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Summary

Concerns about climate change are growing, and so is the demand for information about the costs and benefits of mitigating greenhouse gas emissions. This paper seeks to estimate the benefits of climate change mitigation, as measured by the public's willingness to pay for such policies. We investigate the preferences of Italian and Czech households towards climate change mitigation policy options directly related to residential energy use. We use discrete choice experiments, which are administered in a standardized fashion to representative samples in the two countries through computer-assisted web interviews. The willingness to pay per ton of CO2 emissions avoided is €132 Euro for the Italians and 94 Euro for the Czech respondents (at 2014 purchasing power parity). We find evidence of considerable heterogeneity in WTP driven by income. The two samples differ in their "domestic" income elasticities of WTP, but comparison across the two countries suggests an income elasticity of WTP of one.

Keywords: Energy-efficiency Incentives, Stated Preferences, CO2 Emissions Reductions, CO2 Mitigation Policies, Conjoint Choice Experiments, WTP for CO2 Emissions Reductions

JEL Classification: Q41, Q48, Q54, Q51

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Preferences for Energy Efficiency vs. Renewables: How Much Does a Ton of CO_2 Emissions Cost?

By

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Abstract
Concerns about climate change are growing, and so is the demand for information about the costs and benefits of mitigating greenhouse gas emissions. This paper seeks to estimate the benefits of climate change mitigation, as measured by the public's willingness to pay for such policies. We investigate the preferences of Italian and Czech households towards climate change mitigation policy options directly related to residential energy use. We use discrete choice experiments, which are administered in a standardized fashion to representative samples in the two countries through computer-assisted web interviews. The willingness to pay per ton of CO_2 emissions avoided is €132 Euro for the Italians and 94 Euro for the Czech respondents (at 2014 purchasing power parity). We find evidence of considerable heterogeneity in WTP driven by income. The two samples differ in their "domestic" income elasticities of WTP, but comparison across the two countries suggests an income elasticity of WTP of one.

Keywords: Energy-efficiency incentives; Stated preferences; CO_2 emissions reductions; CO_2 mitigation policies, conjoint choice experiments, WTP for CO_2 emissions reductions.

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

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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 economy-wide effects of climate change, attach a monetary value to each of them, discount them to the present, and then compute the sum of such values (Nordhaus 1994). Alternatively, one may use variation in temperatures across locales and over time and use 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.

Any one of these three approaches can be summarized into a figure known as the social cost of carbon (SCC), i.e. the dollar value of reduced climate change damages associated with a one-metric-ton reduction in carbon dioxide (CO_2) emissions (Pizer et al. 2014). When the first or second of the approaches listed above are used, computing the SCC generally requires integrated assessment models that make assumptions about future population growth, economic activity and technology, and link the associated greenhouse gas emissions with their effects on climate (Greenstone et al., 2013).

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$).

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

Studies that have used stated preference methods to elicit the public's willingness to pay for mitigation policies 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), Löschel et al. (2010), Löschel et al. (2013), and Diederich and Goeschl (2014). Tol (2013) reviews many of these and other studies, and concludes that the amount of money that people appear to be prepared to pay for carbon taxes is in line with its estimates based on the other approaches: The WTP per metric ton of CO_2 emissions reductions from stated preference studies ranges from a few to a few thousand dollars (or Euro) per ton.

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, how much would people say that they would be prepared to pay for each ton of CO_2 emissions reductions? Second, are the responses to hypothetical questions, and the WTP per ton that they imply, reasonable, and how do they compare with their counterparts from earlier stated-preference studies or from damage-function based approaches? Third, how does such WTP per ton vary with income?

We use discrete choice experiments, which we administer in a standardized fashion to two samples of respondents—one in Italy and one in the Czech Republic. Unlike earlier studies that elicited the additional price one would be prepared to pay to reduce emissions from a given product traded in the market (e.g., airline travel, see Brouwer et al. 2008, or MacKerron et al. 2009, or cars, see Achtnicht 2009), we focus on public policies. Our context is energy use in buildings, and more specifically dwellings, and, unlike Longo et al. (2008) and Longo et al. (2012), we clearly specify the baseline annual emissions that the average household can expect to generate through the use of electricity, gas and other fuels at home.

Using the responses to the discrete choice experiments and the coefficients from the associated conditional logit models, we estimate the willingness to pay per ton of CO_2 emissions avoided to be €133 – 164 2014 PPS Euro for the Italians and 94 2014 PPS Euro for the Czech respondents. These figures are reasonable when compared with the WTP per ton from other stated preference surveys (which vary between six and thousands of Euro per ton) and with other approaches to estimating the social cost of carbon.

Moreover, our respondents appeared to trade off the attributes of the alternative policies they were to choose from in ways that are consistent with economic theory, and indicated that developing energy from renewables is more desirable than improving energy efficiency, and that carbon taxes are undesirable. This result is in contrast with a recent survey in the US, which indicated that at least 57% of the respondents were willing to pay a $1 fee on top of their utility bill to support a carbon tax policy (Greenstone, 2016).

