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Willingness to Pay for Individual Greenhouse Gas Emissions Reductions: Evidence from a Large Field Experiment*

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Abstract

In the climate policy debate, a rhetoric has evolved that attributes a high potential to "voluntary climate action". We turn to the population of Germany, the fourth largest cumulative GHG emitter, to obtain an (Internet-)representative estimate of the individual willingness to abate one ton of CO_2, the equivalent of 10 percent of annual per-capita CO_2 emissions. The estimate derives from a large-scale (n=2,440) framed field experiment in which subjects choose between a guaranteed reduction of one ton of EU CO_2 emissions and a randomly drawn cash award between €2 and €100. At €6.30, estimated mean WTP is considerably lower than prior hypothetical or non-representative estimates. Median WTP is non-positive. The almost bimodal nature of WTP in the population has important policy implications.

Keywords: climate change mitigation, field experiment, voluntary climate action, willingness to pay

JEL-Classifications: C93, Q51, Q54

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"Each and every one of us can make changes in the way we live our lives and become part of the solution [to climate change]." – Al Gore

1 Introduction

Valuing the preferences of the general public about climate change mitigation is a key challenge in informing the climate policy debate. While the need for decisive action on greenhouse gas (GHG) emissions reductions is now well understood among policy-makers and the public at large, the optimal design and political feasibility of ambitious climate policies remain unclear: A global agreement on a two degree ceiling on warming, for example, implies a path of emissions reductions in industrialized countries that—if implemented—would be unprecedented in terms of scale and pace. This amounts to a policy challenge of new proportions as ambitious climate policies will impact on the daily lives of ordinary citizens in a palpable way.

Within the climate policy debate, a rhetoric has evolved among influential commentators, climate researchers, and government bodies that attributes a high potential to "voluntary climate action". Voluntary action, it is argued, might eliminate or at least reduce the need for coercive policies to bring about emissions reductions (Gore and Guggenheim 2006, Pachauri 2007, European Commission 2011). While economists are generally sceptical about the premise that voluntary private provision might make much of a difference, the empirical evidence is less clear-cut: A number of researchers investigate the willingness to pay (WTP) for voluntary GHG emissions reductions and find mean WTP results of €25 (Brouwer et al. 2008), £24 (MacKerron et al. 2009), or €12 (Löschel et al. 2010) per ton of individually provided GHG emissions reduction. It cannot be ruled out, therefore, that given the opportunity, voluntary behavior might give rise to substantial GHG emissions reductions.

Although indicating potential, there are at least three methodological reasons for climate policy to be cautious about the evidence on voluntary action so far. One is the inherent hypothetical bias of the numbers reported: So far, research provides WTP estimates for mitigation efforts that are derived using stated preferences, with the exception of Löschel et al. (2010). Estimates derived by this route are important benchmarks, but inherently likely to overstate WTP (Cummings et al. 1995, Carlsson and Martinsson 2001). Secondly, all existing studies tend to be representative for specific subgroups of the general population such as frequent fliers passing through a specific airport (Brouwer et al. 2008), young adults with higher education (MacKerron et al. 2009), or residents of a specific city (Löschel et al. 2010). Understanding how the WTP of such a subgroup relates to that of the general population is difficult. Thirdly, existing studies' participants faced bid prices for emissions reductions that predominantly fall in the neighborhood of current offset prices. However, estimates of real marginal abatement costs are up to one order of magnitude higher (e.g. Tol 1999, 2009, 2010).

The present paper embarks on providing the first study of preferences for voluntary climate action based on both non-hypothetical choices and a large and representative sample. Specifically, we report on the WTP for the abatement of one ton of CO_2 emissions. The method we employ is a large-scale framed field experiment. "Large-scale" and "framed field experiment" refers to a num-

ber of design choices. The term 'experiment' invokes the controlled setting in which a number of subjects take a consequential decision at minimal transactions costs, in this case a discrete choice between two real goods: On the one hand a cash amount randomly drawn from an economically meaningful range of €2 to €100 and on the other a guaranteed and verifiable emissions reduction of one ton of CO_2, carried out through the documented retirement of an EU emissions allowance (EUA) under the European Union Emissions Trading Scheme (EU-ETS). 'Framed field' experiment refers to the specific field experimental design, which confronts members of the public who regularly participate in incentivized polls with a setting that is broadly indistinguishable from a 'normal' polling round and which operates during their everyday routine.[1] 'Large-scale' refers to the sample of 2,440 voting-aged subjects who are representative for the Internet-using population of Germany, the sixth largest current and fourth largest cumulative carbon emitter (e.g. United Nations 2011).

Our key results can be summarized as follows: First, the estimated mean WTP for an individual emissions reduction of one ton of CO_2 is €6.30. Stated differently, this mean WTP could be expected to be sufficient to reduce CO_2 emissions in Germany by four percent. Median WTP, however, is non-positive. This is an implication of our second result that the support of the mean WTP is essentially a bimodal distribution: The vast majority of subjects (around 70 percent) have a non-positive WTP while a minority is willing to sacrifice particularly high amounts. Thirdly, WTP strongly correlates with policy-relevant characteristics of the subjects: The level of education, the informational status about climate change as reflected in perceptions of expected benefits from today's emissions reductions, as well as a perceived lifestyle-related responsibility for climate change are key predictors of a higher WTP. Voluntary action is thus likely to increase with increased knowledge on the time structure of benefits as well as on the personal impact of actions. Fourthly, there is evidence that exogenous environmental controls such as meterological conditions around the time of the experiment matter for WTP estimates.

The paper proceeds as follows: We explain the experimental design considerations and the experimental protocol in the following section. We then outline the analysis in section 3 and report on data, experimental results, and the resultant WTP estimates in section 4. Section 5 discusses the results, and section 6 concludes.

2 Experimental design

The basic design of the framed field experiment is a closed-ended single-bounded valuation question implemented under a random incentive system (Grether and Plott 1979, Starmer and Sugden 1991, Lee 2008). Experimental subjects indicate their preference between, on the one hand, a randomly drawn cash award and, on the other, a guaranteed and verifiable GHG emissions reduction of one ton of CO_2. The cash prize presented to the subject is the outcome of an equiprobable draw from prizes between €2 and €100 in steps of €2, the upper bound reflecting an economically meaningful maximum abatement cost for CO_2 emissions under a two degrees centigrade warming scenario (Tol 1999, 2009,

[1] We follow the taxonomy of field experiments introduced by Harrison and List (2004).

2010). The GHG emissions reduction is in the form of the documented retirement of an emissions allowance under the EU-ETS. We use between-subjects randomization (Baltussen et al. 2010, Abdellaoui et al. 2011, Tversky and Kahneman 1981) with odds of 1 in 50 that a subject's choice of either cash or emissions reductions is realized. The choice is taken by an internet-representative sample of 2,440 participants drawn from a population of approximately 65,000 panel members of an internet polling firm. Subjects received the firm's standard invitation to participate in the familiar format of a poll incentivized through a lottery.

