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Willingness-to-pay and policy-instrument choice for climate-change policy in the United States

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HIGHLIGHTS

- First willingness-to-pay (WTP) estimates for actual national climate-change policy in the U.S.
- WTP does not vary among the instruments of a cap-and-trade program, a carbon tax, or a GHG regulation.
- There are differences in the characteristics of those willing to pay across policy instruments.
- No differences after controlling for opinions about whether global warming is actually happening.

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ABSTRACT

This paper provides the first willingness-to-pay (WTP) estimates in support of a national climate-change policy that are comparable with the costs of actual legislative efforts in the U.S. Congress. Based on a survey of 2034 American adults, we find that households are, on average, willing to pay between $79 and $89 per year in support of reducing domestic greenhouse-gas (GHG) emissions 17% by 2020. Even very conservative estimates yield an average WTP at or above $60 per year. Taking advantage of randomized treatments within the survey valuation question, we find that mean WTP does not vary substantially among the policy instruments of a cap-and-trade program, a carbon tax, or a GHG regulation. But there are differences in the sociodemographic characteristics of those willing to pay across policy instruments. Greater education always increases WTP. Older individuals have a lower WTP for a carbon tax and a GHG regulation, while greater household income increases WTP for these same two policy instruments. Republicans, along with those indicating no political party affiliation, have a significantly lower WTP regardless of the policy instrument. But many of these differences are no longer evident after controlling for respondent opinions about whether global warming is actually happening.

1. Introduction

The United States has experienced a changing landscape of potential policy instruments for the regulation of greenhouse-gas (GHG) emissions. Though no policy has been implemented at the national level, two recent efforts in the U.S. Congress centered on a "cap-and-trade" system of emission permits, whereby emissions would be capped at a maximum level, and firms could buy and sell pollution permits under the cap. More recently, many economists have advocated for a carbon tax on GHG emissions (e.g., Metcalf and Weisbach, 2009; Nordhaus, 2010), citing the climate and energy benefits, ease of administration, and potential government revenues. At present, however, the attention of policymakers is focused on the prospect of GHG regulation under authority of the Clean Air Act, which called for specific standards to be promulgated by the U.S. Environmental Protection Agency (EPA) (U.S. Environmental Protection Agency, 2011a, 2011b) and are now under review as the Carbon Pollution Standard for New Power Plants (U.S. Environmental Protection Agency, 2012).

Despite variation among the policy instruments for reducing emissions, debate about climate-change policy in the United States often centers more directly on the costs of taking action. Contributing to the debate is the fact that relatively little evidence exists on the willingness-to-pay (WTP) of households in support of climate-change policy and on the political acceptability of

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different policy instruments. This paper helps fill the gap with estimates of household WTP to reduce domestic GHG emissions in the United States. The estimates are based on a stated-preference (i.e., contingent valuation) question included in two nationally representative surveys, one in 2010 and one in 2011, with a combined sample size of 2034 American adults. While acknowledging that stated-preference estimates of WTP are sometimes questioned, we believe the estimates reported in this paper make an important contribution to the literature. Stated-preference surveys are the only way to estimate total economic value, which includes use values and non-use values and considerations for future generations; and the results of our survey provide the first WTP estimates of a national climate policy that are comparable with the costs of legislative efforts that have taken place in the U.S. Congress. The estimates thus establish a useful benchmark for other studies and policy analysis.[1] The results also provide a complement to other approaches that seek to quantify the benefits of climate-change mitigation with estimates of the social cost of carbon (SCC).[2]

Beyond the benefit estimates themselves, the paper also contributes to the literature on policy-instrument choice. We include in the valuation question three randomized treatments for the choice of policy instrument: a cap-and-trade program, a carbon tax, and a GHG regulation. These three policy instruments have received the greatest attention and serve as the basis for most political debate, and here we investigate the ways that instrument choice affects WTP. While the costs associated with different policy instruments may differ, economic theory implies that the benefits of meeting an emissions target should be invariant to instrument choice. Whether such invariance holds is therefore an important question of political economy. We emphasize that even if one questions the magnitudes of our WTP estimates, many of our findings are of interest because they are based on relative comparisons of randomized treatments, among which any methodological biases are constant.

We find that the mean WTP of U.S. households to reduce domestic GHG emissions 17% by 2020 – that is, the near-term target specified in recent U.S. House and Senate bills – ranges between $79 and $89 per year for the next 10 years. We also find empirical evidence that mean WTP does not vary substantially among the policy instruments of a cap-and-trade-program, a carbon tax, or a GHG regulation. But the sociodemographic characteristics do differ among those willing to pay for emission reductions under different policy instruments. While some of these differences are explained by political party affiliation, respondent beliefs about whether climate change is actually happening are even more important for explaining differences in WTP.

The remainder of the paper is organized as follows. The next section further motivates our analysis with a brief overview of leading efforts for national climate policy in the United States. Section 3 reports the details of our survey design and data collection, Section 4 describes our statistical methods and reports the results, and finally, Section 5 provides further discussion of the policy implications and concludes the paper.