In addition, we examine how WTP per ton of CO_2 emissions varies with the respondent's income. We specify models that let the marginal utility of emissions reductions, and the income elasticity of the WTP for each ton of CO_2, depend on income, without restricting to be below or above one.

We find that there is significant heterogeneity in the WTP per ton of CO_2 emissions reductions and in the income elasticity of WTP, this heterogeneity being driven by income. The mean income elasticity in each sample is less than one, and the Czech Republic exhibits low income elasticities—on average 0.35 in one specification and 0.46 in another. (A third and more flexible specification suggests an even lower elasticity of 0.22.) This result is explained in part by the fact that in the Czech Republic the marginal utility of emissions reductions grows weakly with income, and the marginal utility of income is actually greater among wealthier respondents.

This low "domestic" income elasticity is in sharp contrast with the income elasticity of WTP implied by the comparison of the two countries' WTP, which is one.

These results can be placed in the context of practices followed in many studies, policy analyses and some integrated assessment models, which assume a constant income elasticity of WTP of one (Pearce 2006; Ready and Navrud 2006; Lindhjem and Navrud 2015). This means that if information about WTP is available at location A but not at location B, B's WTP can be predicted as A's WTP times the ratio of B's and A's income. In stated preference studies about environmental quality and health improvements, however, the income elasticity of WTP is typically less than one (Kriströ̋m and Riera 1996; Jacobsen and Hanley 2009; Czajkowski and Ščasný 2010; OECD 2012). Our models, which allow for the income elasticity to depend on income, is consistent with Czajkowski and Ščasný (2010) and Barbier et al (2016), who show that the income elasticity of the WTP for a marginal reduction in pollution is only constant under very restrictive assumptions and is most likely increasing in income.

The remainder of this paper is organized as follows. Section 2 describes our choice experiments, the questionnaire and the administration of the survey. Section 3 lays out the statistical model of the responses to the choice questions. Section 4 presents the data and section 5 the estimation results. Concluding remarks are offered in section 6.

2. Choice Experiments, Structure of the Questionnaire and Survey Administration

A. Choice Experiments to Understand Preferences for Policies

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 one they prefer out of a set of K alternatives, usually goods or policy packages, where K≥2. The alternatives are defined by a finite set of attributes whose levels differ across alternatives. Respondents are usually asked to engage in several such choice tasks within one survey instrument in hope of collecting more information about preferences for any given number of completed questionnaires.

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 the current emissions, and iv) the cost of the policy to the respondent's household. Items iii) and iv) are expressed as per year for each of 10 years.

We included attribute iii) and iv) because they are essential for computing the WTP per ton of CO_2, our key research question. Unlike Longo et al. (2012), who focus on percentage reductions in greenhouse gas emissions with respect to national levels, we focus on household-level emissions associated with residential energy use, and specify the reductions in both tons and as a percentage of the baseline.

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, 2013; Cole and Brännlund, 2009; Kallbekken et al.

2010, 2011). Respondents that 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 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. 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 (or Czech) household. 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.

B. The Valuation Section of the Questionnaire

Prior to administering the choice experiment questions, we provided general information about public programs designed to reduce emissions of CO_2 from homes and buildings. The respondents were told that two major approaches to reducing CO_2 emissions from homes and buildings are possible. 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.

We then told respondents that we would be asking them to indicate their preferences for policies that attempt to reduce CO_2 emissions, and that these policies would be described in a stylized fashion by the four attributes listed in section 2.A. 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 taxes or 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 and to measure his or her energy literacy.

C. Questionnaire and Survey Administration

For both Italy and the Czech Republic, the choice experiments, the debriefing questions and the climate change belief questions were placed roughly in the middle of the questionnaire. The questionnaire ended with the usual questions about socio-demographics (family status, education, income, etc.).

The front-end of the questionnaire was slightly different across the two countries. In Italy, it focused on eliciting information about energy use and recent energy-efficiency upgrades in the respondent's home, while the Czech survey's emphasis was on recent or planned purchases of electric appliances such as refrigerators and washing machines. The design of the choice experiments was identical across the two surveys.

In Italy, 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 Italy survey was conducted in July 2014.

The Czech survey was conducted using CAWI in August and September 2014. The Czech sample was comprised of persons recruited from the panel of consumers maintained by a Czech survey firm, and was representative of the Czech population in terms of geography, age, gender, education and income. We received a total of 1385 completed questionnaires.

