on a postal survey and home interviews conducted in the county of Nottinghamshire in the UK. His research concluded that, in response to the prospect of a PCT scheme, households preferred improving home energy efficiency, changing their car or using public transport, taking holidays closer to home, changing job- or home location and increasing working at home. Support for PCT was equal to opposition to it.

Jagers et al. (2010) conducted a similar study to examine critical aspects of the public's support for a PCA scheme, focusing on attitudes to PCA and trust in politicians, perceived fairness and its underlying ideology. The study was conducted through a mail questionnaire sent out to a random sample in Sweden. They conclude that there is a positive relationship between attitudes to an increase in the current carbon tax rate and their attitudes to the alternative of implementing a PCA scheme. They found stronger support among Swedes for a tax rather than a new PCA scheme. They noted that this was consistent with the expectation that people generally have a tendency to favour the state they are currently in. They compared their results to the empirical findings in the UK showing that people prefer PCA over taxation, even though the support for both schemes is low.

Bristow et al. (2010) use stated preference techniques to explore the influence of key design attributes on the acceptability of a PCT scheme, in isolation and when compared to a carbon tax. Drawn from a UK sample, they find that the initial permit allocation is perceived as the most important design element with regard to personal carbon trading. Their results further indicate that the "best" scheme designs could be acceptable to the majority of respondents.

A variety of PCT schemes have been piloted in real-world settings. Carbon Rationing Action Groups (CRAGs) operate in a number of places in the UK. These groups are testing a version of carbon measurement and, in some cases, are applying financial incentives for emission reductions. However, these groups are not representative of larger populations as they consist of self-selecting and highly motivated individuals (Capstick and Lewis 2010).

The Royal Society for the encouragement of Arts, Manufactures and Commerce (RSA) conducted a trial of over 100 volunteers who used shopping loyalty cards at BP garages to record how much fuel they purchased. This formed part of RSA's *CarbonLimited* project to explore technological means for participating in a PCT scheme. This was supported by the RSA's *CarbonDAQ*, an online experiment aimed at providing the infrastructure for any individuals to form groups and trade, as a means to achieve a group-wide emissions target (Prescott 2008).

The trial collected and processed data on carbon emissions using a loyalty card used to buy fuel. The author of *A Persuasive Climate,* a report on RSA's *CarbonLimited* project, suggested that the trial showed that costs of implementing and operating such a scheme could be much lower than previously thought (Prescott 2008). Prescott noted the difficulty in trying to pilot a PCT and highlighted the unpredictability that is likely to accompany such a scheme, due to individuals not having perfect information or hindsight, not acting rationally or making optimal decisions consistently. "Poor information, high implicit discount rates, and capital constraints are common reasons for inactivity in the carbon market" (Prescott 2008: 12). The RSA's research found that, if carbon trading were to be introduced on an "opt-in" basis, people would be more willing to get involved and greater reductions in emissions could be achieved (Prescott 2008).

2.4 Experimental design

"The critical factor is to design experiments that appropriately capture the situation as it occurs in reality" (Plott 1994).

This section summarizes the literature that informed some of the more important design elements of the experiment. Brohe (2010) lists the following five essential elements that need to be considered for a scheme to be environmentally, economically and socially effective:

- Defining a scope (a cap and a commitment period)
- Allocating allowances
- Managing the price volatility
- Monitoring, reporting and tracking allowances in a registry
- Reconciling emissions with allowances and setting penalties for non-compliance

Some of the most important design elements highlighted in the literature are focused on measuring and reporting verifiable data and allocating emission allowances (Wrake et al. 2008; Brohe 2010). The following two treatments were chosen based on this assessment and also on the overall objectives of this experiment.

1. Honesty declaration versus none: cheating effect
2. Targets: group versus individual targets

The first treatment aims to provide insight into the importance of verifiable data and the efforts that will need to go into ensuring accurate data based on the tendency of participants to cheat. Treatment 2 addresses issues around allocation, which has important implications in terms of, among other things, the acceptability of the schemes. Additional variables were considered but, in order to keep the experiment simple, only the above treatments were assessed.

The experiment will assess the impact of the two treatments on the following:

- Final emission reductions achieved
- Quantity and price of emission traded
- Motivations for reducing emissions
- Motivations for trading
- Perceptions of fairness
- Acceptance of the scheme

2.4.1 Honesty declaration versus none: cheating effect

Gathering accurate emissions data is identified as one of the key design challenges associated with implementing a PCT scheme (Brohe 2010). This has two elements: the administrative requirements to achieve this (i.e. feasibility) and the accuracy of the data. This study does not focus on issues around feasibility of implementation specifically. However, the accuracy of emissions data was expected to have a material impact on the outcomes of the study. International negotiations and discussions on carbon markets place importance on data being measurable, reportable and verifiable (MRV).

Brohe (2010) notes that clear rules, and the development of standardized methods for calculating emissions, are prerequisites for the credibility of an emissions trading scheme. Monitoring, reporting and verification are also key issues in terms of associated costs and, therefore, represents an important element in the PCT scheme as a possible policy option (Brohe 2010). There has been little research into the MRV issues in the PCT literature (Brohe 2010). Unfortunately, this results in a lack of analysis into monitoring and controls.

No emissions trading scheme has monitored or calculated emissions in real time. The reconciliation of emissions with allowances occurs on an annual basis in most cases (Brohe 2010). Many PCT schemes propose the introduction of a swipe card system (Prescott 2008); although this would make real time monitoring possible as it would increase transaction costs significantly. Capstick and Lewis (2010) asked participants to self-report emissions using a calculator provided by the researchers. They accepted a certain loss of accuracy and assumed that figures reflected realistic and representative values.

2.4.1.1 Overcoming the incentive to cheat

Various authors have explored motivations behind cheating and how to overcome these (Mazar et al. 2008; Mead et al. 2009; Gibson et al. 2009; and Prescott 2008). It has been suggested that an honesty declaration can reduce cheating and that the tendency to cheat increases with subsequent moments of temptation.

Mazar et al. (2008) examine people's "self-concept"; that is, the way people view and perceive themselves. They suggest that people are mindful of their own moral standards and will update their self-concept as a consequence of their actions. This implies that, if moral standards are accessible (e.g. through a reminder such as an honesty declaration), people will confront the meaning of their actions more readily and, therefore, be more honest.

Their work also discusses the attention people pay to their own standards of conduct. Their idea is related to Duval and Wicklund's (1972) theory of objective self-awareness and Langer's (1989) concept of mindlessness. They hypothesized that when people are mindful of their own moral standards, any dishonest action will cause them to update their self concept, which in turn will cause them to adhere to a stricter definition of honest and dishonest behaviour. When people are not mindful of their own moral standards, their actions are not evaluated relative to their standards, their self-concept is less likely to be updated, and, therefore, their behaviour is likely to diverge from their standards. "Thus, the attention to standards mechanism predicts that when moral standards are more accessible, people will need to confront the meaning of their actions more readily and therefore be more honest (Mazar et al. 2008: 635).

One way of encouraging attention to standards is to remind participants of their moral standards. The potential value of such a reminder is that people will compare their behaviour to their standards in the moment of temptation (Mazar et al. 2008). In their study, Mazar et al. (2008) found a significant interaction between the reminder and the ability to cheat. In line with the authors' theory of self-concept maintenance, reminding participants of standards of morality eliminated cheating completely. The authors' analysis of variance (ANOVA) revealed a highly significant effect due to the attention to standards manipulation. The authors also varied the types of reminders. They found that participants were not affected by whether a threat of punishment was real or not, or whether they believed in the Ten Commandments they were required to state. It was rather the reminder of morality that influenced behaviour.

However, cheating may not only be a function of internal drivers. Mazar et al. (2008) also found that people's motivation to cheat is a function of their perceived risk of getting caught. They found that participants cheated up to the point where they estimated that the probability of being caught and/or the severity of punishment would be negligible. This is supported by Nagin and Pogansky (2003) who suggest that increasing the probability of getting caught is much more effective than increasing the severity of the punishment.

Another alternative is that cheating is a function of what others are likely to do (the norm compliance argument). This has been suggested by psychologists as part of socialization, where people internalize the norms and values of their society (Campbell 1964; Henrich et al. 2001). However, Mazar et al. (2008) found no evidence of participants being sensitive to others' reported behaviour.

Gibson et al. (2009) conducted an experiment to explore predictions of a behavioural theory whereby agents consider truth-telling as a "sacred value." They find that individuals with stronger sacred values for truth forgo monetary gains to preserve the truth. It is not the intention of this study to determine those individuals who are more likely to cheat than others; however, it is important, when viewing the results, to know that an agent's actions are not always geared towards maximising material value.

Mead et al. (2009), through laboratory experiments, find that cheating increases when people's self control[1] resources have been taxed by a prior act of self control. This implies, in the case of this experiment, that participants would be more likely to cheat in latter instances of reporting emissions data. Therefore, efforts to keep people honest need to be ongoing and so constant reminders were included in the design.

Prescott (2008) notes anecdotal feedback suggesting that cheating has not been a problem for *CarbonDAQ*. "Self-assessed calculator revisions more commonly increase participants' footprints, suggesting that they are not pursuing additional virtual pounds, or whatever other incentives their group has set up, but rather attempting to achieve a better or more dynamic carbon footprint." (Prescott 2008: 22)

2.4.2 Targets: group versus individual targets

An emission trading scheme sets a cap on emissions. The right to emit is then determined by the regulator. The process of allocating emission allowances or carbon credits has been debated in both theory and practice. There are two main allocation approaches: either selling emission rights or giving them away. The debate around this process is based on an assumption about who should initially own the property right to the environment – the polluter or the public at large (i.e. the taxpayer and the government) (Brohe 2010). Free allocation involves distributing pollution rights either on an equal per capita basis or under a rule such as grandfathering (Brohe 2010).

The allocation of a right to pollute on an equal per capita basis is a key principle of many of the proposed PCT schemes. Research into PCT has not considered unequal per capita allowances (Eyre 2010). Equal per capita allocation involves allocating the quantity of emissions rights allocated to a nation in a given year by dividing the rights to the permitted global emissions for that year by the global population in that year (or an agreed base year) and then multiplying the quotient by the nation's population in that year (or the agreed base year). This is the approach advocated by the well-known Contraction and Convergence proposal (Starkey 2008; Brohe 2010).

Proponents of this approach argue on the basis of fairness. Starkey (2008), however, has questioned the philosophical basis of the claim based on what he calls "brute luck" factors. Brute luck could be that you have ended up in a colder part of the country and, therefore, have different energy needs. Lockwood (2010) suggests that there is a good case for exploring initial allocations that reflect factors that can be construed as "brute luck", since many of the decisions that people have taken may be long term or even irreversible and so have the characteristics of "brute luck" in the short term. Lockwood (2010) also notes that another concern that does not seem to be adequately addressed in the PCT literature is that individuals have different abatement opportunities, influencing the capacity of the individual to reduce emissions, which will also impact the fairness of initial allocations.

In a free allocation process, the allocation is political. Therefore, it is influenced by various forms of lobbying, which can make the process laborious. Brohe (2010) suggests that this often results in

[1] Self control is referred to as the capacity to overcome selfish impulses so as to act in socially desirable ways, has therefore been called the "moral muscle" (Mead et al. 2009: 594)

over-allocation. Grandfathering is similar, in that the rights to pollute are allocated on the basis of prior use. This approach is usually advocated by polluters (Brohe 2010; Beder 2010). Issues around grandfathering can become contentious when other organizations have already made investments in reducing their emissions and, therefore, would be allocated lower allowances based on their more recent historic emissions.

Alternatively, if the government decides to sell permits, then there is an assumption that polluters had no prior right to the environment and that the atmosphere is a commons owned by all (Brohe 2010). In practice, governments have used a hybrid approach to allocate pollution rights (Brohe 2010).

Member States of the EU ETS drew up national allocation plans (NAPs) in Phase I and Phase II of the scheme. This set their total level of emissions, and the number of allowances allocated to each installation, falling into the scope of the Directive located on their territory. Excessive allocation limited the environmental benefits in the first trading period and, following a publication of this over-allocation in May 2006, the market reacted by lowering the price. The price of the EUA never recovered. Following criticisms of the distortions in competition created by the 27 NAPs, a new approach will be adopted whereby the Commission will allocate allowances on the basis of harmonized rules. A significantly higher share of allowances will be auctioned, instead of allocated free of charge (Brohe 2010).

With regard to setting targets, Prescott (2008) set an endogenous target of almost 10% from the average emissions. Capstick and Lewis (2010) set group-wide personal carbon allowances 20% lower than participants present carbon footprints. In a second round they set them at 40% lower than their present carbon footprints.

The allocation of allowances in this study aims to test some of the concerns raised above. Most noticeably, it has assessed acceptability and perceptions of fairness, and the implications of different allocation approaches in terms of emissions reduced, levels of trading, price, and other significant outcomes.