2. Background on leading efforts for U.S. climate-change policy

On June 26, 2009 the U.S. House of Representatives passed the American Clean Energy and Security Act (ACES). Though it did not become law, the bill would have established targets for the reduction of domestic carbon-dioxide emissions and achieved them primarily through a cap-and-trade system. Among the key targets were a 17% reduction in emissions (below 2005 levels) by 2020 and an 80% reduction by 2050. In the Senate, the American Power Act (APA) was introduced as a draft bill on May 12, 2010 and also sought to establish a cap-and-trade system with similar emission targets, a 17% reduction by 2020 and a 83% reduction by 2050. A vote on the Senate bill was never taken despite much political attention during the summer of 2010.

Opposition to both the House and Senate bills tended to focus (and still does) on the economy-wide costs of reducing emissions. The Congressional Budget Office (CBO) estimates that ACES would cost the average American household $175 per year in 2020 but reported in $2010s (Congressional Budget Office, 2009). A comparable analysis by the EPA finds that ACES would cost households between $74 and $117 per year, which is the discounted average annual cost between 2010 and 2050 (U.S. Environmental Protection Agency, 2010a). In a separate study, the EPA also estimates the cost of implementing APA, with estimates ranging from $79 to $146 per household per year, which is again the discounted average cost between 2010 and 2050 (U.S. Environmental Protection Agency, 2010b).

Missing from the debate, however, is evidence on the economic benefits of addressing climate change through the emissions targets of such legislation. As explained in the U.S. EPA *Guidelines for Preparing Economic Analyses*, the economic benefits of an environmental policy are measured as the public's WTP to obtain the specified change in environmental quality (U.S. Environmental Protection Agency, 2010c). In what follows, therefore, we focus on estimates of household WTP to reduce domestic GHG emission 17% by 2020—that is, the near-term target specified in both the House and Senate bills. Our WTP benefit estimates are thus roughly comparable with the EPAs estimates of household costs. We say roughly comparable because the CBO and EPA estimates include the cost of emission reductions of 17% by 2020 and also further reductions of at least 80% by 2050. For purposes of comparison, therefore, our measure of WTP should be interpreted as an underestimate with respect to the ultimate emission target itself.

Currently, however, the EPA is exercising its authority under the Clean Air Act to regulate carbon dioxide as a pollutant, set targets for emission reductions, and establish mechanisms for achieving them. On March 27, 2012, the EPA announced a Proposed Carbon Pollution Standard for New Power Plants. The primary requirement of the standard is that electricity generating units must comply with an output-based emissions standard of 1000 pounds of CO_2 per MW-h of gross generation.[3] The proposed standards are currently under review and underscore the need for information on the benefits of GHG emission reductions and on how public support may differ among the choice of policy instruments.

3. Methods, data, and survey design

We conducted two surveys of Americans aged 18 and older using the nationally representative online research panel of Knowledge Networks. The surveys were conducted approximately one year

[1] Carlsson et al. (2010) also conduct a contingent valuation survey to estimate WTP for climate change mitigation. The aim of their study, however, was to make comparisons of WTP among different nations (i.e., China, Sweden, and the United States), rather than to estimate WTP for an actual legislative proposal within the United States.

[2] See the Interagency Working Group on the Social Cost of Carbon (2010) for the estimate of $21 per metric ton on CO_2 for use in regulatory impact analysis in the United States. Greenstone et al. (2011) also provide a useful summary.

[3] See Kotchen and Mansur (2012) for a detailed analysis of the stringency of the EPA's proposed carbon pollution standard.

Table 1
Summary statistics of respondent sociodemographic characteristics by year of survey.

	Survey year	
Variable	2010	2011
Education (years)	13.40	13.46
	(2.63)	(2.61)
Male (1=yes)	0.48	0.48
	(0.50)	(0.50)
Household size (# people)	2.72	2.87
	(1.60)	(1.69)
Income ($s)	56,605	60,826
	(43,265)	(45,516)
Age (years)	45.96	45.89
	(16.25)	(16.92)
Republican (1=yes)	0.22	23.4
	(0.41)	(0.42)
Democrat (1=yes)	0.38	30.9
	(0.49)	(0.46)
Independent (1=yes)	0.23	0.23
	(0.42)	(0.42)
No party (1=yes)	0.16	0.20
	(0.37)	(0.40)
Global warming "don't know"	0.21	0.18
	(0.41)	(0.38)
Global warming "no"	0.18	0.18
	(0.39)	(0.38)
Global warming "yes"	0.61	0.64
	(0.49)	(0.50)
Global warming "yes, very sure"	0.57	0.54
	(0.50)	(0.50)

Notes: Reported statistics are means and standard deviations (in parentheses) weighted for sample representativeness. The number of observations for all sociodemographic variables is 1024 and 1010 for the 2010 and 2011 surveys, respectively. There are 3 and 12 missing observations for the two surveys, respectively, for the global warming questions. The reported proportions for the "yes, very sure" global warming question are conditional on having answered "yes" to the previous question.

apart: the first between May 15 and June 1, 2010 and the second between April 23 and May 12, 2011. The samples were independent with sizes of 1024 and 1010 adults, respectively, yielding a total sample size of 2034 observations. The surveys were designed to evaluate public attitudes and knowledge about an array of climate and energy issues.

