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Summary

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Keywords: Climate Change Mitigation, WTP per ton of CO2 Emissions Reduced, Choice Experiments

JEL Classification: Q41, Q48, Q54, Q51

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By

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Abstract.

The implementation of decarbonization policies depends crucially on the public's willingness to pay for them. We use stated preference methods to investigate the public's preferences for such policies. We ask three research questions. First, does the willingness to pay (WTP) for each ton of CO_2 emissions reductions depend on the policies and on individual characteristics of the respondents? Second, how extensive is the variation associated with these factors? Third, what factors affect support for or opposition to a carbon tax? Based on the responses to discrete choice experiments from a sample of Italians, we find that the WTP per ton of CO_2 ranges between € 6 and 130, depending on whether the public program is based on taxes, incentives, information-based approaches or standards. Further allowing for individual characteristics of the respondents, such as gender or education, and knowledge of climate change, results in a 300% change in WTP, holding the policy instrument the same. We conclude that the variation associated with the policy instrument is approximately of the same order of magnitude as that associated with individual characteristics of the respondents.

JEL Classification: Q41 (Energy: Demand and Supply; Prices); Q48 (Energy: Government Policy); Q54 (Climate; Natural Disasters; Global Warming); Q51 (Valuation of Environmental Effects).

Keywords: climate change mitigation; WTP per ton of CO_2 emissions reduced; choice experiments.

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1 Introduction

Growing concerns about climate change (IPCC, 2007, IPCC, 2014) have spurred efforts to estimate the benefits of greenhouse gas emissions mitigation strategies (e.g., Nordhaus 1994, 2007; Tol 2005; Stern 2007; Agrawala et. al. 2011). One approach to estimating such benefits is to list all of the possible physical and societal effects of climate change, attach a monetary value to each of them, and then compute the sum of such values (Nordhaus, 1994). Alternatively, one may use variation in temperatures across locales and over time and regression analyses to infer losses or gains to society (Mendelsohn et al., 2000).[2] Finally, one could simply ask the beneficiaries of the mitigation policies to state their willingness to pay for them.

Tol (2013) provides an exhaustive survey of the literature on the damages of climate change. Tol's meta-analysis spans over 588 estimates from 75 published studies, finding that "The mean estimate in these studies is a marginal cost of carbon of $196 per metric ton of carbon (tC), but the modal estimate is only $49/tC. Of course, this divergence suggests that the mean estimate is driven by some very large estimates." Converting these figures from carbon to CO_2 yields a modal value of 13.36$/t$CO_2$, while the mean is 53.45$/t$CO_2$ (1995 US$).

Studies that have used stated preference methods to elicit the public's willingness to pay for mitigation include Berk and Fovell (1999), Roe et al. (2001), Berrens et al. (2004), Li et al. (2004), Li et al. (2005), Nomura and Akai (2004), Viscusi and Zeckhauser (2006), Brouwer et al. (2008), MacKerron et al. (2009), Achtnicht (2012), and Alberini et al. (2016). Tol (2013) reviews these and other studies, and concludes that laypeople are generally more pessimistic about climate change than are the experts. In general, however, the amount of money that people are prepared to pay for carbon taxes is in line with estimates of the social cost of carbon based on the other approaches: The WTP per metric ton of CO_2 emissions reductions from stated

[2] Tol (2013) terms the latter the "statistical" approach, and the former the "enumerative" approach.

preference studies ranges from a few to a few thousand dollars (or euro) per ton. For example, Longo et al. (2008) estimate the WTP to be $967 per ton based on a sample around the city of Bath in the UK, and Longo et al. (2012) from € 26 – 332, depending on the scenario, from a sample of residents of the Basque Country (2008 €).

Casual inspection of these studies suggests that such a large range of estimates might be driven by the different populations surveyed and the different characteristics of the mitigation plans individuals were asked to value. For example, Löschel et al. (2013) and Diederich and Goeschl (2014) derive the WTP per ton of CO_2 emissions directly through a purchase of European Union Allowances, while Löschel et al. (2010) specify the distributional impacts of the policies.[3] Brouwer et al. (2008) and Achtnicht (2012) infer the WTP per ton from the price respondents are willing to pay for private goods such as travel and cars, for which emissions and emissions rates are likely to be secondary attributes.

It is also possible that the WTP estimates from stated preference studies depend on the valuation method used, namely whether respondents are asked to report information about their willingness to pay to obtain a policy (contingent valuation) or choose among policies with different characteristics (choice experiments). For example, a meta-analysis by Allo and Loureiro (2014) indicates that the willingness to pay for CO_2 mitigation plans is systematically lower in studies that deploy choice experiments.