2.5 Other design considerations

2.5.1 Penalties and enforcement

PCT relies on an enforcement system in which the penalty-level determines the price at which constrained actors will breach the cap. Many authors note the need for a limit on the penalty-level and the price of emission credits to ensure political acceptability and avoid price volatility (Eyre 2010; Lockwood 2010). This is referred to as a "safety valve." Without a safety valve the possibility of price spikes presents a significant concern in the form of worsening of fuel poverty for some poorer households and unpopularity, if prices were to rise greatly in excess of carbon prices paid by businesses in other schemes such as the EU ETS (Lockwood 2010).

Safety valves can be applied in a number of ways. A price floor and / or price ceiling could be used to avoid price volatility (Brohe 2010). "The price floor would prevent the collapse of the emissions market due to either an over-allocation of permits or a fall in the demand for permits. The price ceiling would insure the covered entities against extremely high costs of abatement" (Brohe 2010: 465). Additionally a long commitment period, with banking and borrowing of emissions credits between periods, can also reduce price volatility (Brohe 2010).

Safety valves have been applied in the design of actual emission trading schemes. The initial phase of the EU ETS was not successful at managing price volatility. The second phase allowed banking of allowances and access to the baseline and credit schemes implemented by the UNFCCC (Brohe 2010). In the EU ETS, trading allows access to the international carbon market through the purchase of certified emission reductions (CERs) from the Clean Development Mechanism (CDM) and emission reduction units (ERUs) from Joint implementation (JI). This acts as a form of safety valve (Eyre 2010).

Brohe (2010) notes that the use of a safety valve would need to be weighed against the loss in environmental and economic effectiveness. In the case of this experiment, a safety valve was applied to ensure that participants were not subjected to significant personal costs. The implication of the safety valve on environmental effectiveness could not be tested, but the social / political implications were assessed through the post-experiment survey.

Enforcement is also identified as a crucial element in effectively implementing an emissions trading scheme. Enforcement requires legal responsibility and sanctions in the event of failure to achieve the specified outcome. In the EU ETS, a penalty of £100 would be charged for failure to meet obligations in Phase II (£40 in Phase I). This is a penalty for lateness of surrender and actors would still be required to redeem the missing allowances the following year (Brohe 2010).

Enforcement rules have not been described in great detail in the PCT literature (Brohe 2010). Cason and Raymond (2010) noted the importance of enforcement policies within the context of emissions trading schemes. In their experiment they apply random inspections with monetary fines for under-reporting. This sort of approach was not seen to be viable within the context of this experiment and, therefore, the experiment relied only on truthful disclosure.

2.5.2 Scope of the scheme

Amongst the PCT researchers there is no consensus on the scope of emissions to be included in the schemes. Some suggest only household energy should be included but others argue for the inclusion of transport related emissions too (Brohe 2010). Bristow et al. (2010) note that some participants might have a preference for a broader scheme, as it would allow more options for CO_2 reduction; whereas others might prefer modes of transport that they use extensively to be omitted. However, their experimental results show no clear preference for variations in the scope of emissions covered in a PCT scheme.

Defra's pre-feasibility study assumed a mandatory, economy-wide scheme with free carbon credits to all UK adults (Defra 2008). Prescott's (2008) study concluded that, rather than seeing it as essential to capture all emissions within the same initiative, significant progress could be achieved by isolating chunks of emissions that can be reduced and applying a cap-and-trade approach to each of them.

2.5.3 Whether or not to fund participants

It is a standard practice in experimental economics to provide subjects with an initial endowment of money from which they can draw when making decisions (Clark 2002). However, this experiment aims to simulate a situation where participants make decisions based on their own, real costs and benefits.

To achieve this, efforts were made to ensure that subjects did not incur significant losses. These measures included: a limit on the number of credits that each participant could purchase, a ceiling on the price of carbon and a cap on the potential financial penalty that any participant may have been required to pay (refer to the methodology for further detail on these measures). This approach is not seen to be unethical in the experiment adopted by Gneezy and Rustichini (2000). Additionally, Bardsley et al. (2010) support "new" approaches where they can be justified.

2.5.4 Banking emission allowances

In the case of the EU ETS, allowances can be banked for use in a future year (Wrake et al. 2008). In this example we are concerned only with the reduction commitment being met for the whole period. Weekly reduction requirements were estimates and, as such, participants could effectively bank from one week to the next. New caps were not applied after each time period as was the case in the EU ETS (further detail is provided in the methodology below).

Not including banking is consistent with the approach taken by Klaassen et al. (2005) and Holt et al. (2007). "In experiments where no banking is allowed, bidders only bid on allowances that they need to support their production activity" (Holt et al. 2007: 17). Not allowing banking also has the benefit of greater simplicity (Holt et al. 2007).

2.5.5 The shadow price of carbon

Defra (2008) estimated the value of a ton of avoided carbon emissions at £30. They based this on the shadow price of carbon taken from the Stern Review (Stern 2007) which they equated with the social cost of carbon or the damage caused to the global economy. However, there has been debate around the accuracy of these estimates, with many suggesting that, due to uncertainty around the potential damage, the shadow price should be based on the marginal cost of abating carbon (Lockwood 2010).

In theory, prices could be determined by the market, have a ceiling set by the regulator or be fixed by the regulator, as in the initial phase of the CRC Energy Efficiency Scheme in the UK (Bristow et al. 2010). Table 1 provides a summary of carbon prices from a variety of experimental settings, as well as real world examples. These have been converted to a rand equivalent per kilogram of CO_2 to be more relevant for the purposes of this study. Note that these cover differing scopes of emissions and come from a variety of different contexts, with different assumptions and drivers behind them. Therefore, the prices were only used to guide the setting of a price limit.

Table 1: A review of recent carbon prices

Price (Rand/kg CO_2e)	Description	Unconverted price	Source
9.46	The price resulting from the pilot experiment (described earlier)	Not applicable	Pilot study
1.13	A hypothetical price applied in a laboratory setting	£100 / tonne of personal carbon allowance	Capstick & Lewis 2010
0.53	The price used in the Stern Review	£42.61 / tonne of CO_2	Stern 2006
0.37	UK Government shadow price	£26 / tonne of CO_2	Defra 2007
0.66	The new mitigation based central non-traded sector value	£50 / tonne of CO_2	DECC 2009
0.30	The European Trading System trading price as at 24 July 2008	£19.90 / tonne of CO_2	Pointcarbon 2008 (cited in Bristow et al. 2010)
0.16	Certified Emission Reductions (CERs) as at 22 May 2011	€16.38 / tonne of CO_2	Pointcarbon 2011
0.12	European Union Allowance (EUA)	€12.34/ / tonne of CO_2	Pointcarbon 2011

3 Methodology

3.1 A pilot study

A pilot experiment simulated a personal emissions trading scheme at an office in Observatory Cape Town. Eight individuals were involved in the pilot. These individuals measured their transport (non-work) related emissions, committed to reducing their emissions and then conducted one auction to trade carbon credits.

This experiment proved successful in engaging the participants in the debate around how best to motivate for a reduction in individual transport emissions. The experiment was able to determine the price of transport carbon emissions: R 9.46 per kg of CO_2e. However, the real benefit of the experiment was in illustrating the difficulties in establishing a personal emissions trading scheme and providing insights into overcoming some of the potential institutional problems.

Participants were not aware of their individual Marginal Abatement Costs (MACs). This meant that decisions in the first auction were speculative and based on expectations of price rather than individual MACs. This informed the decision to provide participants in this experiment with as much information as possible on the associated costs and carbon emissions of various transport modes (mitigation options).

Consistent with the findings of Holt et al. (2007), this experiment proved extremely useful in identifying potential problems in the institutional design of the auction. Observed outcomes of the different phases and the feedback provided by the participants have contributed towards the design of this experiment. The quality of information, with regard to MACs of different transport emission reduction options, was suggested to be an important factor in establishing an efficient emissions trading scheme.

3.2 Experimental design

3.2.1 The subject pool

This experiment recruited 56 volunteers from the University of Cape Town student body. Students were not paid to participate. According to Cason (2010), participation in experiments can sometimes be induced in exchange for a learning experience. This was the approach adopted in this experiment. The experiment was conducted ahead of the 17th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held in Durban in December 2011. An opportunity to better understand the international climate change policy development process, as well as an opportunity to experience one of the mechanisms to mitigate climate change; were communicated as potential benefits of participating. Other potential benefits communicated to students included a reduced personal transport GHG emissions footprint and a greater understanding of the full costs associated with transportation.

A targeted approach was adopted. Students more likely to experience these benefits were encouraged to participate. Recruitment focused on students enrolled in courses that focus on some element of climate change and various societies or clubs with a possible interest in the subject (such as the Green Campus Initiative). It is accepted that the individuals who participated in the experiment are not necessarily representative of the broader population. Interested students were found to be those who were interested in climate change, believed in the science of climate change and were committed to reducing their climate change impacts (89% indicating that they believed climate change would impact them personally). As participation was voluntary, and because most participants were motivated to participate based on expected educational / experiential benefits rather than a financial incentive, it is expected that there would be a bias towards the environmental objective of carbon trading (the need to mitigate greenhouse gas emissions).

Due to the small sample size, no assumptions could be made regarding normality and homogeneity of variance; therefore non-parametric tests were applied in the analysis. The major disadvantage of this is a greater likelihood of missing significant effects.

3.2.2 Scope of the scheme

Only emissions related to personal transport were included in the scope. It was decided that conducting the experiment based on an individual's full carbon footprint would be too complicated and onerous. Sources of emissions included commuting to and from the university, travelling in the evenings and on weekends and travelling on holidays. Modes of transport included car, taxi, bus, minibus and train. Emissions were measured in Kg of CO_2 equivalents (Kg CO_2e).

As the purpose of this experiment was not to test the feasibility of implementing such a scheme, issues related to double counting (where emissions might already be covered under a larger cap-and-trade scheme) and alignment with other existing or proposed mitigation policies is not considered.

The allocation was determined based on the reduction commitments agreed during COP1 (see phase 4 of the experimental approach for information on this process). In this way, this study adopts a baseline and credit market as described by Jagers et al. (2010). In this market, the credits are equal to emission reductions *vis-a-vis* the baseline. Commitments to reduce emissions by a certain percentage below the baseline were translated into an emissions allowance. Each treatment group's combined allowances represented the cap for that scheme.

3.2.3 Treatments

The 56 volunteers were divided up into three groups (two per treatment and one control group).

Table 2: Summary of the treatment groups

Group name	Treatment	Sample size (n)	Conditions
B1	Treatment 1	21	• Individual targets chosen • **No honesty declaration signed**
B2	Treatment 2	17	• **Group targets chosen (by vote)** • Honesty declaration signed whenever data was submitted
ITH	Control Group	18	• Individual targets chosen • Honesty declaration signed whenever data was submitted

3.2.3.1 <u>Treatment 1: assessing the role of dishonesty</u>

An honesty declaration, signed when submitting baseline emissions data and weekly reported emissions, was an attempt to overcome potential tendencies to be less truthful.

3.2.3.2 <u>Treatment 2: assessing the role of different allocation approaches</u>

A grandfathering approach was used in allocating emission allowances. Participants committed to a reduction relative to their baseline emissions (i.e. a reduction below business-as-usual). Allocations were, therefore, a function of participants' historical emissions. Participants in ITH were able to set individual targets.

Participants in GTH were required to agree on a target reduction applicable to each individual in the group. The allocation approach for GTH was set up to resemble an equal per capita allocation, but with an important difference. An equal per capita allocation results when the total quantity capped for the system is divided equally amongst the individuals within the system. Therefore, each individual has the same emissions allowance. Each participant in GTH, however, was required to make equal relative reductions over the commitment period. The relative reductions were equal but the absolute emission allowances (a function of each individual's baseline) were different. The intention was to mimic the "equal" approach of an equal per capita allocation, but it was felt that, considering the short commitment period and in an effort to limit the potential for large personal costs[2], allocating equal absolute allowances would not be feasible nor ethical in the context of this experiment.

3.2.4 Other important design elements

3.2.4.1 <u>Setting limits on purchasing, price and the final penalty paid</u>

Based on the literature, the following limits were set to act as "safety valves":

- Purchasing limit: maximum of 50% of a participant's emission reduction requirements
- Price ceiling: R2 per Kg CO_2e
- Maximum penalty: R100 (in total)

[2] Some individuals may have emitted far more than the average and have had no cost-effective mitigation options. This would have resulted in the purchase of emissions credits being the only viable option to achieve individual targets. Depending on the difference between the emissions baseline and the emission allowance, the personal costs could have been significant.