Table 1 reports descriptive statistics for the sociodemographic characteristics of respondents by survey year. Most of the variables are very consistent between the two samples. On average, respondents between 13 and 14 years of education, are 48% male, are 46 years old, have household incomes between $57,000 and $61,000, and have less than three people living in the household.[4] With respect to political party affiliation, just under a quarter align with the Republican party, while the same fraction categorize themselves as Independents. The only notable difference between surveys relates the fraction of respondents spilt between the Democratic party and indicating No Party.[5] The former drops from 38 to 31%, while the latter increases from 16 to 20% from 2010 to 2011.

We take advantage of two survey questions pertaining to respondent beliefs about climate change. These questions are intrinsically important given the diversity in public opinion about the reality of climate change, and as we will show, respondent beliefs are a significant explanatory variable of WTP. The first question was written as follows:

> *Recently, you may have noticed that global warming has been getting some attention in the news. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. What do you think? Do you think that global warming is happening? (select one answer)*
> *"Yes," "No," or "Don't know"*

Table 1 summarizes responses to this question: 18% answered "no" in both years; those answering "don't know" decreased from 21 to 18% from 2010 to 2011; and those answering "yes" increased from 61 to 64%. The second question was a follow-up conditional on having answered "yes":

> *How sure are you that global warming is happening? (select one answer)*
> *"Not at all sure," "Somewhat sure," "Very sure," or "Extremely sure"*

To simplify interpretation of subsequent analysis, we collapse the categorical responses to this question into a dummy variable indicating whether a respondent answered at least "very sure." As shown in Table 1, conditional on thinking that global warming is happening, 57% of the respondents are at least very sure that it is happening.[6] Both of these questions on respondent beliefs about global warming preceded the valuation question, which we now discuss and is our focus in this paper.

We elicit respondents' WTP to reduce domestic GHG emissions using the contingent valuation method. This is a stated-preference technique whereby respondents are directly asked about their WTP. Contingent valuation has been a source of debate about whether it yields unbiased estimates because the questions are hypothetical and do not require respondents to actually pay.[7] Nevertheless, stated-preference surveys are the only way to estimate total economic value, which includes both use and non-use values, and the technique is frequently used as part of regulatory impact analysis.

The survey included a valuation question that asked respondents their WTP to reduce domestic GHG emissions 17% by 2020. As part of the valuation question, we also included randomized treatments to investigate the potential effect of policy-instrument choice. The three policy instruments were a "cap-and-trade policy," a "carbon-tax policy," and a "policy to regulate carbon dioxide as a pollutant." As discussed previously, these three policy instruments have received the greatest attention and serve as the basis for most political debate. The specific question and response categories were as follows, where respondents were instructed to choose one of the specified dollar amounts or "don't know":

> *Congress is considering a [randomize "cap-and-trade policy" or "carbon tax policy" or "policy to regulate carbon dioxide as a pollutant"] that would reduce U.S. greenhouse gas emissions 17% by 2020. This policy would increase the cost of living for all American households. In support of this policy, what is the maximum amount your household would be willing to pay each year for the next 10 years? (select one answer)*
> *$0, $26, $60, $121, $157, $193, $250, $475 or more, Don't know*

[4] The annual household income variable is based on taking the mid-point values of 19 possible categorical responses; for example, a response of "$50,000 to $59,999" was coded as $55,000. The highest response category was "$170,000 or more," which we top coded at $187,000.

[5] The response category of No Party was actually worded in the survey "No party/not interested in politics." We also combined in this category a response of "Other, please specify," which accounted for only 3% of the sample.

[6] For completeness, we report the unweighted distribution of all four response categories: 4% for "not at all sure," 41% for "somewhat sure," 34% for "very sure," and 22% for "extremely sure."

[7] A series of important papers that cover different sides of the debate are Diamond and Hausman (1994), Portney (1994), and Hanemann (1994). The standard text which outlines best practices is Mitchell and Carson (1989), and more recent summary chapters are useful in Champ et al. (2003).

Table 2
Percentage distribution of willingness-to-pay responses by policy instrument and survey year.

Response	2010 Survey			2011 Survey		
	Cap-and-trade	Carbon tax	Unspecified policy	Cap-and-trade	Carbon tax	Unspecified policy
$0	34.1	31.4	29.6	25.8	30.5	26.2
$26	15.2	16.0	15.1	14.6	14.8	12.9
$60	10.3	12.5	12.1	16.3	15.4	16.4
$121	6.0	6.7	8.5	7.7	8.1	10.1
$157	4.0	2.3	4.2	2.6	1.7	2.8
$193	0.9	0.9	1.2	1.4	1.2	1.9
$250	3.2	4.9	6.0	4.0	4.4	3.8
$475 or more	3.4	2.3	1.8	2.9	2.6	2.8
Don't know	22.9	21.2	21.5	22.9	20.4	20.2
No answer	0.00	1.7	0.00	1.7	0.9	2.8
Observations	349	344	331	349	344	317

Notes: Columns may not sum to 100 due to rounding.

There was, however, one slight difference between the 2010 and 2011 questions. The 2011 question was exactly as indicated, but the 2010 version included only an GHG "policy" as the third treatment. This treatment was originally included as a comparison category for the cap-and-trade and carbon tax treatments, but because attention became focused on the likelihood of EPA regulating carbon dioxide as a pollutant, we chose to modify language of the treatment to more closely match the actual policy debate. To ease the discussion, we henceforth refer to both of these treatments as a "GHG regulation," and as we discuss later, we test for the validity of considering them as similar treatments.