These basic design choices are intended to address a number of issues that arise in the context of assessing WTP in the field. First, the design combines the advantages of a standard dichotomous choice format (e.g. Lusk and Hudson 2004, Shogren 2006)—such as short administration time, limited cognitive load, and a familiar decision situation—with incentivized choices in order to alleviate the highly problematic hypothetical bias of stated preferences methods (e.g. Cummings et al. 1995, Harrison 2006, Harrison and Rutström 2008): Subjects face a real trade-off between a guaranteed cash prize and guaranteed emissions reductions. Emissions reductions are facilitated and officially documented through the acquisition and retiring of individually traceable EUAs. Retiring of EUAs is an option available to all trading account holders in the ETS and deletes the certificate from the ETS registry. As a result, a retired EUA reduces the total amount of regulated GHG emissions from European Union by one ton of CO_2.[2]

Secondly, the field experimental design combined with the large sample of subjects enhances external validity. The sample of 2,440 subjects whose decisions form the basis of this paper are representative with respect to sex, age, and region of residence for the internet-using population of Germany, a key GHG emitter on a global scale. The framed field character is reinforced by administering the experiment to subjects for whom receiving an invitation to participate in polls with a random incentive feature is normal and takes place within their everyday routine. Also, the dichotomous choice design, accompanied with additional survey questions and lasting for approximately five minutes, is closely related to a common polling format and thus not distinguishable from other polls conducted by an internet polling firm.

Thirdly, the experimental design excludes to the greatest extent possible confounding public or private good attributes associated with the experiment. In order to ensure that the WTP estimated retains a narrow focus on the specific public good of GHG emissions reductions, we employ, on the one hand, a website-based certification procedure of the EUA retirements, and we remind, on the other hand, the subjects of the spatial indifference of local GHG emissions reductions for a global effect on the climate. If subjects received EUA retirement certificates in hardcopy, for example, it would plausibly increase WTP not

[2] The EUAs used in the experiment are Phase II emission allowances with a market price of around €15 apiece at the time of the experiment. EUAs are the vehicle of choice for understanding the WTP for GHG emissions reductions since the reduction occurs in a demonstrable and therefore credible way. In this, they differ from other forms of available emissions reductions certificates (e.g. "Gold Standard" CERs). First, the binding cap of the European Emissions Trading System avoids problems of additionality that are often encountered for project-based offsets. Second, through the system's registry, account holders can directly observe and document the official deletion of each allowance without the need for an intermediary.

because of the GHG emissions reduction, but because of the curiosity dimension of the good or because of private co-benefits derived from an increased visibility of the decision to others.

The fourth consideration in an valuation exercise involving GHG emissions reduction is the informational status of subjects. This is a critical point: Empirical work on the public understanding of climate change indicates that knowledge among the general population about the causes and functional relationships of climate change (Ungar 2000, Lorenzoni and Pidgeon 2006, Lorenzoni et al. 2007, Sterman and Sweeney 2007) and the logic underpinning climate policy (Sinn 2008) varies considerably. Among the existing studies about WTP for individual mitigation, the amount of information about climate change provided by the researchers differs markedly. While Brouwer et al. (2008) appear to be completely silent about causes of climate change and metrics for CO_2 used, MacKerron et al. (2009) provide a minor amount of information on the metrics, and Löschel et al. (2010) provide information on metrics and on climate change based on the IPCC report. Consistent with the field experimental spirit of the valuation elicitation, our design does not make an attempt to inform or educate subjects on these issues before their choice. This implies that the valuation signal of subjects is based on knowledge that may be incomplete or erroneous. The point includes the very good that subjects are valuing: Among the possible alternatives of defining an emissions reduction we deliberately opt for the universal and objective metric of one ton of CO_2, even though subjects coming to the experiment will differ in their familiarity with the metric. The rationale for taking the information status of subjects as given and choosing a highly objective and unbiased measure is threefold: First, we circumvent the inevitable biases, potential misinterpretations, and scientific debates about "unbiased full information" that arise when offering subjects potentially choice-relevant information prior or during the experiment (Arrow et al. 1993, Munro and Hanley 1999). Second, the field nature of the experiment allows subjects to collect relevant information while the experiment is in progress (Berrens et al. 2004), something that the choice of the universal metric deliberately facilitates and that we can indirectly observe. Third, by trying not to confound subjects' potential "homegrown" (Cummings et al. 1995) ignorance, we import the highly heterogeneous information levels that exist within the population. This offers on the one hand a suitable parallel to the problem facing policy-makers today and allows us on the other hand to examine informational status as a determinant of WTP.

2.1 Experimental protocol

The experiment was administered using the infrastructure of YouGov, a large Internet polling company. The recruitment of subjects followed the standard routine of our cooperation partner in which panel members are invited via an email message to proceed to the survey via a hypertext link. The introductory screen explained the thematic focus of the survey, the expected duration of the survey (ten minutes), and the use of the random incentive system with a prize worth up to a three-digit Euro figure.[3] Following the invitation screen, there

[3] These design criteria would have been familiar to panel members from previous polls as they decided on whether to proceed. The polling firm regularly incentivized polls through either a piece-rate reward of approximately €1 for 20 minutes expected survey time or random

was a filter screen to focus on German subjects of voting age.[4] Participants then saw 10 to 13 computer screens asking for 16 to 19 choices or answers, depending on their decisions. Median completion time was approximately 5 minutes.[5]

Subjects' valuation was collected using two screens, one that introduced the good to be valued and set up the choice (the *information screen)* and one that explained the payment procedures and collected the choice (the *decision screen*). The *information screen* explained three features of the experiment, (1) the trade-off between a cash prize and the CO_2 emissions reduction, including a succinct explanation of how the deletion of an EUA reliably reduces EU CO_2 emissions, (2) the public good character of the emissions reduction and (3) the random incentive system with odds of 100 in every 5,000. The *decision screen* explained the consequences if the subject was drawn as a winner and triggered a decision. Important features at this stage were transparent explanations of how subjects that chose the cash amount would receive the award (through their account at the polling company) and how those who chose the emissions reductions would be able to verify that the emissions reduction had been carried out (through an authoritative website). The bottom of the screen presented the two prize alternatives in randomized order, including the randomly determined subject-specific cash amount in Euro, and collected the subject's choice through checking the preferred option.

The experiment concluded with a set of screens containing follow-up questions. For subjects that had chosen the cash prize, a screen testing for field price censoring (Coller and Williams 1999, Harrison et al. 2002) was inserted. All subjects were then asked to provide estimates of the actual EUA price and their availability to subjects outside the experiment. Another set of questions was targeted at subjects' beliefs about benefits from today's emission reductions as well as their perceived personal contribution to climate change. The survey concluded with collecting specific socio-demographic information in addition to subject's socio-demographic profile on record with the polling company.

The Internet experiment ran in two sessions in May and July 2010. Session 1 lasted from May 25th to June 2nd and generated 1,640 complete[6] observations from 1,817 invitations. Session 2 lasted from July 19th to 27th and generated 800 complete observations out of 888 invitations. Among the pooled sample of 2,440 complete observations, anwers to the open-ended questions revealed 85 subjects who either objected to the EU-ETS as a proper method to reduce emissions or said they distrusted the experiment itself. Following the usual procedure in the literature, these observations were excluded from the subesequent analysis.[7] The experiment was preceded by a set of pre-tests and a pilot experiment with 200 economics students in order to test the online implementation and refine

(lottery) prizes, e.g. in the form of a shopping vouchers of €25, €50, or €100. All cash awards accrue to the subject's personal account with the polling company and can be converted into cash as soon as a threshold of €50 is reached. The random incentive scheme was therefore procedurally familiar.

[4] Subjects of other nationalities were redirected to other surveys running at the same time.

[5] Average completion time was 1 hour 18 minutes. This is driven by a small fraction of surveys (about 4%) in which subjects availed themselves of the opportunity to leave the survey and continue hours or days later.

[6] We count an observation as complete if the subject saw the final dismissing screen. All screens required an answer for each question by entering text or choosing at least one of the options (including "I don't know" options) before being able to proceed to the subsequent screen.