3.2.4.2 Providing information on the marginal abatement costs of different mitigation options

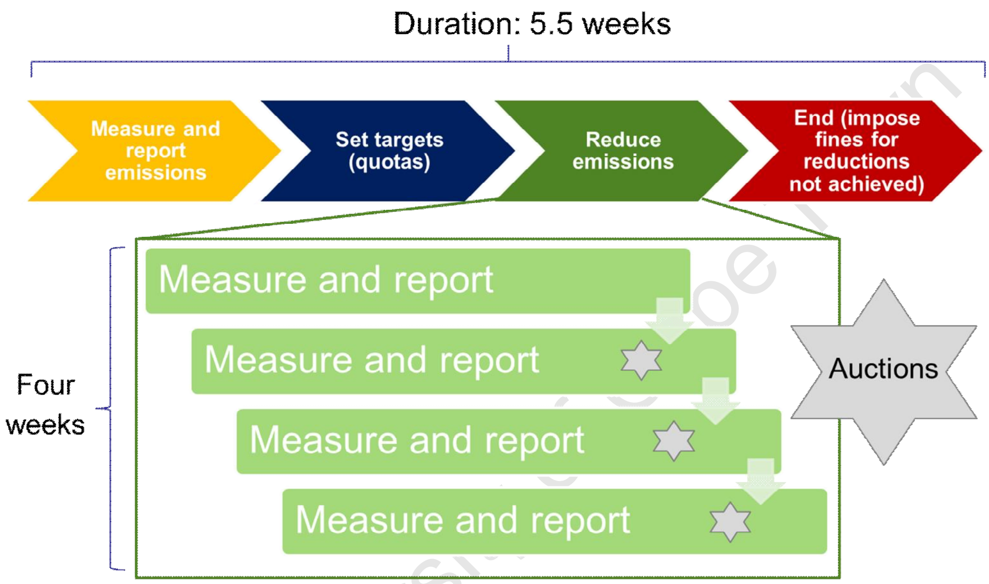
Throughout the experiment participants were provided with the following information help inform their decisions:

- Estimates of the cost (Rands) per km travelled for each mode of transportation
- Estimates of the carbon emissions (Kg CO_2e) per km for each mode of transportation

3.3 Experimental approach

The experiment lasted eight and a half weeks. The process, depicted in Figure 1, included two weeks for the recruitment process, a week to collect baseline data, the four week commitment period and two and half weeks for the project close-out and the conducting of the post-experiment questionnaire.

Figure 1: Experiment procedure



Refer to the Experiment Protocol (Appendix 1) for a more specific explanation of the process followed. A summary of the different phases is provided below:

3.3.1 Phase 1: Recruitment

Recruitment took place over two weeks. Students were contacted and encouraged to participate via email and through an introductory lecture (fifteen minutes) delivered during lecture times where possible. This included an introduction to the project, a description of the potential benefits of participating (particularly with regard to educational benefits) and information on how to get involved.

3.3.2 Phase 2: Project introduction

During an introductory lecture, students were provided with more detail on emissions trading and the experiment. The session included a short lesson on how to capture data into the spreadsheet provided and how to submit offers to buy or sell carbon credits during the auction processes. The infographic used in the introductory session to help explain the experiment process is included in Appendix 2.

3.3.3 Phase 3: Collection of baseline transport data

Participants were required to submit data related to personal transport over a period of one week (the approach was similar to that adopted by Bristow et al. (2010)). Data was entered into a spreadsheet and then sent to the experimenter. Data requested included:

- Kilometres travelled by car (including the vehicle size, fuel used and number of individuals in the vehicle)
- Kilometres travelled by motorbike / scooter (including the vehicle size, fuel used and number of individuals on the vehicle)
- Kilometres travelled by train (the spreadsheet included information on the distances between stations in Cape Town).
- Kilometres travelled by bus
- Kilometres travelled by *Jammie Shuttle*[3] (average distances between stops was provided) and
- Kilometres travelled by minibus.

The spreadsheet provided clear instructions, as well as information to help participants understand the costs and carbon emissions associated with different transport options (to help inform their mitigation decisions) (see Appendix 3Appendix 3).

Groups ITH and GTH were required to enter their names (sign) under a declaration of honesty.

The spreadsheet included a calculator that generated each participant's transport carbon footprint. The calculator was developed for this experiment. Emission factors most suited to the local conditions were chosen (refer to Appendix 3 for a list of the emission factors used).

The data were then extrapolated to provide a total emissions estimate for four weeks, for each participant. This was then used as each participant's emissions baseline: the transport carbon emissions that the individual would have been expected to produce over the four week period if a mitigation intervention had not occurred (i.e. business-as-usual).

3.3.4 Phase 4: Conference of the Parties (COP 1) to agree reduction targets and a penalty for failure to meet commitments

The aim of the meeting, referred to as Conference of the Parties (COP) 1, was to set targets which would translate into absolute commitments for each participant; and to agree a common penalty for failure to meet the commitment by the end of the full commitment period. The structure of the meeting mimicked international COPs. In particular, the meeting aimed to mimic COP15 whereby countries debated how best to share the burden of climate change mitigation and commit to a target for the second Kyoto Protocol commitment period.

Prior to the meeting, participants were emailed a set of instructions and information to consider. The email included each participant's individual baseline emissions data and additional information (such as hypothetical examples of the financial implications of different actions based on a range of assumptions). In most emissions trading studies conducted in a laboratory setting (Klaassen et al. 2005), participants were provided with a domestic cost function and the domestic marginal costs for meeting their agreed emission reduction target. Hence, the studies could determine the efficient price and quantity of trading, and compare experimental results to the efficient market outcome. In this experiment it was assumed that individuals would know their MAC curves. Attempts were made to assist participants in this regard by providing the cost per kilometre and the CO2e per kilometre for each transportation mode.

In determining targets and a penalty, participants were encouraged to consider the following:

- Alternative penalty and target options and to communicate their ideas at the meeting;

[3] The University of Cape Town campus transport service.

- Their likely MACs associated with the different reduction options available to them (this required considering what reductions they could realistically achieve and what those reductions would cost);
- Other participants' ability to reduce transport emissions and their likely MACs; and
- Issues relating to equity, individual incomes, and the fact that certain reductions are not possible for some, in the short time frame considered (refer to the discussion around grandfathering in the literature review section).
- Finally, participants were encouraged to be realistic, but ambitious, about what they could achieve.

Participants from ITH and ITNOH submitted their commitments at their respective COPs[4]. Commitments were expressed as percentage reductions below the baseline. Reduction commitments were treated as confidential. Participants from GTH voted for a common target, also expressed as a percentage reduction below the baseline, to be applied to each participant. Votes were submitted confidentially following some heated discussion around an appropriate "group target."[5]

All participants voted (confidentially) for a penalty to be applied to an individual for exceeding their allocation for the full commitment period. This was expressed as a Rand cost per Kg CO_2e over the individual allocation.

Targets were translated into allocations[6]. A summary of the outcomes of the COP (including the penalty and each individual's allocation) was sent to each participant individually.

3.3.5 Phase 5: Emission reductions

Throughout the commitment period participants attempted to reduce their transport emissions through a variety of means. On the Monday of each week, students submitted their data in the same fashion as in Phase 2. The experimenter then calculated each individual's footprint and sent them a summary indicating how they were doing relative to their weekly allocation. This summary indicated whether they had a surplus or deficit of carbon credits. Although participants would only be held to account on their final emissions relative to their allocation at the end of the commitment period, these weekly summaries helped indicate whether a participant was on track or not. A deficit, for example, merely indicated the need to either buy credits or to increase mitigation efforts in the coming week. This information was intended to inform their actions in the auction. The correspondence included instructions on how to participate in the weekly auction.

3.3.6 Phase 6: Trading emission credits through an auction

The experiment conducted three single bid, uniform price auctions. Participants were provided with written instructions regarding the auction process along with their transport emissions performance summary. All participants received their summaries on the Tuesday of each week. Participants were reminded that they would only be penalised if they failed to meet their commitment at the end of the full commitment period. Conducting auctions each week allowed participants to manage their abatement and purchasing decisions to meet their commitments.

On the Wednesday morning of each week the auction was opened when each participant received an "offer to bid" email. To participate in the auction participants had to complete the offer to bid spreadsheet (see Appendix 4), and email this back to the experimenter before the auction closed at 4pm on the Wednesday (this has been adapted from the approach used by Hizen and Saijo (2001)).

[4] Each group attended a separate COP

[5] Although each participant in GTH was required to adopt the same relative reduction commitment, the absolute reductions that this would require differed depending on each individual's baseline.

[6] A participant's allocation was equal to their baseline minus the percentage reduction from their baseline committed to during the COP. For example, a 10% reduction commitment on a 100 kg CO_2e baseline would translate into an allocation of 90 kg CO_2e.

The time priority rule was applied; and so orders were executed according to the sequence in which they were placed. If several orders had the same price limits, but there was a lower number of buy orders at that price, the sell order that was inputted first was be executed first (time priority). Accepted bids were treated as binding contracts (Holt et al. 2007).

The experimenter entered bids into a spreadsheet to determine the price and quantity to be sold for that auction. Piece-wise demand and supply curves were constructed and the cumulative buy and sell orders were matched together to determine the clearing price at which they executed and the specific orders that executed (the intersection of the two curves). The clearing price was the value of the highest rejected bid in line with the approach taken by Holt et al. (2007).

This process was repeated at each auction. Information on equilibrium prices and volumes traded was made available to all participants (excluding who bought and who sold credits) after each auction. This information was included in the email sent ahead of the next auction (the same email that included the summary of participants' weekly emissions.) Money was only exchanged at the feedback session at the end of the commitment period. The experimenter incorporated sales and purchases of carbon credits into each participant's weekly emissions summary.

3.3.7 Phase 7: Feedback session

According to Croson (2002), subjects are occasionally debriefed and informed of the purpose and design of the experiment. A feedback session was regarded as important, considering the educational benefit of participating (see as one of the main motivators for participating). The feedback session provided a high level summary of the experiment and the results. It also provided the opportunity for participants to come together so that participants could pay for credits purchased, be paid for credits sold and pay any penalties owed. Ahead of the feedback session each participant was sent their final transport emission performance summary. The summary included their emissions relative to their allocation for the full commitment period, money due for credits sold, money owed for credits bought and money owed as a penalty if their emissions exceeded their allocation.

The session included a short explanation of why the experimenter believed people would not always reveal their emissions truthfully. Due to this, an attempt was be made to estimate the extent to which obtained data was biased by "cheating." This was done by requesting that participants indicate, on a paper survey, the extent to which they may have cheated when reporting their baseline and/ or weekly transport emissions. The survey was anonymous but participants were required to indicate their group.

3.3.8 Phase 8: Post-experiment survey

Participants were requested to complete an online post-experiment questionnaire (administered using Google Forms). Ackert et al. (2003) administered a post-experimental questionnaire to collect general information about the participants and how they viewed the experiment. Cason and Raymond (2010) adopted a similar approach. This questionnaire sought to elicit information on the following elements:

- Motivation for reducing emissions and for cooperating or not cooperating
- Perceptions around fairness
- Attitudes towards the environment and environmental regulations (social acceptability)
- Legitimacy of emissions trading

The questionnaire included a question to solicit votes on how revenues generated from the experiment should be used. This approach was aimed at improving the social acceptability of the scheme design[7] (see Appendix 5).

[7] The form can be viewed at https://docs.google.com/spreadsheet/viewform?hl=en_US&pli=1&formkey=dE1XM1VTQkNVZEx3bWRxQS1QZjltYUE6MQ#gid=0

4 Hypotheses

The following hypotheses of what will occur in the lab were expected, based upon empirical evidence from the literature.

4.1 Treatment 1

- The honesty declaration was expected to increase truthful reporting

There is the potential to profit from dishonesty in this experiment. Eyre (2010: 437) notes that "the nature of a cap-and-trade scheme is that there is an economic incentive for evasion." It was, therefore, expected that there would be a certain level of cheating. It was anticipated that those who made an honesty declaration would be less likely to cheat than those with no declaration of honesty.

Participants would benefit from exaggerating their emissions baselines and understating their reported weekly emissions. Exaggerated baselines would, due to the grandfathering approach to allocation, increase an individual's emission allowance. Understated weekly emissions would more likely result in surplus carbon credits that could be sold in the market (allowing participants to make money) or would mitigate the risk of exceeding their individual allowance and having to pay a penalty.

4.2 Treatment 2

- Being able to choose targets independently was expected to be more socially acceptable

Evidence from the pilot study suggested that individuals preferred being able to choose their own targets. Group targets were not seen to take into consideration the variety of mitigation options available and different circumstances faced by different individuals.

In the case of both treatments, one of the main objectives was to assess the outcomes in terms of achieving the overall economic objective of reducing emissions while also being socially and politically acceptable. No hypotheses were developed; but rather the experiment was used as a test-bed to help illustrate the policy implications associated with carbon emissions trading, particularly at the individual level.

