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# Household perceptions of climate change and preferences for mitigation action: the case of the Carbon Pollution Reduction Scheme in Australia

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**Abstract**

The study aims to reveal Australian households' perceptions of climate change and their preferences for climate change mitigation actions. A web-based survey was conducted in November 2008 in which about 600 New South Wales households were asked for their willingness to bear extra household expenditure to support the 'Carbon Pollution Reduction Scheme (CPRS)' as proposed by the Australian government. The Contingent Valuation Method (CVM), a widely used non-market valuation technique, was applied using the single bounded dichotomous choice elicitation format. Results of the study demonstrate that, currently, there is a positive demand for climate change mitigation action in Australia. The main motivation for this positive demand stems from a desire to avoid climate change. However, society's willingness to pay (WTP) for climate change mitigation is shown to be significantly curbed by uncertainties regarding the extent of climate change and the effectiveness of climate change policy. Global co-operation (major greenhouse gas emitting countries implementing similar scheme) plays an important role in determining Australian households' support for the CPRS. Only when a zero unit non-response bias is assumed, do the benefits of the CPRS, as estimated by respondents' WTP, exceed its costs.

Key words: **Contingent valuation, climate change, Carbon Pollution Reduction Scheme, willingness to pay, uncertainty, Australia**

# 1 Introduction

In 2006, Australia emitted a total of 576 million tonnes of carbon dioxide equivalent into the earth's biosphere (Department of Climate Change, 2009). This is less than two percent of total world emissions. Despite this relatively low level of greenhouse gas (GHG) emissions in the global context, the Australian Government has ratified the Kyoto Protocol, a legally binding international agreement under the United Nations Framework Convention on Climate Change (UNFCCC). As part of fulfilling its Kyoto protocol obligation, the Australian Government has proposed a national emissions trading scheme, known as the Carbon Pollution Reduction Scheme (CPRS). The aims of the CPRS are to reduce emissions by 60 per cent of the 2000 level by 2050 and to encourage the development and use of low emission technologies (Department of Climate Change, 2008).

A significant debate surrounds the implication of the CPRS for the Australian economy. The first concern arises from the 'global public good' aspect of climate change policy. Any effective mitigation of climate change requires all actual and potential emitters to comply with a similar set of emission reduction objectives (Karl and Trenberth, 2003). However, under the Kyoto protocol, two major GHG emitting countries–China, India–are not required to comply with the protocol obligations, while the USA, the second largest GHG emitting country in 2006 (UNFCCC, 2007), has chosen not to ratify the protocol. Given that three major GHG emitting countries are outside the current multilateral framework for global climate change mitigation, the implementation of the CPRS in Australia is not expected to make any significant contribution to preventing climate change.

The second concern surrounding the CPRS is related to the numerous gaps in climate scientists' understanding about the complex interaction among atmospheric variables. Due to a lack of information, disagreement about what is known or knowable, statistical variation, measurement error, subjective judgment and disagreement about structural models (Carter, 2007), projections about climate change are associated with large confidence intervals. For instance, according to Fourth Assessment Report of Intergovernmental Panel of Climate Change (IPCC), the global average surface warming

following a doubling of carbon dioxide concentrations relative to the pre-industrial era is "likely" (66 to 90 percent probability) to be between 2°C to 4.5°C (IPCC, 2007). Furthermore, the extent of the benefits to be enjoyed from climate policy interventions, e.g. the CPRS, is poorly understood. Due to inadequate scientific knowledge about the nature of interactions and a potential nonlinear response pattern among the biophysical factors, there is a weak linkage between policy actions over time and the climate change likely to be avoided (Jacoby, 2004, Webster et al., 2003).

Some studies have attempted to estimate the value of the benefits of climate change mitigation. While Stern (2006) estimates the cost of climate change, his analysis presumes that mitigation strategies can avoid all these costs and so he equates the benefits of strategies with the costs. Clearly, this is an overstatement of benefits. Peoples' willingness to pay (WTP) to avoid the costs of climate change was not taken into consideration. The current study aims to explore how the Australian community perceives the CPRS. More specifically, the study investigates how the absence of global co-operation to limit GHG emissions and the various sources of uncertainties surrounding climate change influence households' preferences for the CPRS. This study combines two aspects of climate change uncertainty – scenario and policy – and seeks to examine how public perceptions influence peoples' decisions to support the CPRS with and without the achievement of broader global co-operation. A single bounded dichotomous choice (DC) contingent valuation (CV) study was carried out in Sydney, the state capital of New South Wales, in November 2008. About 600 households were asked for their willingness to bear extra household expenditures to support the CPRS.

The rest of the paper is organised as follows. Section 2 contains a review of the stated preference literature concerning climate change followed by a description of the survey in Section 3. In Section 4 respondents' perceptions of climate change are discussed. Section 5 sets out the WTP results while Section 6 presents results from the econometric modelling including multivariate WTP estimates. Section 7 provides a discussion of the results and includes some concluding remarks.

## 2 Literature review

Different stated preference (SP) application vehicles have been applied to estimate society's WTP for climate change mitigation costs. They range from tree plantation for carbon sequestration (Layton and Brown, 2000, Brouwer et al., 2008), investment in green energy to replace carbon dioxide ($CO_2$) intensive electricity (Roe et al., 2001; Batley et al., 2001; Rowlands et al., 2001), installation of energy saving technology (Banfi et al., 2008; Poortinga et al., 2003; Sadler, 2003), imposition of a fuel surcharge (Viscusi and Zeckhauser, 2006) through to climate change policy in general (Cameron, 2005). Besides household disposable income and the bid level, respondents' WTP to support climate change policy has generally been found to be influenced by respondents' gender (Viscusi and Zeckhauser, 2006; Berk and Fovell, 1999), education (Berk and Fovell, 1999; Wiser, 2007), awareness of the impacts of $CO_2$ emissions (Brouwer et al., 2008), perceptions of responsibility for climate change (Brouwer et al., 2008), increases in temperature during the summer and decrease in precipitation during the winter (Berk and Fovell, 1999), the scope of the climate change impact (Layton and Brown, 2000), and the provision rule (e.g. collective and voluntary payment vehicles, government and private provider) (Wiser, 2007).