Our choice of WTP increments for the survey question was based on a review of the literature. Existing studies provided useful, though not directly applicable, insights for developing priors about the WTP distribution. The existing studies differed from ours because they considered a smaller geographic area, such as the Front Range in Colorado (Layton and Brown, 2000), student samples of convenience (Cameron, 2005; Viscusi and Zeckhauser, 2006), or a policy of different scope than was valued in our study (Viscusi and Zeckhauser, 2006).

Nevertheless, using the existing results for guidance, we set two middle amounts of $157 and $193. We avoided using numbers of $150 or $200 because our experience is that people are more likely to answer yes to even amounts than odd numbers that are very close. Thus, our selection of bid amounts adds conservatism to the design of the valuation question, which is consistent with the recommendations of the NOAA Panel that set guidelines for the conduct of contingent-valuation surveys (Arrow et al., 1993). We then selected two WTP amounts that were lower ($60 and $121) and higher ($250 and $475). We then include $0 for those who would not pay anything, or close to nothing, for a 17% reduction in GHG emissions. Finally, we added $26 based on evidence that many people are likely willing to pay at least a modest amount in support of policies to reduce GHGs.

Because of space constraints in the survey instrument, no additional information was provided in the survey about differences between the three policy instruments of cap-and-trade, carbon tax, or GHG regulation. This means that the WTP estimates that we elicit are based on peoples' perceptions as they are without detailed information about the possible economic and political tradeoffs among the alternatives. Hence the estimates provided here represent a combination of public opinion and economic evaluation – that is, the real policy environment in which decisions must be made – rather than fully informed benefit estimates. Indeed, a primary objective of the research is to test whether WTP differs among the policy instruments for reasons based on public opinion.

Table 2 reports the percentage distributions of responses to the valuation question by survey year and policy treatment. Very few respondents refused to answer the WTP question, and just over 20% answered "don't know" for each treatment in each year. Among respondents not willing to pay anything, there is a noticeable decline from 34 to 26% for cap-and-trade between 2010 and 2011. The percentages remain steadier for the two alternatives, 31% for a carbon tax or 30–26% for a GHG regulation. In general, the frequency tends to decrease with the dollar amounts, with the exception of a pulse at $250, which is somewhat higher than the percent choosing the next higher category of $475 or more. We now turn to questions about how sociodemographic variables and the policy treatments explain the pattern of these responses, which are then used to derive estimates of WTP.

4. Analysis of willingness-to-pay responses

We begin with an analysis of what explains the "don't know" responses to the valuation question. The challenges of climate change communication to the public are well-known (e.g., Sterman, 2011; Pidgeon and Fischhoff, 2011), and public opinion can be an important influence on the success or failure of policy proposals. It is thus important to understand the factors that explain why some people are unsure about their own WTP in support of climate-change policy. To study the question, we estimate linear probability models in which the dependent variable indicates whether the respondent answered "don't know" to the valuation question. The independent variables are the sociodemographic characteristics of the respondent. We estimate and report separate models for each policy treatment in each year.[8]

Table 3 reports the linear probability models of "don't know" responses.[9] Greater education tends to decrease the probability that a respondent answers "don't know," and the result is statistically significant for a carbon tax in 2010 and a GHG regulation in 2011. Males tend to be less likely to respond "don't know", especially when asked about cap-and-trade in 2010, when

[8] We also estimated pooled models and conducted likelihood-ratio tests to determine whether the set of sociodemographic variables explain the "don't know" responses in a way that differs significantly by both policy instrument and year. Because the results were mixed, we report separate models for each treatment and year. For completeness, however, the results of the likelihood-ratio tests for pooling of the "don't know" models in Table 3 are the following: 2010 models $\chi^2=42.08$, $p=0.01$; 2011 models $\chi^2=28.54$, $p=0.16$; cap-and-trade models $\chi^2=12.03$, $p=0.36$; carbon tax models $\chi^2=32.26$, $p=0.00$; GHG regulation models $\chi^2=20.17$, $p=0.04$.

[9] We also estimated logit and probit models that produce very similar marginal effects. Because the magnitudes are so similar and the qualitative significance of variables remains the same, we do not report the results here, preferring to focus on the more easily interpreted linear probability models.

Table 3
Linear probability models of "don't know" responses to the willingness-to-pay question by policy treatment and year of survey.

