Willingness to Pay for Voluntary Climate Action and Its Determinants: Field-Experimental Evidence*

Johannes Diederich†
Department of Economics
Heidelberg University

Timo Goeschl‡
Department of Economics
Heidelberg University

This paper has been published in
Environmental and Resource Economics (2013), DOI 10.1007/s10640-013-9686-3

Abstract

The determinants of individual, voluntary climate action (VCA) in combating climate change and its potential scale are frequently debated in public but largely underresearched. We provide estimates of the willingness to individually reduce EU greenhouse gas emissions by one ton, using the European Union Emissions Trading Scheme. Estimates are derived from an online field experiment with a large, highly heterogenous, and Internet-representative sample of voting-aged Germans. Jointly estimating willingness to pay (WTP), non-indifference to VCA, and prior knowledge, we uncover important determinants of preferences for VCA, such as education, the information structure among the population, and exogenous environmental conditions.

Keywords: climate change, EU ETS, field experiment, online experiment, public goods, voluntary contributions, voluntary climate action, willingness to pay

JEL-Classifications: C93, Q51, Q54

*The authors thank conference participants at the CESifo Summer Institute (Venice 2010), at the annual meeting of the European Association of Environmental and Resource Economists (Rome 2011), at the annual meeting of the Verein für Socialpolitik (Frankfurt 2011), at the Climate Economics and Law Conference (Bern 2011) and at the Summer Meeting of the Association of Environmental and Resource Economists (Asheville, NC 2012) as well as seminar participants at Heidelberg for helpful comments. We also thank Ruth Fieber, Christina Grimm, and Thomas Scheuerle for student assistance and Dr. Svenja Espenhorst and Dennis Mignon at First Climate for support in acquiring EU ETS allowances. Financial support by the German Science Foundation (DFG) under grant GO1604/1 is gratefully acknowledged.

†Corresponding author. Email: diederich@eco.uni-heidelberg.de. Postal address: Bergheimer Str. 20, 69115 Heidelberg, Germany.

‡Email: goeschl@eco.uni-heidelberg.de. Postal address: Bergheimer Str. 20, 69115 Heidelberg, Germany.

"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

Voluntary climate action (VCA) offers members of the general population the opportunity to individually provide additional reductions in greenhouse gas (GHG) emissions above and beyond those implemented by their governments. Within the climate policy debate, a rhetoric has evolved among commentators, climate researchers, and government bodies that attributes a high potential to such voluntary action (e.g. Gore and Guggenheim 2006, Pachauri 2007, European Commission 2011). VCA, it is sometimes argued, might alleviate the need for coercive measures of emissions reductions by governments. The demand for VCA and the factors that determine it are therefore key empirical questions.

A limited number of studies have investigated the demand for VCA, typically with a focus on estimating central measures of willingness to pay (WTP). These studies estimate mean WTP to be €25 (Brouwer et al. 2008), £24 (MacKerron et al. 2009), or €12 (Löschel et al. 2013) per ton of abated carbon (CO_2) emissions. Such numbers point to the possibility that, given the opportunity, voluntary behavior might give rise to substantial GHG emissions reductions. Additional evidence regarding the presence and determinants of VCA would help to substantiate this possibility, and various opportunities for conceptual and methodological improvements present themselves. One opportunity lies in mitigating the potential hypothetical bias of the numbers reported. With the exception of Löschel et al. (2013), existing estimates are derived using stated preferences methods and thus may overstate WTP (e.g. Cummings et al. 1995, Carlsson and Martinsson 2001) or bias covariate effects. Secondy, all existing studies are constrained by comparably small samples ($N < 350$) consisting of a specific subgroup of the general population: 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. 2013). Thirdly, participants faced bid prices for emissions reductions that mostly fall in the neighborhood

of current offset or permit prices. Estimates of true marginal abatement costs, however, are up to one order of magnitude higher (e.g. Tol 2010). The fourth opportunity lies in that the existing studies have not focused on covariates or accounted for the likely presence of indifferent respondents in a way suitable for estimating covariate effects.

The present paper embarks on providing the first study of preferences for VCA and a rich set of covariates based on both non-hypothetical choices and a comparably large sample from the general population. Specifically, we report on the WTP for the voluntary abatement of one ton of CO_2 emissions through the retirement of an emissions allowance (EUA) under the European Union Emissions Trading Scheme (EU-ETS).[1] The basic design of the "framed" field experiment (Harrison and List 2004) 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, the EUA retirement. 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 one ton of CO_2 emissions (Tol 1999, 2009, 2010). We use between-subjects randomization (Tversky and Kahneman 1981, Baltussen et al. 2010, Abdellaoui et al. 2011) 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 Germans of voting age drawn from a population of approximately 65,000 panel members of an Internet polling firm.

Any field study aimed at investigating the public's demand for VCA must take into account that VCA corresponds to a unilateral, private provision of a global public good, GHG emissions reductions (Nordhaus 1993). Therefore, individual behavior will likely be affected by typical behavioral patterns of voluntary giving. First and foremost, some peo-

[1] EUAs are the vehicle of choice for facilitating credible GHG emissions reductions in an experiment as a binding cap of the EU ETS avoids problems of additionality that are often encountered for project-based offsets (e.g. Certified Emissions Reductions (CER) under the Clean Development Mechanism of the Kyoto Protocol). Retirement (or officially, "deletion") of EUAs is an option available to all trading account holders in the EU ETS. As a result, a retired EUA reduces the total amount of GHG emissions in the European Union by one ton of CO_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.

ple will not be willing to pay anything for voluntary emissions reductions, not because they do not value climate change mitigation but because their behavior is determined by strategic "free riding" or the perceived marginality of their individual contribution, for example. Other people will be willing to pay more due to the altruistic component of a contribution. This contribution character of the valued good has not always been sufficiently accounted for by the existing VCA literature. Indeed, our data suggests a significant number of subjects with zero WTP as well as a robust share of contributors even at highest prices. Since our focus is on covariate effects, we explicitly model indifference (or nonparticipation) in the econometric analysis using a mixture model (e.g. McFadden 1994, Hanemann and Kriström 1995, Haab 1995, Kriström 1997) to prevent parameter estimates to be biased if participation and WTP are determined by the same set of covariates (Haab 1999, Werner 1999). Both indifference to the offered environmental change and WTP can also be determined by a subject's endogenous information status about or experience with the good. Empirical work suggests that the 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. Follow-up survey results in our experiment support this picture. We exploit this heterogeneity and jointly model WTP, participation, and endogenous information in the econometric analysis of covariate effects.[2]

Our key results can be summarized as follows. First, we identify a variety of significant drivers and correlates of VCA in our experiment, which points to important heterogeneities regarding VCA among the population. For example, measures of educational status turn out to be a key predictor of VCA: Years of schooling correlate with WTP both directly and indirectly through the information submodel. Similarly, WTP positively correlates with stated perceptions of both selfish and altruistic benefits from today's emissions reductions as well as perceptions of a lifestyle-related responsibility for climate change. Policy-makers interested in harnessing VCA may find it useful to be

[2]Thanks to an anonymous referee and the editor for insightful comments about the presence of nonparticipation and endogenous experience.

aware of these heterogeneities. A second key result is that the empirical reality of VCA is likely to be subtle: Estimated coefficients and WTP are sensitive to accounting for non-participation and endogenous information in the econometric model, necessitating the use of joint modeling. Such modeling reveals, for example, that both subjects' knowledge about climate change and their likelihood of being indifferent with respect to VCA differs by age and gender: The typical young male is more likely to be informed about climate change and also more likely to indicate indifference towards VCA. Third, WTP appears to be influenced by unexpected exogenous drivers: We find evidence that ambient temperatures around the time of the experiment positively affect WTP. Fourth, the empirical distribution of WTP uncovered in our experiment suggests that future research will have to widen the bid range even beyond seemingly reasonable upper bounds in order to cover the tails of WTP. Our experiment extends the upper bound of experimental prices well beyond those in the existing literature and yet, like some of the previous studies, finds significant demand at the maximum bid price. This renders central measures of the estimated WTP distribution sensitive to the assumed utility model and error distribution. While mitigated somewhat by the joint mixture model or the use of nonparametric estimators, ours and similar existing WTP estimates should be interpreted cautiously. The most conservative lower-bound estimate in our data would be €6.30 for mean and €0.30 for median WTP for one ton of voluntary CO_2 emissions reductions.