3. The Model

We posit that the responses to the conjoint choice questions are driven by a random utility model (RUM), where the indirect utility $\overline{V}$ from an alternative depends on the attributes of that alternative. Formally, we assume that

(1) $$\overline{V}_{ij} = \alpha_1 \cdot \mathbf{G}_{ij} + \alpha_2 \cdot \mathbf{M}_{ij} + \alpha_3 \cdot \Delta CO2_{ij} + \beta \cdot (y - C_{ij})$$

where **G** is a vector of dummies denoting the goal of the policy (to promote energy efficiency or renewables as a way to reduce CO_2 emissions), **M** is a vector of dummies denoting the specific mechanisms used by the policy (e.g., fossil fuel taxes, incentives, etc.), $\Delta CO2$ is the CO_2 emissions reduction per household delivered by the policy (in tons per year), y is the respondent's income and C is the cost of the program to the respondent's household. In equation (1), subscripts i and j denote the individual and the alternative, respectively, the αs are the marginal utilities and β is the marginal utility of income.

For simplicity, let $\mathbf{x}_j$ denote the attributes of alternative *j* other than its cost and $\boldsymbol{\alpha}$ the vector of their coefficients in equation (1). On appending an i.i.d. standard type I extreme value error term, ε:

(2) $$V_j = \mathbf{x}_j\boldsymbol{\alpha} + \beta(y - C_j) + \varepsilon_j = \overline{V}_j + \varepsilon_j,$$

it can be shown that the probability that alternative k is chosen is

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

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

When a respondent is asked to examine T choice cards, the log likelihood function is

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

where y_{itk} is a binary indicator denoting whether respondent *i* selects option *k* in choice exercise *t*. Coefficients $\boldsymbol{\alpha}$ and β are estimated by the method of maximum likelihood. The willingness to pay for a marginal change in the level of attribute *m* is obtained as $\hat{\alpha}_m / \hat{\beta}$, where the "hats" denote the maximum likelihood estimates. In practice, β is estimated by entering only cost, rather than residual income (*y*-*C*), in the model, so that the estimation routine produces the negative of β as the coefficient on cost.

Based on equations (1)-(4), we derive the willingness to pay for each ton of CO_2 emissions avoided as $\hat{\alpha}_3 / \hat{\beta}$. We interpret this as the "pure" willingness to pay per ton, after controlling for other policy attributes that may make one or the other policy more or less attractive to the respondents.

To examine interactions of policy instruments (for example, whether people are less strongly opposed to the carbon tax when incentives are also used), we amend equation (1) so that

M contains dummies with the four base policy instruments and the interactions of the carbon tax dummy with the other policy instruments. To study the income elasticity of the WTP per ton of CO_2 emissions reduced, we specify the following random utility model:

(5)
$$\overline{V}_{ij} = \alpha_1 \cdot \mathbf{G}_{ij} + \alpha_2 \cdot \mathbf{M}_{ij} + \left[\alpha_3 + \delta_1 \cdot HINC_i\right] \cdot \Delta CO2_{ij} + \\ + \left[\beta_1 + \theta_1 \cdot QRT1_i + \theta_2 \cdot QRT4_i + \theta_3 \cdot MISSINC_i\right] \cdot (y - C_{ij})$$

where HINC is recoded household income, and MISSINC is a dummy that takes on a value of one if the respondent declined to report income,[3] QRT1 denotes that the households falls in the first quartile of the sample distribution of income and QRT4 in the upper 25%. Equation (5) allows the marginal utility of emissions reductions to change linearly with household income (if reported by the respondent), and places the marginal utility of income in four discrete groups—that for persons that did not report income, that for persons at the bottom 25% of the distribution of income, that for persons at the top 25% of the distribution of income, and that for everyone else.[4]

If a household falls in the bottom 25% of the distribution of income in the sample, then its WTP per ton is $\frac{\alpha_3 + \delta_1 * HINC}{\beta_1 + \theta_1}$, while one in the top 25% of the distribution of income has WTP equal to $\frac{\alpha_3 + \delta_1 * HINC}{\beta_1 + \theta_2}$. All other households' WTP is $\frac{\alpha_3 + \delta_1 * HINC}{\beta_1}$, but $\frac{\alpha_3}{\beta_1 + \theta_3}$ if they fail to report their income.

It is straightforward to show that the income elasticity of the WTP per ton of CO_2 is

[3] When someone does not report his or her income, the recoded household income variable is zero and the missing income dummy MISSINC is equal to one. If someone does report income, then HINC is equal to the actual income amount and MISSINC is zero.
[4] Equation (5) is simplified to equation (1) if all δs and θs are equal to zero.

(6) $$\frac{\delta_1 * HINC}{\alpha_3 + \delta_1 * HINC},$$

and thus that it depends on income, as long as the household reports income. It is not possible to compute the income elasticity of WTP for those households that do not report their income in the questionnaire.

We expect the WTP per ton of CO_2 emissions reduced to increase with income. In other words, we expect δ_1 to be positive, θ_1 to be non-negative (poorer persons have greater or no smaller marginal utility of income) and $\theta_2 \leq 0$ (the wealthiest persons have lower marginal utility of income). If these expectations are borne out in the data, one implication is that the income elasticity of WTP per ton tends to one when income grows and to zero when income becomes very small.