5 Empirical results

This section presents the results of the experiment. First, the summary results for the sample as a whole are provided. This is followed by an assessment of the following key themes: baseline emissions; achieved emission reductions; participation in the auctions and the acceptability of scheme design. The analysis compares differences in the results for each theme observed in the different treatments. These results will then serve as a reference point for discussing the policy implications around climate change mitigation and the use of carbon trading as a mechanism to achieve mitigation objectives.

5.1 Summary results

The overall sample results are presented in Table 3. One of the objectives of the experiment was to achieve a reduction in the transport GHG emissions for the sample as a whole. Individual baselines were aggregated to determine the combined GHG emissions that would have resulted were it not for this experiment. Each individual's reduction commitment (target) translated into an emission allowance. The sum of the individual allowances translated into a target reduction of 14% below the baseline. The actual achieved emission reductions at the end of the experiment, based on reported emissions, came to 34% below the baseline. The difference between the targeted reductions and the achieved emission reductions is significant at the 1% level according to a Wilcoxon Signed Rank Sum test.

Interestingly, the achieved reduction is in line with the South African National Government's conditional commitment to achieve a 34% reduction below business as usual (BAU) by 2020 (Department of Environmental Affairs 2011). This does not suggest that the government's target is appropriate or achievable (as the scope of emissions and timeline are completely incomparable); however, the coincidence did help link the experiment back to climate change policy in the real-world setting and contribute to the educational benefits associated with participating in the experiment.

Table 3: summary of experimental results for the sample as a whole

Emission reductions	
Target reduction	14% below baseline
Reported achieved reduction (%)	34% below baseline
Reported achieved reduction (Kg CO_2e)	2113 KgCO_2e
Achieved reduction adjusted for cheating bias (%)[8]	18% below baseline
Achieved reduction adjusted for cheating bias (Kg CO_2e)	890 KgCO_2e
The Auctions	
Average price of carbon	R 0.35 per KgCO2e
Total credits traded	270
Total credits offered	801
Total credits demanded	318

[8] Based on the post questionnaire responses, there was a significantly higher level of cheating with regard to the reporting of emissions baselines by individuals in ITNOH. An attempt was made to mitigate this bias by assigning individuals in ITNOH emissions baselines equal to the ITH average (92 KgCO2e)who reported no cheating with regard to the reporting of emissions baselines (refer to "Differences in reported emissions baselines" for further discussion on this).

The penalty	
Penalty	R 3.39 per Kg CO_2e over allocation
Participants who had to pay a penalty	13%
Revenue generated from the penalty	R 393

The 34% emissions reduction was equivalent to 2113 Kg CO_2e avoided. Put into context, this is equivalent to driving a small petrol car from Cape Town to Nairobi (Kenya) and back. The value of these emissions, at current market prices[9], is R 338. This value is simplistic and intended only to provide context.

Individuals in ITNOH were found to have exaggerated their baselines significantly (this is discussed in more detail in the section analysing differences in reported baselines, below). Therefore, an attempt was made to account for this and to calculate an achieved reduction adjusting for this bias. Although substantially lower, the adjusted achieved reduction still exceeded the targeted reduction for the sample.

The penalty, based on a vote, was set at R 3.39 per Kg CO_2e over allocation. Only 13% of participants had to pay a penalty, the combined revenue of which was R393. This revenue was used to buy carbon credits in the voluntary market, based on the preference of the participants.

A total of three auctions were conducted, with a total of 270 credits (a credit being a 1 Kg CO_2e) traded at an average price of R 0.35 per Kg CO_2e. The supply of credits exceeded the demand for credits. As can be seen in Table 4, both the quantity of credits offered and the demand for credits increased with each successive auction. However, the increase was greater in the number of credits offered. This put downward pressure on the price causing the market clearing price to decrease with each successive auction. Involvement in the auction (measured by the number of buy and sell bids) increased with each successive auction. The demand and supply curves and the market clearing prices and quantities for each auction are reflected in Figure 2.

Table 4: Summary of auction results

	1st auction	2nd auction	3rd auction
Market clearing price	R **0.50**	R **0.40**	R **0.30**
Market clearing quantity	**22** $KgCO_2e$	**87** $KgCO_2e$	**161** $KgCO_2e$
Total number of sellers at the market price	4	3	1
Total number of buyers at the market price	1	8	7
Total number of sell bids	9	10	16
Quantity offered	146	185	470
Total number of buy bids	6	8	7
Quantity demanded	70	87	161

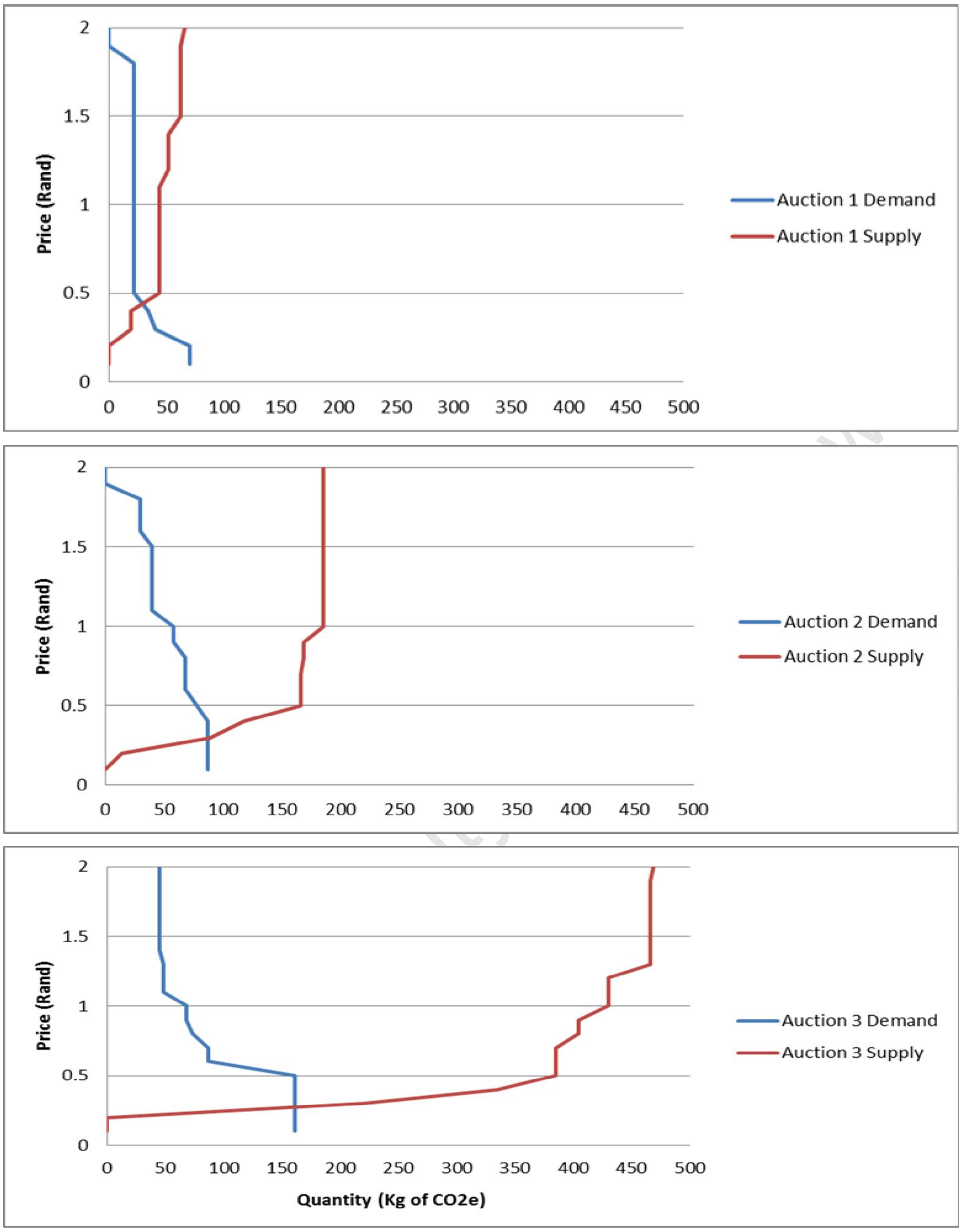
The decrease in price and the increase in the quantity of credits offered may have been the result of some participants realising that it had been easier to achieve reductions than they had originally anticipated (i.e. when they committed to their emission reduction targets). This meant they had surplus emissions to sell at the end. This may have been intentional, in an effort to make money from trading (however only one participant (2%) who responded to the post-experiment questionnaire indicated that this was their main intention), or could have been a result of an inadequate knowledge of individuals' own MACs.

Only one individual sold credits in the final auction (see Table 4). The individual was the first to submit a (large) bid which, according to the time priority rule, was settled first. This participant made

[9] This was the global price of Certified Emission Reductions (CERs) as at 22 May 2011 (refer to Table 1)

R 76.30 over the three auctions. The next highest income earner received R4 at the end of the auction. This highlights the unequal role/ influence of individuals in the market.

Figure 2: Demand and supply curves and market clearing prices and quantities for each auction



5.2 Differences in reported emissions baselines

Table 5 indicates that, as expected, the group that did not sign the honesty declaration (ITNOH) reported a much higher average baseline (almost double) than the average reported by individuals in ITH. Results of a Wilcoxon-Mann-Whitney test[10] indicate that the difference between the underlying distributions of the reported baselines of ITH and ITNOH is significant at the 5% level (refer to Appendix 6 for p-values from the test).

[10] This test is used to compare the means of an interval dependent variable for two independent groups where no assumptions can be made about the distribution of the means due to a small sample size.

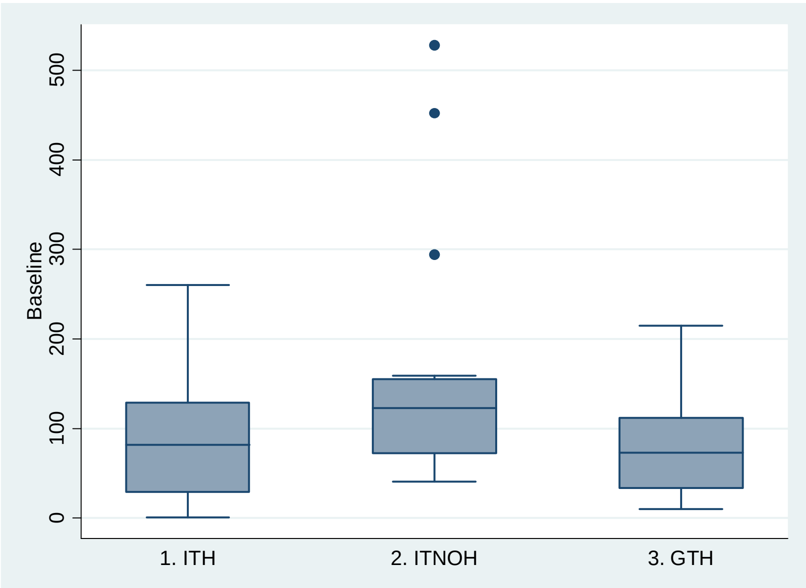
Table 5: Comparative statistics for reported baseline emissions

	Reported baseline emissions (Kg CO2e)		
	Mean	**Min**	**Max**
ITH	92	1	250
ITNOH	150**	41	528
GTH	82	10	215

** denotes statistical difference at the 5% level.

This result may have been influenced by a number of outliers in ITNOH. As can be seen from Figure 3, three individuals in ITNOH reported very high emissions baselines. The individual who reported the highest baseline emissions (528 Kg CO_2e) was the same individual who earned the disproportionately high income from selling credits through the auctions.

Figure 3: Box plot of reported emissions baseline (Kg CO_2e) per group



An attempt was then made to compare baselines while excluding the influence of these possible outliers. The comparative statistics for baseline emissions excluding possible outliers is presented in Table 6. Excluding possible outliers lowers the mean emissions baseline for ITNOH from 150 to 105 Kg CO_2e. A Wilcoxon-Mann-Whitney test fails to confirm that there is a significant difference between the mean reported baselines of ITH and ITNOH when possible outliers are excluded (refer to Appendix 6 for p-values from the test). The small sample size (n = 21 for ITNOH) highlights that any analysis that excludes three observations must be treated with caution.