In this paper, we follow the stated preference approach based on choice experiments to estimate the WTP per ton of CO_2 emissions reduced. We ask three research questions. First, does the WTP per ton change with the characteristics of the policies or the individual characteristics

[3] Dietz and Atkinson (2010) examine tradeoffs between efficiency and equity considerations in two schemes, one for global pollutants and one for local pollution, but do not specify quantities and do not estimate WTP per ton. Other studies elicit preferences for specific carbon emission reduction targets without explicitly mentioning how many tons of carbon emission reductions these targets imply; see, for example, Ščasný et al. (2016).

of the respondent, or both? Second, how extensive is the variation associated with these factors? Third, what factors affect support for or opposition to a carbon tax?

We focus on public policies aimed at reducing CO_2 emissions from energy use and use of renewables in people's homes, and we clearly specify the baseline, namely the emissions generated by the average household in a year through the use of electricity, gas and other fuels at home. Our policies are described by a total of five attributes: 1) the goal of the policy (to improve energy efficiency, which should save energy and therefore emissions, or encourage shifting energy generation to renewable sources), 2) the specific mechanism (a carbon tax, incentives, standards, information-based policies, and combinations thereof), 3) the reduction in CO_2 emissions for the average household (in tons per year and as a percentage of the baseline), and 4) the cost of the policy to the respondent's household (on an annual basis). Respondents were told that the policy would entail payments and emissions reductions for 10 years. Our choice experiments are administered to a sample of Italian households in July 2014.

We expected most respondents to be at least somewhat familiar with the types of policies in our choice experiments. Energy efficiency and shifting to energy from renewable sources are widely accepted goals in the US, the European Union and many other countries. The McKinsey report (2009) considers energy efficiency a relatively untapped "resource" that can deliver reductions in greenhouse gases at very low or even negative costs, and government expenditures on energy efficiency and renewable energy program can be considerable. Allaire and Brown (2012) estimate that expenditures on the 13 federal subsidy programs that most reduced CO_2 emissions totaled over \$ 25 million in 2009, for an average cost of \$209 per ton of CO_2 emissions reduced. The US Congressional Budget Office reports that in fiscal year 2015 tax preferences (credits and deductions) to support the development, production, and use of fuels and energy technologies resulted in $15.8 billion in forgone revenues, and lawmakers appropriated funds for $5.4 billion for the Department of Energy to fund the relevant spending programs.[4]

The European Commission has set goals to cut greenhouse gas emissions by 40% by 2030 and 80-95% by 2050 (both compared to 1990 levels). Two main tools for accomplishing such goas are renewables and improved energy efficiency, and these are two key pillars of European Energy policy in their own right. The EU aims at a minimum 27% share of renewable energy consumption and at least 27% energy savings with respect to the business-as-usual scenario by 2030. A number of Directives define the broad strategy of the European Union in this area, but broad discretion is left to each member state in terms of the actual measures to be implemented. The Energy Efficiency Directive (EED) stipulates that each Member State (MS) must put in place an Energy Efficiency Obligation (EEO) scheme, in order to fulfill the 1.5% annual energy consumption reduction target. Among other things, the EED also seeks to promote renovation of residential and commercial buildings, energy efficiency goals in public buildings, and efficient heating and cooling systems. The Energy Performance in Buildings Directive (2010) contains other measures directed at promoting efficiency in residential energy use such as minimum energy performance requirements (or building codes), energy performance certificates, the obligation for buildings built after 2020 to be nearly zero-energy buildings, and the provision of financial incentives.

In terms of the specific policy mechanisms, carbon taxes and incentives (subsidies) are two well-known examples of instruments based on economic incentives and market mechanisms. They are generally regarded as (potentially) efficient (Goulder and Parry, 2008, Williams III,

[4] See https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/50980-Energy_Support.pdf.

2016), but only few countries have adopted carbon taxes, because they are either politically unappealing or impractical.[5, 6]

By contrast, incentives to adopt renewables (such as home photovoltaics or other microgeneration systems) or to finance energy-efficiency upgrades are offered by national or local government at many locales. In Italy the current feed-in tariff regime was established in 2011, at a time when Italy was the fastest-growing solar market in the world, with 9,000 MW of new installed capacity. The system features nine different tariff levels based on installation size, the highest being reserved for small rooftop systems (€ 0.27/kWh), but is due to expire in December 2016. Subsidies for energy-efficiency upgrades in the home are structured in the form of tax credits, which were first established in 2007 (see Alberini et al., 2014, and Alberini and Bigano, 2015).

Similar policies have been implemented over the years in the US and elsewhere.[7] Energy efficiency standards exist for many energy-using durables and existing and new buildings, and

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[5] Several European countries have established carbon taxes, such as Denmark, Finland, Ireland, the Netherlands, Norway, Slovenia, Sweden, Switzerland (on heating fuels), and the UK. Finland introduced the world's first carbon tax in 1990, initially with exemptions for specific sectors. Australia established a carbon tax in 2012. Carbon pricing roughly applies to Australia's largest 500 emitters, which are companies that emit more than 25,000 tons of carbon dioxide or supply or use natural gas. Initially set at $23 per metric ton of CO_2, the tax was repealed in 2014.