To allow for different patterns of income elasticity of WTP, we estimate variants of RUM (5) where let the marginal utility of CO_2 emissions reductions to be quadratic in income:

(7) $$\overline{V}_{ij} = \alpha_1 \cdot \mathbf{G}_{ij} + \alpha_2 \cdot \mathbf{M}_{ij} + \left[\alpha_3 + \delta_1 \cdot HINC_i + \delta_2 \cdot HINCSQ_i\right] \cdot \Delta CO2_{ij} +$$
$$+ \left[\beta_1 + \theta_1 \cdot QRT1_i + \theta_2 \cdot QRT4_i + \theta_3 \cdot MISSINC_i\right] \cdot (y - C_{ij})$$

where HINCSQ is the square of household income. The income of elasticity of WTP per ton associated with this indirect utility is

(8) $$\frac{\delta_1 * HINC + 2\delta_2 * HINCSQ}{\alpha_3 + \delta_1 * HINC + \delta_2 * HINCSQ}.$$

Depending on the values of the coefficients, the income elasticity of WTP per ton can reach and exceed one.

4. The Data

Descriptive statistics of the respondents in each country are reported in table 2. The Czech sample is even in terms of gender, whereas males account for some 61% of the Italian sample. Even more important, the Czech and the Italy sample differ in terms of respondent educational attainment. Over a third of the respondents have a college or post-graduate degree in the Italy sample, but in the Czech sample this share is only about 14%, which mirrors the share in the general population of that country.[5] The Italian respondents are also more likely to have completed high school than their Czech counterparts (48% v. 36%, respectively).

Respondent education alone can explain why people place a different value on CO_2 emissions reductions. In this paper, however, we focus on the impact of income, and these differences in educational attainment are subsumed into the two samples' income levels. Regressions of household income on educational attainment dummies show a monotonic and significant relationship between them. This is the case in both Italy and the Czech Republic (results available from the authors).

About 10.6% of the Czech and 12.5% of the Italian respondents decline to report their income. On average, monthly net household income is 27,739 CZK or 1,696 PPS Euro (20,352 PPS Euro annual) for those Czech respondents who do report their incomes. Their Italian counterparts reported an average of 30,185 Euro/year (30,789 Euro PPS/year). These figures are reasonably similar to the national averages.[6]

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

[5] 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.

[6] In the 2014 Consumer Expenditure Survey, the average net household income was 30,489 CZK in the Czech Republic. Banca d'Italia (2015) reports that in 2014 the average after tax household income in 2014 was 30,500 Euro (see https://www.bancaditalia.it/pubblicazioni/indagine-famiglie/bil-fam2014/suppl_64_15.pdf).

table 3. Panel (A) of this table, which refers to the Italy sample, suggests that most of the Italian respondents have heard of climate change before and that very few dispute its existence. However, the first two rows of table 3, panel (A), suggest that there is some degree of confusion about ozone layer depletion and climate change. The distribution of the responses provided by the Czech respondents, shown in table 3, panel (B), is qualitatively similar, except that perhaps the Czech respondents are somewhat more agnostic, as suggested by the larger shares of "neutral" ratings.

Again, these differences between the two samples are subsumed into the two samples' incomes. Ordinal logit regressions of the ratings of statements G2_2 ("Climate change is caused by excessive GHG emissions"), G2_4 ("CO2 is one of the most important GHG"), G2_6 ""Climate change doesn't exist") and G2_8 ("I have never heard of climate change before") suggest that the higher household income, the more likely is the respondent to agree with these statements (when correct), disagree that climate change doesn't exist, and reject the notion that he or she has never heard of climate change before.

As shown in table 4, the responses to the policy choice questions appear to be reasonable: About 40% of the Italy survey respondents selected program A, 37% program B, and 23% opted for the status quo. The Czech shares are, in order, 33%, 36% and almost 31%. Clearly, the Czech respondents choose the current situation more often than the Italians, implying that their WTP for the policy packages should be lower. Table 5 shows that the responses are stable over the choice exercises, and that there is no obvious evidence of anomalies or unusual response patterns. This is the case for both the Italy and the Czech Republic respondents.

5. Results

A. Italy

We fit the conditional logit models of section 3 separately for the Italy and Czech Republic samples, and report the results in table 6. For good measure, the standard errors are clustered at the individual level, since we expect responses provided by the same subject to be potentially correlated.

The results from the Italy sample are reasonable and suggest that individuals were correctly trading off the attributes of the policies when selecting their most preferred ones. The status quo is the omitted category, and thus the positive and significant coefficients on the energy efficiency and renewables dummies indicate that these policies were generally preferred over the status quo.