[7] Results presented are not sensitive to inclusion or exclusion of these observations.

the set of texts and questions.

3 Analysis

Both equivalent and compensating variation, and therefore willingness to pay (WTP) and willingness to accept (WTA), are applicable concepts for analyzing the welfare changes in our experiment.[8] Implicit in these concepts is an argument in favor of one of the two possible reference points of the comparative statics, either of which can be defended. First, the experimental task may be written to elicit equivalent variation, E, defined as

$$v(p, q^1, y) = v(p, q^0, y + E) \tag{1}$$

where q^1 and q^0 denote the vector of public goods with and without the one ton emissions reduction, respectively, y denotes income, $v(p, q, y) \equiv \max_x\{u(x, q)|px \leq y, x \geq 0\}$ is the indirect utility function, and x denotes the vector of private goods at given prices p. Without loss of generality, we define the corresponding element of q in terms of abatement of GHG emissions. Thus, E is the amount that would make the subject indifferent between increasing emissions reductions by one ton at present income and going without the change but increasing income by E. Hence, E corresponds to the minimum WTA to forgo the emissions reduction (Hanemann 1999).[9] Second, the experimental design may also be interpreted as eliciting compensating variation and thus WTP: Whereas equation (1) necessarily implies that the individual perceives the experimental choice as a "sale" offer treating the emissions reduction prize as the reference point, the converse, in which the cash prize is seen as the default option and the experimental task resembles a purchasing decision, appears equally, if not more plausible. In this case,

$$v(p, q^1, y' - C) = v(p, q^0, y') \tag{2}$$

defines the compensating variation with income $y' = y + c$ where c is the cash prize offered in the experiment. C corresponds to the maximum WTP to secure the increase in emissions reductions (Hanemann 1999). To retain consistency

[8] Note that most of the reasons believed to create the frequent disparity between WTP and WTA do not apply in our case. Following Hanemann (1999), we summarize these reasons along three dimensions: First, a reference dependence model à la Tversky and Kahneman (1991) will predict a WTP/WTA disparity since in the case of WTA, the situation will resemble a "sale" of the change in q while in the case of WTP, the situation will resemble a "purchase". Thus, a loss-averse individual's WTA will exceed her WTP, corresponding to the endowment effect. In our case, however, the notion of a "loss" is ambigious as described below. Second, for comparable reasons, strategic behavior may induce the individual to understate her "true" WTP and overstate her "true" WTA when answering open-ended survey questions or when bidding in auctions, especially when preference uncertainty is present. Here, our closed-ended experimental format minimizes strategic incentives (Hanemann 1999). Third, a WTP/WTA gap may also arise in standard utility models with and without uncertainty due to low elasticities of substitution between public and private goods and income elasticities larger than unity. Haab and McConnell (2002) argue that when the change in q is small, the WTP/WTA disparity should play a negligible role.

[9] This is true for the case where the individual likes emissions reductions, $\Delta u = v(p, q^1, y) - v(p, q^0, y) > 0$. If the individual dislikes emissions reductions, $\Delta u < 0$, then $-E$ corresponds to the maximum willingness to pay (WTP) to avoid them (Hanemann 1999).

with the existing literature, we subsequently adopt the framework of (2) and report WTP.[10]

To calculate WTP from observed behavior, subjects' dichotomous choices can be parametrically modeled using a random utility model (RUM) (McFadden 1974, Hanemann 1984). For our purposes, we employ a simple linear-in-income[11] RUM (Haab and McConnell 2002) and write subject i's indirect utility as

$$u_i^0 \equiv v(p, q^0, y_i'; z_i) = \alpha^0 z_i + \beta^0(y_i') + \epsilon_i^0 \tag{3}$$

for the case of choosing the cash prize and

$$u_i^1 \equiv v(p, q^1, y_i' - c_i; z_i) = \alpha^1 z_i + \beta^1(y_i' - c_i) + \epsilon_i^1 \tag{4}$$

for the case of choosing the emissions reduction. z_i denotes a vector of individual characteristics and other observable attributes of the choice with parameter vectors $\alpha^0$and α^1 for both states of the world. β^0 and β^1 is marginal utility of income in both states, and ϵ_i^0 and ϵ_i^1 are the respective error terms. Let g_i^* denote the latent propensity to prefer the emissions reduction over cash. Then

$$g_i^* = u_i^1 - u_i^0 = \alpha z_i - \beta c_i + \epsilon_i \tag{5}$$

where $\alpha = \alpha^1 - \alpha^0$. $\beta = \beta^0 = \beta^1$ is assumed to be constant between both states, and $\epsilon_i = \epsilon_i^1 - \epsilon_i^0$ is assumed to be i.i.d. with mean zero and variance σ^2. In what follows, we estimate the vector of parameters $(\alpha/\sigma, -\beta/\sigma)$ using standard logit regressions of the observed choices, $G_i = \mathbf{1}(i \textit{ chose emissions reduction})$, representing $g_i^* > 0$ and $g_i^* \leq 0$, respectively. WTP is calculated the standard way: From equations (2) and (5), $WTP_i = (\alpha/\beta)z_i + \epsilon_i/\beta$ for subject i and, in expectation and based on parameter estimates, $E_\epsilon\left[WTP_i|\alpha, \beta, z_i\right] = \left[(\alpha/\sigma)/(\beta/\sigma)\right] z_i$.

4 Data and Results

4.1 Sample properties

Table 1 reports descriptive statistics of experimental variables. It includes standard socio-demographic variables, variables related to attitudes and beliefs about climate change as stated by subjects in the follow-up questionnaire, and exogenous variables controlling for environmental conditions at the time of the experiment.

Key socio-demographic characteristics of the Internet-representative sample turn out to be statistically different to the characteristics of the general German population of voting age (Table 2). As expected, the average Internet user is more likely to be male and to be younger than the average voter. The latter also explains a positive deviation in the number of children present in the

[10] One potential bias that the comparative statics point to is the possible presence of a "windfall" (Keeler et al. 1985) or "house money" (Thaler and Johnson 1990) effect because subjects always gain irrespective of their choice. Evidence on the presence, direction, and scale of a potential bias in public good situations is inconclusive, however (Harrison 2007).

[11] We performed a linear grid search across Box-Cox transformations of the income variable in our model specifications and find maxima of the log-likelihood function around $\lambda = 1$. Thus, the assumption of constant marginal utility of income between the two options seems reasonable for our data.

Table 1: Descriptive statistics of explanatory variables

Variable	Description	Mean	Std.	Min.	Max.
Socio-demographic characteristics					
Female	1 if female	0.469	0.499	0	1
Age	Years	45.43	14.68	18	89
Children	Number of household members below 18	0.466	0.846	0	6
Education	Years based on highest educational degree	12.27	3.214	9	22
Income	Monthly household net income[a] (Euros)	2,556	1,705	450	8,000
Climate change attitudes and beliefs					
Personal benefits	Degree of agreement to personal benefits from effects of carbon emissions reductions[b]	2.366	0.990	1	4
Future benefits	Degree of agreement to benefits for following generations from today's emissions reductions[b]	2.901	0.968	1	4
Lifestyle impact	Degree of agreement that personal lifestyle has contributed to climate change[b]	2.761	0.952	1	4
Footprint estimate	Estimate of yearly CO_2 emissions from lifestyle (tons)	3,020[c]	15,336	0	100,000
Footprint confidence	Confidence in own footprint estimate, 1 if at least "rather sure"	0.075	0.263	0	1
EUA price estimate	Estimate of EUA spot price (Euros)	1,655[d]	10,304	0	100,000
Price confidence	Confidence in own EUA price estimate, 1 if at least "rather sure"	0.106	0.308	0	1
EUA availability	Believes that EUAs would be available for purchase somewhere (1 if at least "rather yes")	0.197	0.398	0	1
Environmental controls					
Media coverage	Number of hits in a climate change related keyword search[e] in German print and online media[f]	136.9	28.13	69.5	160
Temperature	Mean ambient air temperature in subject's region of residence[f,g] (°C)	15.1	4.186	8.05	25.8