[6] Current carbon taxes and permit trading programs only cover about 12% of global emissions (Parry, 2014). Current research suggests that their levels may be far from optimal: In some cases the tax rate is too high compared to the actual external damages (Parry and Small, 2005), and in others too low (e.g. Máca et al. 2012; Somanathan et al. 2014). The coverage of different sectors also varies. According to OECD (2016), the *effective* carbon tax (that implied by the excise taxes levied on energy, fuels, etc.) in the residential and commercial sector covers a relatively small proportion of the carbon emissions base (only 17%) compared to 98% of emission priced in road, 36% in electricity generation, or 26% in industry sector. The average effective carbon rate from carbon tax and ETS together for all 41 OECD countries is € 31 per ton of CO2, but the overlap between the two instruments is limited to a very narrow proportion of the emissions base. OECD (2016) further finds that in Italy in 2012 about 93% of carbon emissions were priced, but a large share of these priced emissions was from road transport. Overall, about 40% were priced at an effective carbon price above € 30 per ton of CO2, which represents "a conservative minimum estimate of the damage that results from emitting one tonne of carbon…" We remind the reader that there is no explicit carbon tax in Italy but excise taxes on motor fuels, coal, gas and electricity as required by European legislation result in an average effective carbon tax rates on CO2 of about € 76. About 80% of the emissions from the residential and commercial sectors are priced at a rate of € 57–65. On average, however, the average effective tax rate in Italy is about is about € 20.2 in the residential and commercial sector in Italy, and € 16 in heating and process energy (OECD 2016).

approaches based on disclosure of a good's energy performance apply to many products, including homes. The EU's Energy Performance of Building Directive (2003, 2010) requires energy efficiency certification and the display of energy efficiency labels in homes and buildings at the time of purchase/sale and rental agreements. Despite the wide application of the policies in our choice experiments, our questionnaire included background information and examples of real-life policies prior to the choice experiments

Briefly, we find that people are willing to pay for reductions in CO_2 emissions, but their WTP per ton varies dramatically, depending on the policy instrument, ranging from € 6 to 133 euro per ton. The lowest value is that associated with a carbon tax. In models that allow the WTP to depend on *both* policy and individual characteristics, we find that the policy mechanism changes the WTP per ton by up to € 78. Holding the policy mechanisms the same, individual characteristics and climate change awareness are associated with a € 166-range in WTP per ton. Support for a carbon tax is lowest among women without a college degree and with no awareness of climate change, for whom the WTP is even negative. Based on our survey results, we conclude that the variation in WTP induced by the policy scenario is at least of the same magnitude as that associated with sociodemographics and knowledge of climate change.

The remainder of this paper is organized as follows. Section 2 describes our approach. Section 3 presents the econometric models, section 4 the data and section 5 estimation results. Section 6 concludes.

[7] See Energy Policy Act of 2005, Public Law 109–58 (https://www.gpo.gov/fdsys/pkg/PLAW-109publ58), or American Recovery and Reinvestment Act of 2009, Public Law 111-5 (https://www.gpo.gov/fdsys/pkg/PLAW-111publ5/content-detail.html). The ODYSSEE-MURE database provides information on energy efficiency policies and measures in the European Union (http://www.measures-odyssee-mure.eu).

2. Approach

We study the public's preferences for policies seeking to reduce CO_2 emissions using a survey-based approach, namely stated-preference choice experiments. In conjoint choice experiments, study participants are asked to indicate which they prefer out of a set of K alternatives, usually goods or policy packages, where $K \geq 2$. The alternatives are defined by a finite set of attributes whose levels differ across alternatives.

In our choice experiments, the alternatives are policy packages described by four attributes: i) the goal of the policy, i.e., addressing energy efficiency or promoting renewable energy; ii) the policy mechanism(s) (which may entail one or more of the following: incentives, taxes on fossil fuels, standards, or information); iii) the reduction in CO_2 emissions per household, expressed both in tons and as percentage reduction with respect to current emissions, and iv) the cost of the policy to the respondent's household. Items iii) and iv) are expressed as per year for a total of 10 years.

We included attribute iii) and iv) because they are essential for computing the WTP per ton of CO_2. We included attributes i) and ii) because we are interested in assessing whether people care about *how* emissions reductions are delivered, and earlier research on this issue is limited.

Some studies have found that people generally tend to prefer policy instruments resulting in lower prices of environmentally friendly products and services (e.g. subsidies for renewable energy sources) over instruments that increase the prices of environmentally harmful goods (see Schade and Schlag, 2003; Eriksson et al., 2006). A policy instruments labelled as "tax" is found to be significantly less acceptable than an unlabelled policy instrument, even when they have the same characteristics (Brännlund and Persson, 2012; Cole and Brännlund, 2009; Kallbekken et al.