The impact of uncertainty associated with climate change on individual decisions regarding support for climate change policy was first examined by Cameron (2005). That study used a Bayesian information updating model in a single bounded CV framework to estimate individual option price for future climate change using a convenience sample of college students. Regional annual average temperature rise was used as an indicator of climate change. Cameron (2005) found a quadratic relationship between expected future temperature change and individual support for climate change policy. This implies that respondents were willing to pay more with increased expected future temperature change but the amount increased at a decreasing rate. Individual support for climate change mitigation policies, furthermore, varied negatively with the level of uncertainty (measured by the variance of the subjective estimate of future temperature rise), i.e. the more uncertain the respondents were about the expected increase in average temperatures, the less they were willing to pay to prevent such an increase.

A similar approach was taken by Viscusi and Zeckhauser (2006). They conducted a CV study where a payment card method was applied using a gas tax as the payment mechanism. Over 250 Harvard University graduate students were recruited for the survey using convenience sampling. The respondents were asked to provide an upper bound, lower bound and best guess of temperature rise in Boston by 2100. Like Cameron (2005), Viscusi and Zeckhauser (2006) showed that respondents' expected temperature increases had a significant, positive effect on their WTP. However, the relationship between respondents' climate change expectation and their WTP was found to be linear. Contrary to Cameron's (2005) results, Viscusi and Zeckhauser (2006) showed that greater climate change uncertainty leads to higher support for policy action.

## 3 Description of the survey

Following Cameron (2005) and Viscusi and Zeckhauser (2006), increases in future temperature were used as an indicator to reflect climate change expectations. Respondents were asked to indicate their perceptions about future temperature change in Australia in 2100 relative to the current year in the form of a best guess, a high guess and a low guess. The best guess of future temperature change is used as a measure of climate change expectations whereas the difference between high guess and low guess estimate of temperature change was treated as a measure of ambiguity (Riddel and Shaw, 2006). A numerical probability scale was used to elicit respondents' perceptions of policy uncertainty. Respondents were asked two separate questions to distinguish policy uncertainty arising from a lack of scientific knowledge that caused by a lack of global co-operation. Global co-operation was defined as a situation where, in addition to European Union countries and Australia, at least three major greenhouse gas emitting countries i.e. US, China and India, implement a similar emission reduction scheme.

In the valuation part of the questionnaire, respondents were asked two sequential WTP questions. First, respondents were asked if they would be willing to bear (specified) extra household expenses each month on behalf of their entire household to support the CPRS (hereafter called the 'first WTP question'). Increased prices of goods and services were used as the payment vehicle. Eight different bids ranging from AUS$20 to AUS$400 per

month per household were randomly assigned across the respondents[1]. Respondents were not given any information about the potential for global co-operation at this stage. Instead, they were advised to keep their perceptions about the likelihood of reaching a broader global consensus about emissions reduction targets in mind when answering the first WTP question. The respondents who said 'No' to the first WTP question were followed up with a second WTP question (hereafter called the 'second WTP question') in which they were asked whether they would be willing to pay the offered bid amount if global co-operation could be achieved.

A web-based survey was conducted with 634 respondents in Sydney from the third week of November 2008 until the first week of December 2008. The questionnaire was primarily developed based on a series of focus group discussions with up to 12 participants in each session. During the first focus group, participants were asked to provide feedback on the level of comprehensibility of the information provided in the questionnaire. Participants, were furthermore, asked if the questionnaire appeared to be biasing their responses. Based on the feedback received from the first focus group, the questionnaire was revised and tested in a second round of focus groups. Before pilot testing, the questionnaire was sent to two climate change policy experts[2] in Australia in order to ensure that the information included in the questionnaire was consistent with existing scientific knowledge and policy prescriptions.

## 4. Sample characteristics and perceptions

Table 1 compares the socio-economic characteristics of the 634 sampled households with the regional and national population statistics. A chi-square test of proportions revealed that the differences between the sample and the Sydney population and the Australian population with respect to sex ratio are not statistically significant. However, although the educational attainments of the sample were not found to be significantly different than the Sydney population (chi square=0.24, $p$=.97), they were significantly different than the educational attainments of the Australian population (chi square=16.26, $p$<0.01).

[1] These bid amounts were based on responses obtained from an open-ended WTP question asked during the first round focus group. The bid amounts were tested in a second round of focus groups and a pilot survey.
[2] Dr. Frank Jotzo and Dr Stephen Howes are gratefully acknowledged for their inputs.

Table 1: **Summary statistics of respondents' socio-economic characteristics.**

| Respondent characteristic | | Sample | Sydney average | National average |
|---|---|---|---|---|
| Sex ratio (male/female) | | .90 | 1.16 | .99 |
| Respondent median age (years) | | 34 | 35 | 37 |
| Highest level of education (%) | Year 12 or below | 32 | 36 | 51 |
| | Certificate | 30 | 21 | 16 |
| | Bachelor's degree or above | 38 | 44 | 22 |
| Gross average household income (AUS$/week) | | 1450 | 1360 | 1305 |

Source: Australian Bureau of Statistics (2008)

Finally, Z tests for mean difference revealed that the sample respondents' age and weekly household income are not significantly different than the median age and weekly average income of the Sydney population and the national population. These test results demonstrate that the sample is representative of the Sydney population as well as the Australian population at least with respect to sex ratio, age and household income.

Less than a quarter (20 percent) of the respondents indicated that they were "highly concerned" about the impact of climate change in Australia. The majority (40 percent) were "concerned". About a third of the respondents said that they were "somewhat concerned" while around ten percent of the respondents were "not so concerned" or "not at all concerned" about climate change. As expected, respondents' levels of concern about climate change were found to be positively associated with their levels of media exposure. Those respondents who had watched the movie 'An Inconvenient Truth' or TV news/documentaries about climate change or read newspaper articles about climate change, on average, stated significantly higher levels of concern about climate change than other respondents (see Table 2). These findings are consistent with empirical evidence that reveals the significant role the media plays in shaping public perceptions of climate change issues (Lowe et al., 2006; Sampei and Aoyagi-Usui, forthcoming).