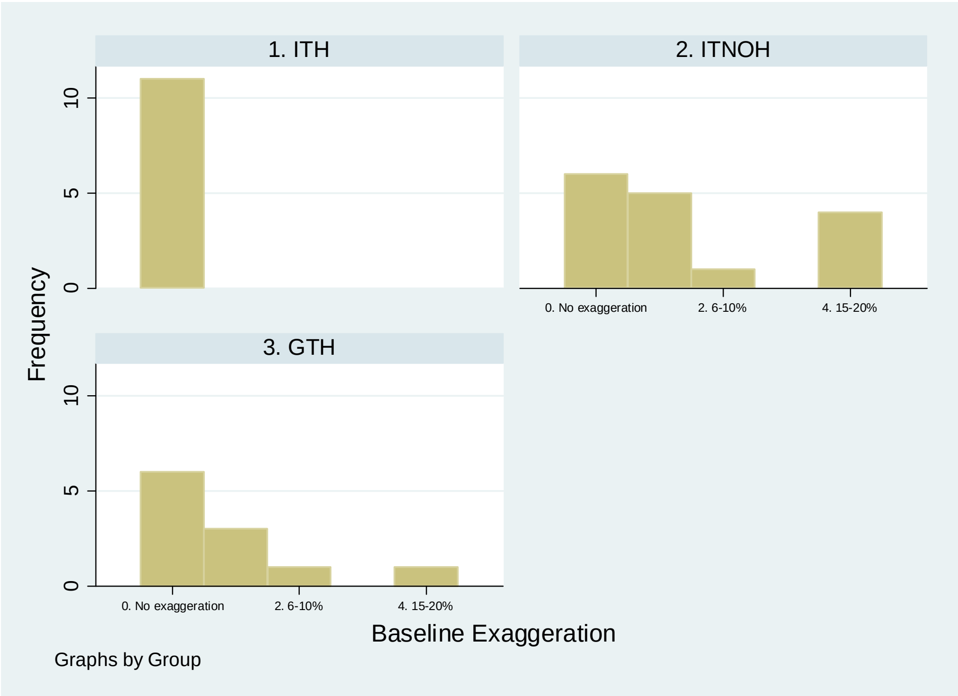
Table 6: Comparative statistics for reported baseline emissions excluding outliers

	Reported baseline emissions		
	Mean	**Min**	**Max**
ITH	92	1	250
ITNOH	105	41	159
GTH	82	10	215

5.2.1 Assessing cheating in the reporting of emissions baselines

Thirty eight participants submitted anonymous questionnaires providing some indication of their level of cheating, if any (11 from ITH, 16 from ITNOH and 11 from GTH). Some participants were not able to attend the final close-out session and were not able to provide this feedback. Figure 4 indicates that the two groups that signed an honesty declaration (ITH and GTH) indicated lower levels of cheating than the group that did not sign the honesty declaration (ITNOH). ITNOH reported a higher level of cheating than GTH relative to ITH. According to Pearson Chi-squared tests[11] (see Appendix 7) the difference between ITH and ITNOH is significant at the 1% level and the difference between ITH and GTH is significant at the 10% level.

Figure 4: Histograms showing the extent to which emissions baselines were exaggerated, by group



5.3 Differences in emission reductions

Table 7 summarizes the comparative statistics related to emission reductions. There was no statistical difference between targets of individuals in ITH and the individuals in GTH who were each assigned a target of 11% (based on the group vote). No minimum and maximum targets are depicted for GTH, as the same target was applied to all participants in the group. There was also no statistical difference between targeted reductions across the groups. In both cases, a Wilcoxon-Mann-Whitney test was used (refer to Appendix 8 for p-values from the tests).

Table 7: Comparative statistics related to emission reductions

	ITH			ITNOH			GTH		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Target (% below baseline)	**16.5%**	5%	65%	**9.8%**	1%	20%	**11%**		

[11] As the variables are categorical, a Pearson Chi squared test is used (expected values were not found to be below five and therefore Pearson Chi squared, as opposed to Fischer's Exact test, was used). Earlier analysis compared interval variables and therefore a Wilcoxon-Mann-Whitney test was used.

Targeted reductions ($KgCO_2e$)	**20**	0.1	121	**14**	1.6	53	**9**	1.1	24
Reported reductions in $KgCO_2e$	**26**	-28	116	**55**	-66	380	**28**	-82	98
Reported reductions excluding outliers[12]	**21**	-28	70	**29**	-66	92	**35**	-6	98
Estimated reductions accounting for cheating bias[13]	-	-	-	**25**	-25	68	-	-	-

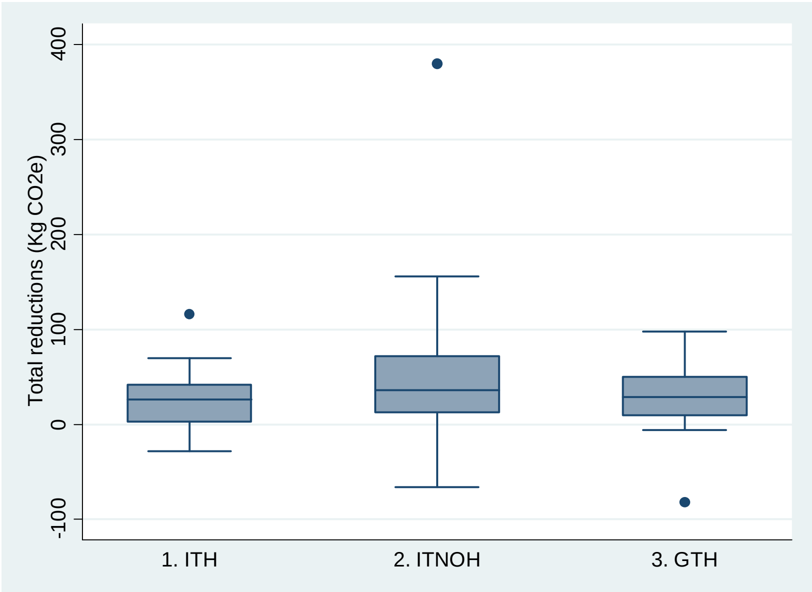
The average reported emission reductions of ITH and GTH were similar (26 and 28 Kg CO_2e respectively). The average reported emission reductions of ITH and ITNOH was substantial (26 versus 55 Kg CO_2e). This could partly be explained by the fact that the average baseline emissions of ITNOH were significantly higher than those of ITH (as shown earlier) and that artificially exaggerated baselines would make it easier to report substantial emissions reductions. However, in this case, the difference was not proven to be significant using a Wilcoxon-Mann-Whitney test. Differences in relative reductions were also not proven to be significant (refer to Appendix 8 for p-values from the tests).

As can be seen in Figure 5, there are outliers in the total reductions reported by individuals in each group. An additional analysis was carried out having excluded these outliers. The results are also shown in Table 7. Excluding outliers substantially reduces the average reductions achieved in ITNOH, with slight changes in the average reductions in ITH and GTH. Once again, however, the difference between the groups is not significant.

[12] The same three individuals that were excluded for the analysis depicted in Table 6 have also been removed for the purposes of this analysis. In addition, the box plot of reported emissions (see Figure 5) indicated a number of additional outliers. These have also been removed for the purposes of this analysis.

[13] Based on the post questionnaire responses, there was a significantly higher level of cheating with regard to the reporting of emissions baselines by individuals in ITNOH. An attempt was made to mitigate this bias by assigning individuals in ITNOH emissions baselines equal to the ITH average (92 $KgCO_2e$) who reported no cheating with regard to the reporting of emissions baselines.

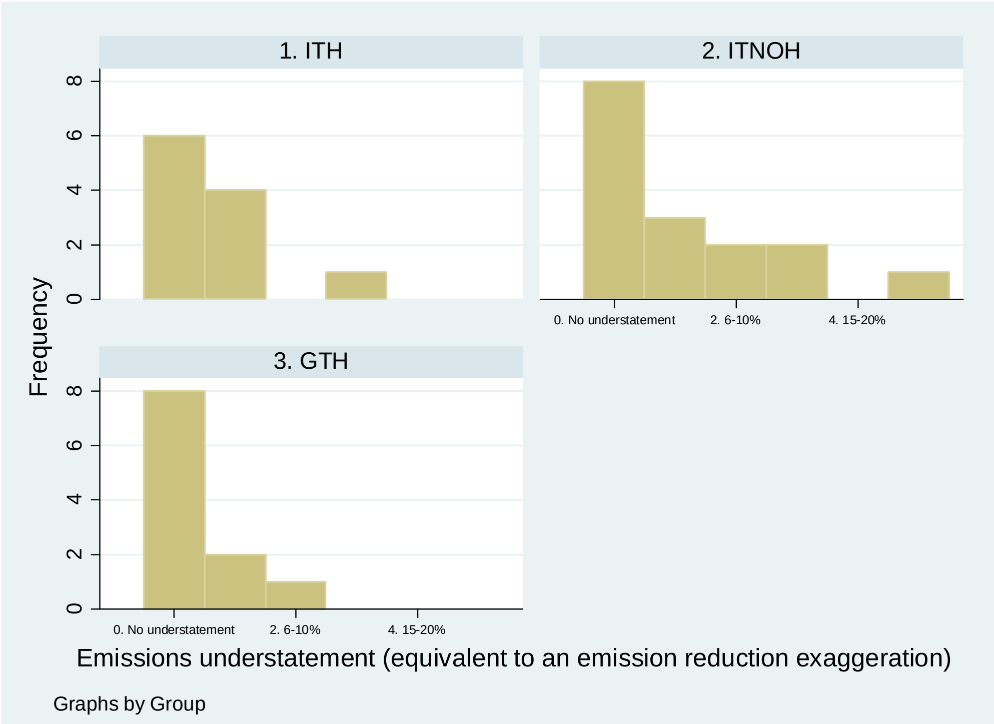
Figure 5: Box plot of reported achieved reductions (Kg CO2e) per group



Reported reductions are equal to the difference between individuals' reported baseline emissions and their total reported emissions. As indicated in Figure 4, ITNOH reported an exaggeration of their baselines as compared to ITH (significant at 1%). As the final reductions are a function of reported emissions baselines, this cheating effect could exaggerate the achieved emission reductions reported by ITNOH. In an attempt to overcome this bias, all reported emission reductions were compared relative to an adjusted baseline for individuals in ITNOH. Each individual in ITNOH was assigned a baseline of 92 KgCO_2e (equal to the mean baseline reported by ITH). The results showed no significant difference in average reported emissions when these baselines were adjusted (note that outliers were also excluded in this analysis).

The feedback from the anonymous cheating disclosure showed that some individuals in all three groups had cheated, to a minor extent, with regard to the reporting of emissions data on a weekly basis. Figure 6 shows that most participants did not understate their weekly emissions. According to Pearson Chi-squared tests (see Appendix 9) there was no significant difference in this cheating effect between the groups.

Figure 6: Histograms showing the extent to which weekly reported emissions were understated, by group



5.4 Differences in participation in auctions

The majority of individuals participated in the auctions. Submitting at least one "buy" or "sell" bid is regarded as having participated in the auctions. Twelve individuals (67%) submitted either a buy or sell bid in ITH; 14 individuals (67%) in ITNOH and 10 individuals (59%) in GTH. There was no statistical difference between auction participation between groups using this simple indicator (refer to Appendix 10 for a description of the p-values associated with a Wilcoxon-Mann-Whitney test).

Table 8: Comparative statistics related to auction participation

		Combined results over 3 auctions	
		Buy	**Sell**
Number of bids			
	ITH	11	10
	ITNOH	6	14
	GTH	4	12
Volume offered/ demanded			
	ITH	153 KgCO2e	87 KgCO2e
	ITNOH	75 KgCO2e	460 KgCO2e
	GTH	90 KgCO2e	254 KgCO2e
Average price of each participants' bids			
	ITH	R 0.95 / KgCO2e	R 0.94 / KgCO2e
	ITNOH	R 0.60 / KgCO2e	R 0.81 / KgCO2e
	GTH	R 0.45 / KgCO2e	R 0.47 / KgCO2e*

The volume of credits demanded exceeded the volume offered in ITH. In both ITNOH and GTH the volume offered exceeded the volume demanded. In the case of ITNOH the volume offered was substantially higher than that of ITH. This difference was, however, not shown to be significant using a Wilcoxon-Mann-Whitney test (refer to Appendix 10 for the associated p-values). This is surprising and may, once again, be due to the small sample size or the disproportionate role of a small number of individuals in the auctions. There was found to be no significant differences between the average price of each participants' bids between ITH and ITNOH and ITH and GTH, except in the case of the average price of sell bids between ITH and GTH (significant at the 10% level). The average sell prices were lower: 47c versus 94c.

Nevertheless, the results do suggest that there may have been a stronger incentive to cheat in ITNOH (at least amongst a small number of individuals) and that the cheating may have been motivated by an opportunity to make money from the auction. This is supported by anecdotal evidence from the post experiment questionnaire which shows that four individuals in ITNOH indicated that making money was one of their motivations for offering to sell credits. A similar number, three individuals, reported this as a motivator in GTH. No individuals in ITH had indicated that this was a motivating factor. All groups included a similar number of individuals offering to sell credits. These results are summarised in Table 9. Other reasons for offering to sell credits included "I thought someone might need my extra credits ", "I felt like I should" and "I wanted to experience the auction." The number of individuals providing feedback on their motivation for participating in the auctions (of those who submitted offers to sell credits) was too low to be able to conduct a statistical analysis of the results. Further research and a larger sample size would be needed to confirm this.