The paper proceeds as follows: We describe the experimental design, protocol, and data in the following section. We then outline the econometric analysis in section 3 and present and discuss the results in section 4. Section 5 concludes.

2 Experimental design and data

The basic design choices of the experiment 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 potential hypothetical bias of stated preferences methods (e.g. Cummings et al. 1995, Harrison 2006, Harrison and Rutström 2008). Secondly, the field experimental design combined with the comparably large sample, that is representative with respect to sex, age, and region of residence for the Internet-using population of Germany, enhances external validity. Thirdly, the design excludes to the greatest extent possible confounding public or private good attributes associated with the experimental good by employing, on the one hand, a website-based certification procedure of the EUA retirements, and by reminding, on the other hand, the subjects of the spatial indifference of local reductions for a global effect on the climate. If subjects received EUA retirement certificates in hardcopy, for example, it would plausibly increase WTP not 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. Fourthly, with a focus on endogenous, "homegrown" values (Cummings et al. 1995), we do not provide any exogenous information regarding the issue of climate change or the employed metric for emissions reductions.[3] This allows us to investigate endogenous knowledge as a driver of WTP in the joint estimation (Cameron and Englin 1997) and parallels the problem policy makers would face when promoting VCA, at least in the short run. While this is not a necessary design choice,[4] providing "unbiased full information" (Arrow et al. 1993, Munro and Hanley 1999) would be difficult given the complexity of the issue on the one hand and the requirement of a particularly low cognitive load in an experiment that runs online and with members of the general population on the other. The "snap shot" character of the design extends to the point that our experiment, like others, elicits demand given the current market equilibria for (im)perfect substitutes for the experimental good and given existing national or

[3] Note that the field nature of the experiment allows subjects to collect additional information while the experiment is in progress (e.g. by consulting Internet resources on the side in a separate browser window). In the data on subjects' speed of progress in the experiment, however, we do not find much evidence for simultaneous endogenous information acquisition—an observation that has also been made in the literature (Berrens et al. 2004).

[4] Among the existing studies on VCA, the amount of information provided by the researchers differs. While Brouwer et al. (2008) appear to be silent about causes of climate change and used metrics, MacKerron et al. (2009) provide a minor amount of information on metrics, and Löschel et al. (2013) provide information on both climate change and metrics (based on the IPCC report).

international climate policies.[5] Thus, some of a subject's demand may already be met, and the results need to be interpreted in this light.

2.1 Procedures

The experiment was administered using the infrastructure of 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.[6] Following the invitation screen, there was a filter screen to focus on German subjects of voting age.[7] Participants then saw 10 to 13 computer screens asking for 16 to 19 choices or answers, depending on their decisions.[8] Median completion time was approximately five minutes.[9]

Subjects' valuation decision was collected using two screens, one that introduced the good to be valued and set up the choice (subsequently called "information screen") and one that explained the payment procedures and collected the choice (subsequently called "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 carbon emissions, (2) the public good character of the emissions reduction and (3) the random incentive system with odds of 100 in 5,000.[10] The decision screen explained the consequences if the subject was drawn as a winner, and elicited the subject's choice. Subjects that chose the cash amount

[5] Thanks to an anonymous referee for pointing this out.

[6] These design criteria would have been familiar to panel members from previous polls as they decided on whether to proceed. The polling firm would regularly incentivize polls through either a piece-rate reward of approximately €1 for 20min expected survey time or random (lottery) prizes, e.g. in the form of a shopping vouchers.

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

[8] Some screens and questions were due to a second valuation question posed after the independent first one reported here. For a translation of the relevant experimental screens, see Diederich and Goeschl (2011b). Screen shots are available from the authors upon request.

[9] Mean 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.

[10] The number of participants implied here is due to additional treatments running at the same time.

received the award through their personal account at the polling company[11] while those who chose the emissions reductions could verify that the emissions reduction had been carried out through authoritative certification presented on a university website. The two prize alternatives were presented in random order, including the randomly determined subject-specific cash amount, and subjects had to check the preferred option.

The experiment concluded with a set of screens containing follow-up questions on the knowledge, attitudes, and beliefs about climate change, EUAs, and the metrics used. For subjects that had chosen the cash prize, a screen testing for field price censoring was inserted. Finally, the survey collected socio-demographic variables.

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[12] observations from 1,817 invitations. Session 2 lasted from July 19th to 27th and generated 800 complete observations out of 888 invitations. In the pooled sample, answers 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 subsequent analysis.[13] 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 the set of texts and questions.

2.2 Data

Table 1 reports descriptive statistics of experimental variables and matched environmental controls. Table 2 compares the sample means of key socio-demographic characteristics with census data. While showing considerable variation, all compared demographics of the Internet-representative sample turn out to be statistically different from those of the general German population. As one might expect, the average Internet user is more likely to be male, younger, and educated, and lives with more children. Regarding household

[11] A panel member can convert his or her account balance into cash as soon as a threshold of €50 is reached.

[12] 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 next screen.

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

income, both very low and very high income categories are slightly underrepresented: While mean income in the census data is higher,[14] the difference reverses if one drops incomes above €5,000.

[Tables 1 and 2 about here]

Subjects' stated views regarding climate change in Table 1 are in line with a characterization that citizens are generally concerned about climate change and have some understanding about the physical inertia of the climate problem, but also differ in their knowledge about the metrics 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% feel at least somewhat certain about their guess. A similar pattern arises for estimates of spot prices of EU emissions allowances (about €15 at the time of the experiment).

Environmental controls were matched to subjects using data from a print and online media database (LexisNexis) and from the National Meteorological Service (DWD). The Germany-wide media coverage can be matched to subjects by experimental day while the temperature data can be matched by both experimental day and region of residence (Bundesland). Both variables reflect the 2-day moving average of daily values of the day at which the subject decided to start the experimental survey and the day before. In order 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).

Descriptive results regarding subjects' valuation choices can be summarized as follows. In total, 382 (16.2%) of 2,354 subjects chose the emissions reduction through the retirement of an EUA. 1,972 (83.8%) chose the cash amount. Despite a bid range that is

[14] Income categories above €5,000 were checked by 6% in our sample, while census data indicate a share of around 19%.

considerably larger than in previous studies, offered prices do not cover the tails of the WTP distribution: At the lowest two bids (€2 and €4), still about two third of subjects are not willing to take the reduction and thus, reveal an even lower WTP or complete indifference to the choice. At the highest bid of €100, still about one sixth of subjects choose the reduction and thus reveal a WTP even larger. Note that in general, a low price elasticity appears not unusual for voluntary contributions to public goods (Green 1992, Diederich and Goeschl 2011a).