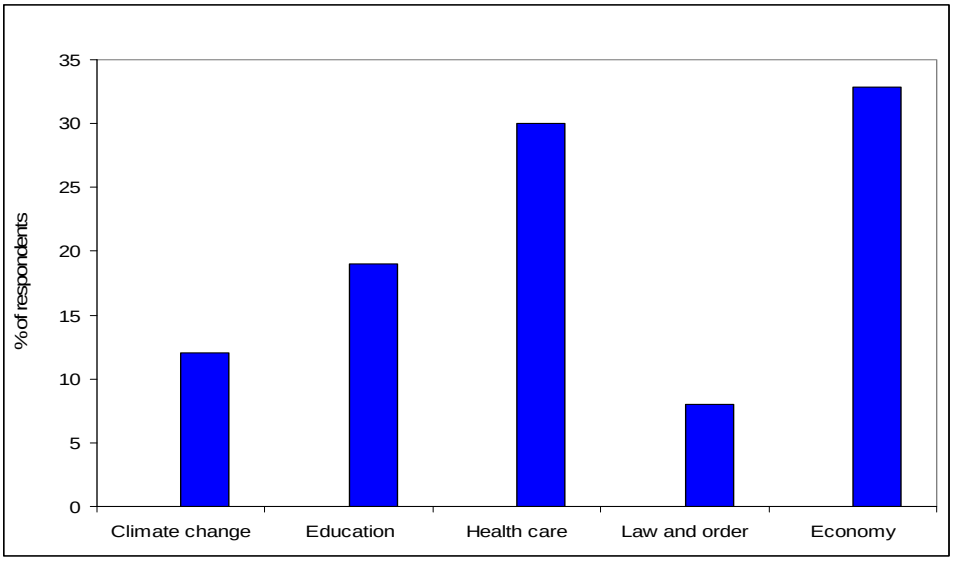
Table 2: **Pearson correlation coefficients between respondents' levels of concern and exposure to mass media**

| | Levels of concern about climate change | Watched the movie "An Inconvenient Truth" | Read newspaper articles on climate change | Watched the TV news and/or documentaries on climate change |
|---|---|---|---|---|
| Levels of concern about climate change | 1 | | | |
| Watched the movie "An Inconvenient Truth" | 0.20*** | 1 | | |
| Read newspaper articles on climate change | 0.142*** | 0.164*** | 1 | |
| Watched the TV news and/or documentaries on climate change | 0.182*** | 0.177*** | 0.390*** | 1 |

*** Correlation is significant at the 0.01 level (2-tailed).

Respondents were asked to rank five policy issues (climate change, education, health care, law and order and the economy) in Australia according to their levels of relative importance. Twelve percent of the respondents ranked climate change as the most important policy issue in Australia (see Figure 1). About a third of the respondents indicated the economy is the most important policy issue while a further third felt that health care facility is the top priority. Respondents' levels of concern about climate change and the levels of relative importance they attached to climate change as a policy issue, as expected, were positively correlated (r=0.301, $p$<0.001).

Figure 1: **Policy issue ranking.**



Over a quarter (27%) of the respondents expressed strong agreement with the statement that climate change is caused by human activity. Almost half of the sample respondents (49%) indicated a moderate level of agreement. Sixteen percent of the respondents neither agreed nor disagreed and the rest opposed the statement. A statistically significant positive correlation ($r=0.425$, $p<0.001$) was observed between respondents' levels of agreement towards this statement and their levels of concern about climate change. This implies, on average, respondents who stated higher levels of concern about climate change, also believed that human actions were responsible for the changing climatic conditions.

Figure 2: **Respondents' perceptions of climate change impact on Australia.**

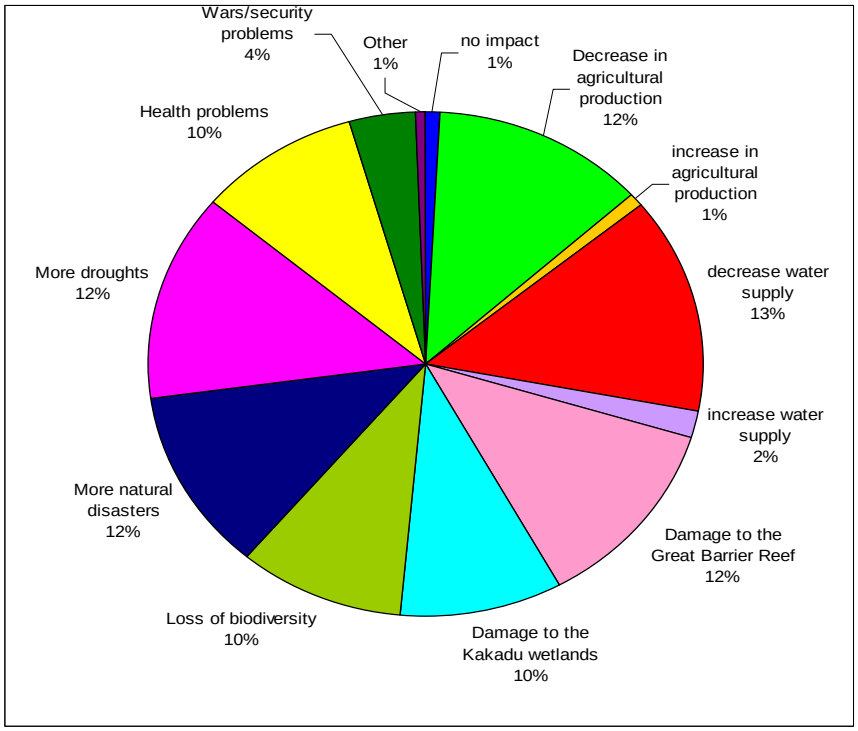
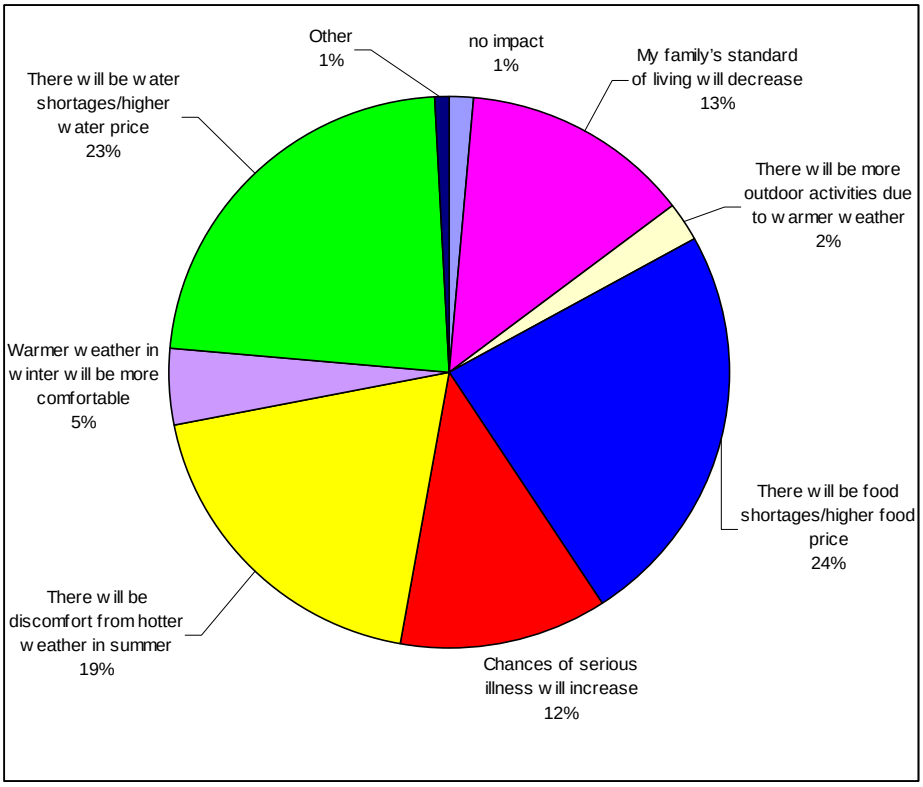