Notes: [a] In our income approximation from subjects' reported income categories, for the 'less than €500' category, we assume €450. For the two categories above €5,000, we assume €8,000 for compatibility with German census data. The remaining categories have widths of €500. [b] 1='no', 2='rather no', 3='rather yes', 4='yes' [c] Median is 10 [d] Median is 50 [e] Keywords used: '*climate change*', '*climate protection*', '*global warming*', '*carbon dioxide*', 'CO_2'. Source: LexisNexis [f] Average of the daily values of the day the subject took the online experiment and the day before [f] Source: National Meteorological Service (DWD)

Table 2: Socio-demographics: sample vs. census

Variable	Mean values		T-test (two-sided)
	Experimental sample	German census data	
Female	0.469	0.521	$p < 0.01$
	(0.499)	(0.500)	
Age	45.43	50.05	$p < 0.01$
	(14.68)	(18.31)	
Children	0.466	≈0.340	$p < 0.01$
	(0.846)	(≈0.900)	
Education	12.27	11.02	$p < 0.01$
	(3.214)	(3.01)	
Income	2,556	4,057	$p < 0.01$
	(1,705)	(1,170)	
Income $\leq 5,000$	2,205	2,150	$p < 0.05$
	(1,030)	(1,300)	

Notes: Standard errors are in parantheses. Source: Federal Statistical Office (Destatis), Mikrozensus 2008, 2009, EVS 2008 and own computations

household when comparing our sample and the German population average. In the household income category, both very low and very high incomes are slightly underrepresented: While mean income in the census data is higher,[12] the difference reverses if one drops incomes above €5,000.[13]

Subjects' stated views regarding climate change in Table 1 support the picture of generally concerned citizens with some understanding about the physical inertia of the climate problem but varying awareness regarding the metric involved. A majority accepts that their lifestyle is contributing to climate change and understands that current emissions reductions do not benefit themselves but instead constitute an intertemporal benefit transfer to future generations. The evidence on the understanding of the metrics is mixed: While the median subject provides a surprisingly close estimate to the yearly per-capita carbon emissions in Germany (about 10 tons), a number of subjects has difficulties in giving a reasonable estimate, and only 7.5 percent feel at least somewhat certain about their guess. A similar pattern arises for estimates of spot prices of EU emissions allowances. Regarding respondents' willingness to improve on their information status during the survey (e.g. Berrens et al. 2004), we find tentative evidence against substantial information acquisition (e.g. by consulting Internet resources before the decision on the prize or answering knowledge questions) during the online experiment: There is no discernible link between the time subjects took to take the relevant decisions, the nature of their decision, or the level of understanding of the policy context (Diederich and Goeschl 2011).

Environmental controls on media coverage and outside air temperature were obtained through a media database keyword search (LexisNexis) and through data from the National Weather Service (DWD), respectively, and matched to subjects. Both variables reflect the average of the values of the day at which the subject decided to start the experimental survey and the day before. In order

[12] Income categories above €5,000 were checked by six percent in our sample, while census data indicates a share of around 19 percent.

[13] While these deviations play an insignificant role in the subsequent analysis, caution seems to be generally advised when dealing with results by the Internet-based polling industry that are sometimes quoted as representative for the population.

Table 3: Empirical probability distribution of WTP

Cash prize interval[a]	[2,10]	[12, 20]	[22, 30]	[32, 40]	[42, 50]
# of cash choices	163	171	208	214	198
# of reduction choices	64	53	34	28	28
% WTP $\geq$ cash prize	28.2	23.7	14.0	11.6	12.4
	[34.1, 22.3]	[29.3, 18.1]	[18.5, 9.6]	[15.6, 7.5]	[16.7, 8.1]
Cash prize interval[a]	[52, 60]	[62, 70]	[72, 80]	[82, 90]	[92, 100]
# of cash choices	206	218	201	207	187
# of reduction choices	32	40	32	36	35
% WTP $\geq$ cash prize	13.4	15.5	13.7	14.8	15.8
	[17.8, 9.1]	[19.9, 11.1]	[18.2, 9.3]	[19.3, 10.3]	[20.6, 10.9]

Notes: 95 percent confidence intervals in square brackets. [a] Each cash prize interval pools observations from five cash prize amounts

to verify the robustness of the media coverage variable, we used two mutually exclusive sets of keywords who turned out to be highly correlated (correlation coefficient 0.81). Note that the Germany-wide media data varies with time only while the temperature data is specific to the time of completing the experiment as well as the subject's region of residence.

The dependent variable in the subsequent analysis is the subject's choice of a prize. In total, 382 (16.2 percent) out of 2,355 subjects chose the emissions reduction through the retirement of an EUA. 1,973 (83.8 percent) chose the cash amount that was offered to them. Table 3 summarizes subjects' prize choices for cash prize intervals pooling the choices of five amounts in each column. It can be seen that the elasticity with respect to the cash prize appears low as one would expect in the case of contributions to a public good (Green 1992, Diederich and Goeschl 2011). The average probability that subjects choose the emissions reduction prize does not exceed 30 percent for the lowest prize category and lies around 15 percent for the highest.

Field price censoring (FPC) is a potentially important source of bias in valuation experiments. FPC can arise in valuation experiments because prices for goods within the experiment cannot easily be isolated from prices of those same goods or close substitutes in the real world (Harrison et al. 2004, Cherry et al. 2004). As a result, there are circumstances when the experimentally observable WTP is censored at the level of the real-world price as subjects avail themselves of arbitrage opportunities. Careful examination of the data leads us to conclude that FPC is an unlikely source of bias in the present experiment. Here, FPC were present if a subject with a reservation price for emissions reductions r_i accepts the experimental cash prize c_i even though $r_i > c_i$ simply because the field price of emissions reductions $\hat{f}_i$ estimated by the subject obeys $c_i > \hat{f}_i$.[14] In cases then where $r_i > c_i > \hat{f}_i$, the experimenter may mistakenly conclude that the unobservable reservation price r_i is smaller than c_i on the basis of the subject choosing cash instead of the good and therefore systematically understate WTP. In our data, FPC with respect to perfect substitutes does not play

[14] Since there is no secondary market for retired EUAs, we need not be concerned about the situation $\hat{f}_i > c_i > r_i$ in which subjects opt for the EUA despite $r_i < c_i$ in order to pocket the arbitrage margin $\hat{f}_i - c_i$.

a significant role: Only 10.6 percent of subjects feel at least somewhat informed about the true EUA price, and only 6.2 (13.5) percent of subjects confidently (tentatively) believe that they would personally have access to the EUA market. Excluding potentially field price censored subjects of these groups from the analysis does not alter results significantly. Evidence on FPC with respect to imperfect substitutes such as offsets or costly behavior that reduces emissions reductions is less clear-cut. The possibility of imperfect substitutes is often overlooked in valuation experiments (Cherry et al. 2004). We adopt the debriefing questionnaire strategy of preceding papers (Coller and Williams 1999, Harrison et al. 2002) as an *ex post* choice filter to detect subjects constrained by any type of FPC from revealing that $r_i > e_i$. These debriefing responses are inconsistent with FPC.[15] In sum, we find little evidence that awareness of outside opportunities introduces a substantial downward-bias in the results.