3 Analysis

The econometric analysis jointly models (1) the WTP decision whether to contribute the emissions reduction, (2) the participation decision whether the individual is indifferent to the offered choice, and (3) the endogenously determined knowledge regarding the valued good. To model the WTP decision, we employ a version of the classic Bishop-Heberlein model, which is a frequently used model for dichotomous choice data in contingent valuation. Thus, subject i's probability to choose the emissions reduction instead of the money can be expressed as

$$\Pr{}_i\,(\text{choice is emissions reduction}) = \begin{array}{cc} 1 - G_\varepsilon\left(-Z_i'\alpha + \beta \ln t_i\right) & \text{if } t_i < y_i \\ 0 & \text{if } t_i \geq y_i \end{array} . \qquad (1)$$

where G_ε is the cdf of the error term of the utility difference[15], t_i denotes the offered cash amount, y_i is income, Z_i is a vector of covariates, and (α, β) is the parameter vector. The Bishop-Heberlein model has two advantages in our case. First, it bounds WTP from below at zero, a necessary assumption for a mixture model with a spike at zero, without further need of truncation.[16] Second, it assumes constant marginal utility of income

[15] Shown is the formulation as a random utility model (RUM) censored from above by income (Hanemann and Kanninen 1999). The formulation as a expenditure difference model (Cameron 1988) is analogue (Haab 1999, Hanemann and Kanninen 1999).

[16] Our data provides little evidence on the presence of negative WTP. When asked about the reason for choosing the cash prize, only two of 1,972 subjects expressed some disutility from the emissions reduction, with harmful consequences for the economy as one of the main arguments. However, since subjects were not forced to use this open-ended answer option, this number may understate the true share. By contrast, 71% of subjects expect some benefits for future generations from the reduction, 45%

which appears reasonable for our data.[17]

In order to account for indifference, choice probabilities in the experiment become

$$\begin{aligned}\widetilde{\Pr}_i\,(\text{choice is emissions reduction}) &= (1-\gamma_i)\,\Pr{}_i\,(\text{choice is emissions reduction})\\ \widetilde{\Pr}_i\,(\text{choice is money}) &= \gamma_i + (1-\gamma_i)\,\Pr{}_i\,(\text{choice is money}) \qquad (2)\end{aligned}$$

where $(1-\gamma_i)$ denotes subject i's probability of participation, i.e., of being not indifferent but having a positive WTP (Haab 1999, Hanemann and Kanninen 1999). In order to estimate $(1-\gamma_i)$, we follow two complementary approaches. One is to make $(1-\gamma_i)$ a function of covariates,

$$(1-\gamma_i) = Q_i'\theta + \zeta_i, \qquad (3)$$

and to identify participation for each subject through an indicator variable, POSWTP. In order to classify subjects, we analyze answers to two open-ended survey questions. One asked whether the subject intentionally behaves climate protecting and solicited examples of individual behavior or measures aimed at mitigating climate change. The other question asked for reasons for choosing the money instead of the emissions reduction. Coding of these answers was done conservatively such that unclear answers were treated as participation, POSWTP=1. The other approach is to assume $(1-\gamma_i) = (1-\overline{\gamma})$ as constant across individuals and exogenously given by the share of subjects who chose the reduction in a separate treatment with 39 subjects which was identical to the one described here except that subjects faced an alternative cash prize of €0.[18] Since there are several other plausible reasons for choosing cash besides indifference in this case (e.g. "protest voting" due to disappointment from being assigned a zero cash prize) we interpret this share as a lower bound of $(1-\overline{\gamma})$.[19]

expect some personal benefits, and 72% give examples of personal climate-friendly behavior.

[17] Performing a linear grid search using a single-equation Box-Cox model, we find maxima of the log-likelihood function around $\lambda = 1$.

[18] 21 of 39 subjects (46.15%) facing a zero cash prize chose the emissions reduction.

[19] Other approaches used in the literature are to estimate $(1-\gamma)$ endogenously if no information about individual indifference is available (An and Ayala 1996, Haab 1999) or to utilize a follow-up question on indifference without estimating it as a function of covariates (Kriström 1997). The downside of both approaches is that if the assumed distribution of WTP and the true distribution of $(1-\gamma)$ depend on the same covariates, then treating $(1-\gamma)$ as constant or treating both equations as independent can bias the estimates of covariate effects on WTP (Werner 1999) and makes them more sensitive to the assumed

For the information submodel, we follow Cameron and Englin (1997) in assuming that the error terms of the WTP equation (1) and the information equation,

$$\mathrm{INF}_i^{\mathrm{obj,subj}} = R_i'\delta + \eta_i, \tag{4}$$

are correlated. In addition, we assume information and participation to be correlated. In the estimation results, we subsequently compare two possible proxies for information in our data as alternative dependant variables. The first, $\mathrm{INF}^{\mathrm{obj}}$, provides a measure of the "objective" knowledge related to carbon emissions and is constructed from the standardized deviation variables of subjects' EUA price and carbon footprint estimates. The second, $\mathrm{INF}^{\mathrm{subj}}$, represents "subjective" knowledge and is constructed from subjects' standardized self-assessed quality of both estimates. Both variables are distributed approximately normally.

4 Results

4.1 Estimation results

If we assume ε_i, ζ_i, and η_i to be multivariate normally distributed with correlations ρ and ν, then the individual log-likelihood can be written as

$$\begin{aligned} \log L_i \;=\; & \ln\left[(1/\eta_i)\phi\left((\mathrm{INF}_i^{\mathrm{obj,subj}} - R_i'\delta)/\eta_i\right)\right] \\ & +\mathrm{POSWTP}_i I_i \ln\left[\Phi\left(P_i\right)\Phi\left(W_i\right)\right] \\ & +\mathrm{POSWTP}_i(1-I_i)\ln\left[\Phi\left(P_i\right)\left(1-\Phi\left(W_i\right)\right)\right] \\ & +(1-\mathrm{POSWTP}_i)\ln\left[1-\Phi\left(P_i\right)\right] \end{aligned} \tag{5}$$

distribution for the error terms (Haab 1999). If we estimate $(1-\gamma)$ endogenously using (2), we obtain participation probability estimates of around 70% for the lognormal, 60% for the log-logistic, and about 50% for the Weibull version of (2).

where

$$
\begin{aligned}
P_i &= \frac{Q_i'\theta - \nu\left((\mathrm{INF}_i^{\mathrm{obj,subj}} - R_i'\delta)/\eta_i\right)}{(1-\nu^2)^{0.5}}, \\
W_i &= \frac{(Z_i'\alpha - \beta \ln t_i) - \rho\left((\mathrm{INF}_i^{\mathrm{obj,subj}} - R_i'\delta)/\eta_i\right)}{(1-\rho^2)^{0.5}}
\end{aligned}
$$

and I_i is the subject's discrete prize choice with $I_i = 1$ if the subject chooses the reduction over the offered cash amount t_i. The log-likelihood function $\log L = \sum_{i=1}^{N} \log L_i$ can then be maximized with respect to the coefficient vectors $(\alpha, \beta, \delta, \theta)$ and the parameter values (η, ν, ρ).

If $(1-\gamma_i) = (1-\overline{\gamma})$, then individual log-likelihood of the resulting two-equations model becomes

$$
\begin{aligned}
\log L_i &= \ln\left[(1/\eta_i)\phi\left((\mathrm{INF}_i^{\mathrm{obj,subj}} - R_i'\delta)/\eta_i\right)\right] \\
&\quad + I_i \ln\left[(1-\overline{\gamma})\Phi\left(W_i\right)\right] \\
&\quad + (1-I_i)\ln\left[(1-\overline{\gamma})\left(1-\Phi\left(W_i\right)\right) + \overline{\gamma}\right]
\end{aligned} \tag{6}
$$

and $\sum_{i=1}^{N} \log L_i$ is maximized with respect to the coefficient vectors (α, β, δ) and parameter values (η, ρ).