Table 9: Summary of sell offers

	ITH	ITNOH	GTH
Number of individuals submitting sell offers	7	9	8
Number of individuals indicating that making money was a motivator for submitting sell offers	0	4	3

5.5 Differences in perceived acceptability of the scheme

Overall, perceptions around fairness and appropriateness of different elements of the scheme design suggest that PCT is not broadly acceptable as a policy option. Most participants felt that it was not fair to allow people to trade carbon. Evidence from the post experiment questionnaire suggest possible reasons, including the sentiment that individuals should not be able to buy their way out of reducing their own emissions or that people should not make money from challenges presented by climate change. These concerns may reflect the bias of the sample population towards the environmental objective of reducing emissions. Participants in this experiment were shown to be committed to reducing their GHG emissions. Individuals for whom the social and economic objectives of climate mitigation (such as reducing the economic costs and unequal sharing of the burden) are more important, may have found trading to be a more appropriate policy option. However, the results are echoed by Capstick and Lewis (2010) who found that respondents in their study preferred systems that imposed purchasing limits, one reason being a general reluctance to let high emitter buy their way out.

Table 10: Perceptions around fairness and appropriateness of different aspects of the scheme design

	ITH	ITNOH	GTH
Fair **allocation approach** (% "Yes")	43%	43%	23%
Fair to allow **trading** (% "Yes")	21%	29%	23%
Fair **penalty** (% "Yes")	14%	29%	15%
Penalty limit appropriate (% "Yes")	50%	62%	15%*
Fair **auction approach** (% "Yes")	29%	24%	31%
Price limit appropriate (% "Yes")	50%	48%	23%

Table 10 shows that, generally, GTH indicated less support than ITH for the different aspects of the scheme design. The most substantial difference related to the appropriateness of the penalty limit. Fifteen percent of individuals in GTH felt the R100 limit was fair compared to 50% of the individuals in ITH. This difference was found to be significant at the 10% level using a Pearson Chi-squared test (refer to Appendix 11). Individuals in GTH may have felt more exposed to a potential penalty, considering they were forced to adopt a group target. Concern around paying a penalty may have been higher in this group; contributing to the lower acceptance of the penalty limit. In contrast, individuals in ITH had full control over their allocations and may have felt less exposed to the risk of paying a penalty. There was no statistically significant difference between the perceptions of ITNOH and ITH participants (refer to Appendix 10 for the summary of Pearson Chi squared tests).

Interestingly, the penalty was not perceived as fair, even though participants were responsible for choosing the penalty. It may have been the case that the lack of options (the penalty had to be financial in nature) and lack of control (the penalty was decided by vote) influenced this result.

Although acceptability of the allocation approach was substantially lower in GTH (23%) than ITH (43%), this difference was not found to be statistically significant using a Pearson Chi-squared test. Table 11 highlights the preferred allocation approach for the sample as a whole. Most individuals 48%[14] supported an approach that embodied the principle of grandfathering, whereby allocations are a function of historical emissions. A greater proportion of these individuals (27% of the sample) showed some level of support for the principle of equality by indicating a preference for allocating emissions allowances based on historical emissions but with equal relative reduction requirements. Fewer participants supported the principle of equality with regard to absolute emissions, and no participants supported an allocation approach based on an equal per capita emissions allowance. However, 23% of participants were willing to support an allocation approach based on equal per capita emissions with allowances for those with greater need. This is consistent with the results obtained by Bristow et al. (2010).

Table 11: Preferred approach for allocating emission allowances

Option	Percent
Based on historical emissions (grandfathering) where each individual has to reduce emissions by the same relative (%) amount	27%
Equally per person, with extra allowances for those with greater need	23%
Based on historical emissions (grandfathering) where individuals commit to their own target reduction	21%
Based on a government/ regulator assessment of needs	21%
Equally per person, with financial support for those with greater	8%

[14] This figure combines the percentage of individuals who supported allocation based on historical emissions (grandfathering) where each individual has to reduce emissions by the same relative (%) amount and the percentage of individuals who supported allocation based on historical emissions (grandfathering) where individuals commit to their own target reduction.

need	
Equally per person	0%

5.6 Additional results

In line with the findings of Capstick and Lewis (2010) and Brohe (2010), the feedback from the post experiment questionnaire suggests that participation in the experiment has increased awareness or "visibility" around the full implications of peoples' transport activities. This could have resulted in improved behaviour (in the form of lower transport emissions) of individuals after the experiment. Further research would be needed to verify this claim.

The experiment claimed, in order to recruit volunteers, that participation would provide a number of educational benefits. Feedback from the post-experiment questionnaire suggested that most participants had experienced educational benefits. Table 12 summarizes responses to the question of whether participation in the experiment improved participants' understanding of climate change.

Table 12: Participants' perceptions regarding the changes in climate change understanding due to participating in the experiment

Participation improved understanding of climate change:	
Yes, a great deal	29%
Yes, a little bit	42%
Not really	21%
No	8%

Sixty seven percent of respondents indicated that involvement had improved their understanding of the role of economic instruments in mitigating climate change. Sixty percent said it improved understanding of my own contribution to climate change and 50% said it had improved their understanding of the international climate policy development process.

6 Discussion

The objective of this experiment was to provide a test-bed for PCT as a mitigation policy option. Results of the two treatments have revealed important policy implications. The following discussion highlights the policy implications based on the results described above.

6.1 Policy implications associated with obtaining accurate emissions data

Obtaining accurate emissions data, similar to the challenge of ensuring measurable, reportable and verifiable (MRV) data in the real world context, was assessed through comparing differences in the results of ITNOH to ITH. As anticipated, the incentive to cheat did have an influence on the way individuals engaged in the scheme. The reported baseline emissions of individuals in ITNOH were significantly higher than those of individuals in ITH. This was supported by a higher level of self-confessed cheating (exaggerating of the baseline) reported by individuals in this group.

The incentive to cheat was expected to result in less ambitious targets reported by ITNOH compared to ITH. This would have contributed to a greater surplus of emission credits with which to trade. Additionally, greater understatement of reported emissions would have achieved the same result. In both cases there was found to be no statistical differences between the results of ITNOH and ITH.

Participation in the auction too, was expected to provide insight into the potential role of cheating. Cheating was expected to result in greater opportunities for participants to make money through trading credits in the auctions. Although individuals In ITNOH offered to sell more credits in the market than individuals in ITH, these results were not significant. Participation in the auction was similar except for a small number of individuals who had a disproportionate impact on the auction results.

The conclusion is that the incentive to cheat is driven more by a desire to mitigate risks associated with participating in such a scheme, rather than to take advantage of any opportunities to make money. Interestingly, from a policy perspective, the role of cheating did not have a significant influence on the final achieved emission reductions, especially when excluding potential outliers. This could be a function of potential sample bias (individuals volunteering to participate were likely to be more committed to reducing their transport related GHG emissions than the average UCT student) or due to the small sample size. In both cases further research is required to better understand the motivators for reducing GHG emissions.

Finally, policing emissions reporting in a voluntary scheme will present significant challenges. Although this study did not provide insight into how best to overcome this challenge, it has highlighted the importance of ensuring that emissions data is accurate.

6.2 Policy implications associated with scheme design and the impacts on scheme acceptability

Social acceptability is one of the most widely researched aspects of PCT (Fawcett & Parag 2010). This, together with environmental acceptability (the contribution of the scheme to achieving GHG emission reductions), is one of the most important indicators of what would be an effective scheme. Based on the literature, allocation was seen to be one of the most important design considerations in this regard. The analysis of the differences in results of GTH compared to ITH provided insight into the potential social and environmental acceptability of PCT.

Although reported baseline emissions were not shown to be significantly different, the post-experiment assessment of cheating showed a slightly higher tendency to exaggerate emissions baselines (significant at the 10% level) by individuals in GTH compared to ITH. This incentive to cheat may have been seen as an internal justification for being forced into having to adopt a common group target. Cheating may also have been viewed as a way of mitigating some of the risk associated with an aspect that was partly out of their control.

This incentive to mitigate risk was expected to have also resulted in significantly understated reported emissions. This was not found to be the case, suggesting that participants may have found it was possible to achieve (and in most cases exceed) the required reductions and avoid having to pay a penalty at the end of the full commitment period. The difference between the average reported emission reductions of ITH and GTH were similar. This implies that the environmental objective of reducing GHG emissions was not significantly affected by the choice of allocation method. If the allocation approach had been more fundamentally different (i.e. based on an equal per capita emissions allocation rather than one that, similarly to the ITH allocation, was based on historical emissions) there might have been more of a difference in achieved emissions reductions. This represents an important policy consideration that requires further research.

Reflections on the perceived appropriateness of the penalty cap (set at R100) showed a lower acceptance of the approach in individuals in GTH compared to individuals in ITH. This was seen to be the result of greater concerns among GTH individuals around the risk of having to pay a penalty.

There was also found to be a lack of evidence showing a difference in levels of participation in the auctions between individuals in GTH compared to ITH. The only significant difference was seen in the average price of sell bids between ITH and GTH (significant at the 10% level) which were lower in GTH. Once again, the incentive to mitigate risk proved more influential than the incentive to make money through selling carbon credits.

6.3 Achieving the overall objective: reducing greenhouse gas emissions

During the COPs, participants indicated concern around the potential financial risks they would face if they exceeded their allowances. This may have contributed to a general commitment to less ambitious targets. The fact that overall achieved reductions (both reported and adjusted for cheating) were greater than targeted reductions could indicate possible over-allocation. From the perspective of achieving emission reductions (the environmental objective), an alternative approach to allocating emissions could be more efficient.

The price of carbon credits decreased with each consecutive auction. Due to the extent to which supply of credits exceeded demand, it is expected that this trend would continue with subsequent auctions. This further supports the evidence that over-allocation reduced the environmental effectiveness of the scheme. This is comparable to the first phase of the EU ETS where over-allocation drove down the market price.

While an alternative approach may prove to be more environmentally acceptable, this study showed that not all allocation options are equally socially acceptable. The most accepted approach to allocation was seen to be one that embodied the principle of common- but differentiated responsibility. Some level of equality is supported, either in terms of absolute or relative reduction obligations, but also a consideration of differences in respective capacities to mitigate.

To mitigate concerns around personal risk, substantial and effective communication would need to accompany any carbon trading scheme. A gradual increase in the ambition of the targets (translating to a gradual decrease in emission allowances) may prove to be a more socially acceptable approach to implementing such a scheme. This would likely prove more feasible than trying to enforce ambitious reductions (or allocate smaller allowances) from the beginning of implementation.

7 Conclusion and recommendations

This experiment successfully implemented an emissions trading scheme in the context of a South African university. The majority of individuals participated in the auction and a total of 270 Kg CO_2e were traded at an average price of R 0.35 per Kg CO_2e. These results suggest that the auction platform proved beneficial in contributing to the reduction of GHG emissions associated with personal transport. These benefits were not, however, equally distributed. A small number of individuals had a disproportionate influence on the outcomes of the auctions.

The experiment successfully contributed to achieving the objective of reducing GHG emissions associated with personal transport. Based on reported emission reductions, 2113 Kg CO2e emissions were avoided. Participants indicated additional educational benefits related to an improved awareness of their own contribution to climate change, of opportunities to reduce emissions and of the role of economic instruments within the context of international climate change policy.

The experiment also provided useful insights into some of the design elements associated with implementing a PCT scheme. Some of the most important design elements highlighted in the literature are focused on measuring and reporting verifiable data and assessing social acceptability mostly related to allocating emission allowances. The two treatments in this experiment were designed to analyse these two areas. Treatment 1, which assessed the role of cheating, showed that cheating did have a significant impact on the reported baseline emissions and therefore on the allocation that participants received.

Evidence of cheating, and the challenges experienced in gathering emissions data (from an administrative point of view), highlight the importance of developing clear rules and standardized methods for calculating emissions. Some form of enforcement of these rules is required. This will have significant cost implications and, consistent with the findings of many researchers (Cason & Raymond 2010, Defra 2008), suggests that PCT is not a feasible policy option at this stage. This holds for South Africa where, as a developing country, meeting other national objectives would be seen to be a more important use of the country's scare resources.

Treatment 2 assessed the implications of applying different allocation approaches, particularly in terms of the social acceptability of the scheme. There was no clear evidence that the different allocation approach affected the level of overall emission reductions achieved (the environmental objective). Forcing participants to adopt a group target did influence the social acceptability of the scheme. The research suggested that limits play an important role in ensuring social acceptability with most individuals supporting a penalty and a price limit. Individuals in GTH did not support the penalty limit used in this experiment, feeling more exposed due to their allocation approach. The design of the limits therefore needs to be carefully thought out with scheme participants involved in the setting of these limits.