Figure 2 presents respondents' expectations of the effect of unmitigated climate change. Decreases in water supply and in agricultural production and increases in drought events and damage to the Great Barrier Reef were cited by a majority of the respondents as impacts that Australia would experience due to anticipated climate change. Loss of biodiversity, damage to Kakadu wetlands and increased health problems were also mentioned by respondents as expected consequences of climate change. Respondents were asked to indicate how they expected their households would be affected by climate change if no climate change mitigation action was

undertaken. The responses to this question are summarised in Figure 3. Higher prices for food and water resulting from lower food and water supplies were the major concerns reported at the household level. Discomfort due to hotter weather and overall decreases in standard of living were also mentioned. About seven percent of the total respondents, nevertheless, referred to some positive impacts of climate change such as increased amount of outdoor activities and relatively warmer weather during winter time.

Figure 3 **Respondents' perceptions of climate change impact of climate change on households.**




## 5. WTP Results

### 5.1 Responses to the WTP questions

67 percent of the 634 respondents interviewed rejected their offered bid. Although this percentage of rejection appears to be relatively higher than other CV studies, such high rates of refusal are not rare (e.g. Jones et al., 2008; Alberini et al., 2005; Dziegielewska and Mendelsohn, 2005; Kenyon, 2001; Halvorsen, 1996). Respondents who were willing to pay were primarily

motivated by their levels of concern and care about environment (25%), urge to avoid future natural disasters (24%) and responsibility for their contribution to climate change (21%). Respondents who rejected the bid amount were asked in a follow-up question to indicate their reasons for not paying. Some of the reasons mentioned by the respondents are common to most CV studies concerning to the provision of public good: financial constraints (18%) and holding other parties (Government, polluters) responsible for paying (33%). Some respondents refused to support the CPRS because of reasons that could be broadly translated into the imprecision of climate science. Five percent of those who refused to pay expressed their disbelief about the effectiveness of the CPRS in slowing down climate change while eight percent indicated the lack of scientific evidence about climate change as the reason for not wanting to pay. Eleven percent stated that they did not want to pay because they were not told what to expect in terms of climate change benefit if they did pay. About eight percent of the respondents indicated that they would pay on the condition that major GHG emitting countries had implemented a similar scheme.