Variable	2010 Survey			2011 Survey		
	(1) Cap-and-trade	(2) Carbon tax	(3) GHG regulation	(4) Cap-and-trade	(5) Carbon tax	(6) GHG regulation
Education	−0.013	−0.039***	0.003	−0.008	0.001	−0.018*
	(0.011)	(0.009)	(0.009)	(0.010)	(0.009)	(0.011)
Male	−0.134***	−0.092*	−0.032	−0.018	0.017	−0.102**
	(0.049)	(0.047)	(0.045)	(0.046)	(0.043)	(0.046)
Household size	−0.001	−0.013	−0.001	0.043**	0.019	0.041***
	(0.016)	(0.016)	(0.015)	(0.018)	(0.016)	(0.015)
Income ($10,000s)	−0.005	0.002	0.003	−0.010*	−0.012**	−0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)
Age	0.002	−0.000	0.005***	−0.001	0.003**	0.003
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
Republican	−0.070	−0.175***	0.009	−0.065	−0.130**	0.038
	(0.066)	(0.066)	(0.064)	(0.065)	(0.061)	(0.065)
Independent	−0.133**	−0.094	−0.003	−0.093	−0.160***	−0.028
	(0.065)	(0.061)	(0.062)	(0.065)	(0.059)	(0.060)
No party	−0.040	−0.007	0.087	−0.034	−0.072	0.095
	(0.070)	(0.071)	(0.069)	(0.064)	(0.063)	(0.071)
Global warming "no"	−0.125*	−0.210***	−0.090	−0.265***	−0.384***	−0.229***
	(0.074)	(0.077)	(0.073)	(0.077)	(0.077)	(0.078)
Global warming "yes"	−0.009	0.063	−0.034	−0.131**	−0.252***	−0.155**
	(0.059)	(0.058)	(0.059)	(0.063)	(0.059)	(0.062)
Constant	0.538***	0.906***	−0.029	0.509***	0.375**	0.420**
	(0.182)	(0.175)	(0.170)	(0.174)	(0.172)	(0.188)
Observations	348	337	330	341	341	307
R-squared	0.088	0.139	0.042	0.083	0.152	0.124

Notes: The dependent variable is an indicator for whether the respondent answered "don't know" to the valuation question. All regressions are weighted for sample representativeness. Standard errors are reported in parentheses. Democrat is the omitted category for political party, and "global warming 'don't know'" is the omitted category for the global warming question. The relatively few respondents that refused to answer the WTP question are excluded from the models reported here. *, **, *** indicate statistical significance at the 90, 95 and 99% levels, respectively.

they were 13.4 percentage points less likely to respond "don't know" than female respondents. Respondents in larger households tended to be more likely to respond "don't know" for policy treatments in 2011. The effect is largest for cap-and-trade, whereby an additional person in the household increases the probability of a "don't know" response by roughly 4 percentage points. When statistically significant, greater income decreases the probability of a "don't know" response, as is the case for cap-and-trade and a carbon tax in 2011, in which cases a $10,000 increase in annual household income increases the probability of a "don't know" response by approximately one percentage point. There is evidence that older respondents are more likely to respond "don't know" for a GHG regulation in 2010 and a carbon tax in 2011.

We find that Republicans and Independents are less likely to answer "don't know" than are Democrats, the omitted category. The coefficient estimates on these variables are negative in 10 of 12 instances, and are negative and statistically significant in four instances. When it comes to a carbon tax, Republicans are significantly less likely to respond "don't know;" they are 18 and 13 percentage points less likely than Democrats in 2010 and 2011, respectively. Independents are 16 percentage points less likely than Democrats to answer "don't know" for a carbon tax in 2011, and they are 13 percentage points less likely for cap-and-trade in 2010. Respondents with the No party categorization are not statistically different from Democrats in any of the models.

The most robust results are for the variables "global warming 'no'" and "global warming 'yes,'" which are interpreted relative to "global warming 'don't know,'" the omitted category. People who think that global warming is not happening are significantly less likely to answer "don't know" about their WTP in five of the six cases. People who think that global warming is happening are also significantly less likely to answer "don't know," but only for the policies in 2011. Moreover, when comparing the two groups to each other in 2011, we find statistically significant differences for cap-and-trade and a carbon tax (both with $p<0.05$); in both cases, those who think global warming is happening, compared to those who do not, are roughly 13 percentage points more likely to respond "don't know." These results suggest that that while there are more people who think global warming is happening than is not happening (64 *vs.* 18% in 2011, Table 1), people who think global warming is happening are less certain about their WTP in support policies to reduce GHGs. One possible explanation of these results is that even individuals who think global warming is happening still remain unclear about how policies to reduce domestic GHGs will affect global warming.

While it is not surprising that people who have more certain opinions about global warming would be less likely to answer "don't know" to questions about WTP for policies to reduce GHG emissions, it is somewhat surprising that people who are certain the global warming is happening were not less likely to answer "don't know" in 2010. A potentially related observation is that fewer coefficient estimates are statistically significant in 2010 than 2011. In 2010 the number of variables with significant coefficients ranges from one (GHG regulation) to four (carbon tax) and the range for 2011 is four (cap-and-trade) to six (carbon tax). Together, these results suggest that as discussions about global warming and GHG emissions have progressed over time, people may be becoming more organized (for good or bad) in their thinking and preferences about the problem and potential solutions.

We now turn to analysis of WTP responses to the valuation question. Consider a model in which a respondent's true WTP is a linear function of his or her sociodemographic characteristics: $WTP^* = \alpha + \beta' X + \varepsilon$, where WTP* is a respondent's true but unobserved WTP, X is a vector of sociodemographic variables, and ε is a normally distributed error term. Despite not observing WTP*, it is possible to obtain unbiased estimates of α and β using a censored regression model, whereby for each respondent we only observe

Table 4
Censored regression models of willingness-to-pay responses by policy treatment.