Results also suggested that individuals are not likely to support an ambitious scheme. This was evidenced by the low level of ambition of their reduction targets as well as through concerns expressed throughout the experiment. However the emission reduction results suggest that reducing transport emissions proved easier than participants originally anticipated. This suggests that there could be greater support for a scheme where the level of ambition is escalated over time such as in the experiment conducted by Capstick and Lewis (2010). It is expected that this would apply to GHG mitigation policy in South Africa more generally. The proposed escalation of a carbon tax over time may therefore prove to be more socially acceptable, but further research is required to validate this argument.

The experiment contributed to an understanding of the likely reaction of the South African population to mitigation policy (such as a cap-and-trade scheme). Participants displayed a great level of uncertainty and concern around their personal exposure to financial risk. Participants were committed to the overall objective of achieving emission reductions but, in the face of personal risk, were not incentivised to change. In the pilot experiment, this was evidenced by the divergent views on how to share the burden of achieving emission reductions. In agreeing on targets (allocations) there was a heated debate around capacity to reduce emissions (income) versus historical contributions and historical efforts to reduce emissions. In the experiment, many participants also raised concerns around having already invested in emission reductions and expressing concern that further reductions would be difficult, putting them at a disadvantage.

Exposure to personal financial risk was found to play a significant role in the perceived acceptability of the scheme. Any mitigation policy designed in South Africa therefore needs to try to overcome this through providing adequate information, involving the public in the design of the policy and implementing the policy over an appropriate time period. In the case of a cap-and-trade scheme, a longer commitment period would allow people to better understand the implications of their actions and adjust accordingly.

The potential contribution of PCT in the suite of options to mitigate GHG emissions remains highly uncertain. Much will depend on the outcomes of international negotiations aimed at setting legally binding agreements to reduce GHG emissions. Consistent with the finding of the study by Defra (2008), this experiment found that carbon trading is a potentially important way to engage individuals and that while a socially acceptable design is possible, the implementation costs associated with such a scheme are too high to be financially viable.

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8 Appendices

Appendix 1: Experiment protocol

Activity	Description
Phase 1: Recruitment	
Target potential classes presented with the opportunity to participate (two weeks: ad hoc)	The experimenter contacted lecturers, staff and students in departments and societies that would potentially see a benefit in the members of their classes or societies participating in the project. This involved an explanation of the project and potential benefits of participating.
Introduction to the project (short) (15 minutes)	The experimenter introduced the project to interested students. The introductory lecture included: • An introduction to the climate change challenge • An introduction to market-based mechanisms for reducing emissions • An introduction to the project • An explanation of the potential benefits of participating • An explanation of what was required of participants • An outline of the timeline of the project
Email request for voluntary participants	An email containing similar information to the introductory lecture was sent to potentially interested students. Students were given the opportunity to sign up directly or to attend an introductory lecture (described above) held outside of lecture times.
Completion of form with intent to participate	Students were asked to provide their names and email addresses if they were interested in participating. • This served the purpose of allowing the experimenter to send a reminder email regarding the introductory session. • All interested parties were encouraged to invite other interested parties to the Introductory meeting
Phase 2: Project Introduction	
Introduction to the project (15 minutes)	The experimenter introduced students to the project. This included the following elements: • Introduction to emissions trading theory within the context of climate change (more detail than provided in the recruitment lecture); • Explanation of the relevance of the project for students; • Project objectives; • Project procedure; • Project outcomes; • Expectations of students - Opportunity for participants to ask questions
Ensuring understanding of data collection requirements	The experimenter illustrated how to collect and record baseline emissions data:

(20 minutes)	• Participants were supplied with an electronic emissions calculator (MS Excel) in which to enter data - Opportunity for participants to ask questions
Ensuring adequate understanding of the auction procedure (15 minutes)	The experimenter illustrated how to submit an buy / sell bid (an offer to buy or sell a certain number of carbon credits at a certain price) • Additional supporting information and a summary of participants' performance (in terms of their transport emissions footprint) was emailed ahead of each auction. • A summary of the results of each auction was emailed to participants each week (along with the request for the next week's emissions data) • This process was explained to participants - Opportunity for participants to ask questions.
Questionnaire (Once-off)	Each student was asked to complete a questionnaire providing demographic and other information as part of the sign-up process. This questionnaire included demographic information and questions relating to expectations and awareness of climate change. Students had the option to refuse to answer any questions.
Treatment groups	*There were different project introduction meetings for each treatment group*
Phase 3: Baseline Data Collection	
Collection of baseline transport emissions data (1 week)	Students were required to collect data over the course of 1 week. The type of data to be entered into the spreadsheet could include emissions from the following: • Kilometres travelled by car (including the vehicle size, fuel used and number of individuals in the vehicle) • Kilometres travelled by motorbike / scooter (including the vehicle size, fuel used and number of individuals on the vehicle) • Kilometres travelled by train (the spreadsheet included information on the distances between stations in Cape Town). • Kilometres travelled by bus • Kilometers travelled by *Jammie Shuttle*[15] (average distances between stops was provided) and • Kilometres travelled by minibus.
Treatment groups	*All individuals except those in **ITNOH** had to include a declaration of honesty on their spreadsheets.*
Calculation of individual's baselines	The spreadsheet included a calculator that generated each participant's transport emissions baseline.
Phase 4: Conference of the Parties (COP 1)	
Background information sent to students ahead of the COP (sent via email)	Prior to the meeting students were emailed a set of instructions and information to consider. These instructions clearly articulated the agenda for the meeting and what the required outcomes would be. The document emailed to participants included the following

[15] The University of Cape Town campus transport service.

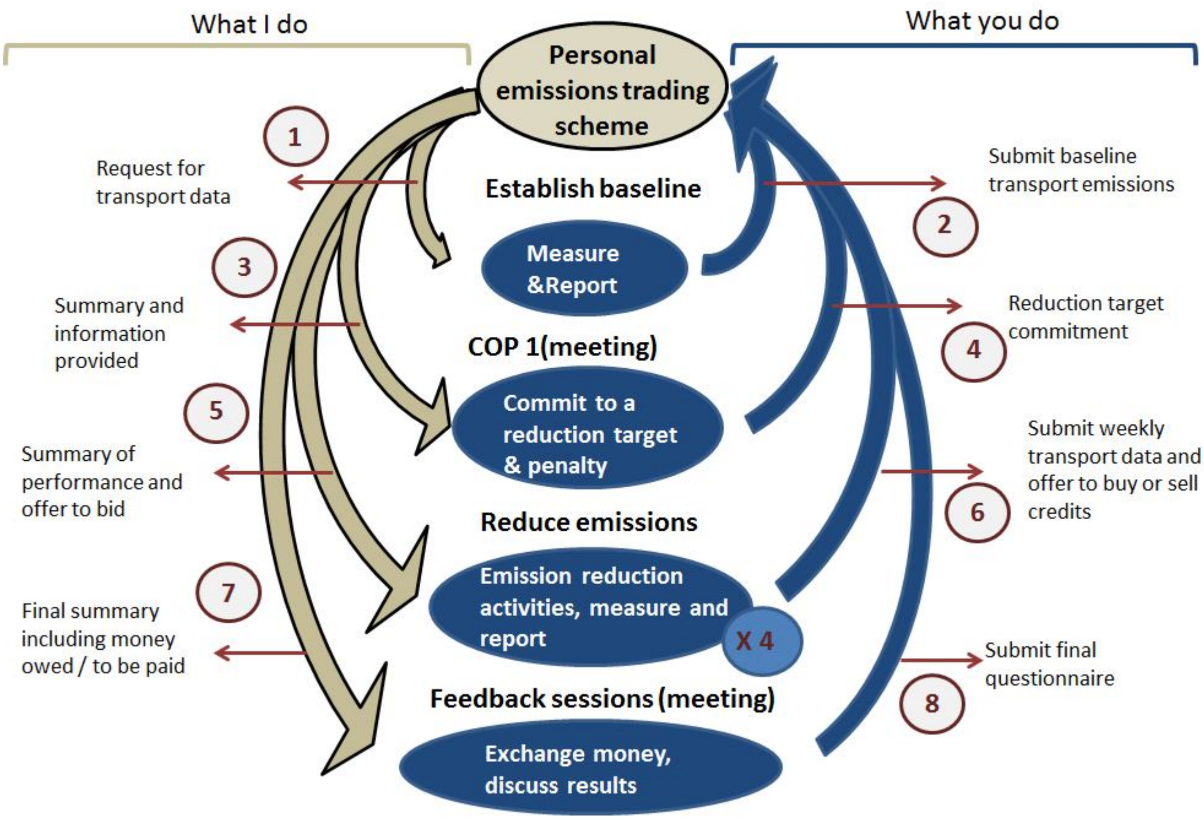
	information: • Individuals' baseline emissions data (individuals' data was not made publicly available) • A list of mitigation options intended to help students understand their marginal abatement costs (MACs); - This included the cost per kilometre and the carbon emissions per kilometer for each transportation mode (this information also accompanied the transport data spreadsheet that each participant filled in on a weekly basis) • Penalty options; and • Commitment target options. These varied depending on the treatment group: - **GTH**: Choosing a common intensity (percentage) reduction target applied to all. For example 34% below business as usual, in line with South Africa's commitment to the UNFCCC. Each participant would then have to reduce their emissions by a different absolute amount (34% below their business as usual emissions); or - **ITH** and **ITNOH**: Each participant chose their own target and commit to this in writing (in line with international approaches). The target was a percentage reduction relative to the baseline.
COP 1 (meeting to set individual targets and a penalty) (45 minutes)	The experimenter facilitated a discussion in which the following were finalised: • Agreeing targets - The experimenter explained the process and highlighted certain considerations in setting individual targets. Students were encouraged to consider issues relating to equity, individual incomes, and the fact that certain reductions were not possible for some, in the short time frame considered (e.g. some live in areas where no public transport is available). - GTH participants were required to agree a group target - Voting took place anonymously. - Following the discussion around possible options, participants were asked to write their preferred target on a piece of paper, fold it and drop it into a box. - The median value was chosen - All other participants were required to set their own individual targets - Targets were converted into emission allowances (by the experimenter) • A penalty for failing to meet the required reductions by the end of the commitment period. - The experimenter explained the process and highlighted certain considerations in deciding on an appropriate penalty. - The penalty would be imposed should participants not meet their commitment target by the end of the period.

	- The penalty was to be financial: R/gCO2e above the level of emissions that the participant committed to achieving over the full commitment period (e.g. a baseline of 200 kgCO2e with a target reduction of 10% would translate into a commitment to only emit 180 kgCO2e. If the participant were to emit (including any purchased CO2 credits) 190 kgCO2e and the penalty was R5/kgCO2e, then the participant would incur a penalty of R 50.) - Participants were allowed to decide what the revenues generated from the penalties should be used for. - A cap on the penalty was imposed (R100) • Opportunity for students to ask questions
Treatment groups	*There were different COPs conducted for each treatment group*
Phase 5: Emission Reductions	
Individual efforts to reduce emissions (Ongoing)	Throughout the commitment period students needed to reduce their transport emissions through a variety of means. • The experimenter provided information on the relative carbon emissions of different transport options- this helped inform how best to reduce emissions. • Other suggestions on how to reduce emissions were provided.
Continuous collection of emissions data (Ongoing and submitted once a week)	Participants were required to collect and submit data in the same fashion as in Phase 2. • Spreadsheets had to be submitted to the experimenter on Mondays (by 18h00). • The experimenter provided each participant with a summary of their performance to help inform their actions in the auctions (Phase 6). This was emailed to students the day before the auction.
Phase 6: Auctions	
Weekly auctions to allow individuals to trade emission allowances (Ongoing: on the Wednesday of each week)	The process: • An email was sent to each participant ahead of each auction: - Each participant was provided with a summary of how well they were doing (see above). This indicated if each they were behind, ahead or on track to achieving their required reduction. This informed whether participants should sell or buy credits. - Each participant's summary was private - The email included written instructions regarding the auction process - Students were reminded that they will only be penalised if they failed to meet their commitment at the end of the full commitment period. Conducting auctions each week would allow students to manage their abatement and purchasing decisions in order to meet their commitments. • The auction was be a closed, single bid auction: - Each student had the opportunity (voluntary) to submit an

	offer to buy or sell credits (e.g. 1kg of CO2e at R0.20/kg). This occurred in the form of a bid submitted via email to the experimenter. - The auction was opened at 9am on the Wednesday morning (when "Option to bid" emails were sent) and students had until 4pm on the Wednesday to submit a bid. - Participants were encouraged not to collude or share their bidding choices with others (this process relied on honesty as no systems will be in place to monitor this) - The experimenter calculated the demand and supply curves and therefore the market clearing price for the round. (Bids collected by the experimenter were entered into a spreadsheet to determine the price and quantity to be sold for that round. A piece-wise demand curve was constructed and the cumulative buy and sell orders matched together to determine the clearing price at which they executed and the specific orders that executed (the intersection of the two curves). The clearing price was the value of the highest rejected bid). - Credits were allocated at the market clearing price. - Each participant could purchase a maximum of 50% of their emission reduction requirements in the form of carbon credits - Participants were allowed to retire credits out of the system rather than selling them. • The experimenter made publicly available the number of credits bought and sold at the market clearing price. This information was included in the email sent ahead of the next auction (the same email that included the summary of participants' weekly emissions.) • Money was only exchanged at the feedback session at the end of the commitment period. • The experimenter incorporated sales and purchases of carbon credits into each participants' weekly emissions summary.
Treatment groups	*All groups had the option to participate in the auctions*
Phase 7: Feedback session	
Final submission of data and preparation for the feedback session (Once-off: in advance of the close-out meeting)	Penalties were calculated and imposed: • Participants submitted their final electronic spreadsheets • The experimenter calculated whether or not participants met their emission reduction targets and calculated penalties in cases where targets were not met.
A final feedback meeting was held (45 minutes)	The experimenter presented the final results. • Penalties were paid by participants • Net buyers of credits had to pay the appropriate amount to the experimenter • Net sellers of credits were paid the appropriate amount to the experimenter