The coefficient on the renewables dummy is greater than the one on the energy efficiency goal dummy, and a Wald test indicates that they are significantly different from one another at the conventional significance levels (Wald statistic: 23.31, p value less than 0.00001). It is possible that respondents failed to grasp the possible role of energy efficiency in reducing energy consumption and hence emissions, despite our effort in drafting the policy background material in the questionnaire. Alternatively, they may simply have a preference for renewables, because they appear more environmentally friendly than other options.

Our survey respondents also have a preference for incentives over other implementation options. The coefficient on fossil fuel taxes is negative and significant, and similar in absolute magnitude to those on energy efficiency standards and information-based approaches, but the latter two are statistically significant only at the 11% and 8% levels, respectively. Combining the fossil fuel tax with incentives, standards or information campaign does little to improve the appeal of such a tax (results available from the authors).

The larger the CO_2 emissions reductions delivered by the program, the more likely a respondent to choose that policy. The coefficient on CO_2 emissions reductions is positive and statistically significant at the conventional levels, which means that the responses to the choice tasks are sensitive to "scope" (Carson, 2012, p. 17 and others) and consistent with economic theory.[7] The lower the cost, the more attractive the policy, all else the same. Both of these effects are strongly statistically significant at the conventional levels. The willingness to pay for each ton of CO_2 emissions avoided is a very reasonable €130.21 (standard error €14.02).[8]

Table 7, panel (A), shows the results of the conditional logit that lets the marginal utility of the emissions reductions vary with income, but keeps the marginal utility of income constant with respect to income (i.e., the RUM in equation (5) with all θ coefficients set to zero). This table provides some initial evidence of heterogeneity in the WTP per ton of CO_2. As summarized in table 9, the WTP per ton is only 31.48 € (s.e. 23.37) when someone does not report his or her household income, and 144.01 € (s.e. 15.54) when they do. The WTP is 83.76 € (s.e. 15.77) for those with income in the bottom 25% of the distribution of income in the sample and 181.22 € (s.e. 8.88) for those in the top 25%. The income elasticity of the WTP per ton ranges from 0.54 to 0.90, for an average of 0.74 (table 7).

We report the results from the full RUM of equation (5) in table 7, panel (B). The marginal utility of emissions reductions does increase significantly with household income, but the marginal utility of income is different only for the respondents at the bottom 25% of the

[7] Briefly, the responses to stated preference questions are sensitive to scope when they imply that people are prepared to pay more for a larger quantity of the good to be valued or a broader, more comprehensive policy package.

[8] In 2014 PPS, these figures are 132.81 € (s.e. 14.30). The 2014 PPS equivalents are obtained through dividing the Czech crowns by 16.3563 and multiplying the Italy Euro by 1.02 (based on Eurostat 2014 data).

distribution of income in the sample, for whom it is about 62% greater than the rest of the sample. In practice, this means that the WTP is on average 160.92 Euro per ton of CO_2 emissions reduced (164.14 2014 PPS Euro), and that there is considerable heterogeneity in the sample, depending on income. The WTP is on average 182.92 € (s.e. 52.49) for those respondents who report their income, 67.02 € (s.e. 12.23) for those with income at the bottom 25% of the distribution of income in the sample, 228.86 € (s.e. 66.24) for persons with income equal to or greater than the top 25%, and only 39.10 € (s.e. 27.18) for those respondents who decline to report their income. (In 2014 PPS, these WTP figures are 174.32, 68.36, 233.44, and 39.88, respectively.)

As shown in Section 3, the income elasticity likewise depend on income, and is increasing in income as long as the marginal utility of emissions reductions is increasing in income (i.e., δ_1 is positive and the marginal utility of income is not increasing with income). We find that with this RUM specification it ranges from 0.51 to 0.89, for an average of 0.72. This is less than one, but not very far from one. Indeed, a simple calculation shows that the ratio between the WTP at the bottom and top 25% incomes is 0.29, and the ratio of the averages income within the first and fourth quartile is 0.35, suggesting an income elasticity of WTP slightly higher than one (about 1.15).

We attempted a model based on the RUM in equation (6), but found no evidence that the marginal utility of emissions reductions is quadratic in income. We also tried a mixed logit model that allowed all coefficients except for the marginal utility of income to be random variables, but found little evidence that parameters are random variables (with the only exception on the parameter on the carbon tax dummy).

B. Czech Republic

The results for the Czech Republic are striking. Much like the Italians, the Czechs favor renewable-oriented policies over energy efficiency, support emissions reductions, and are opposed to a carbon tax, although not quite with the same intensity as the Italians (table 6, panel (B)). All else the same, more expensive policies are judged less attractive, yielding a positive and significant marginal utility of income. Interactions between policy instruments do not improve the fit of the model.

The WTP per ton from the simplest model (the one in equation (1), and table 6, panel (B)) is 93.83 € (2014 PPS €). Could this figure be predicted using the WTP from the Italy sample, if adjustments were made for the different incomes? For people who report their income, the WTP per ton is 97.5 and 146.88 € (2014 PPS) for the Czech and Italian samples, respectively. The WTP ratio is thus 1.51. The average incomes are 20,351 and 30,789 € (2014 PPS), respectively, for an income ratio of 1.51. The implied income elasticity of WTP is thus exactly 1. This means that the WTP is strictly proportional to the income ratio between the two samples.