[Table 3 about here]

Table 3 presents the estimation results. The first column corresponds to the standard lognormal single-equation model (1). The second and third columns report results of the joint three-equations model (5), and the last two columns report results of the joint two-equations model (6) with exogenous participation probability. In all five columns, the significance levels of the estimated parameters rarely change between models and specifications. At the same time, there is reason to suspect the presence of a bias in the single equation model, indicated by differences in the magnitudes of the significant coefficients estimates between the single and the joint models. In addition, the significance of the EUA price and footprint estimates in the single equation model justifies employing a joint model that endogenizes prior information among subjects. Across the

joint models, the choice of the proxy for participation clearly matters as a comparison of the coefficient estimates of the two and the three-equation model shows. This points to a strong impact of the participation rate $(1 - \gamma)$ on estimates. Finally, comparing the two specifications for each of the joint models, coefficient estimates are largely invariant with respect to the information proxy used: Subjective (left column) and objective (right column) measures of subjects' knowledge return broadly similar estimates, except for the coefficient estimates in the information submodel itself.

The estimation results in Table 3 return signs for the significant variables that are within expectations. Starting with the WTP submodel, the price variable has the desired negative effect and is highly significant, irrespective of the model. Among the socio-demographic variables, education stands out as a highly significant correlate of the choice of the emissions reduction. Among attitudinal variables, the expectation of benefiting future generations shows a higher correlation with the propensity to choose the EUA than the expectation of personal benefits or the acknowledgement of personal negative contributions to climate change. Finally, the two matched environmental controls deliver an unexpected effect: While a larger number of recent news items related to climate change has no direct effect, higher mean temperatures in subjects' regions of residence around the time of the experiment are associated with a higher propensity to opt for the GHG emissions reduction.[20] Moving on to the participation submodel, we observe important subtleties regarding the determinants of the prize choice: Female subjects, older subjects, and, in part, subjects with more children in the household are more likely to indicate non-indifference to VCA. In addition, attitudinal variables reverse their role in the participation submodel compared to the WTP submodel: Personal benefits and acknowledged lifestyle impacts are much stronger correlated with participation than are future benefits. Both recent media coverage as well as temperatures decrease statements of participation in VCA. At around 84%, the predicted average probability of participation in the three-equations-model is close to the observed share of subjects who indicate non-indifference to VCA. Finally, in the information submodel, female and

[20] The effect is robust to including maximum instead of mean temperatures at the ten percent level of significance.

older subjects are both subjectively and objectively less informed. Subjects with more children in the household feel better informed, but do not differ significantly in objective terms. As expected, education is a significant driver of endogenous information status, thus adding to the direct effect of education on WTP through ρ. Interestingly, higher recent media coverage has a slightly negative effect on the subjective assessment of information. The correlation of the endogenous information status, both subjective and objective, and WTP is always highly significant. In contrast, endogenous information status is not correlated with indifference, as ν is insignificant.

4.2 Willingness to Pay

The specific experimental design permits interpretation of the welfare measure elicited as both WTP and willingness to accept (WTA) since either of the two implied reference points can be defended.[21] We subsequently follow the literature and report WTP.

Table 4 reports WTP computations and illustrates the impact of covariates on mean and median WTP estimates. Beginning with the covariates, the main results of the first five columns can be summarized as follows. First, the joint models, which allow for indifferent subjects, feature considerably higher mean and median WTP estimates than the single-equation model.[22] The strong impact of accounting for indifference is also emphasized by substantial differences in estimates between the three-equations model and the

[21] First, the experimental task may be interpreted as eliciting minimum WTA to forgo the emissions reduction. To see this, denote the vector of public goods with and without the emissions reduction as q^1 and q^0, respectively, and let the corresponding element of q be given in terms of abatement. Then, the equivalent variation $v(p, q^1, y) = v(p, q^0, y + E)$ defines WTA, where p is the vector of prices for private goods. Second, however, the converse of perceiving the the experimental choice as a purchasing decision appears equally if not more plausible. In this case, maximum WTP is given by the compensation variation, $v(p, q^1, y' - C) = v(p, q^0, y')$, with income $y' = y + t$. Note that most of the reasons believed to create the frequent disparity between WTP and WTA do not apply in our case (Hanemann 1999). First, the notion of a "loss" à la Tversky and Kahnemann and thus, loss aversion is ambiguous and depends on the reference point used as described above. Second, we use a closed-ended and paid elicitation format, which has been suggested to minimize the strategic incentives to understate WTP and overstate WTA found for open-ended, unpaid elicitation formats and paid auctions. Third, when the change in q is small, a WTP/WTA disparity due to low elasticities of substitution between public and private good and income elasticities larger than unity should play a negligible role. One potential bias in this context is the possible presence of a "windfall" (Keeler et al. 1985) or "house money" (Thaler and Johnson 1990) effect common to all experiments in which 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).

[22] Running separate regressions including either the participation or the information submodel shows that the changes in WTP estimates are almost entirely due to allowing for indifference.

two-equations model with exogenous participation rate. In contrast to the observed sensitivity to the participation rate, WTP estimates of the joint models are highly robust to employing either the subjective or the objective proxy for knowledge. Second, calibrating the vector of covariates using values from the census (Table 2) gives mean and median WTP estimates of about 77% of the values for the experimental sample. Thus, we would expect estimates for a truly representative sample to result in numbers that are about one quarter below ours. Third, changes in climate change attitudes and education affect WTP considerably. For example, the calibration to reflect a well-informed "realist", who acknowledges future benefits and personal lifestyle impacts but not personal benefits from today's reductions, more than doubles median WTP compared to the sample mean.

[Table 4 about here]

Turning to the absolute level of WTP, the differences between mean and median estimates are considerable in all versions of the models. This points to the fact that despite censoring by income and even though the joint models allow for indifference, the effect of the "fat tails" (Boyle et al. 1988) on both sides of the empirical WTP distribution persists. Thus, mean estimates are sensitive to the assumed model of utility, the imposed distribution of the error terms, and the bounds implied by non-negativity and income restrictions. The challenges of distributional and model assumptions also affect the median estimates since the empirical median falls below the lowest bid price (Hanemann and Kanninen 1999).[23] The estimated levels, particularly of mean WTP, therefore need to be interpreted with caution. Observing that (1) the exogenous participation probability of 46% in the two-equation model can be interpreted as a lower bound of participation in the sample and (2) the conservative coding of POSWTP for the three-equation model can be interpreted as an upper bound, the two models may be plausibly viewed as estimating an upper and lower bound for median WTP in our data. Regarding mean WTP, the last column of Table 4 reports estimates from the Turnbull Distribution-Free Estimator (Turnbull 1976, Carson et al. 1994) which has been suggested as a conservative approach for mean WTP in the presence of "fat tails" (Haab and McConnell 1997, 2002). Similar

[23] For example, mean (median) WTP estimates in the first column at the sample mean are €127.40 (€0.22) if errors are assumed log-logistic and €139.36 (€0.22) if errors are distributed Weibull.

to our parametric model, the Turnbull allows for nonparticipation but indifferent subjects do not need to be uniquely identified.[24] In its most conservative lower bound version, the Turnbull exlusively relies on the assumption of non-negativity and the information that the WTP of a subject who chooses the reduction is not less than the alternative cash prize. Taken together, we would suggest a mean WTP of €6.31 and a median WTP between €0.30 and €12 as the most conservative and best available estimates for central measures of WTP in our sample. The Turnbull estimator has limited power to quantify covariate effects, however, as it does so by simply confining the estimator to subsamples that exhibit the desired configuration. If we compute the Turnbull for our subsamples of "enthusiasts" and "realists" (defined by including the "rather yes" and "rather no" categories to increase subsample size), lower bound estimates increase to about €22 and €17, respectively.