4.2 Parameter estimates

Table 4 reports the results of the Logit regressions of the prize choices for three different specifications. Parameter estimates and significance levels are highly robust across specifications.[16]

Starting with the price variable (*Cash prize*), the coefficient on the experimental cost of reduction has the desired negative sign and is significant at the one percent level across model specifications. Among the socio-demographic variables, neither sex nor age nor the number of children in the household is significant. The level of education, however, is a robust determinant that is highly significant across all specifications. Income cancels out in a linear-in-income RUM and therefore is not included as regressor. If included, the variable turns out to be insignificant.[17] In contrast to the socio-demographic characteristics, the majority of attitudinal variables contributes to explaining the subjects' choices in favor of the emissions reduction: The expectation of benefiting personally from emissions reductions, the expectation of benefiting following generations, and an acknowledgement of a personal contribution to climate change all raise the propensity of a subject to choose the EUA retirement. Informational variables such as an estimate of the carbon footprint and the perceived availability of EUAs to ordinary consumers fail to deliver individually. However, we find that those who feel more confident about the estimates they are asked for have a significantly different propensity to choose the emissions reduction. The effects, decreasing for higher certainty about the carbon footprint estimate and increasing for higher certainty about the EUA price estimate, are as one might expect them for subjects who, on average, overestimate both their footprint (which would imply a smaller benefit from the one ton reduction) and the EUA spot price (which would imply a better deal at given experimental prices).[18] An additional result among the informational variables is that when subjects expect higher EUA field prices, they are more likely to choose the experimental

[15] In particular, the propensity to claim to be subject to a FPC constraint decreases in the cash prize. For a more detailled analysis, see Diederich and Goeschl (2011).

[16] A probit approach returns comparable results for the covariates employed (Diederich and Goeschl 2011).

[17] Compare footnote 11.

[18] In fact, closer inspection using interaction effects shows that the effect of confidence in the carbon footprint is driven by a small fraction of subjects who strongly acknowledge lifestyle-related negative contributions.

Table 4: Logit parameter estimates

	(1)	(2)	(3)
Cash prize	-0.0074***	-0.0079***	-0.0072***
	(0.002)	(0.002)	(0.002)
Female	0.1572	0.1420	–
	(0.134)	(0.137)	
Age	0.0032	0.0010	–
	(0.005)	(0.005)	
Children	-0.0777	-0.0777	–
	(0.082)	(0.085)	
Education	0.0871***	0.0911***	0.0869***
	(0.019)	(0.019)	(0.018)
Personal benefits	0.2385***	0.2500***	0.2401***
	(0.090)	(0.093)	(0.088)
Future benefits	0.4753***	0.4748***	0.4633***
	(0.109)	(0.112)	(0.108)
Lifestyle impact	0.2849***	0.2816***	0.2905***
	(0.090)	(0.093)	(0.089)
Footprint estimate	-0.0000	-0.0000	–
	(0.000)	(0.000)	
Footprint confidence	-1.0787***	-1.0743***	-1.0880***
	(0.300)	(0.309)	(0.298)
EUA price estimate[a]	0.0107**	0.0115**	0.0107**
	(0.005)	(0.005)	(0.005)
Price confidence	0.4515**	0.4426**	0.4064*
	(0.212)	(0.221)	(0.209)
EUA availability	-0.0640	-0.0329	–
	(0.153)	(0.157)	
Media coverage	0.0009	0.0005	–
	(0.002)	(0.005)	
Temperature	0.0315*	-0.0129	0.0269*
	(0.016)	(0.044)	(0.015)
Constant	-5.9940***	-5.2568***	-5.6235***
	(0.700)	(1.132)	(0.461)
Day effects	No	Yes	No
Daytime effects	No	Yes	No
Region effects	No	Yes	No
N	1898.000	1898.000	1900.000
Log-likelihood	-786.248	-762.996	-790.003
χ^2	202.765	249.268	199.100
Pseudo R^2	0.114	0.140	0.112

Notes: Dependant variable: 1 if subject chose the emissions reduction, 0 if subject chose the cash. Standard errors are in parentheses. *** Significant at or below 1 percent ** Significant at or below 5 percent * Significant at or below 10 percent [a] In Thousands of Euros

emissions reduction. However, since price estimates are stated after the valuation choice, endogeneity might be an issue. A final contribution to explaining the observed variation in subjects' choices comes from the matched exogenous environmental controls: Higher mean temperatures in subjects' regions of residence are associated with a higher propensity to opt for the GHG emissions reduction ($p = 0.056$). The effect is robust to including maximum instead of mean temperatures at the ten percent level of significance. A comparable effect for media coverage of the climate change issue cannot be established. Including fixed effects for the day the subject took part in the experiment and the region of residence naturally eliminates identification of the matched environmental controls. All other parameter estimates are highly robust to the inclusion of fixed effects.

4.3 WTP results

The empirical distribution of WTP in Table 3 illustrates an interesting phenomenon: Despite a price range that is considerably larger than previous studies, "fat tails" are still present in our data. WTP estimates are therefore likely to be sensitive to assumed bounds or distributional assumptions. Several assumptions are crucial in the presence of 'fat tails' when experimental prices do not cover the tails of the empirical distribution (e.g. Hanemann and Kanninen 1999, Haab and McConnell 2002): One assumption concerns the possibility of negative WTP. The simple linear RUM does not distinguish between WTP and WTA, i.e. negative WTP,[19] when fitting the distribution of WTP. A frequent approach when free-disposal of the environmental change can be assumed is to bound WTP from below at zero. For the case of greenhouse gas emissions reductions, free disposal cannot be assumed *ex ante*, and the presence of negative WTP is an empirical matter. Our data provides little evidence on negative WTP. When asked about the reason for choosing the cash prize, only two of 1,973 subjects expressed some disutility from the emissions reduction[20] in an open-ended answer possibility. By contrast, 71 percent expect some future generation benefits from the reduction, 45 percent some personal benefits. A second assumption concerns the possibility of indifferent subjects. Since the linear model assumes a continuous transition from utility increase to decrease,[21] it excludes the possiblity of a point mass at zero from subjects who simply do not care about the proposed environmental change, $v(p, q^0, y_i'; z_i) = v(p, q^1, y_i'; z_i)$. From a theoretical perspective, indifference is likely to be present when one wants to value contributions to public goods since free riding behavior will probably be expressed through zero WTP. In our data, 60 of 1,973 subjects can be plausibily related to indifference from their stated reasons for choosing cash.[22] However,

[19] If the individual dislikes emissions reductions, $\Delta u < 0$, then $-C$ in eq. (2) corresponds to the maximum willingness to accept (WTA) for the emissions reduction (Hanemann 1999, Hanemann and Kanninen 1999). Following a frequent abuse of terminology, we will sometimes speak of negative WTP when referring to this WTA.

[20] Main arguments included harmful consequences for the economy. Since the survey did not provide an anwer category related to negative utility and subjects were not forced to use the open-ended answer option, this number may understate the presence of negative WTP in the sample.

[21] Note that the error term on the utility difference in eq. (5) is assumed to have infinite support.

[22] Approximately half of these statements expresses doubts about climate change itself, about one third indicates variants of free-riding behavior (other individuals, the government,

since the survey did not provide an "I don't care" answer category and subjects were not forced to use the open-ended answer option, this number may understate the true number of indifferent subjects.