Variable	Model					
	(1) Cap-and-trade	(2) Carbon tax	(3) GHG regulation	(4) Cap-and-trade	(5) Carbon tax	(6) GHG regulation
Education	6.240***	5.490***	3.678*	5.702***	4.088**	3.566**
	(1.910)	(1.735)	(1.879)	(1.711)	(1.660)	(1.758)
Male	−3.813	10.555	2.464	−0.534	8.853	2.235
	(9.195)	(8.724)	(8.776)	(8.283)	(8.229)	(8.292)
Household size	−1.766	−11.190***	−4.258	−2.063	−7.818***	−4.489
	(3.447)	(3.062)	(3.010)	(3.081)	(2.913)	(2.822)
Income ($10,000s)	0.801	5.768***	2.245*	1.210	5.077***	2.365**
	(1.150)	(1.051)	(1.198)	(1.031)	(1.000)	(1.121)
Age	0.349	−0.957***	−0.895***	0.398	−0.599**	−0.822***
	(0.293)	(0.294)	(0.312)	(0.263)	(0.284)	(0.293)
Republican	−37.343***	−54.552***	−54.066***	0.609	−28.190**	−18.034
	(12.473)	(11.462)	(11.656)	(11.693)	(11.443)	(11.945)
Independent	−9.986	1.543	−18.636	12.005	17.533	8.532
	(12.453)	(11.664)	(11.371)	(11.353)	(11.169)	(11.163)
No party	−24.781*	−31.954**	−32.735**	−0.139	−18.327	−8.996
	(13.612)	(13.251)	(13.869)	(12.360)	(12.710)	(13.340)
Global warming "no"	–	–	–	−28.672**	−19.826	−28.129**
				(13.077)	(13.707)	(14.025)
Global warming "yes"	–	–	–	21.687*	9.062	14.408
				(12.587)	(12.959)	(12.905)
Global warming "yes, very sure"	–	–	–	57.742***	59.694***	54.216***
				(10.668)	(10.484)	(10.640)
Year 2011	2.741	4.803	7.843	−5.473	−1.835	7.269
	(9.217)	(8.636)	(8.942)	(8.289)	(8.211)	(8.409)
Constant	−1.888	61.274*	93.800***	−42.919	26.586	52.696
	(33.130)	(32.563)	(33.745)	(31.025)	(31.609)	(32.838)
Observations	532	536	504	529	535	502

Notes: The dependent variable is the censored responses to the valuation question excluding the "don't know" and missing responses. All regressions are weighted for sample representativeness. Standard errors are reported in parentheses. Democrat is the omitted category for political party, and "global warming 'don't know'" is the omitted category for the global warming question. *, **, *** indicate statistical significance at the 90, 95 and 99% levels, respectively.

whether WTP* lies somewhere within an interval [a,b], as is the case with our data.[10]

We first estimate models excluding the "don't know" and refusal responses, as it is a standard practice when analyzing stated-preference data and has been shown as legitimate for maintaining sample representativeness (Krosnick et al., 2002). As a point of comparison, however, we later include the observations in models that conservatively assume these responses represent a WTP of zero (Carson et al., 1998). We report in Table 4 the results based on data pooled by year and separately for each of the three policy instruments.[11]

Columns (1–3) in Table 4 report results for the first set of models, which include the socio-demographic variables but not those about whether respondents think global warming is happening (we include those next). There are no statistically significant differences in WTP responses between the 2010 and 2011 surveys, as indicated by the coefficient on the dummy variable for Year 2011 in all three models. We find that higher educational attainment is associated with greater WTP for all three policy instruments: each year of education increases WTP somewhere between roughly $4 and $6 per year. While gender has no statistically significant effect on WTP regardless of the policy instrument, household size has a negative and significant effect on WTP through a carbon tax, whereby an additional member of the household decreases WTP by approximately $11. Household income has a positive effect on WTP for a carbon tax and a GHG regulation; a $10,000 increase in annual household income increases annual WTP nearly $6 and just over $2 for the two policy instruments, respectively. These results are consistent with the finding of other studies that find positive income elasticities of WTP for environmental goods in the United States and other nations (e.g., Kristrom and Riera, 1996; Hökby and Söderqvist, 2003). Older respondents have a lower WTP for these same two instruments, with magnitudes such that an additional year decreases WTP close to $1.[12] One possibility for this result is that older respondents are willing to pay less because they are less likely to be around to experience any negative consequences of future climate change. Regarding political party affiliation, the WTP of Republicans is significantly less than that for Democrats in all three cases with magnitudes of $37 for cap-and-trade, $55 for a carbon tax, and $54 for a GHG regulation. Independents are not statistically different from Democrats, but respondents with No party affiliation are, with a lower WTP of $25 for cap-and-trade, $32 for a carbon tax, and $33 for a GHG regulation.

The models in columns (4–6) include the variables on whether respondents think global warming is happening and, for those who think "yes," the further indicator for whether they are at least "very sure." Results for the new variables are of interest themselves, but their inclusion in the models has noteworthy effects on the other coefficients as well, which is why we present

[10] Specifically, the response categories to our valuation question lead to a natural censoring as follows: $0∈[0,26), $26∈[26,60), $60∈[60,121), $121∈[121,157), $157∈[157,193), $193∈[193,250), $250∈[250,475), 475 or more∈[475,∞).

[11] Here again, for completeness, we report the likelihood-ratio test results that support our level of data aggregation for the models reported in Table 4. Based on the specifications in columns (1–3), the test results are as follows: cap-and-trade models $\chi^2=13.67$, $p=0.19$; carbon tax models $\chi^2=15.04$, $p=0.13$; GHG regulation models $\chi^2=11.94$, $p=0.29$; pooling all three policy instruments for both years $\chi^2=76.01$, $p=0.01$.