2011). People who are opposed to taxes may, however, be mollified by policies that propose to recycle the revenue from those taxes into environmentally-oriented measures, such as support for public transport and alternative means of transportation, development of clean technologies, etc. (Saelen and Kallbekken, 2011). In a voting experiment, Cherry et al. (2012) found that subjects prefer taxes over regulation and subsidies over taxes. This study and others show that opposition against an instrument is strengthened when the instrument is viewed as coercive (Attari et al., 2009, Baron and Jurney, 1993, Jakobsson et al. 2000, or Steg et al. 2006).

In each choice question, respondents were asked to choose between two hypothetical policies and the status quo, and so in our survey K=3. Attributes and attribute levels are summarized in table 1. Prior to the choice experiments, we told respondents that the CO_2 emissions associated with home electricity and heating fuel usage come to a total of 5 tons a year for the average Italian household. We then asked them to consider two major approaches to reducing CO_2 emissions from homes and buildings. One is to improve energy efficiency, and the other is increasing the share of renewable energy. Respondents were reminded of other benefits of these approaches, including savings for the consumers, improved energy security, and others.

Our hypothetical policies would deliver reductions in emissions of 5, 10, 20 and 33% with respect to this baseline, which correspond to 0.25, 0.5, 1, and 1.65 ton CO_2 per year, respectively. The cost amounts were selected so as to cover a broad range of possible willingness to pay figures per ton of CO_2 emissions reductions (14 – 1200 Euro per ton). The current situation (status quo) was clearly presented to the respondent as delivering no emissions reductions at zero additional cost to the respondent's household.

In each discrete choice task, the respondents were asked to choose between policy A, policy B and the status quo. Choosing the status quo implied no additional costs to the household, and no reductions in the current level of CO_2 emissions. A sample choice card is displayed in figure 1.

Respondents engaged in a total of five such choice tasks, then moved on to a series of debriefing questions. These were followed by a number of questions meant to assess the respondent's beliefs and information about climate change. Specifically, they were asked to indicate their agreement or disagreement with a number of statements about climate change. We used a Likert scale where 1 denotes complete disagreement and 5 means complete agreement. The statements were non-technical in nature, and ranged from naming CO_2 as one of the most important greenhouse gases to claiming "I have never heard of climate change before."

The choice experiments, the debriefing questions and the climate change belief questions were placed roughly in the middle of a questionnaire that focused on energy use and recent energy-efficiency upgrades in the respondent's home. The questionnaire ended with the usual questions about socio-demographics (family status, education, income, etc.).

The questionnaire was self-administered using computer-assisted web interviewing (CAWI) by a total of 1005 respondents recruited from the population that owns and resides in homes built before or in 2000. We focused on this segment of the population (roughly 84% of the entire population of Italy) because we were interested in energy-efficiency upgrades and retrofits, and these typically happen when a home is sufficiently old. About one-third of the sample had done one or more such retrofits within the last 5 years, one-third 5-15 years prior to the survey, and the remaining one-third none whatsoever. The survey was conducted nationwide in July 2014.

3. Econometric Models

We posit that the responses to the conjoint choice questions are driven by a random utility model (McFadden, 1974), where the indirect utility $\bar{V}$ from an alternative depends on the attributes of that alternative. The attributes may also appeal to a different extent to different individuals. Formally, we assume that

$$\bar{V}_{ij} = \alpha_1 \cdot \mathbf{G}\text{OAL}_{ij} + \Delta CO2_{ij} \cdot \left(\alpha_2 + \mathbf{INSTR}_{ij}\boldsymbol{\alpha}_3 + \mathbf{X}_i\boldsymbol{\alpha}_4\right) + \beta \cdot (y - COST_{ij}) \quad (1)$$

where subscripts i and j denote the individual and the alternative, respectively, and **GOAL** is a vector of dummies denoting the goal of the policy (to abate CO_2 emissions by promoting energy efficiency (EE) or renewables (RES)). In practice, this means that we are including alternative-specific intercepts in the discrete choice model. Variable $\Delta CO2$ is the CO_2 emissions reduction per household delivered by the policy (in tons per year), y is the respondent's household income and COST is the cost of the program to the respondent's household (euro per year). In equation (1), the α's are the marginal utilities and β is the marginal utility of income.

As shown in equation (1), we allow the marginal utility of emissions reductions to depend on the policy instruments, including a carbon tax, incentives, standards (here captured by vector **INSTR)** and information-based approaches (such as campaigns or labels (INFO)). We also allow the marginal utility of the emissions reductions to depend on a vector **X** of individual characteristics and beliefs about climate change.

On appending an i.i.d. standard type I extreme value error term, ε, it can be shown that the probability that alternative k is chosen is

$$\Pr(k) = \exp(\bar{V}_k) / \sum_{j=1}^{3} \exp(\bar{V}_j)\,, \quad (2)$$

which is the contribution to the likelihood in a conditional logit model (see Train, 2003).