4.3 Discussion

In this section, we compare our findings to the existing literature and discuss two potential limitations of the preference elicitation. To begin with the former, Table 5 provides a comparison of covariate results with the VCA literature. In addition, results can be compared to some extent with two related strands: (1) papers on preferences for mandatory, collective climate policies (CCP) and (2) papers on voluntary contributions to public goods in general. Table 5 includes a selection of the former category[25] while the latter has been discussed to some extent elsewhere (Diederich and Goeschl 2011a). The present study benefits from a larger set of covariates than most other studies on VCA or CCP. Among the socio-demographic variables, education stands out as the most frequent and unanimously positive driver. In contrast to our findings, income is positively correlated in most studies where available. A possible explanation for the ambigious results for gender and age may be countervailing effects in both variables that are specific to climate

[24] The assumption here 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 $t_i > 0$.

[25] 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 CCP.

change. For example, the delayed arrival of benefits from emissions reductions may militate against older subjects contributing who in general have been found to give more (List 2004). The second panel in Table 3 reports on stated climate change attitudes. Making the variables comparable across the literature involves some imprecise adjustments, such as pooling the expectations of personal and future generation benefits. The almost equivocal finding is that of a positive correlation between WTP and benefit expectations as well as the acknowledgement of personal responsibility for climate change. The latter may not only arise from concerns of justice (Konow 2003) or offset motives (Kotchen 2009) but could also be driven by an "outrage" premium for human-made environmental damages (Bulte et al. 2005). A novel element in the present study is the matching of exogenous data of environmental conditions at the time and location of the valuation choice. While this allows to establish causality, it limits comparability to previous findings which are based on respondents' statements. If the effect uncovered in our results is not a general effect in public good provision but rather context-specific, a possible explanation may be a heuristic shortcut: subjects might associate lower GHG emissions with lower temperatures, making emissions reductions—without further reasoning—appear instantaneously more desirable. Without further evidence, however, such reasoning is entirely speculative.

[Table 5 about here]

The large range of estimates for central measures of WTP in our data and their sensitivity puts existing estimates of the VCA literature with comparable survey designs into perspective and warrants cautious interpretation of the available welfare measures for VCA. In comparison, we would expect our estimates in Table 4 to be lower than those of the two contingent valuation studies on VCA as they are based on stated preferences and respondents which—in light of the covariate results—will probably display an above-average WTP. Regarding results based on the Turnbull lower bound estimator, our data indeed suggests a lower mean WTP than found by Brouwer et al. (2008) at €25/tCO_2 by employing the Turnbull. Our parametric mean WTP estimates, however, considerably exceed the RUM based estimates around £24/tCO_2 by MacKerron et al. (2009). One plausible reason for this is that the "fat tail" in MacKerron's et al. data is at a lower

maximum bid (£20) than ours (€100). Moreover, MacKerron et al. (2009) employ an unresticted linear RUM which allows for negative WTP. Among the existing estimates, our results most closely correspond to Löschel et al. (2013) who nonparametrically calculate a mean WTP at €12/tCO_2 (median at €0) from observed demand in a variant of the Becker-DeGroot-Marshak mechanism.

The literature as well as our design suggest two qualifications for our results. First, field price censoring (FPC) can arise in valuation experiments because prices for goods within the experiment cannot easily be isolated from prices "in the field" (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 field 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 (Diederich and Goeschl 2011a). Additional evidence to the analysis provided in Diederich and Goeschl (2011a) comes from answers to the post-experimental survey in which only 6.2 (13.5) percent of subjects confidently (tentatively) believe that they personally have access to the EUA market. Any remaining effect of FPC on covariate estimates will be at least partly accounted for by the information submodel while for WTP, estimates would be downward biased. Second, the number of sceptics about the reduction technology that is identified in the ex-post survey and excluded from the sample may be a lower bound as some subjects may be reluctant to mention their dislike about the employed reduction technology or other reservations in their answers.[26] Since they probably show up as participants in the data who place a positive value on climate change mitigation but choose cash due to unidentified scepticism, WTP estimates would be biased downward. A potential effect on covariate estimates would again be partially accounted for by the information submodel.

5 Conclusions

Individual, unilateral action to reduce GHG emissions, it has been suggested, could play an important part in the endeavor to tackle climate change. Empirical estimates of the

[26] Thanks to an anonymous referee for pointing this out.

public's willingness to engage in VCA are sparse, however, and its key drivers are not well understood. In this paper, we provide non-hypothetical estimates of the preferences for VCA by giving subjects the costly opportunity to reduce GHG emissions by one ton through the retirement of an EU ETS emissions allowance. To do so, we run a dichotomous choice online valuation experiment with a sample of voting-aged Germans. In contrast to prior studies, our sample is large, highly heterogeneous and Internet-representative, and subjects face a considerably larger range of bid prices. Furthermore, we explicitly take into account the public nature of the good and the voluntary contribution character of the valuation exercise and allow for zero WTP in our econometric analysis through a mixture model. Consistent with the approach to elicit "homegrown values" (Cummings et al. 1995), we focus on endogenous information status and model it jointly with WTP and the proxy for participation in VCA activities.

In the joint estimation, the main correlates of WTP in our experiment are subjects' education—both directly and indirectly through the endogenous information status—, their perceived benefits from emissions reductions—with a greater weight of altruistic compared to selfish benefits—, the acknowledgement of personal responsibility for climate change, and matched outdoor temperatures around the time and place of the experiment. Regarding subjects indication of not being generally indifferent towards VCA, the likelihood of participation is higher for females and increases with age, with stated benefit expectations and with perceived personal responsibility for climate change. Regarding the proxies for information status about climate change, young males with higher education are both subjectively and objectively better informed about climate change related facts. In addition, the subjective measure of information correlates positively with the number of children in the household and negatively with recent coverage of climate change in German media. Finally, subjects' endogenous information status and WTP highly significantly correlate.

Central measures of the estimated WTP distribution vary considerably with the identified drivers. When calibrated with German census means of covariates, we obtain estimates of about 77% of the estimates for our sample. In turn, a calibration to "real-

istic" expectations of benefits and personal lifestyle impact considerably increases WTP estimates compared to the sample mean. In absolute terms, both mean and median estimates are sensitive to model assumptions despite a much larger bid range than previous studies. If one wanted to arrive at a welfare measure based on the data we obtained, we would suggest a mean WTP of €6.30 and a median WTP of €0.30 for an individual voluntary contribution of one ton of GHG emissions reductions as conservative lower-bound estimates.

References

Abdellaoui, M., Baillon, A., Placido, L. and Wakker, P. P.: 2011, The rich domain of uncertainty: Source functions and their experimental implementation, *The American Economic Review* **101**, 695–723.

Akter, S. and Bennett, J.: 2011, Household perceptions of climate change and preferences for mitigation action: the case of the Carbon Pollution Reduction Scheme in Australia, *Climatic Change* **109**(3-4), 417–436.

An, Y. and Ayala, R. A.: 1996, A mixture model of willingess to pay distributions, *Working Paper* .