[12] We also estimated specifications with both age and income included with a quadratic functional form, but these results were not statistically significant.

both sets of specifications. Compared to those who are unsure about whether global warming is happening (the omitted category), respondents who think it is not happening have a lower WTP. The result is statistically significant for cap-and-trade and a GHG regulation, whereby WTP is $28 lower in both cases. Results for those who think global warming is happening are estimated separately for respondents who are less sure and those who are at least very sure. Coefficients on "global warming 'yes'" correspond with the less sure respondents, and while the sign of all three coefficients is positive, only the one for cap-and-trade is statistically significant, indicating a greater WTP of $22. Note that this is $50 more than for those who think global warming is not happening. But the differences are even more pronounced for those who are at least very sure that global warming is happening. All of the coefficients on "global warming 'yes, very sure'" are positive and statistically significant and are interpreted as the difference in WTP between those who are at least very sure and those who are less sure that global warming is happening. The results clearly show that greater confidence in one's opinion has a large effect on WTP, between $54 and $60 for all three policy instruments.[13] Moreover, the difference between these respondents and those who think global warming is not happening is $108 for cap-and-trade, $89 for a carbon tax, and $97 for a GHG regulation.[14]

Differences in the results between columns (1)–(3) and (4)–(6) occur because of inclusion of the global warming questions as explanatory variables. While the qualitative pattern for most of the sociodemographic variables remains much the same, many of the coefficients have smaller magnitudes. There are, however, substantial differences in the effect of political party affiliation. After controlling for opinions about global warming, the WTP of Republicans is no longer statistically different from that of Democrats, except when it comes to a carbon tax, in which case the magnitude is reduced 50%. Those indicating no party affiliation become statistically indistinguishable from Democrats in all three cases. Together, these differences point to the importance of understanding public opinion about climate change that goes beyond simply relying on political party affiliation, for without doing so, models of the type presented here are susceptible to significant omitted variable bias.

We also estimate, as mentioned above, models with the same specifications but including all the "don't know" and refusal responses under the assumption that they represent a WTP of zero. We estimate these models to test the robustness of our results under a very conservative assumption about what the WTP might be of those who are unsure about or refuse to report their WTP. We report these results in an Appendix Table in parallel with those reported in Table 4. The general pattern of results remains quite similar, with some coefficients changing statistical significance. One noticeable change is that Independents emerge as having a higher WTP than Democrats after controlling for opinions about whether climate change is happening. In general, however, the magnitudes of many coefficients become lower, and this is not surprising given that inclusion of the "don't know" and refusal responses as indicating a WTP of zero effectively decreases the overall mean WTP, which we now discuss for models that both exclude and include these responses.

The final step of our analysis is to use the censored regression models to predict WTP* to reduce domestic GHG emissions 17% by 2020. Our approach is to simply predict WTP* using the estimated parameters for each observation upon which the models were estimated. This yields empirical distributions of WTP* that we use directly to calculate the weighted means, 95% confidence intervals of the means, and medians. Table 5 reports the WTP results corresponding to the models that include the global warming opinion variables. Panel A includes the results based on models in Table 4 when "don't know" and refusal responses are omitted from the analysis. The estimate of annual mean WTP for the next 10 years ranges from $79 for cap-and-trade to $89 for a GHG regulation, with a carbon tax in the middle at $85. Inspection of the confidence intervals indicates no significant differences between cap-and-trade and a carbon tax, and between a carbon tax and a GHG regulation. But, interesting, the confidence intervals do not overlap for cap-and-trade and a GHG regulation, suggesting that WTP is in fact higher for the latter. Panel B reports results based on the corresponding models that include "don't know" and refusal responses as indicating a WTP of zero. Not surprisingly, the inclusion of these observations under such a conservative assumption has a significant effect on the results. Mean WTP decrease by approximately 25%: $58 for cap-and-trade, $63 for a carbon tax, and $70 for a GHG regulation. With these estimates, the confidence intervals suggest no meaningful differences in WTP across policy treatments.

Table 5
Means, confidence intervals, and medians for willingness-to-pay by policy treatment and inclusion or exclusion of "don't know" and non-response observations.

Statistic	Treatment		
	(2) Cap-and-trade	(3) Carbon tax	(4) GHG regulation
Panel A (excluding "don't know" and non-response observations)			
Mean WTP	79	85	89
95% confidence interval	75–83	80–90	86– 93
Median WTP	72	80.09	90
Observations	529	535	502
Panel B (including "don't know" and non-response observations as WTP of zero)			
Mean WTP	58	63	70
95% confidence interval	55–60	60–67	67–73
Median WTP	56	60.74	68
Observations	692	686	641

Notes: Statistics report in Panel A correspond with predictions based on the corresponding censored regression models reported in columns (4), (5), and (6) of Table 4. Those reported in Panel B correspond with models in columns (4), (5), and (6) in the Appendix Table. All statistics are weighted for sample representativeness.