Figure 4: **Responses to the WTP questions.**

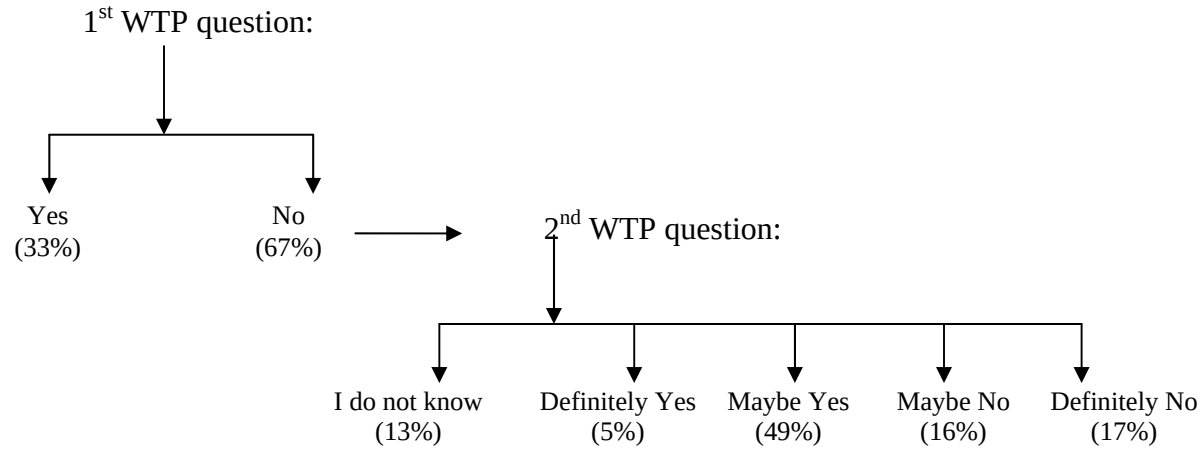


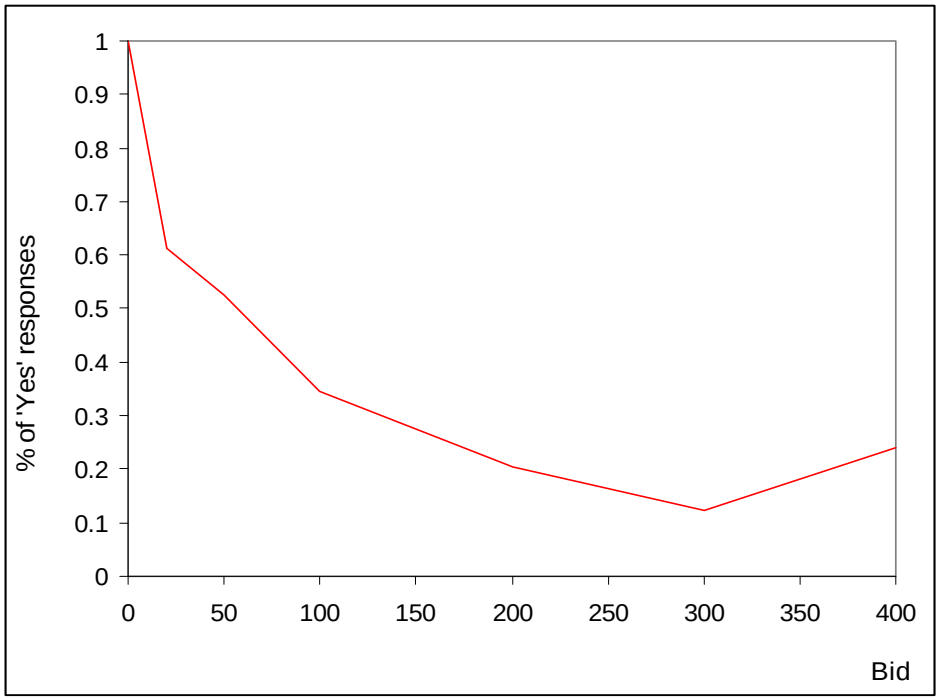

Figure 4 summerises the responses to the first and the second WTP questions. All of the 67 percent of the respondents who replied 'No' to the first WTP question were asked the second WTP question using a polychotomous (PC) choice format (I don't know, Definitely Yes, Maybe Yes, Definitely No, Maybe No). They were asked whether they would be willing to pay the offered bid amount if a global co-operation could be reached. A PC response format was applied to allow respondents to express their levels of confidence with their decision (Whitehead et al., 1998). Five percent (n=21) of those who said 'No' to the first WTP question indicated that they

would definitely pay if the major GHG emitting countries implement a similar scheme while about fifty percent (n=208) selected the 'Maybe Yes' option as a response to this question. Thirteen percent of the respondents said that they were unsure about their preferences and the rest said that they would not pay.

### 5.2 The cumulative distribution function of WTP

The cumulative distribution function (CDF) of the stated WTP for the CPRS based on a total of 634 valid observations for the WTP question is presented in Figure 5. The CDF function falls sharply starting from bid level $20 up to bid level $300. At the bid level $400, the proportion of 'Yes' responses rises, instead of approaching towards zero. This pattern of the CDF function suggests the presence of a 'fat tail' (Boyle et al., 1988).

Figure 5 **Cumulative probability distribution function of the stated WTP.**




Two reasons are generally held responsible for generating a fat tail in the distribution of WTP responses. First, the so called 'yea-saying' bias which indicates that the respondents tend to agree to pay regardless of the bid level (Blamey et al., 1999 and Michelle and Carson, 1989). Second, the highest range of the bid level was too low to pull the tail of CDF down to zero. Given the low rate of 'Yes' responses (33%) to the first WTP question and the well-behaved shape of the CDF until the highest bid ($400), the potential for 'yea-saying' as a suspect for the

fat tail problem can be disregarded[3]. Solving the fat tail problem is important to avoiding an overestimation of true WTP. A range of suggested statistical approaches can mitigate this problem (e.g. Bishop and Heberlein, 1979; Boyle et al., 1988; Ready and Hu, 1995). A common and relatively simple statistical approach is to truncate the distribution of individual WTP at some upper limit, usually the largest bid (Bishop and Heberlein, 1979).

## 6. Estimation of economic benefit

### 6.1. Multivariate regression results

Based on the findings of other empirical studies and expectations from behavioural decision theories (e.g. Ellsberg , 1961; Khan and Sarin, 1988), WTP for the CPRS is expected to vary depending on individual respondent characteristics (INDCHR) such as respondent attitudes, knowledge and familiarity with the policy, age, sex, income and educational attainment, expectations of climate change (TEM), climate change uncertainty (TEM_UN), policy uncertainty (POLICY), policy ambiguity (POLICY_AM), income and bid price (Bid):

$$Y = \alpha + \beta_1 Income + \beta_2 Bid + \beta_3 INDCHR + \beta_4 TEM + \beta_5 TEMSQ + \beta_6 TEM\_AM + \beta_7 POLICY + \beta_5 POLICYSQ + \beta_6 POLICY\_AM \quad (1)$$

where Y refers to the probability that the respondent accepts the offered bid level and $\alpha$ is a constant. A quadratic relationship between subjective climate change expectation and WTP for climate policy is hypothesized based on the findings of Cameron (2005).

Table 3 presents descriptive statistics of the explanatory variables included in the regression analysis. The binary logistic regression approach was applied to estimate the effects of the explanatory variables on the binary discrete choice of paying for the CPRS.

[3] The differences in socio-economic characteristics of two groups of respondents – those who were presented with the $400 amount and all others–were examined. No statistically significant differences were observed in terms of age, education income or occupation.

Table 3 **Descriptive statistics of the independent variables**

| Variable Name | Description | Mean | SD |
|---|---|---|---|
| BID | 20, 50, 100, 150, 200, 250, 300, 400 | 185 | 122 |
| TEM | Best guess of temperature change in 100 years time | 3.72 | 2.86 |
| TEMSQ | Square of TEM | 22 | 30 |
| TEM_UN | Uncertainty (differences between subjective high guess and low guess of temperature change) over best guess tem change | 0.90 | 0.88 |
| POLICY | Best guess probability of the CPRS not being effective in slowing down climate change | 55 | 26 |
| POLICYSQ | Square of POLICY | 3787 | 3120 |
| POLICY_AM | Policy ambiguity over policy uncertainty | 6.05 | 12.81 |
| INCOME | Household yearly income ($0-7800 to $104,000-120,000) | 71,777 | 31,175 |
| AGE | Respondents' age group (1-24=1, 25-34=2, 35-44=3, 45-54=4, 55-64=5, 65 and above=6) | 2.82 | 1.33 |
| HUMAN | Climate change caused by human actions (Strongly disagree=1, Strongly agree=5) | 3.92 | 0.96 |
| IPCC | Respondents have read or heard discussions about IPCC report (Yes=1, No=0) | 0.18 | 0.38 |
| CPRS | Respondents have heard of CPRS (Yes=1, No=0) | 0.55 | 0.49 |
| OFFSET | Respondents have purchased carbon offset (Yes=1, No=0) | 0.11 | 0.31 |
| SOLAR | Respondents have installed solar panel in their house (Yes=1, No=0) | 0.12 | 0.32 |