Arrow, K. J., Solow, R., Portney, P. R., Leamer, E. E., Radner, R. and Schuman, H.: 1993, Report of the NOAA panel on contingent valuation, *Technical report*. Washington D.C.

Baltussen, G., Post, T., Van den Assem, M. J. and Wakker, P. P.: 2010, Random incentive systems in a dynamic choice experiment. Working Paper.

Berrens, R. P., Bohara, A. K., Jenkins-Smith, H. C., Silva, C. L. and Weimer, D. L.: 2004, Information and effort in contingent valuation surveys: Application to global climate change using national internet samples, *Journal of Environmental Economics and Management* **47**(2), 331–363.

Boyle, K. J., Welsh, M. P. and Bishop, R. C.: 1988, Validation of empirical measures of welfare change: Comment, *Land Economics* **64**(1), 94–98.

Brouwer, R., Brander, L. and Van Beukering, P.: 2008, "A convenient truth": Air travel passengers' willingness to pay to offset their CO2 emissions, *Climatic Change* **90**(3), 299–313.

Bulte, E., Gerking, S., List, J. A. and de Zeeuw, A.: 2005, The effect of varying the causes of environmental problems on stated WTP values: Evidence from a field study, *Journal of Environmental Economics and Management* **49**(2), 330–342.

Cai, B., Cameron, T. and Gerdes, G.: 2010, Distributional preferences and the incidence of costs and benefits in climate change policy, *Environmental and Resource Economics* **46**(4), 429–458.

Cameron, T. A.: 1988, A new paradigm for valuing non-market goods using referendum data: Maximum likelihood estimation by censored logistic regression, *Journal of Environmental Economics and Management* **15**(3), 355–379.

Cameron, T. A. and Englin, J.: 1997, Respondent experience and contingent valuation of environmental goods, *Journal of Environmental Economics and Management* **33**(3), 296–313.

Carlsson, F., Kataria, M., Krupnick, A., Lampi, E., Lofgren, A., Qin, P., Chung, S. and Sterner, T.: 2010, Paying for mitigation: A multiple country study, *Resources For the Future, Discussion Papers* .

Carlsson, F. and Martinsson, P.: 2001, Do hypothetical and actual marginal willingness to pay differ in choice experiments?: Application to the valuation of the environment, *Journal of Environmental Economics and Management* **41**(2), 179–192.

Carson, R. T., Wilks, L. and Imber, D.: 1994, Valuing the preservation of Australia's Kakadu conservation zone, *Oxford Economic Papers* **46**, 727–749.

Cherry, T., Frykblom, P., Shogren, J., List, J. and Sullivan, M.: 2004, Laboratory testbeds and non-market valuation: The case of bidding behavior in a second-price auction with an outside option, *Environmental and Resource Economics* **29**(3), 285–294.

Cummings, R. G., Harrison, G. W. and Rutström, E. E.: 1995, Homegrown values and hypothetical surveys: Is the dichotomous choice approach incentive-compatible?, *The American Economic Review* **85**(1), 260–266.

Diederich, J. and Goeschl, T.: 2011a, Giving in a large economy: Price vs. non-price effects in a field experiment, *Discussion Paper No. 514* . Department of Economics, Heidelberg University.

Diederich, J. and Goeschl, T.: 2011b, Willingness to pay for individual greenhouse gas emissions reductions: Evidence from a large field experiment, *Discussion Paper No. 517* . Department of Economics, Heidelberg University.

European Commission: 2011, You control climate change. Available at: http://ec.europa.eu/clima/sites/campaign/index.htm [Accessed September 23, 2011].

Gore, A. and Guggenheim, D.: 2006, *An Inconvenient Truth: A Global Warning*, Paramount Pictures. Documentary Movie.

Green, D. P.: 1992, The price elasticity of mass preferences, *The American Political Science Review* **86**(1), 128–148.

Grether, D. M. and Plott, C. R.: 1979, Economic theory of choice and the preference reversal phenomenon, *The American Economic Review* **69**(4), 623–638.

Haab, T. C.: 1995, *The Impact of Nonparticipants on Nonmarket Valuation Techniques*, PhD thesis.

Haab, T. C.: 1999, Nonparticipation or misspecification? The impacts of nonparticipation on dichotomous choice contingent valuation, *Environmental and Resource Economics* **14**(4), 443–461.

Haab, T. C. and McConnell, K. E.: 1997, Referendum models and negative willingness to pay: Alternative solutions, *Journal of Environmental Economics and Management* **32**(2), 251–270.

Haab, T. C. and McConnell, K. E.: 2002, *Valuing environmental and natural resources: The econometrics of non-market valuation*, Edward Elgar Publishing, Northampton.

Hanemann, W. M.: 1999, The economic theory of WTP and WTA, *in* I. J. Bateman and K. G. Willis (eds), *Valuing Environmental Preferences. Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries*, Oxford University Press, Oxford, pp. 42–96.

Hanemann, W. M. and Kanninen, B.: 1999, *The Statistical Analysis of Discrete-Response CV Data*, Oxford University Press, Oxford, chapter 11, pp. 302–441.

Hanemann, W. M. and Kriström, B.: 1995, Preference uncertainty, optimal designs and spikes, *in* P.-O. Johansson, B. Kriström and K.-G. Mäler (eds), *Current issues in environmental economics*, Manchester University Press, Manchester, pp. 58–77.

Harrison, G. W.: 2006, Experimental evidence on alternative environmental valuation methods, *Environmental and Resource Economics* **34**(1), 125–162.

Harrison, G. W.: 2007, House money effects in public good experiments: Comment, *Experimental Economics* **10**(4), 429–437.

Harrison, G. W., Harstad, R. M. and Rutström, E. E.: 2004, Experimental methods and elicitation of values, *Experimental Economics* **7**(2), 123–140.

Harrison, G. W. and List, J. A.: 2004, Field experiments, *Journal of Economic Literature* **42**(4), 1009–1055.

Harrison, G. W. and Rutström, E. E.: 2008, Experimental evidence on the existence of hypothetical bias in value elicitation methods, *in* C. Plott and V. Smith (eds), *Handbook of Experimental Economics Results*, Vol. 1, North Holland, Amsterdam, chapter 81, pp. 752–767.

Johnson, E. and Nemet, G. F.: 2010, Willingness to pay for climate policy: A review of estimates, *La Follette School Working Paper No. 2010-011* . La Follette School of Public Affairs at the University of Wisconsin-Madison.

Kaczan, D., MacDonald, D. H., Morrison, M. and Hatfield-Dodds, S.: n.d., Willingness to pay to reduce the risk of severe climate change: Evidence from Australia, *Working Paper* . Reviewed in Johnson and Nemet (2010).

Keeler, J. P., James, W. L. and Abdel-Ghany, M.: 1985, The relative size of windfall income and the permanent income hypothesis, *Journal of Business & Economic Statistics* **3**(3), 209–215.

Konow, J.: 2003, Which is the fairest one of all? A positive analysis of justice theories, *Journal of Economic Literature* **41**(4), 1188–1239.

Kotchen, M. J.: 2009, Voluntary provision of public goods for bads: A theory of environmental offsets, *Economic Journal* **119**(537), 883–899.

Kriström, B.: 1997, Spike models in contingent valuation, *American Journal of Agricultural Economics* **79**(3), 1013–1023.

Lee, J.: 2008, The effect of the background risk in a simple chance improving decision model, *Journal of Risk and Uncertainty* **36**(1), 19–41.