In our questionnaire, each respondent is faced with T=5 choice cards, and the log likelihood function is

(3) $$\log L = \sum_{i=1}^{N}\sum_{t=1}^{T}\sum_{k=1}^{3} y_{itk} \cdot \ln\left(\exp(\overline{V}_{itk}) \Big/ \sum_{j=1}^{3} \exp(\overline{V}_{itj}) \right).$$

where y_{itk} is a binary indicator denoting whether respondent *i* selects option *k* in choice exercise *t*. All coefficients are estimated by the method of maximum likelihood. In practice, β is estimated by entering only cost, rather than residual income (*y-COST*), in the model, so that the estimation routine produces the negative of β as the coefficient on cost.

If α_3 and α_4 are all equal to zero, then the willingness to pay for each ton of CO_2 emissions avoided is $\hat{\alpha}_2 / \hat{\beta}$, where the "hats" denote the maximum likelihood estimates. In this paper, however, we are specifically interested in seeing if the WTP per ton changes with the policy or the characteristics of the individual, or both—and by how much. This helps us explore whether the range of WTP per ton of CO_2 observed in the literature is due to the features of the policies individuals were asked to consider, or the populations being surveyed, or both.

We also wish to study what factors influence support for a carbon tax. Candidate factors include gender (to be *male*), education (to have a university degree, *college*), not having heard of climate change before (*neverheard*), or believing that climate change means global cooling (*cooling*).[8] The reference category in model (1) is a female without university degree who is informed about climate change. Quantity $\hat{\alpha}_2 / \hat{\beta}$ is thus the WTP per ton of CO_2 emissions reduced for such a respondent. The WTP for another type of respondent is obtained by adding the coefficient(s) on the interaction between ΔCO2 and the individual characteristic(s) of that

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[8] We explore how the WTP per ton of CO2 varies with income in Alberini et al. (2016).

respondents, all of them divided by $\hat{\beta}$. For example, the WTP per ton under a carbon tax is $(\hat{\alpha}_2 + \hat{\alpha}_{3,TAX})/\hat{\beta}$, and that under standards and for college-educated woman is $(\hat{\alpha}_2 + \hat{\alpha}_{3,STDS} + \hat{\alpha}_{4,COLLEGE})/\hat{\beta}$.

To see if the WTP per ton varies with the policy instrument to a different extent for persons with different characteristics, we fit the following RUM:

$$\text{(4)} \quad \overline{V}_{ij} = \alpha_1 \cdot \mathbf{G}\text{OAL}_{ij} + \Delta CO2_{ij} \cdot \left(\alpha_2 + \mathbf{INSTR}_{ij}\boldsymbol{\alpha}_3 + \mathbf{X}_i\boldsymbol{\alpha}_4 + \mathbf{X}_i \times \mathbf{INSTR}_{ij}\boldsymbol{\alpha}_5\right) + \beta \cdot (y - COST_{ij})$$

where the reference category and the coefficient α_2 still refer to a female without university degree but with knowledge of climate change, and to information-based policies. Notice that this model entails two-way as well as three-way interactions between emissions reductions, policies and individual characteristics.

Finally, we allow for the possibility that respondents may favor or oppose certain policies regardless of how much they deliver and cost. We examine this possibility with the model:

$$\text{(5)} \quad \overline{V}_{ij} = \alpha_1 \cdot \mathbf{G}\text{OAL}_{ij} + \mathbf{INSTR}_{ij}\boldsymbol{\delta} + \left(\mathbf{INSTR}_{ij} \times \mathbf{X}_{ij}\right)\boldsymbol{\theta} + \alpha_2 \cdot \Delta CO2_{ij} + \beta_1 \cdot (y - COST_{ij}) .$$

This model allows for such favor or opposition to depend on individual characteristics of the respondent.

4. The Data

Descriptive statistics of the respondents are reported in table 2. Men account for some 61% of the sample,[9] and, in terms of educational attainment, over a third of the respondents have

[9] The questionnaire invited a member of the family who is familiar with energy bills and energy efficiency updates at home to participate in the survey. This is most likely the reason why men are overrepresented in our sample.

a college or post-graduate degree and some 48% of the respondents completed high school.[10] Income levels are similar to those in the population (Banca d'Italia, 2014), at least for those respondents who did report their income (87.5% of the sample).

When asked about their preferences for mitigation policies, it is reasonable to expect that people's stated-preference responses should be affected by their knowledge of climate change and concern about it. The shares of the sample ratings about climate change are displayed in table 3. This table suggests that most of the Italian respondents have heard of climate change before and that very few dispute its existence. However, there is low or no correlation between the two basic measures of knowledge of climate change used in our empirical models and respondent education (see table 4). This bodes well for statistical analysis below (as it reduces collinearity) but is somewhat surprising.[11]

As shown in table 5, the responses to the policy choice questions appear to be reasonable: Program A was selected about 40% of the times, program B 37%, and the status quo 23% of the times. Table 6 shows that the responses are stable over the choice exercises. We did not find any obvious evidence of anomalies or unusual response patterns.