We would, however, arrive at a completely different conclusion if we had relied on the income elasticity of the WTP within each country's sample. The models of table 8 imply that the income elasticity of WTP in the Czech Republic sample is on average 0.35 in one specification and 0.46 in the other. Had we used Italy's WTP figure but the Czech Republic's income elasticity, which is very low, we would have overestimated the Czechs' WTP. Using the estimates from model (A) of table 7 and 8, we would have predicted the Czechs' WTP to be 124 2014 PPS € per ton, when the direct estimate is 97.50 €. Had we used Italy's WTP and income elasticity, we would have still overestimated the Czech WTP, but this time by less than 9 € (predicted 106 € v. direct 97.50 €).

In sharp contrast with the Italy sample, in the Czech sample the marginal utility of income actually appears to be greater for wealthier persons and the marginal utility of emissions reductions grows only weakly with income. The net effect, based on the results in table 8, panel (B), is that the average WTP per ton in the Czech sample is 93.85 2014 PPS Euro, and that there is a difference of only 9 PPS Euro between the WTP of persons in the bottom 25% of the distribution of income (95.24€ PPS) and in the top 25% of the distribution of income (104.85 € PPS). The WTP for persons that report their income is 101.83€ PPS (s.e. 11.56), that of persons who do not report their income 45.96 2014 € PPS (s.e. 17.58).

When we fit the conditional logit corresponding to the RUM of equation (6), we do find some evidence that the marginal utility of emissions reductions is quadratic in income for the Czechs. This model results in an even lower income elasticity of WTP—only 0.22. As for evidence that the coefficients are random, our mixed logit estimation results suggest that, much like for Italy, the one parameter that appears to be random, and to have a considerable amount of variation across the sample, is the one on the carbon tax attribute.

6. Discussion and Conclusions

We have used a standardized stated preference survey, which we administered on-line to a sample of homeowners in Italy and a sample that is representative of the population for geography, age, education and income in the Czech Republic, to answer three key research questions: First, what is the WTP per ton of CO_2 emissions reduced by a public program? Second, is this WTP reasonable? Third, how does income influence the WTP per ton?

We have found that the WTP for each ton of CO_2 emissions reductions delivered by public programs is 130 – 161 Euro (133 - 164 2014 PPS Euro) in Italy, depending on the model specification, and 94 2014 PPS Euro in the Czech Republic. These figures are reasonable when compared with estimates from other stated preference studies, in the sense that they fall roughly in the middle of the range of figures reported in these other studies. Our WTP figures are greater than those in the 2014 study by Diederich and Goeschl (6.30 Euro per ton) and smaller than the 332 Euro per ton from policies that promote energy efficiency in the Basque country (Longo et al., 2012) or the $967 (2005 $) from renewable energy programs in the Bath area in the UK (Longo et al., 2008).

We took great care to provide a context that respondents could relate to, and for this reason we chose residential energy consumption and household-level emissions. Our emissions reductions were expressed in both tons and as a percentage of the baseline, which was common across the two countries and was 5 tons CO_2 per year per household. This approach is in sharp contrast with others that have expressed the emissions reductions as (very small) percentage of Kyoto-agreed national target (Longo et al., 2008; Longo et al., 2012). We also set the time horizon for emissions reductions and payments at 10 years.

An alternative way to answer our second research question is to examine whether the responses were consistent with economic theory and whether respondents were sensitive to certain attributes of the policy packages in a manner similar to that reported in earlier studies. The results from our econometric models indicate that respondents were sensitive to scope (i.e., they were willing to pay more for greater emissions reductions) and, all else the same, less inclined to choose a more expensive policy package. They also indicated a preference for *how* the emissions reductions are delivered: They were opposed to a carbon tax (although in the

Czech Republic with less intensity than in Italy) and favored renewable energy over energy efficiency goals.

Finally, we found that the marginal utility of emissions reductions does increase with the respondent's household income, but the marginal utility of income varies with income in opposite directions in the two countries. In the Italy study, the marginal utility of income is higher among poorer households, while in the Czech Republic it appears to be higher among wealthier households. The net result is that the WTP grows with income in both samples, but much less so in the Czech Republic sample, where people at the bottom and top 25% of the distribution of income hold WTP amounts that are only 8 Euro apart. The income elasticities of WTP were low in the Czech Republic and about 0.7 in the Italy sample—but a direct "benefit transfer" from one country to the other implied an income elasticity of WTP of one. This suggests to us that an income elasticity of one might be a reasonable choice in many benefit transfer and integrated assessment modeling applications.