Lee, J.-S., Yoo, S.-H. and Kwak, S.-J.: 2010, Public's willingness to pay for preventing climate change, *Applied Economics Letters* **17**(4-6), 619–622.

List, J. A.: 2004, Young, selfish and male: Field evidence of social preferences, *Economic Journal* **114**(492), 121–149.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L.: 2007, Barriers perceived to engaging with climate change among the UK public and their policy implications, *Global Environmental Change* **17**(3-4), 445–459.

Lorenzoni, I. and Pidgeon, N.: 2006, Public views on climate change: European and USA perspectives, *Climatic Change* **77**(1), 73–95.

Löschel, A., Sturm, B. and Vogt, C.: 2013, The demand for climate protection—empirical evidence from Germany, *Economics Letters* **118**(3), 415–418.

Lusk, J. L. and Hudson, D.: 2004, Willingness-to-pay estimates and their relevance to agribusiness decision making, *Review of Agricultural Economics* **26**(2), 152–169.

MacKerron, G. J., Egerton, C., Gaskell, C., Parpia, A. and Mourato, S.: 2009, Willingness to pay for carbon offset certification and co-benefits among (high) flying young adults in the UK, *Energy Policy* **37**(4), 1372–1381.

McFadden, D.: 1994, Contingent valuation and social choice, *American Journal of Agricultural Economics* **76**(4), 689–708.

Munro, A. and Hanley, N.: 1999, Information, uncertainty, and contingent valuation, *in* I. Bateman, K. G. Willis and K. J. Arrow (eds), *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries*, Oxford University Press, Oxford, chapter 9, pp. 258–279.

Nordhaus, W. D.: 1993, Reflections on the economics of climate change, *The Journal of Economic Perspectives* **7**(4), 11–25.

Pachauri, R.: 2007, Conference of the Parties to the UNFCCC serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP), opening ceremony 12 December 2007 – WMO/UNEP Intergovernmental Panel on Climate Change. Video presentation, available at: http://www.un.org/webcast/unfccc/2007/index.asp [Accessed September 23, 2011].

Shogren, J. F.: 2006, Experimental methods and valuation, *in* K. G. Mäler and J. R. Vincent (eds), *Valuing Environmental Changes*, Vol. 2 of *Handbook of Environmental Economics*, Elsevier, pp. 969–1027.

Sinn, H.-W.: 2008, Public policies against global warming: A supply side approach, *International Tax and Public Finance* **15**(4), 360–394.

Solomon, B. D. and Johnson, N. H.: 2009, Valuing climate protection through willingness to pay for biomass ethanol, *Ecological Economics* **68**(7), 2137–2144.

Starmer, C. and Sugden, R.: 1991, Does the random-lottery incentive system elicit true preferences? An experimental investigation, *American Economic Review* **81**(4), 971–978.

Sterman, J. and Sweeney, L.: 2007, Understanding public complacency about climate change: Adults' mental models of climate change violate conservation of matter, *Climatic Change* **80**(3), 213–238.

Thaler, R. H. and Johnson, E. J.: 1990, Gambling with the house money and trying to break even: The effects of prior outcomes on risky choice, *Management Science* **36**(6), 643–660.

Tol, R. S. J.: 1999, The marginal costs of greenhouse gas emissions, *Energy Journal* **20**(1), 61–81.

Tol, R. S. J.: 2009, The economic effects of climate change, *Journal of Economic Perspectives* **23**(2), 29–51.

Tol, R. S. J.: 2010, The economic impact of climate change, *Perspektiven der Wirtschaftspolitik* **11**, 13–37.

Turnbull, B. W.: 1976, The empirical distribution function with arbitrarily grouped, censored and truncated data, *Journal of the Royal Statistical Society. Series B (Methodological)* **38**(3), 290–295.

Tversky, A. and Kahneman, D.: 1981, The framing of decisions and the psychology of choice, *Science* **211**(4481), 453–458.

Ungar, S.: 2000, Knowledge, ignorance and the popular culture: Climate change versus the ozone hole, *Public Understanding of Science* **9**(3), 297–312.

Viscusi, W. and Zeckhauser, R.: 2006, The perception and valuation of the risks of climate change: A rational and behavioral blend, *Climatic Change* **77**(1), 151–177.

Werner, M.: 1999, Allowing for zeros in dichotomous-choice contingent-valuation models, *Journal of Business & Economic Statistics* **17**(4), 479–486.

Table 1: Descriptive statistics of experimental variables and matched controls

Variable	Description	Mean	S.d.	Min.	Max.
A. Socio-demographic characteristics					
Female	1 if female	0.469	0.499	0	1
Age	Years	45.42	14.68	18	89
Children in HH	Number of household members below age 18	0.466	0.846	0	6
Education	Years based on highest educational degree	12.27	3.213	9	22
Income	Monthly household net income[a] (Euros)	2,556	1,706	450	8,000
> 1 citizenships	1 if has citizenship besides German	0.017	0.129	0	1
B. Climate change attitudes and beliefs					
Personal benefits	Degree of agreement to personal benefits from effects of carbon emissions reductions[b]	2.367	0.990	1	4
Future benefits	Degree of agreement to benefits for following generations from today's emissions reductions[b]	2.902	0.967	1	4
Lifestyle impact	Degree of agreement that personal lifestyle has contributed to climate change[b]	2.761	0.951	1	4
Footprint estimate	Estimate of yearly CO_2 emissions from lifestyle (metric tons)	3,021[c]	15,340	0	100,000
Footprint est. confidence	Confidence in own footprint estimate, 1 if at least "rather sure"	0.075	0.263	0	1
EUA price estimate	Estimate of current EUA spot price (Euros)	1,656[d]	10,306	0	100,000
Price est. 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 personally available for purchase somewhere else (1 if at least "rather yes")	0.197	0.398	0	1
C. Matched environmental controls					
Media coverage	Number of hits in a climate change related keywords search in German print and online media[e,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 a width of €500 each. [b] Answer categories: 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'. Database: LexisNexis [f] The variable is the moving 2-day average of the daily values of the day at which the subject took the experiment and the day before [g] Source: German 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 in HH	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 in parantheses. Source: Federal Statistical Office (Destatis), Mikrozensus 2008, 2009, EVS 2008 and own computations