5. Results.

Our estimation results indicate that the association between policy attributes and the probability of selecting any one of the alternatives in a choice card is almost always statistically

[10] By contrast, population statistics from Italy indicate that only 12.30% of the population has a university degree and that about 29% has a high school diploma. Our Italy sample thus over-represents highly educated adults.
[11] To further elaborate on this, the rating for the statement that the earth is globally cooling is only weakly associated with education, in that the share of people that disagree completely is about 5 percentage points higher among college-educated respondents, and the share that agree completely is about 5 percentage points lower among the college educated. Education does not appear to be related to the rating of the statement "I have never heard of climate change before."

significant, regardless of the functional form we selected for the RUM (whether equation (1) or the others).

We begin our discussion of the results with the simplest version of RUM of equation (1), namely one where the individual characteristics **X** are omitted (in other words, $\boldsymbol{\alpha_4}$=0).[12] As shown in table 7, top panel, the implied WTP per ton of CO_2 emissions reductions ranges by two orders of magnitude—from 6.44 to 133.15 Euro. It is lowest with a carbon tax and highest with incentives. While standards and incentives are similarly regarded by the respondents (Wald test 1.54, p value 0.22), and incentives and information-based approaches are weakly statistically different (Wald test 5.54, p value 0.02), the figures for all of these policies are dramatically different from those for the carbon tax (Wald test: 34.12, p value < 0.00001).

The results displayed in Appendix A.1, column (B) refer to a variant of the RUM in equation (1) where the $\boldsymbol{\alpha_3}$ are restricted to zero, allowing us to focus on the effect of demographics and climate change beliefs. The WTP figures are displayed in table 7, bottom panel. Clearly, there is a ten-fold difference between the lowest and highest WTP per ton values and the WTP range is even larger compared to its counterpart in the top panel. Education and climate change knowledge have a major impact on the WTP per ton. To illustrate, a woman with high-school diploma and at least basic information on climate change is willing to pay 86 Euro per ton of CO_2 emissions avoided. This figure increases to 144 Euro for a woman with similar background but college-degree education, and drops to 17.57 Euro for a woman who is completely uninformed about climate change and has no college degree. Men hold systematically higher WTP values. For example, a college-educated men who is informed about climate change is prepared to pay 185 Euro per ton of CO_2 emissions avoided, and even an

[12] Full estimation results are displayed in table A.1 in Appendix A, column (A).

uninformed man without college education would be prepared to pay 59 Euro per ton, although this figure is not statistically different from zero.

We are, of course, especially interested in whether a given policy is more or less appealing to a certain group of individuals. The results from the broadest specification of the RUM in equation (1), where both α_3 and α_4 are unrestricted, are displayed in table A.1 in appendix A, column (C). As summarized in table 8, their implications in terms of WTP are striking: Opposition to a carbon tax is extreme among the less highly educated persons in our sample and persons with no knowledge of climate change, for whom the WTP can be even negative (but statistically insignificant). All else the same, men are prepared to pay some 40 Euro per ton more than women. Having a college degree translates into being willing to pay about 50 Euro more for each ton of CO_2 emissions reduced. Incentives and standards are the policies for which people are prepared to pay the largest amounts (up to 230 and 209 Euro per ton, among college educated men). The carbon tax is worth 78 Euro per ton less than incentives.

We explore whether gender, education and climate change awareness are important in influencing the acceptance of a carbon tax in table A.1, column (D), which corresponds to the RUM in equation (4), but the coefficients on the three-way interaction terms are imprecisely estimated and the only additional evidence with respect to the results in column (C) is the especially strong opposition to a carbon tax on the part of those who have not heard of climate change before. Additional specifications—such as variants on equation (5)—do not uncover any additional evidence about the downright opposition to a carbon tax (see table A.2 in Appendix A).

6. Conclusions

We have used stated preference methods to study the determinants of heterogeneity in the WTP per ton of CO_2 emissions abated through mitigation policies. We have focused on exploring whether heterogeneity in the WTP is due to the attributes of the policies or individual characteristics of the respondents. We have found that both can induce large changes in the WTP per ton. In our simplest specification, the WTP range across policies is € 127. In our broadest specification, the WTP per ton values range between € -14 and 230, depending on the policy. Holding the policy the same, the WTP per ton can increase by 300%, depending on the individual characteristics and awareness of climate change of the respondents.