In Table 4, a series of multivariate regression results for three different models is set out. The models vary based on the different WTP responses used as the dependent variable. The 'Yes/No' responses to the first WTP question were used as the dependent variable in Model 1. To create the dependent variables for analysis of WTP when global co-operation was assured, the 'No' responses obtained from the first WTP question were calibrated (recoded to 'Yes') based on the responses to the second WTP question. Two different calibration exercises were undertaken. First, if respondents replied 'Definitely Yes' to the second WTP question then the corresponding 'No' responses to the first WTP question were recoded to 'Yes'. These recoded responses were

used as dependent variable in Model 2. Second, the 'No' responses to the first WTP question were recoded to 'Yes' if the respondents replied 'Definitely Yes' or 'Maybe Yes' to the second WTP question. These recoded responses were used as the dependent variable in Model 3.

Table 4 **Estimated linear-logistic WTP models ('Yes/No' replies to DC WTP question is response variable).**

| **Variable Name** | **Model 1** [a] | **Model 2** [b] | **Model 3** [c] |
|---|---|---|---|
| Constant | -.008 | .113 | -.582 |
| | (.762) | (.763) | (.730) |
| BID | -.006*** | -.005*** | -.003*** |
| | (.001) | (.001) | (.001) |
| *Expected scenarios, uncertainty and ambiguity* | | | |
| TEM | .250** | .174 | .108 |
| | (.123) | (.115) | (.106) |
| TEMSQ | -.027** | -.020* | -.012 |
| | (.012) | (.011) | (.010) |
| TEM_UN | -.281** | -.248* | -.041 |
| | (.143) | (.132) | (.105) |
| POLICY | -.043** | -.042** | -.010 |
| | (.017) | (.017) | (.018) |
| POLICYSQ | -.000* | .000 | .000 |
| | (.000) | (.000) | (.000) |
| POLICY_AM | -.013 | -.116 | .000 |
| | (.001) | (.138) | (.008) |
| *Socio-economic* | | | |
| INCOME | .000* | .000* | .000*** |
| | (.000) | (.000) | (.000) |
| AGE | -.070 | -.050 | .002 |
| | (.075) | (.072) | (071) |
| SOLAR | .569* | .575** | .101 |
| | (.293) | (.285) | (300) |
| *Attitude, knowledge, information and experience* | | | |
| HUMAN | .210* | .253** | .414*** |
| | (.115) | (.111) | (.104) |
| IPCC | .499** | .509** | .550** |
| | (.253) | (.254) | (.276) |
| CPRS | 0.412** | .312 | .198 |
| | (.199) | (.191) | (.192) |
| OFFSET | .551* | .333 | .408 |
| | (.293) | (.287) | (.326) |
| *Model fit statistics* | | | |
| -2 Log-likelihood | 670.412 | 710.960 | 703.437 |
| Wald $^2$ | 127.636 | 115.006 | 94.305 |
| | (df=14, $p$<0.001) | (df=14, $p$<0.001) | (df=14, $p$<0.001) |
| Nagelkerke R Square | 0.25 | 0.23 | 0.19 |

| | | | |
|---|---|---|---|
| Percentage correctly predicted | 76% | 74% | 71% |
| N | 634 | 634 | 634 |

Explanatory notes:
[a] Responses to the first WTP question as dependent variable.
[b] 'No' response to the first WTP question was recoded to 'Yes' if response to the second WTP question was 'Definitely Yes'.
[c] 'No' response to the first WTP question was recoded to 'Yes' if response to the second WTP question was either 'Definitely Yes' or 'May be Yes'.
Standard errors of the parameter estimates between brackets.
***: p<0.01; **: p<0.05; *: p<0.10.

Although all the estimated regression models presented in Table 4 are statistically significant at less than one percent level, Model 1 is the best fitting in terms of Nagelkerke R Square. In all models, the coefficients of the variable BID, the extra monthly expenses households were asked to pay for the CPRS, are statistically significant and show the *a priori* expected negative sign (the higher the bid, the lower the probability that respondents were willing to pay, *ceteris paribus*). Household income, as expected, shows a significant positive impact on stated WTP for the CPRS (the higher the income level, the higher the likelihood that respondents were willing to pay the offered bid). Furthermore, respondents' attitudes towards climate change (respondents' levels of agreement with the statement 'Climate change is caused by human action') and their knowledge about the IPCC have statistically significant influences on WTP in all three models.

The coefficients of the variable 'CPRS' (respondents' familiarity with the CPRS) and OFFSET (respondents purchased a carbon offset certificate) are significant only in Model 1. This implies that when global co-operation about climate change mitigation action is not guaranteed, respondents who are familiar with the CPRS or who purchased a carbon offset certificate to reduce their carbon footprint, were significantly more likely to accept the offered bid level. However, the influences of these two variables become statistically insignificant on household decision of supporting the CPRS when major emitting countries commit towards limiting their national emission levels.

The coefficients of the variables TEM, TEMSQ, TEM_AM are all statistically significant with theoretically expected signs in Model 1. The signs of the coefficients of variables TEM (positive) and TEMSQ (negative) demonstrate that the utility function is concave in climate change expectations. As expected future temperatures increase, the likelihood of paying for the CPRS increases. However, the likelihood increases at a decreasing rate. The coefficient of climate

change uncertainty (TEM_UN) exhibits a negative sign. This means that, *ceteris paribus*, as respondents become more unsure about the scale of climate changed impact, the likelihood that they would accept the offered bid amount decreases. The coefficients of the variables POLICY and POLICYSQ are statically significant in Model 1. This implies that, *ceteris paribus,* the respondents were willing to pay less with increasing policy risk uncertainty. WTP decreases at an increasing rate as the policy uncertainty increases. The coefficient of the variable POLICY_AM was statistically insignificant in all models.