Table 3: Parameter estimates

	Standard censored lognormal	Joint censored lognormal-normal-normal, subjective information	Joint censored lognormal-normal-normal, objective information	Joint censored lognormal-normal, with exog. part., subjective inf.	Joint censored lognormal-normal, with exog. part., objective inf.
A. WTP submodel					
Cash prize amount	-0.2012***	-0.2037***	-0.2106***	-0.3327***	-0.3592***
	(0.039)	(0.043)	(0.044)	(0.075)	(0.078)
Female	0.0650	0.0422	0.0303	0.0175	-0.0150
	(0.077)	(0.085)	(0.086)	(0.135)	(0.138)
Age	0.0008	0.0021	0.0015	0.0030	0.0023
	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)
Children in HH	-0.0348	-0.0703	-0.0754	-0.0726	-0.0876
	(0.047)	(0.051)	(0.052)	(0.075)	(0.078)
Education	0.0495***	0.0575***	0.0587***	0.0833***	0.0845***
	(0.011)	(0.012)	(0.012)	(0.020)	(0.020)
Personal benefits	0.1489***	0.1368**	0.1358**	0.2575***	0.2458***
	(0.051)	(0.057)	(0.058)	(0.086)	(0.089)
Future benefits	0.2467***	0.2256***	0.2145***	0.3095***	0.3130***
	(0.059)	(0.066)	(0.067)	(0.093)	(0.095)
Lifestyle impact	0.1504***	0.1332**	0.1208**	0.2737***	0.2683***
	(0.051)	(0.057)	(0.057)	(0.086)	(0.088)
EUA availability	0.0025	-0.0292	-0.0554	-0.0797	-0.0790
	(0.089)	(0.098)	(0.099)	(0.157)	(0.160)
Price est. precision	0.1779***	–	–	–	–
	(0.042)				
Price est. confidence	0.3195**	–	–	–	–
	(0.128)				
Footprint est. precision	-0.0220	–	–	–	–
	(0.056)				
Footprint est. confidence	-0.5699***	–	–	–	–
	(0.164)				
Media coverage	0.0000	-0.0009	-0.0011	-0.0034	-0.0036
	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
Ambient temperature	0.0185**	0.0204**	0.0196*	0.0300*	0.0338**
	(0.009)	(0.010)	(0.010)	(0.016)	(0.017)
Constant	-2.9099***	-2.5286***	-2.3676***	-2.5931***	-2.4328***
	(0.402)	(0.443)	(0.445)	(0.666)	(0.677)
B. Participation submodel					
Female	–	0.3028***	0.2861***	–	–
		(0.089)	(0.090)		
Age	–	0.0071**	0.0069**	–	–
		(0.003)	(0.003)		
Children in HH	–	0.0918*	0.0787	–	–
		(0.052)	(0.053)		
Education	–	-0.0196	-0.0196	–	–
		(0.013)	(0.013)		
Personal benefits	–	0.2347***	0.2413***	–	–
		(0.060)	(0.060)		
Future benefits	–	0.1011*	0.0941*	–	–
		(0.055)	(0.056)		
Lifestyle impact	–	0.2950***	0.3189***	–	–
		(0.052)	(0.053)		
EUA availability	–	-0.1325	-0.1219	–	–
		(0.105)	(0.105)		
Media coverage	–	-0.0035**	-0.0029*	–	–
		(0.002)	(0.002)		
Ambient temperature	–	-0.0209**	-0.0185*	–	–
		(0.011)	(0.011)		
Constant	–	0.0556	-0.1141	–	–
		(0.426)	(0.426)		
$(1-\gamma)$	1	0.8421	0.8392	0.4615	0.4615
	(–)	(0.133)	(0.137)	(–)	(–)
C. Information submodel					
Female	–	-0.1401***	-0.0791**	-0.1407***	-0.0793**
		(0.045)	(0.031)	(0.045)	(0.031)
Age	–	-0.0057***	-0.0040***	-0.0057***	-0.0040***
		(0.002)	(0.001)	(0.002)	(0.001)
Children in HH	–	0.0884***	0.0253	0.0887***	0.0254
		(0.026)	(0.018)	(0.026)	(0.018)
Education	–	0.0188***	0.0092**	0.0190***	0.0093**
		(0.007)	(0.005)	(0.007)	(0.005)
Income	–	0.0000	0.0000	0.0000	0.0000
		(0.000)	(0.000)	(0.000)	(0.000)
>1 citizenships	–	0.2694	-0.0588	0.2628	-0.0624
		(0.169)	(0.116)	(0.169)	(0.116)
Media coverage	–	-0.0019**	0.0003	-0.0020**	0.0003
		(0.001)	(0.001)	(0.001)	(0.001)
Constant	–	0.3384**	-0.7869***	0.3394**	-0.7864***
		(0.163)	(0.112)	(0.163)	(0.112)
ρ	–	0.1076***	0.1270***	0.1234*	0.2078***
		(0.041)	(0.038)	(0.063)	(0.067)
ν	–	-0.0650	-0.0323	–	–
		(0.043)	(0.042)		
N	1842	1597	1552	1597	1552
Log-likelihood	-757.462	-3225.815	-2531.033	-2664.652	-1983.074
χ^2	219.989	124.219	116.112	114.448	105.675
Pseudo R^2	0.127	–	–	–	–

Notes: Standard errors in parentheses. *** Significant at or below 1 percent. ** Significant at or below 5 percent. * Significant at or below 10 percent. Controls for experimental date, region of residence, or Eastern Germany are not included in the regressions reported here. If included they would not yield further significances and would not change WTP coefficient estimates much. See Diederich and Goeschl (2011b) for specifications that include some of these controls.

Table 4: Mean and median WTP

	Standard censored lognormal	Joint censored lognormal-normal-normal, subjective information	Joint censored lognormal-normal-normal, objective information	Joint censored lognormal-normal with exog. part., subjective inf.	Joint censored lognormal-normal with exog. part., objective inf.	Turnbull LB / UB
At sample mean	€ 109.82	€ 135.69	€ 132.48	€ 189.26	€ 173.76	€ 6.31 / €45.69
	[€ 0.18]	[€ 0.34]	[€ 0.41]	[€ 10.39]	[€ 12.03]	–
At German census average	€ 85.47	€ 105.50	€ 102.59	€ 148.02	€ 136.38	–
	[€ 0.14]	[€ 0.27]	[€ 0.32]	[€ 8.16]	[€ 9.50]	–
At example calibrations of variables:[a]						
"Enthusiast"	€ 371.07	€ 394.73	€ 370.98	€ 818.21	€ 751.97	€ 22.20 / € 73.18[b]
(Personal benefits=4, Future benefits=4, Lifestyle impact=4)	[€ 5.95]	[€ 7.77]	[€ 7.35]	[€ 283.16]	[€ 283.16]	–
"Enthusiast" with university degree	€ 546.04	€ 608.52	€ 582.32	€ 1,219.78	€ 1,150.56	–
	[€ 24.32]	[€ 39.11]	[€ 36.24]	[€ 1,188.96]	[€ 930.13]	–
"Realist"	€ 178.40	€ 205.40	€ 191.77	€ 317.75	€ 298.70	€ 16.87 / € 22.30[b]
(Personal benefits=1, Future benefits=4, Lifestyle impact=4)	[€ 0.65]	[€ 1.04]	[€ 1.06]	[€ 27.79]	[€ 31.03]	
"Realist" with university degree	€ 288.90	€ 350.32	€ 333.46	€ 596.56	€ 569.06	–
	[€ 2.64]	[€ 5.21]	[€ 5.23]	[€ 116.67]	[€ 119.41]	–

Notes: Mean WTP is calculated as $\int_0^{y^*} \Phi(\bar{Z}'\hat{\alpha} - \hat{\beta}\ln t)\mathrm{d}t$ where y^* is the median monthly income of the sample (EUR 2.250) or the German census (EUR 1.750), respectively. Median WTP is calculated as $\min(y, \exp(\hat{\alpha}/\hat{\beta}))$ and reported in square brackets (Hanemann and Kanninen 1999). [a] Values of explanatory variables not made explicit are mean values of the sample, $\bar{Z}$. [b] Values are derived by pooling answer categories 1 and 2 as well as 3 and 4 of the three attitude variables

Table 5: Covariate effects on WTP for voluntary climate action and for collective climate policies

	WTP for VCA ($1tCO_2$)				WTP for CCP							
	This study	Brouwer et al. (2008)	MacKerron et al. (2009)	Löschel et al. (2013)	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. (n.d.)
A. 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.	–
B. Climate change attitudes and beliefs												
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.
C. 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 climate change. [g] Based on stated importance of personal activity against climate change. [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 increase. [j] Based on self-reported influence through media reports. [k] Respondents stated to have watched Al Gores's "An Inconvenient Truth". [l] Based on respondents' stated perception of generally rising temperatures.