In Table 5, we report two types of WTP estimates, one derived through the linear RUM and one based on the non-parametric Turnbull estimator that assumes non-negativity but allows for indifference. Columns (1) and (2) of Table 5 show RUM based WTP estimates for Models (1) and (3) of Table 4. Confidence intervals were calculated using the Krinsky and Robb (1986) procedure and the WTPCIKR package in STATA (Jeanty 2007). Columns (1) and (2) show that the linear RUM predicts negative expected WTP (EWTP) for a large part of the sample including calibrations of the explanatory variables at the sample mean and the mean socio-demographic census values. As contribution rates are below 50 percent even for the lowest experimental prices, the unbounded distribution of WTP in the linear RUM puts the bulk of the probability mass below the range of prices covered in the experiment, predicting expected WTP way below zero. Table 5 also provides examples for more extreme calibrations of attitudinal and socio-demographic variables to illustrate the effect of covariates on WTP. A positive EWTP is obtained for calibrations where education is higher than average and where subjects' vector of beliefs is (unrealistically) large and enthusiastic. The effect of the attitudinal variables in the data is strong enough so that a more realistic calibration in which a well-informed subject acknowledges future benefits and personal lifestyle impacts but not personal benefits from today's reductions still increases WTP considerably compared to the sample mean.

Column (3) in Table 5 provides the non-parametric WTP estimates that assume non-negativity of WTP but allow for indifference in the sample. Given the empirical evidence on indifference versus negative WTP in our data and the theoretical reasons to expect free riding, these assumptions appear more plausible than the huge amount of probability mass assigned to negative WTP by the linear RUM. Estimates are derived using the Turnbull Distribution-Free Estimator (Turnbull 1976, Haab and McConnell 1997). In contrast to parametric spike models (Hanemann and Kriström 1995, Kriström 1997) the Turnbull estimator has the advantage that indifferent subjects do not need to be uniquely identified (Haab and McConnell 1997).[23] We report lower bound estimates of expected WTP using the most conservative version of the Turnbull estimator, which relies only on the information that the WTP of a subject who chose the reduction is not less than the alternative cash prize. Mean EWTP for a one ton GHG emissions reduction is estimated at €6.30 with a standard error of €0.76. Median EWTP is zero. Estimates for subsamples consisting of 'enthusiasts' or 'realists' are considerably higher at about €22 and €17, respectively. One drawback of the Turnbull estimator is that in order to investigate covariate effects, one needs to split the sample into subsamples of the covariate calibrations. Thus, more observations in the education cells within these calibrations would be required to calculate meaningful estimates for the other calibrations.

firms, or countries should move first), and the remaining cases explicitely fall into the "don't care" category.

[23] The assumption is that subjects with $v(p, q^0, y_i'; z_i) = v(p, q^1, y_i'; z_i)$ choose cash at all prices $c_i > 0$.

Table 5: Expected WTP for one ton of reduced CO_2

	Model (1)	Model (3)	Turnbull LB
At sample mean	€ -191.61	€ -196.70	€ 6.31
	[-556.73, -99.29]	[-562.15, -101.71]	(0.76)
At German census average	€ -203.50	€ -213.91	–
	[-587.25, -106.59]	[-606.93, -112.53]	
At example calibrations of variables:[a]			
'Enthusiast'	€ -24.01	€ -25.23	€ 22.21[b]
(Personal benefits=4, Future	[-144.75, 14.00]	[-152.72, 13.07]	(2.64)
benefits=4, Lifestyle impact=4)			
'Enthusiast' with college degree	€ 17.61	€17.37	–
	[-51.40, 52.34]	[-55.92, 52.72]	
'Enthusiast' with university degree	€ 41.05	€ 41.38	–
	[-15.31, 86.61]	[-16.05, 88.72]	
'Enthusiast' with Ph.D.	€ 87.91	€ 89.41	–
	[32.56, 190.38]	[33.08, 192.83]	
'Realist'	€ -120.28	€ -124.73	€ 16.87[b]
(Personal benefits=1, Future	[-393.38, -37.51]	[-412.34, -40.15]	(6.71)
benefits=4, Lifestyle impact=4)			
'Realist' with college degree	€ -78.65	€ -82.14	–
	[-297.47, -6.57]	[-316.00, -7.98]	
'Realist' with university degree	€ -55.22	€ -58.12	–
	[-243.04, 15.68]	[-256.59, 13.57]	
'Realist' with Ph.D.	€ -8.36	€ -10.09	–
	[-144.27, 70.48]	[-157.11, 67.60]	

Notes: 95 percent confidence intervals in square brackets. Standard errors are in parantheses.
[a] Values of explanatory variables not listed are sample means [b] Values are derived by pooling answer categories 1 and 2 as well as 3 and 4 of the three variables to reduce variance

5 Interpretation of results

How do our findings compare to those of previous studies using alternative methodologies? We offer a comparison and a discussion of the most salient policy implications in what follows. Drawing on the existing published and yet unpublished literature, Table 6 summarizes available results on mean and median WTP as well as on selected determinants of WTP identified in Tables 4 and 5. The papers included here comprise both the small set of existing studies on WTP for individual emissions reductions and papers that examine WTP for collective climate policies.[24] Including the latter allows a comparison of how covariates of WTP for collective climate action relate to those of individual WTP.

Table 6 reports the lower bound Turnbull estimate of the mean WTP derived from the data. This choice of estimate not only reflects its greater plausibility over and above the RUM estimates, but also facilitate comparison with those in the existing literature.[25] Mean WTP estimates for offsetting emissions from air travel are provided by Brouwer et al. (2008) and MacKerron et al. (2009) at €25/tCO_2 and £24/tCO_2, respectively.[26] Both estimates draw on stated preferences rather than observed choices, providing one explanation for the larger figures. Also, both studies rely on considerably smaller samples than ours, each consisting of a subgroup of the population that—in light of the results on covariates—is likely to exhibit a larger than average WTP.[27] MacKerron et al. (2009) note that their data shows a fat tail above their maximum bid of £20 which is in line with our observation of a significant density of WTP at higher prices. Löschel et al. (2010) conducted a framed field experiment on the individual demand for EUAs using a variant of the Becker-DeGroot-Marshak mechanism. Within their sample of 202 local residents, 62 percent revealed zero or negative WTP by not demanding any emissions reductions at any price. While this is in line with our finding of a large share of non-positive WTP, the authors report a somewhat higher mean WTP of about €12. Since their design allowed the purchase of multiple units of EUAs rather than one unit as in this design, a comparison of the WTP is likely to understate the differences in WTP measured. Sampling issues (size, region) and design choices (such as an experimenter demand effect and the information provision) are possible sources. In particular, one obvious source of differences in the level of WTP are alternative approaches with respect to subjects' information status: While this experiment does not manipulate the information status of subjects, Löschel et al. (2010) deliberately inform as well as question subjects about climate change prior to their purchase decision. Despite the differences in the level of WTP, there are important common features across the empirical findings so far, irrespective of

[24] The selection of papers is based on comparability of the valued scenario and availability of covariates. See Johnson and Nemet (2010) for a more comprehensive survey of the growing literature on WTP for climate policy.

[25] Both MacKerron et al. (2009) and Löschel et al. (2010) constrain WTP from below at zero: Brouwer et al. (2008) employ the Turnbull estimator while in Löschel et al. (2010), WTP is restricted to fall between €0 and €40. Both papers do not provide empirical evidence on these assumptions. MacKerron et al. (2009) use a linear RUM and do not restrict WTP.