The expectations and uncertainty variables associated with climate change and climate policy start loosing significance in explaining individual decisions to supporting the CPRS when the dependent variable is calibrated depending on the responses to the second WTP question. In Model 2, the coefficients of TEM and POLICYSQ become insignificant. Uncertainty concerning to climate change expectations and uncertainty associated with CPRS success were found to have statistically significant influences on respondents' likelihood of accepting the offered bid level in Model 2. When a more stringent calibration is undertaken for Model 3, all the subjective expectations and uncertainty variables are insignificant.

### 6.2. WTP estimates

The estimated WTP values and their confidence intervals are presented in Table 5. Referendum CVM programs in GAUSS written (Cooper, 1999) were used to estimate the Krinsky and Robb (1986) confidence intervals for the point estimates of mean WTP. The estimation of mean WTP involved exclusion of variables that were not statistically significant at the ten percent level, as inclusion of these variables inflates the confidence intervals. Note that a truncation operation was undertaken at this stage at bid level $400 to overcome the fat tail problem associated with the CDF function. However, in order to compare the impact of truncation on the estimated social benefit of the CPRS, WTP estimate was also obtained from an untruncated CDF function.

The lowest value of mean WTP, $135 per household per month, is obtained from Model 1 ($WTP_1$). The mean WTP from Model 2 ($WTP_2$) is $150 which is eleven percent higher than $WTP_1$. The confidence intervals around the mean WTP obtained from Model 1 and Model 2, it is apparent that these confidence intervals overlap each other. This indicates that there is no statistical difference between the $WTP_1$ (without global co-operation) and $WTP_2$ (with global co-operation). The WTP estimate obtained from Model 3 ($WTP_3$) is higher again ($414). The

confidence interval around WTP3 furthermore does not overlap with the confidence interval obtained for $WTP_1$ and $WTP_2$. This implies that $WTP_3$ is significantly different than $WTP_1$ and $WTP_2$. However, $WTP_3$ is associated with larger confidence intervals and, as a result, performs poorly on efficiency grounds[4] in comparison with $WTP_1$ and $WTP_2$. The inefficiency associated with the $WTP_3$ is attributed to the lack of confidence manifested in respondents' decision about supporting the CPRS. Thirty percent of respondents included in Model 3 were not certain about their decisions. Their lack of confidence in turn translates into larger confidence intervals of the estimated WTP. This implies that, although $WTP_3$ shows substantial increase in welfare gain under the condition of global co-operation, the estimate is less reliable as a base for inference.

Table 5 **Krinsky and Robb confidence intervals of Mean WTP for the CPRS using 1000 repetitions.**

| | Per household/per month (AUS$) | | | |
|---|---|---|---|---|
| | | Truncated Models | | |
| | Untruncated Model | Model 1 | Model 2 | Model 3 |
| Mean WTP | 172 | 135 | 150 | 414 |
| 99 % C.I | 138 to 286 | 108 to 191 | 120 to 210 | 289 to 813 |
| 95 % C.I | 145 to 242 | 113 to 166 | 126 to 188 | 307 to 630 |
| 90 % C.I | 149 to 224 | 117 to 160 | 130 to 180 | 317 to 565 |

The mean WTP estimate obtained from untruncated CDF distribution ($WTP_U$) is, as expected, higher than both $WTP_1$ and $WTP_2$. However, the confidence intervals around the $WTP_U$ overlap with the confidence intervals around $WTP_1$ and $WTP_2$. This, again, indicates that there is no statistical difference between the $WTP_U$ and $WTP_1$ and $WTP_2$. On efficiency grounds, $WTP_U$ performs worse than $WTP_1$ and $WTP_2$. The efficiency score for the $WTP_U$ calculated at the 95 percent confidence interval equaled 0.6 which is higher than the efficiency scores obtained for $WTP_1$ and $WTP_2$ (0.4). This implies that $WTP_1$ and $WTP_2$ are the most reliable estimators.

[4] Efficiency of the mean WTP estimate was calculated base on the following formula: Efficiency= 95% confidence interval of WTP/mean WTP. The efficiency score for $WTP_1$ and $WTP_2$ were .4 whereas the efficiency score of $WTP_3$ was 0.7.

### 6.3 Aggregation of WTP estimates

The estimated mean WTP values were extrapolated across the whole population (8.1 million households in Australia) to calculate the aggregate benefit from the CPRS. This approach was considered appropriate given that the key socio-economic characteristics of the sample respondents are not significantly different than the population characteristics. While aggregating the estimated average WTP values, it is important to take into consideration any potential unit non-response bias. Unit non-response bias occurs when part of the sample frame does not participate in the survey. Mitchell and Carson (1989) suggested the following way to treat unit non response bias:

$$\overline{WTP} = \sum_{m} WTP + \sum_{n} \lambda(WTP) \qquad (2)$$

In equation 2, $\overline{WTP}$ refers to the weighted aggregated WTP, m refers to the proportion of respondents, n refers to the proportion of non- respondents and $\lambda$ is the multiplier or weight attached to the WTP of non-respondent population. Different values of $\lambda$ can be assumed. For example, $\lambda$=1 implies that non-respondents have the same mean WTP as respondents, i.e. unit non-response bias equals to zero. Similarly $\lambda$=0 means non-respondents have zero WTP. These are two extreme assumptions. The former is the most generous and the later is the most conservative. Any value of $\lambda$ in between these two extremes can also be assumed.

Out of 17,000 chosen respondents, 5,100 (30 percent) respondents attempted to complete the survey[5]. 2,142 respondents actually completed the survey[6]. We assume that the 5,100 respondent who attempted to complete the survey have the same mean WTP as those respondents who completed the survey. This assumption produces a relatively higher response rate of thirty percent. This implies a non-response rate of seventy percent. Three different assumptions were made about the values that these non-respondents hold. First we assumed that non-respondents had a zero WTP ($\lambda$=0). The second assumption was that the non-respondents' mean WTP was half of the respondents mean WTP ($\lambda$=0.5). Finally, we assumed a zero unit

[5] Eighteen percent of those who opened the e-mail could not complete the survey because of technical problems, eleven percent dropped out, one percent was screened out through a quality control device and the rest did not meet the representativeness criteria.