Finally, and perhaps even more important, Alberini and Bigano (2015) find that, based on a survey sample that largely overlaps with the sample of Italian respondents in this paper, the cost-effectiveness of residential energy efficiency policies is of the order of 279 Euro per ton of CO_2 emissions reduced. The existing residential energy efficiency program in Italy attains CO_2 emissions reductions at a cost per ton that is similar, or even higher (ENEA, 2009, 2015) suggesting that the current policy is much more expensive than what Italian households would be prepared to pay.

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Figure 1. Example of Choice Card used in the survey in the Czech Republic.

PRVNÍ VOLBA

Požádáme Vás celkem **pětkrát** volit mezi dvěma státními programy a současným stavem.

Uvažujte dva státní programy, program A a program B, které jsou popsány níže spolu se současným stavem.

	Program A	**Program B**	Současný stav
Cíle programu	Obnovitelné zdroje energie	Obnovitelné zdroje energie	-
Opatření programu	Daně na fosilní paliva + Informace	Daně na fosilní paliva	-
Snížení emisí CO_2 z domácností (ročně po dobu 10 let)	o 0.25 tun za rok (-5%)	o 1.65 tun za rok (-33%)	0 tun (žádné snížení)
Náklady na program pro Vaši domácnost (ročně po dobu 10 let)	800 Kč	2000 Kč	0 Kč
Upřednostnil/a byste program A, program B, nebo byste raději ponechal/a současný stav?	program A	program B	upřednostňuji stávající situaci

Table 1. Summary of attributes and attribute levels used in the conjoint 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) 400, 800, 2000, 5000 Czech crowns (Czech Republic)	4
	number of possible profiles	224

Table 2. Descriptive statistics of the respondents, percent or sample mean.

Variable	**Italy**	**Czech Republic**
Gender		
Male	61.59%	49.35%
Education		
high school diploma	47.78%	35.72%
college degree	26.47%	4.23%
Master's or PhD	7.16%	9.90%
Income		
After-tax annual household income (nominal, 2014 local currency or PPS €)		
Mean	€30,185	CZK 332,865 [PPS €20,351]
Median	€27,500	CZK 321,012 [PPS €19,626]
Bottom 25% of distribution of income, mean (exact 25th percentile)	€14,024 (€17,500)	CZK 152,000 [PPS €9,290] CZK 204,000 [PPS €20,351]
Top 25% of distribution of income, mean (exact 75th percentile)	€40,165 (€37,500)	CZK 538,000 [PPS €32,894] CZK 390,000 [PPS €23,845]
Missing income (refused)	12.54%	10.62%

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

(A) Italy

	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

(B) Czech Republic

	Completely disagree 1	2	Neutral 3	4	Completely Agree 5
The greenhouse effect is caused by a hole in the atmosphere	14.44	11.70	42.53	19.93	11.41
Climate change is caused by excessive greenhouse gas emissions	3.83	8.59	35.74	32.06	19.98
Climate change means that in the future the Earth will be warmer	9.68	14.15	40.87	22.96	12.35
Carbon dioxide is one of the most important greenhouse gases	3.68	6.64	38.99	30.97	19.71
Burning fossil fuels is the most important cause of greenhouse gases	4.26	9.75	46.14	26.79	13.07
Climate change doesn't exist	37.98	21.44	27.51	8.45	4.62
Actually, the Earth is globally cooling	15.38	16.97	43.31	11.70	6.64
I have never heard of climate change before	48.75	19.35	19.78	6.35	6.56

Table 4. Policy Choices made by the Respondents.

		Italy		Czech Republic	
	response	Freq.	Percent	Freq.	Percent
policy A	1	1,992	39.64	2301	33.23
policy B	2	1,869	37.19	2500	36.10
status quo	3	1,164	23.16	2124	30.67
	Total	5,025	100	6,925	100.00

Table 5. Responses by pair.

(A) Italy

Pair	response 1 = Policy A	2 = Policy B	3 = 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

(B) Czech Republic

Pair	response 1 = Policy A	2 = Policy B	3 = Status Quo	Total
1	523	476	386	1,385
	37.76	34.37	27.87	100
2	433	511	441	1,385
	31.26	36.90	31.84	100
3	405	539	441	1,385
	29.24	38.92	31.84	100
4	440	528	417	1,385
	31.77	38.12	30.11	100
5	500	446	439	1,385
	36.10	32.20	31.70	100
Total	2301	2500	2124	6,925
	33.23	36.10	30.67	100

Table 6. Conditional logit model. Dep. var.: Policy Choice. Full samples. Standard errors clustered at the individual respondent level.