[26] Brouwer's et al. (2008) estimate is calculated from a distance-based estimate of €0.6 for every 100km flown.

[27] Brouwer's et al. (2008) sample consists of 349 air travel passengers while MacKerron et al. (2009) sample 321 young adults with higher education.

the extent of information provision by the experimenter: These are, e.g., the presence of fat tails (MacKerron et al. 2009, Löschel et al. 2010) and a large share of non-contributors (Löschel et al. 2010). Our results share these features, adding further robustness. At the same time, the issue of information status clearly merits further investigation.

The present study benefits from access to a larger set of variables to study covariates than most existing studies on WTP for individual or collective climate action. Among socio-demographic variables, education stands out as significant driver in our results and confirms its role among subject characteristics in stated preferences research. The effect of education may, in part, proxy for other drivers not accounted for, such as subjects' cognitive ability. In contrast to our findings, income is positively correlated in most cases where available. Since income is invariably self-reported, firm conclusions are difficult to draw.[28]. In the voluntary contribution context, some researchers have found that gender and age matter: There, being female and being older is positively correlated with pro-social behavior (List 2004). In this experiment, neither gender nor age are significant. This is closer to the unequivocal findings on gender and age effects in the literature. A possible explanation for the absence of gender and age effect may be countervailing effects in both variables that are specific to climate change: On the one hand, climate change may affect genders asymmetrically. On the other, the delayed arrival of benefits from emissions reductions may militate against older subjects contributing.[29] Consistent across papers is the insignificant effect of the number of children on WTP.

The second panel of covariates in Table 4 reports on the effects of stated climate change attitudes, in particular, benefit expectations and the acknowledgement of having personally contributed to climate change. Making the benefit variables comparable across the literature involves some imprecise adjustments. For example, some studies phrase benefits of emissions reductions as benefits, some as avoided climate change impacts. For the sake of comparison, we treat these as equivalent, even though there are some differences in substance. On a related point, our paper divides benefits into separate dimensions of personal and future generation benefits. Most of the existing literature lumps the two dimensions together. For the sake of comparison, we follow the majority of papers by reporting both variables jointly. Once these adjustments are made, the almost equivocal finding is that of a positive correlation between benefits and WTP. Regarding subjects' acknowledgement of a personal contribution to climate change, we find strong evidence that such an acknowledgement drives WTP. This strengthens previous findings in the literature: Brouwer et al. (2008) find a significant effect of travellers' perception of their own responsibility for climate change on their WTP for offsets per flight. Cai et al. (2010) find WTP to be driven by the allocation of cost shares for a mitigation policy, both domestic and international. In particular, WTP is higher when the incidence is larger for parties perceived as more responsible for climate change. The latter reason also

[28] With a correlation coefficient of 0.29 between income and education, multicollinearity does not appear to be an issue.

[29] It is therefore interesting to look at gender-specific effects of covariates. Using a split-sample approach, we find that older men are significantly more likely to choose the emissions reduction while for females, age is insignificant. With respect to climate change attitudes, females' choices are insignificantly correlated to the expectations of personal benefits while for males, correlation with the acknowledged lifestyle impact is insignificant.

resonates findings by, for example, Bulte et al. (2005) on an "outrage" premium on WTP for human-made environmental damages.

A novel element in the present study is the inclusion of exogenous controls for environmental conditions at the time and location of the valuation choice. So far, temperature effects as well as the effects of media coverage have been based on respondents' stated perceptions. While we cannot identify an effect of media coverage, the possible link between ambient temperature and WTP suggests an interesting and plausible physiological pathway between environmental factors and economic choices. However, the temperature effect uncovered here could be either context-specific or a generic phenomenon. If the effect is specific, a possible explanation might be a heuristic shortcut that associates lower GHG emissions with lower temperatures, making emissions reductions—without further reasoning—appear instantaneously more desirable. At this stage and without further evidence, however, such reasoning is entirely speculative.

Our field-experimental results are based on a large sample of the general population. A simple extrapolation would imply that a large majority of the population is unwilling to provide a substantial contribution to climate change mitigation on a voluntary basis. There are grounds, however, to expect well-defined subgroups within the population to willingly incur significant sacrifices in order to reduce GHG emissions. The question that arises then is how much those subgroups will deliver in aggregate to society. Consider the following thought experiment. At current carbon prices and assuming perfect price discrimination,[30] the elicited mean WTP would be sufficient to reduce emissions by at least 0.4 tons per individual. Given a yearly per-capita CO_2 footprint of around 10 tons (United Nations 2011), our field experiment predicts a one-shot aggregate WTP among the population sufficient to reduce at least 4% of annual German emissions. Given current policy targets, this amount of potential voluntary commitment is substantial, but not as ambitious as prior estimates have suggested.

6 Conclusion

The starting point of this paper was the tension between political rhetoric and empirical evidence regarding voluntary GHG abatement by the public. The rhetoric emphasizes the need for individual action to reduce greenhouse gas emissions. However, there is at present little empirical evidence to what extent the public is willing to engage in such individual action, and what the nature of such a willingness would likely be. The contribution of this paper is to address this tension by providing a non-hypothetical measure of the willingness to pay of a representative sample of the population of Germany, the world's fourth largest cumulative greenhouse gas emitter, for the voluntarily provision of a specific amount of abatement activities (1 ton of CO_2) when such a provision incurs zero transaction costs. Our headline results demonstrate that harnessing individual action for emission reductions faces a number of important challenges. In terms of the level of WTP, the mean WTP for the voluntary abatement of one ton of CO_2 is estimated at €6.30 under the optimistic, but plausible assumption that WTP is bounded from below at €0. So even under benign circumstances,

[30] The EUA spot price was around €13 at the European Energy Exchange (EEX) in September 2011.

non-hypothetical WTP is considerably lower than the stated-preference estimates available in the literature so far. More challenging yet, the best estimate of median WTP for abating a ton of CO_2 emissions is non-positive. Combining the observations on the mean and the median WTP points to important heterogeneities within the population. These give rise to an essentially bimodal distribution of WTP: While the majority in the population is not willing to incur economic sacrifices to provide emissions abatement on a voluntary basis, a small minority of around 15 percent is—within the experimental cost range—willing to do so almost irrespective of the price. Any attempt to galvanize the public into action will therefore need to target that specific subset of the population that makes a significant contribution, despite its small size. The distribution of WTP in the population follows a number of empirical regularities that facilitate such targeting. Prime among these is the importance of education for predicting WTP as well as attitudes about climate change and personal responsibility that are—in part—subject to informational status, plus the surprising finding on meteorological conditions at the time of the experiment. These findings provide obvious points of departure for subsequent research: The link between informational status and WTP, the relationship between WTP and ambient variables, and the challenge of targeting without inducing motivation crowding are only three dimensions for further study.