[6] Note that the number of completed survey indicates the number of responses obtained for the whole project. The full project was divided into six split samples. It was not possible to record a split sample specific response rate.

non-response bias. This assumption implies that the non-respondents hold the same WTP as the respondents.

The results of the benefit aggregation exercise are presented in Table 6. As expected, the $\lambda$=0 assumption generate the lowest aggregate benefits of the CPRS and the $\lambda$=1 assumption produces the highest values. The estimated economic benefits of the CPRS under different values of $\lambda$ are compared with the cost estimate. The estimated economic cost of the CPRS is $14.7 billion per year for a five percent emission reduction target by 2020 (The Commonwealth Treasury, 2008). This is equivalent to $150 per month per household. When a value of $\lambda$ = 0 is assumed, the estimated economic cost of CPRS consistently exceeds its gain. By relaxing the assumption about non-respondents WTP from zero to half of respondents' mean WTP ($\lambda$=.5), economic benefit exceeds economic costs only in case of $WTP_3$, the least efficient WTP estimate. Finally, under the most generous assumption about unit non-response bias ($\lambda$ = 1), estimated economic benefit approximately equals the estimated economic cost.

Table 6: **Aggregation of mean WTP estimates.**

| | | $\lambda$ = 0 | | $\lambda$ = 0.5 | | $\lambda$ = 1 | |
|---|---|---|---|---|---|---|---|
| | WTP /household /month (A$) | Aggregate benefits /per year (bn A$) | Benefit-cost ratio | Aggregate benefits /per year (bn A$) | Benefit-cost ratio | Aggregate benefits /per year (bn A$) | Benefit-cost ratio |
| Aggregation approach | | | | | | | |
| $WTP_U$ | 172 | 5.02 | 0.3 | 10.87 | 0.7 | 16.72 | 1.1 |
| $WTP_1$ | 135 | 3.94 | 0.3 | 8.53 | 0.6 | 13.12 | 0.9 |
| $WTP_2$ | 150 | 4.37 | 0.3 | 9.48 | 0.6 | 14.58 | 1.0 |
| $WTP_3$ | 414 | 12.07 | 0.8 | 26.16 | 1.8 | 40.24 | 2.7 |

## 7. Discussions

This study aims to understand Australian households' perceptions of climate change and their preferences for the proposed CPRS. Sample households attached relatively low levels of importance to climate change in comparison to other competing policy issues in Australia. Consistent with their priorities, a majority of 67 percent of the respondents rejected the prospect of paying more for their households' consumption in a DC CV question. It was observed that

respondents were willing to trade off more money as the expectations of temperature increases rose. However, that WTP increased at a decreasing rate. The estimated relationship between expected future temperature change and individual support for climate change policy corresponds with the finding reported in Cameron (2005). Climate change uncertainty was found to affect individual decisions to support the CPRS. This result is consistent with the empirical findings of Cameron (2005). Furthermore, the negative sign of the coefficient of scenario uncertainty, reflecting uncertainty aversion behaviour, is consistent to the empirical results documented by Cameron (2005).

The study provides an estimate of the economic benefits associated with the CPRS. The results indicate that there is a demand for climate change mitigation action. Respondents were found to place a positive value on climate change risk mitigation. The estimated WTP ($WTP_1$) is about two percent of average monthly household income of the sample population. In comparison, the option price estimated by Cameron (2005) was close to five percent of average expected future monthly income while Viscusi and Zeckhauser (2006) found the mean WTP to be three percent of sample monthly income. The difference between the values of welfare estimate can be attributed to a number of factors. First, the studies conducted by Cameron (2005) and Viscusi and Zeckhauser (2006) involved convenience sample (a group of college students were recruited as sample) whereas the current study involved a public survey. Second, Cameron (2005) and Viscusi and Zeckhauser (2006) did not incorporate policy uncertainty in the decision model. The current study takes the impact of policy uncertainty into consideration which has been found to have a negative impact on individual WTP to support climate change policy. Eliminating the policy uncertainty of climate change (i.e. setting $\mu_{\pi_P}$ and $(\mu_{\pi_P})^2 = 0$) increases mean WTP for the CPRS to $319 per household per month. Adjusting for inflation rate and exchange rate, this amount turns out to be 90 percent of the welfare estimate calculated by Cameron (2005).

The mean WTP estimates obtained from different models were aggregated across the whole population. Various assumptions were made about unit non-response bias during the aggregation exercise. The aggregated economic benefits from the CPRS were compared against the estimated economic costs of the CPRS. The benefit cost ratio (BCR) of the CPRS has been found

insensitive to the calibration techniques except $WTP_3$. However, the BCR of the CPRS has been found to be sensitive to the assumptions made about unit non-response bias. Only under the most generous assumption of a zero unit non-response bias do the economic benefits obtained from the CPRS exceed its estimated cost. Any departure from this assumption generates lower benefit estimates and lower BCR. Although global co-operation played an important role in respondents' decision of paying for the CPRS, a proportion of the respondents were not certain about their decisions. When respondents' uncertainty about their WTP when global co-operation was assumed is taken into account using a liberal recoding policy ($WTP_3$), WTP is significantly higher. Only in that case do the benefits of the CPRS exceed its costs under the assumption that non-respondents have a positive WTP.

## 8. Conclusions

In this study, two aspects of climate change uncertainty – scenario and policy – are considered. We examined how these two distinct forms of uncertainty influence peoples' decisions to support climate policy intervention. The WTP for climate change mitigation was found to be significantly reduced by the uncertainty associated with the expectations of future temperature increases. This indicates that the social benefit of the CPRS could be enhanced if more certain forecasts of climate change were available. Furthermore, the WTP for the CPRS was found to be negatively affected by respondents' lack of confidence in the CPRS being effective in slowing down climate change. This implies that the welfare gain from the CPRS would increase if the general public were more convinced about the effectiveness of the CPRS.

Finally, the results of the current study convey useful message for researchers seeking to estimate the social benefits arising from public policy intervention in the event of multi dimensional uncertainty. Our results demonstrate that, in addition to scenario uncertainty (as previously shown by Riddel and Shaw (2006) and Cameron (2005)), policy uncertainty significantly influences society's WTP to support a proposed policy action. Ignoring such an important element in individual decision making framework may potentially overestimate the economic benefit of public policy intervention.

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