In our study, the policy-induced heterogeneity in WTP values and that associated with individual characteristics and opinions on climate change are of roughly the same magnitude. Our results can be compared, for example, with those in Kotchen et al. (2013), who report that the willingness to pay for a national climate change policy that reduces CO_2 emissions by 17% by 2020 does not vary much across a cap-and-trade program, a carbon tax and regulation of greenhouse gas emissions. Age, education and political party affiliation are associated with higher or lower WTP for certain policy mechanisms, but these differences disappeared when the regressions control for whether climate change is actually taking place.

We found mixed evidence in terms of support for a carbon tax. The range of WTP values in a carbon tax context ranged from practically zero to about € 151/ton, and was strongly associated with education and knowledge of climate change. In general, the results from our analysis are broadly consistent with preferences observed at other locales: Greenstone (2016) reports that some 57% of Americans would support a carbon policy, whether a tax, a cap-and-trade, or regulations.

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Table 1. Summary of attributes and attribute levels used in the stated-preference choice experiments.

Attribute	attribute levels	number of levels
goal of the policy	energy efficiency, renewables	2
mechanism(s)	incentives, regulation, taxes on fossil fuels, information-based approaches	7
reduction in CO_2 emissions (for each of 10 years)	0.25 tons (5%), 0.50 tons (10%), 1 ton (20%), 1.65 (33%)	4
cost to the household for each of 10 years	25, 50, 100, 300 Euro (Italy)	4

Table 2. Descriptive statistics of the respondents' sociodemographics.

Variable	Percent or sample mean
gender:	
Male	61.59%
Education	
high school diploma	47.78%
college degree	26.47%
Master's or PhD	7.16%
Income (net annual household income)	€30,185

Table 3. Respondents' opinions about climate change. Percent of the sample that select each rating score.

Statement	Completely disagree 1	2	Neutral 3	4	Completely Agree 5
The Greenhouse effect is caused by a hole in the atmosphere	12.14	10.45	32.34	27.46	17.61
Climate change is caused by excessive greenhouse gas emissions	2.29	5.47	25.17	36.82	30.25
Climate change means that in the future the Earth will be warmer	1.69	5.07	29.15	36.72	27.36
Carbon dioxide is one of the most important greenhouse gases	1.69	5.47	29.75	35.02	28.06
Burning fossil fuels is the most important cause of greenhouse gases	1.49	5.97	33.33	37.61	21.59
Climate change doesn't exist	58.61	12.44	18.81	6.97	3.18
Actually, the Earth is globally cooling	27.96	18.51	39.5	9.25	4.78
I have never heard of climate change before	64.18	9.15	16.52	7.76	2.39

Table 4. Percentage of respondents who agreed or disagreed with climate change statements by education

	Strongly disagree 1	2	Neutral 3	4	Strongly agree 5	Pearson's χ^2 test
In reality the Earth is cooling globally						
without university degree	25.83	17.42	39.92	9.98	6.85	χ^2 (4)=12.35 p=0.015
with university degree	30.16	19.64	39.07	8.5	2.63	
I have never heard of climate change before						
without university degree	62.43	9.00	17.03	8.22	3.33	χ^2(4)=4.80 p=0.308
with university degree	65.99	9.31	15.99	7.29	1.42	

Tables 5. Policy Choices made by the respondents.

	Freq.	Percent
policy A	1,992	39.64
policy B	1,869	37.19
status quo	1,164	23.16
Total	5,025	100

Table 6. Responses by pair: frequencies and percentages of row totals.

	response			
Pair	Policy A	Policy B	Status Quo	Total
1	427	354	224	1,005
	42.49	35.22	22.29	100
2	359	414	232	1,005
	35.72	41.19	23.08	100
3	377	402	226	1,005
	37.51	40	22.49	100
4	406	367	232	1,005
	40.4	36.52	23.08	100
5	423	332	250	1,005
	42.09	33.03	24.88	100
Total	1,992	1,869	1,164	5,025
	39.64	37.19	23.16	100

Table 7. WTP per ton of CO_2 figures based on two specifications of the RUM in equation (1). All amounts in euro.

	WTP per t CO_2	Standard error.
(A) α_4=0 Only policies		
CARBON TAX	6.44	(11.26)
INCENTIVES	133.15***	(16.83)
STANDARDS	112.44***	(17.23)
INFO	95.24***	(16.26)
(B) α_3=0 Only individual characteristics		
…woman		
with university, with knowledge	144.03***	(28.44)
no university, with knowledge	85.89***	(25.79)
with university, no knowledge	75.71	(50.77)
no university, no knowledge	17.57	(48.62)
…man		
with university, with knowledge	185.49***	(24.80)
no university, with knowledge	127.34***	(24.33)
with university, no knowledge	117.16**	(49.63)
no university, no knowledge	59.02	(48.68)

*** p value<0.01, ** p value<0.05, * p value<0.10

Table 8. WTP estimates based in the RUM in equation (1), no restrictions on the coefficients. Standard errors in parentheses. All amounts in euro.