	Italy		Czech Republic	
	Coeff	t stat	Coeff	t stat
energy efficiency	0.3490	3.84	0.1278	1.42
Renewables	0.5425	5.96	0.2025	2.28
Incentives	0.2919	3.98	0.2131	3.36
Standards	0.1191	1.61	0.1605	2.53
Tax	-0.1382	-3.19	-0.0411	-0.98
Info	0.1390	1.82	0.1341	2.00
CO_2	0.4292	11.28	0.3758	11.02
Cost	-0.0033	-15.98	-0.00024	-18.15
No obs.	15,075		20,910	
No ID	1,005		1,394	
Log likelihood	-5,157.17		-7289.83	
LR test of the null that all coefficients are zero	726.71		727.06	
P value	0.0000		0.0000	

Table 7. Conditional logit model with marginal utilities of emissions reductions and income that depend on income: Italy. Standard errors clustered at the individual respondent level.

	(A)		(B)	
	Coeff	t stat	Coeff	t stat
energy efficiency	0.3543	3.25	0.3589	3.30
Renewables	0.5568	5.12	0.5612	5.17
Incentives	0.2880	3.90	0.2879	3.90
Standards	0.1174	1.56	0.1168	1.56
Tax	-0.1362	-2.90	-0.1356	-2.89
Info	0.1408	1.76	0.1402	1.75
CO_2	0.1043	1.34	0.1139	1.44
CO_2 x HINC (10,000)	0.1240	4.77	0.1190	4.56
Cost	-0.0033	-13.31	-0.0026	-3.63
cost x QRT1			-0.0016	-1.86
cost x QRT4			-0.0006	-0.73
cost x MISSINC			-0.0003	-0.34
income elasticity,	0.744		0.722	
mean (s.d.)	(0.099)		(0.104)	
No obs.	15,075		15,075	
No ID	1,005		1,005	
LogLik	-5,124		-5,119	
Wald chi square	341.39		345.62	
Pseudo R^2	0.072		0.073	

Table 8. Conditional logit model with marginal utilities of emissions reductions and income that depend on income: Czech Republic. Standard errors clustered at the individual respondent level.

	(A)		(B)	
	Coeff	t stat	Coeff	t stat
energy efficiency	0.1287	1.43	0.1271	1.42
Renewables	0.2031	2.28	0.2031	2.28
Incentives	0.2144	3.38	0.2163	3.40
Standards	0.1600	2.52	0.1615	2.54
Tax	-0.0410	-0.97	-0.0424	-1.00
Info	0.1350	2.01	0.1369	2.04
CO_2	0.2487	3.40	0.2025	2.81
CO_2 x HINC(10,000)	0.0512	1.99	0.0703	2.76
Cost	-0.0002	-18.14	-0.0002	-12.25
cost x QRT1			0.0001	1.59
cost x QRT4			-0.0001	-1.91
cost x MISSINC			0.0000	-0.74
income elasticity, mean (s.d.)	0.346 (0.108)		0.464 (0.122)	
No obs.	20,910		20,910	
No ID	1,394		1,394	
LogLik	-7,284		-7,274	
Wald chi square	429.25		437.50	
Pseudo R^2	0.049		0.050	

Table 9. Summary of WTP figures.

(A) Italy. Nominal 2014 Euro in regular typeface. 2014 PPS Euro in boldface. Standard errors in parentheses. 2014 PPS Euro are obtained by multiplying nominal 2014 Euro by 1.02.

WTP per ton…	Model of table 6	Model (A) of table 7	Model (B) of table 7
Income not reported		31.48 **32.11** (23.37) **(23.84)**	39.10 **39.88** (27.18) **(27.72)**
Income reported		144.01 **146.89** (15.54) **(15.85)**	182.92 **186.58** (52.49) **(53.54)**
All	130.21 **132.81** (14.02) **(14.30)**	129.90 **132.50** (14.53) **(14,82)**	160.92 **164.14** (41.93) **(42.77)**
Bottom 25% income (subsample mean)		83.76 **85.43** (15.77) **(16.08)**	67.02 **68.36** (12.23) **(12.47)**
Top 25% income (subsample mean)		181.22 **184.84** (8.88) **(9.06)**	228.86 **233.44** (66.24) **(67.56)**

(B) Czech Republic. Nominal 2014 Czech crowns in regular typeface. 2014 PPS Euro in boldface. Standard errors in parentheses. 2014 PPS Euro are obtained by dividing nominal 2014 Czech crowns by 16.3563.

WTP per ton…	Model of table 6	Model (A) of table 7	Model (B) of table 7
Income not reported		1015.35 **62.06** (302.36) **(18.48)**	751.74 **45.96** (287.54) **(17.58)**
Income reported		1,595.38 **97.50** (157.09) **(9.60)**	1,665.56 **101.80** (189.14) **(11.56)**
All	1,535.33 **93.83** (153.04) **(9.35)**	1,533.80 **93.74** (163.07) **(9.97)**	1,535.04 **93.85** (165.20) **(10.10)**
Bottom 25% income (subsample mean)		1,280.12 **78.26** (199.33) **(12.19)**	1,557.81 **95.24** (313.29) **(19.15)**
Top 25% income (subsample mean)		1,952.88 **119.40** (262.30) **(16.04)**	1,714.98 **104.85** (236.28) **(14.45)**

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