	A survey was administered to try to determine the level of cheating that took place • The experimenter explained to participants why it was believed that people would not always reveal their emissions truthfully. The survey was an attempt to estimate by how much the data obtained was biased by such "cheating" without having to ask each person in private. Hence the experimenter asked participants to complete a questionnaire indicating the percentage of the time that they told the truth and their group number. Completed questionnaires were posted into a box. Participants were encouraged to complete the online post-experiment questionnaire
Treatment groups	*All groups attended the same feedback session*
Phase 8: Post-experiment survey	
A questionnaire to elicit perceptions regarding various elements of the scheme (once off: this took approximately 20 minutes)	Participants were sent a link to an online questionnaire and asked to complete it in their own time.

Appendix 2: infographic to assist participants understand the experiment process



Appendix 3: relative costs and emissions per mode of transport (and sources of emissions factors)

Transport mode		Rand per km	kg CO2e per km
Car			
Petrol[1]			
	Small petrol car, up to 1.4 litre engine	0.73	0.17
	Medium petrol car, from 1.4 - 2.0 litres	0.91	0.22
	Large petrol cars, above 2.0 litres	1.27	0.30
	Average petrol car	0.89	0.21
Diesel[1]			
	Small diesel car, up to 1.7 litre or under	0.50	0.15
	Medium diesel car, from 1.7 to 2.0 litre	0.63	0.18
	Large diesel car, over 2.0 litre	0.85	0.25
	Average diesel car	0.67	0.20
Hybrid[1]			
	Medium petrol hybrid car	0.51	0.12
	Large petrol hybrid car	0.92	0.22
	Average petrol hybrid car	0.70	0.17
Bus[2]		0.87	0.11
Train[3]		0.93	0.06
Minibus[2]		0.80	0.05
Motocycle[1]			
	Small petrol motorbike (mopeds/scooters up to 125cc)	0.37	0.09
	Medium petrol motorbike (125-500cc)	0.45	0.11
	Large petrol motorbike (over 500cc)	0.59	0.14
	Average petrol motorbike (unknown engine size)	0.50	0.12
Taxi[1]	Average (meter) taxi	10.00	0.20
Bicycle		0.00	0.00
Jammie shuttle[2]		0.00	0.11

[1] Emission factors provided by UK Government Department of Environment, Food and Rural Affairs (Defra), Guideline to Defra's
GHG Conversion Factors for Company Reporting; AnnexesUpdated August 2010. Available: http://www.defra.gov.uk/environment/business/reporting/conversion-factors.htm.
[2]. Emission factor provided by Project90x2030
http://www.90x2030.org.za/view.asp?pg=calculator&ccsub=assumptions

[3]. Emission factors provided by Project90x2030: The national rail factor refers to an average emission per passenger kilometre for diesel and electric trains in 2007. The calculation of the factor is based on the total electricity and diesel consumed by the railways in 2007/08 from the DfT National Modelling Framework Environment Module, and DfT transport statistics on the total number of passenger kilometres for 2007/08. Emission factors for freight rail are provided in Annex 7, Table 7f.

Appendix 4: example of the offer to bid spreadsheet

PCT Auction	**Offer to bid**	**Student number / name:**	
		Date:	14-Sep-11

Participation in the auction is voluntary - you can continue to participate in the project and not make any offers to buy or sell carbon credits

Instructions

1	Decide whether you want to be a **buyer** or a **seller** (you cannot be both but you can change between different auctions)	
2	Decide on an order, enter it into the space provided (see below), and send it back to the auctioneer (Anthony Dane: imbovane@gmail.com). The order must include:	
	a	Quantity (Kg CO_2e) that you wish to buy or sell
	b	Price that you are willing to pay/accept for the quantity of emissions demanded/offered.
	c	Prices must be between R0 and R2 and must be factors of 10 cents (e.g. R0.10, R0.20, R0.30,………R1.90, R2.00)
		R2 is the price limit
3	**Reply** to the "Option to bid" email and **include this file as an attachment**	
		This information must be submitted by **16:00 on Wednesday** to be included in the auction

Offer to buy or sell		**Example**	
Please indicate (with an X) whether you are a buyer or a seller		Please indicate (with an X) whether you are a buyer or a seller	
Buyer		Buyer	X
Seller		Seller	
Please enter figures into the yellow cells		Please enter figures into the yellow cells	
Quantity demanded / offered (Kg CO2e)		Quantity demanded / offered (Kg CO2e)	6
Price per unit (Rand per Kg CO2e)		Price per unit (Rand per Kg CO2e)	0.2

Appendix 5: Post experiment questionnaire

CARBON TRADING: Post experiment questionnaire

This questionnaire aims to elicit qualitative feedback that will form an important part of my results.

The questionnaire will seek to elicit information on the following elements:

- Attitudes towards the environment
- Motivation
- Perceptions around fairness and acceptibility
- General perceptions regarding climate change challenges and regulation

Agreeing on how money generated from penalties should be spent

Please choose the most appropriate option. In many instances you may choose more than one option. Please provide additional detail where relevant.

Name *This information is required. The final data will be reported in an aggregated form. Where individual responses or quotes are highlighted these will remain anonymous (being ascribed to a group member rather than a specific individual)

Attitudes towards the environment

1. Do you believe that climate change will affect you directly? *

- ☐ Yes
- ☐ No
- ☐ Other:

2. Do you think that you can contribute to stopping/ preventing climate change? *

- ☐ Yes, my actions have a significant impact
- ☐ Yes, but my actions are not very significant

- No, my contribution to climate change is insignificant
- Unsure

3. Do you believe that market-based mechanisms such as carbon trading schemes can prevent dramatic climate change? *

- Yes
- No
- Unsure

Motivation

**4. What was the main reason for participating in this experiment? ***You can indicate more than 1 option

- To reduce your personal GHG emissions
- To learn more about GHG mitigation policy
- To understand carbon markets
- To make some money
- Other:

5. What was the main reason for reducing your emissions? * You can indicate more than 1 option

- To contribute to the fight against climate change
- To generate carbon credits to sell
- Other:

6. Did you participate in any of the auctions? *

- Yes
- No

6a If yes: Why did you participate in any of the auctions? You can indicate more than 1 option

- It was cheaper for me to buy emissions than to reduce on my own
- I wanted to experience the auction
- I wanted to make money from selling credits
- Other:

6b If no: Why didn't you participate in any of the auctions? You can indicate more than 1 option

- Participants should not be allowed to buy their way out of reducing emissions
- Participants should not be able to make money from a scheme like this
- It wasn't important to me to participate
- I did not have enough time
- I did not understand the system
- Other:

Perceptions around fairness and acceptability

7. Do you think the method for allocating emission allowances in this experiment was fair? *

- Yes
- No

7a. Please explain your answer

7b. Emission allowances should be allocated: *Choose the most appropriate option from the drop-down list below

8. Do you think carbon trading is a fair approach to achieving emission reductions? *

- Yes
- No

8a. Please explain your answer

9. Did you feel the system for setting a penalty was fair? *

- Yes
- No

9a. Please explain your answer

9b. Do you feel it is necessary to limit the potential penalty incurred (in this case the limit is a total fine of R100)? *

- Yes
- No

10. Do you think the auction approach was fair? *

- Yes
- No

10a. Please explain your answer

10b. Participants should: *Choose the most appropriate option from the drop-down list below:

10c. Participants should: *Choose the most appropriate option from the drop-down list below:

10d. Do you think it was necessary to put a cap on the price of carbon (R2 per KgCO2e in this case)? *

- Yes
- No

11. The scheme should include the following sources of emissions (scope): *

- Transport emissions only
- Transport emissions and emissions from household energy use only
- All personal emissions (including emissions associated with transport, household energy use and indirect emissions associated with consumptions of goods and services (e.g. food)
- Other:

General perceptions regarding climate change challenges and regulation

12. Personal emissions trading (i.e. individual responsibility to achieve emissions reductions with the options to trade) should be implemented in: * You can indicate more than 1 option

- More developed countries (e.g. USA; UK)
- Less developed countries (e.g. South Africa)
- Nowhere: emissions trading schemes are only appropriate at the national or organizational level

13. Would you participate in a real personal emissions trading scheme? *

- Yes
- No

13.1 Please explain

14. Has the experiment improved your understanding of climate change? *

- Yes, a great deal
- Yes, a little bit
- Not really
- No

15. What have been some of the greatest benefits from participating in this experiment? * You can indicate more than 1 option

- Improved understanding of my own contribution to climate change
- Improved understanding of the role of economic instruments in mitigating climate change
- Improved understanding of the international climate policy development process

- I reduced my GHG emissions
- I made money
- Other:

16. What do you think would be the biggest obstacle to implementing such a scheme on a larger scale?

17. Has the experiment met your expectations? *

- Yes
- No

17.1 Please explain why

Please add any other comments or suggestions

Agreeing on how money generated from penalties should be spent

R 393 was generated from penalties. This will be spent based on the outcome of a vote. The options below have been chosen by you, the participants, during the close-out meeting. Please choose your preferred option.

Money generated from penalties should be: *

- Donated to the Green Campus Initiative
- Used to buy carbon offsets from Food and Trees for Africa
- Used to plant trees in underprivileged areas through the organisation Green Pop

Appendix 6: P-values from Pair-Wise Tests (two-sample Wilcoxon rank-sum (Mann-Whitney)) of disclosed emission baselines

		ITNOH	GTH
ITH	Reported Baseline	0.047	0.779
	Reported baseline (excluding outliers)	0.1687	0.779

Appendix 7: P-values from Pair-Wise Tests (Pearson Chi2) of reported exaggeration of reported emissions baselines (cheating)

		ITNOH	GTH
ITH	Baseline exaggeration	0.012	0.091

Appendix 8: P-values from Pair-Wise Tests (two-sample Wilcoxon rank-sum (Mann-Whitney)) of emission reductions

		ITNOH	GTH
ITH	Relative reductions	0.57	0.32
	Total reductions	0.26	0.68
	Relative reduction excluding outliers	0.78	0.24
	Total reductions excluding outliers	0.44	0.30
	Relative reductions adjusted for cheating bias	0.65	NA[16]
	Total reductions adjusted for cheating bias (and excluding all outliers)	0.69	NA

Appendix 9: P-values from Pair-Wise Tests (Pearson Chi2) of reported understatement of emissions (cheating)

		ITNOH	GTH
ITH	Emission understatement	0.57	0.4

Appendix 10: P-values from Pair-Wise Tests (two-sample Wilcoxon rank-sum (Mann-Whitney)) of participation in auctions, the quantity of credits demanded/ offered and the average price of each participant's' buy and sell bids

		ITNOH	GTH
ITH	Participation in the auctions	1	0.631

[16] Not applicable as reported cheating with regard to exaggerating baselines was only marginally different from the treatment group, ITH (and significant at the 10% level). The cheating bias was not felt to be strong enough to warrant an adjustment

	Quantity of credits demanded (buy bids)	0.73	0.46
	Quantity of credits offered (sell bids)	0.59	0.31
	Average price of each participants' buy bids	0.34	0.14
	Average price of each participants' sell bids	0.60	**0.01**

Appendix 11: P-values from Pair-Wise Tests (Pearson Chi2) of perceptions associated with elements of the scheme design

		ITNOH	GTH
ITH	Fair allocation approach (% "Yes")	1	0.516
	Fair to allow trading (% "Yes")	0.636	0.918
	Fair penalty (% "Yes")	0.324	0.936
	Penalty limit appropriate (% "Yes")	0.486	0.057
	Fair auction approach (% "Yes")	0.752	0.901
	Price limit appropriate (% "Yes")	0.89	0.148