	INCENTIVES	STANDARDS	INFO	TAX
…woman				
+with university, with knowledge	190.59*** (31.62)	169.75*** (31.33)	155.91*** (31.10)	112.15*** (28.36)
+no university, with knowledge	133.81*** (28.59)	112.97*** (28.67)	99.13*** (28.6)	55.37** (26.16)
+with university, no knowledge	121.13** (51.7)	100.29* (52.45)	86.45* (51.76)	42.69 (50.87)
+no university, no knowledge	64.35 (49.17)	43.51 (50.17)	29.67 (49.56)	-14.08 (48.93)
…man				
+with university, with knowledge	230.26*** (28.83)	209.42*** (28.00)	195.58*** (27.57)	151.83*** (24.25)
+no university, with knowledge	173.49*** (27.88)	152.65*** (27.44)	138.81*** (27.19)	95.05*** (24.42)
+with university, no knowledge	160.81*** (50.84)	139.96*** (51.31)	126.13** (50.52)	82.37* (49.52)
+no university, no knowledge	104.03** (49.57)	83.19* (50.28)	69.35 (49.58)	25.59 (48.85)

*** p value<0.01, ** p value<0.05, * p value<0.10

Appendix A.

Table A.1. Estimation results for conditional logit models with two-way and three-way interactions for CO_2 emission reductions. 1,005 respondents, 5025 responses. Standard errors in parentheses. Standard errors are clustered at the respondent level.

	(A)	**(B)**	**(C)**	**(D)**
EE	0.5049*** (0.0779)	0.4211*** (0.0775)	0.4211*** (0.0777)	0.4218*** (0.0777)
RES	0.721*** (0.0795)	0.636*** (0.0798)	0.6286*** (0.08)	0.6298*** (0.0801)
ΔCO2		0.2788*** (0.0821)	0.3252*** (0.0922)	0.2292** (0.1039)
ΔCO2 × TAX	0.0209 (0.0365)		-0.1435*** (0.0448)	0.0155 (0.0823)
ΔCO2 × INCENTIVES	0.4321*** (0.0472)		0.1138** (0.0468)	0.1163** (0.0469)
ΔCO2 × STANDARDS	0.3649*** (0.0498)		0.0454 (0.0508)	0.0434 (0.0507)
ΔCO2 × INFO	0.309*** (0.0488)			
ΔCO2 × cooling		-0.0291 (0.1273)	-0.0283 (0.1273)	-0.0103 (0.1549)
ΔCO2 × neverheard		-0.1926 (0.142)	-0.1995 (0.1419)	-0.2278 (0.1709)
ΔCO2 × college		0.1887** (0.0911)	0.1863** (0.0911)	0.285*** (0.1071)
ΔCO2 × male		0.1345 (0.0933)	0.1301 (0.0934)	0.2067* (0.1093)
ΔCO2 × TAX × cooling				-0.0288 (0.1334)
ΔCO2 × TAX × neverheard				0.0547 (0.1496)
ΔCO2 × TAX × college				-0.1677** (0.0848)
ΔCO2 × TAX × male				-0.1287 (0.0873)
COST	-0.0032*** (0.0002)	-0.0032*** (0.0002)	-0.0033*** (0.0002)	-0.0033*** (0.0002)
LogLik	-5183.29	-5163.52	-5152.00	-5148.40
Wald chi2	306.55	302.66	319.61	323.46

*** p value<0.01, ** p value<0.05, * p value<0.10

Table A.2. Estimation results for conditional logit models with two-way interactions between individual-specific characteristics and carbon tax (A) or incentives (B). 1005 respondents, 5025 responses. Standard errors in parentheses. Standard errors are clustered at the respondent level.

	(A) CARBON TAX	**(B) INCENTIVES**
EE	0.3511*** (0.1088)	0.3513*** (0.1088)
RES	0.5444*** (0.1089)	0.546*** (0.109)
ΔCO2	0.4296*** (0.0404)	0.4287*** (0.0404)
Incentives	-0.1686* (0.0915)	-0.1412*** (0.0466)
Tax	0.2902*** (0.0736)	0.1174 (0.1068)
Standards	0.1179 (0.0749)	0.1193 (0.075)
Policy indicated in the header of column (A) or (B)	0.1375* (0.08)	0.1389* (0.08)
… × male	0.0136 (0.1005)	0.1416 (0.1056)
… × college	0.0434 (0.0956)	0.1859* (0.1028)
… × neverheard	0.0711 (0.1687)	-0.0848 (0.1722)
… × cooling	-0.0511 (0.1418)	0.0198 (0.1529)
COST	-0.0033*** (0.0002)	-0.0033*** (0.0002)
LogLik	-5156.68	-5152.91
Wald chi2	328.44	331.13

*** p value<0.01, ** p value<0.05, * p value<0.10

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