Table 6: WTP estimates and covariate effects: comparison with literature

	WTP for $1tCO_2$	WTP for mitigation policy									
	This study	Brouwer et al. (2008)	MacKerron et al. (2009)	Löschel et al. (2010)	Berrens et al. (2004)[a]	Viscusi and Zeckhauser (2006)[b]	Solomon and Johnson (2009)	Cai et al. (2010)	Carlsson et al. (2010)[c]	Lee et al. (2010)	Akter and Bennett (2011)[d]	Kaczan et al. (forth.)
A. WTP estimates for $1tCO_2$												
Mean	€6	€25	£24	€12								
Median	€0	n.a.	n.a.	€0								
B. Coviariate effects												
Socio-demographic characteristics												
Female	○	○	+	–	–	–	○	+	–	n.a.	n.a.	○
Age	○	○	n.a.	–	○	n.a.	n.a. / ○	n.a	–	○	n.a.	○
Children	○	○ / n.a.	○	○	n.a.	n.a.	n.a.	n.a.	○	n.a.	n.a.	○
Education	+	○ / n.a.	n.a.	+	+	n.a.	n.a.	n.a.	+	+	+	+
Income	○	+	○	+	+	n.a.	+	n.a.	+	+	n.a.	–
Climate change attitudes and believes												
Personal or future benefits	+	+[e]	n.a.	+[f]	n.a.	n.a.	+[f]	+	n.a. / ○	n.a.	+	n.a.
Lifestyle impact or personal responsibility	+	+	n.a.	+[g]	n.a.	n.a.	n.a.	+[h]	+[i]	n.a.	n.a.	n.a.
Environmental controls												
Media attention	○	n.a.	n.a.	+[j]	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	+[k]	n.a.
Temperature	+	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	+[l]

Notes: +: positive effect, significant at 10 percent level or less –: negative effect, significant at 10 percent level or less ○: insignificant effect n.a.: variable or estimate not available [a] Based on the "pooled" model of Table 6. [b] Based on "Gas tax remedy till 2100" in Table IV. [c] Based on the unconditional WTP results for Sweden. [d] Based on stated WTP to support the proposed Australian carbon trading scheme. [e] Based on perceived effectiveness of a carbon tax. [f] Based on stated general concerns about CC. [g] Based on stated importance of personal activity against CC. [h] Based on the finding that WTP rises when a policy assigns larger cost share to groups or countries that are believed to be more responsible for climate change. [i] Based on the general statement that humans have affected the temperature incr! ease. [j] Based on self-reported influence through media reports. [k] Respondents stated to have watched Al Gores's "An Inconvenient Truth". [l] Based on respondent's stated perception of generally rising temperatures.

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A Appendix

A.1 Experimental screens: translations into English

A.1.1 Welcome screen

Dear participants,

we would like to invite you to participate in two lotteries and to answer some questions about CO_2-emissions and climate change.

Your participation will take approximately ten minutes. In the lotteries, you have the chance to win points worth up to a three-digit amount in euros.

As usual, all your information will be treated confidentially.

A.1.2 Citizenship screen

Of which country do you hold citizenship?

In case you hold more than one, please tick all applicable boxes!

A.1.3 Information Screen

"In the lotteries, you may choose between the following two prizes:

A cash prize in points
or
the reduction of carbon (CO_2) emissions by 1 ton

How will the reduction of the CO_2 emissions take place? We will make use of a reliable opportunity provided by the EU emissions trading system: We will purchase and delete an *EU emissions allowance* for you. Emissions allowances are needed by power plants and other large installations within the EU in order to be allowed to emit CO_2. Since there is only a fixed overall amount of allowances in place, deleted ones are no longer available to facilitate emissions. Emissions in Germany and other EU countries decrease by exactly one ton through one deleted allowance.

Because of the way in which CO_2 mixes in the air, it does not matter for the effect on the climate where CO_2 emissions are reduced. What counts is only total emissions worldwide.

In the lotteries, 100 winners will be randomly selected out of about 5,000 participants. The following two lotteries may differ in the prizes offered as well as in the payoff procedures."

A.1.4 Decision Screen

"In this lottery, you have the choice between the two prizes listed below.

- If you choose the cash amount and win, then the corresponding amount of points will be transferred to your points account within the next few days. All winners will receive a short notification email.

- The deletion of emissions allowances will, in this lottery, take place as a collective order for all winners. For every winner who chooses the emissions reduction one additional allowance will be deleted. Winners will receive a short notification email containing a hyperlink to Heidelberg University webpages where they can reliably verify the deletion."

Please choose now, which prize you prefer if drawn as winner:

( ) The reduction of CO_2 emissions by one ton through the deletion of one EU emissions allowance

( ) 46 Euro[31] in bonus points

A.1.5 FPC filter question

Please give now any particulars as to why you chose the amount in euros. In order to do this, please tick all applicable boxes. Please answer spontaneously.

( ) Given the two prizes, I did not want to forgo the chance of winning 46 euros.

( ) I assume that there is another possibility for me to reduce CO2-emissions by one ton for less than 46 euros.

( ) There were other reasons as to why I chose the amount of euros, namely:

_____

A.1.6 Introduction follow-up questions

Thank you. On the following pages we would like to ask you some concluding questions.

A.1.7 Follow-up questions

What is your estimate of the current market price for one ton of CO_2 in the EU emissions trading system?

____ euros

How sure are you about your estimate?

( ) I know the price

( ) Very sure

( ) Rather sure

( ) Rather unsure

( ) Very unsure

( ) I don't know

[31] Example amount. The order in which the two prizes appeared was randomized.

A.1.8 Follow-up questions

In this lottery, EU emission allowances are bought and deleted by the organizer. Do you think that there exists a possibility for you to personally buy and delete EU emissions allowances?

( ) Yes

( ) Rather yes

( ) Rather no

( ) No

( ) I don't know

Do you think that you will personally benefit from positive effects of reduced CO_2 emissions (for example from the mitigation of climate change)?

( ) [Same answer options as above]

Do you think that future generations in Germany (for instance your children and grand-children) will benefit if climate change mitigating CO_2 emissions reductions are undertaken in the present time?

( ) [Same answer options as above]

Do you think that your personal behavior or lifestyle has contributed or is contributing to climate change?

( ) [Same answer options as above]

A.1.9 Follow-up questions

What is your estimate of the yearly CO_2 emissions caused by your lifestyle?

_____ tons

How sure are you about your estimate?

( ) I had the emissions calculated

( ) Very sure

( ) Rather sure

( ) Rather unsure

( ) Very unsure

( ) I don't know

A.1.10 Follow-up questions

Do you consciously act in a climate-protecting way? If yes, please list some forms of behavior, decisions and measures through which you have consciously contributed or are contributing to the reduction of CO_2 or other greenhouse gases (in keywords).

A.1.11 Enquiry of socio-demographic information (if not or only partially on record)

Please state your gender.

( ) male

( ) female

In what year were you born? _ _ _
How many children under 18 live in your household? _ _ _

A.1.12 Enquiry of socio-demographic information if not on record

What is your highest educational degree?

( ) Still in school

( ) Special-needs school

( ) Elementary secondary school ('Hauptschule', 9th grade)

( ) Polytechnic school of the GDR (10th grade)

( ) Highschool ('Realschule', 10th grade)

( ) Advanced technical college entrance qualification

( ) A-levels (12th or 13th grade)

( ) Advanced technical college (Diploma (advanced technical college), Bachelor, Master)

( ) University degree (diploma, magister, bachelor, master)

( ) Ph.D.

( ) Dropout

( ) No specification

What is the overall net income of the household that you live in?

( ) under EUR 500

( ) from EUR 500 up to EUR 1000

( ) from EUR 1000 up to EUR 1500

( ) from EUR 1500 up to EUR 2000

( ) from EUR 2000 up to EUR 2500

( ) from EUR 2500 up to EUR 3000

( ) from EUR 3000 up to EUR 3500

( ) from EUR 3500 up to EUR 4000

( ) from EUR 4000 up to EUR 4500

( ) from EUR 4500 up to EUR 5000

( ) from EUR 5000 up to EUR 10000

( ) EUR 10000 and more

( ) no specification

A.1.13 Closing screen

Dear participant,

Thank you very much for your participation in this survey. If you are one of the winners, we will contact you by e-mail shortly.