5. Discussion and conclusion

This paper provides the first WTP benefit estimates of a national climate policy that are comparable with the costs of actual legislative proposals considered by the U.S. Congress. The magnitude of mean WTP of households in support of a 17% reduction in domestic GHG emissions by 2020 stands in contrast to frequently made arguments that the costs of GHG policies are grossly disproportionate to the received benefits. Our analysis indicates that households are willing to pay, on average, between $79 and $89 per year in support of a 17% reduction in emissions by 2020. Moreover, these estimates meet or exceed the EPA's lower-bound estimates of actually meeting the target through either the Waxman–Markey bill in the House ($74) or the Boxer–Kerry bill in the Senate ($79), but they are below the CBO estimates for the Senate bill ($175) Importantly, though, it should be recognized that the cost estimates for the House and Senate

[13] These results are consistent with those of other studies finding that greater certainty about global warming is positively associated with WTP for mitigation (Cameron, 2005; Viscusi and Zeckhauser, 2006).

[14] These numbers come from the difference between the coefficient on "global warming 'no'" and the sum of the coefficients on "global warming yes'" and "global warming 'yes, very sure.'"

bills include additional reductions of at least 80% by 2050, meaning that our WTP estimates should be considered an underestimate of the benefits for purposes of comparison. The result implies that the average per household public benefit of implementing these policies may exceed the per household cost. Finally, even under a very conservative assumption, that survey respondents answering "don't know" to the valuation question have a WTP of zero, we find substantial benefits, with an overall mean WTP at or above $60 per year. While the estimates considered here quantify WTP of households and actually costs of implementing the policy, other costs and benefits that occur because of uncertainties and additional nonmarket effects might be important as well.

There is, however, more to learn from our analysis than the benefit estimates themselves, due to the investigation of "don't know" responses and especially the comparisons between randomized policy treatments. When asked about their WTP in support of climate-change policy, just over 20% of the survey respondents answered that they do not know. Regardless of the policy instrument, an important predictor of these responses is uncertainty about whether people think climate change is happening, and this is especially true in the more recent 2011 survey. The result emphasizes the importance of climate-change communication to the public in order the more clearly evaluate public support for various GHG policies. We also find that uncertainty about WTP tends to be greater among older respondents with less education, along with larger households and lower annual income. Interestingly, uncertainty about WTP also tends to be greater among Democrats compared to Republicans and Independents, and this effect appears strongest in 2011 when asked about emission reductions that would occur through a carbon tax.

When it comes to actual WTP responses, the explanatory power of sociodemographic variables differs across the policy treatments. Greater education always increases WTP, but household size decreases WTP, particularly when asked about a carbon tax. Older individuals have a lower WTP for a carbon tax and a GHG regulation, while greater household income increases WTP for these same policy instruments. Republican and No party respondents (who differ from Independents) have a significantly lower WTP in support of emission reductions regardless of the policy instrument, but their difference from Democrats is greatest when it comes to a carbon tax or a GHG regulation. This result is perhaps unsurprising given the political economy of tax policy and the positions of both parties. Nevertheless, most of the differences due to political party affiliation no longer hold after controlling for whether respondents think that global warming is happening. People who are very sure that global warming is happening have a WTP that is significantly higher than those who think it is not happening and those who think it is happening with less certainty. But even after accounting for these differences, when it comes to support for a carbon tax, Republicans continue to have a significantly lower WTP.

In conclusion, policymakers will benefit from taking the insights of our analysis into account when they evaluate new initiatives for climate-change policy. The current state of affairs is one in which political support for cap-and-trade has diminished, supporters of a carbon tax are becoming more vocal, and the Obama administration is advocating GHG regulations through EPA authority. While the costs of different policy instruments are likely to differ, economic theory implies that the benefits of meeting a specific emissions target should be invariant to the instrument choice. We find empirical evidence that mean WTP for

Table A1
Censored regression models of willingness-to-pay responses by policy treatment and inclusion of "don't know" and non-response observations.

Variable	Model					
	(1) Cap-and-trade	(2) Carbon tax	(3) GHG regulation	(4) Cap-and-trade	(5) Carbon tax	(6) GHG regulation
Education	5.846***	6.220***	3.947**	5.402***	5.011***	3.443**
	(1.591)	(1.475)	(1.596)	(1.491)	(1.442)	(1.537)
Male	3.621	12.701*	6.477	3.753	11.552*	6.360
	(7.295)	(7.207)	(7.384)	(6.857)	(6.992)	(7.163)
Household size	−3.228	−7.962***	−4.825**	−4.009	−6.958***	−5.240**
	(2.614)	(2.312)	(2.414)	(2.460)	(2.249)	(2.334)
Income ($10,000s)	1.343	4.784***	1.256	1.488*	4.376***	1.463
	(0.915)	(0.891)	(0.979)	(0.855)	(0.864)	(0.942)
Age	0.241	−0.731***	−1.025***	0.253	−0.584**	−1.051***
	(0.225)	(0.238)	(0.261)	(0.211)	(0.234)	(0.253)
Republican	−18.630*	−27.737***	−38.859***	3.489	−9.660	−13.758
	(9.877)	(9.585)	(9.796)	(9.587)	(9.921)	(10.200)
Independent	5.934	15.322	−7.837	18.382*	25.987***	11.324
	(10.018)	(9.594)	(9.630)	(9.485)	(9.437)	(9.697)
No party	−13.587	−21.749**	−29.062***	0.559	−9.871	−14.050
	(10.204)	(10.420)	(11.188)	(9.674)	(10.290)	(10.957)
Global warming "no"	–	–	–	−17.550	−8.139	−16.458
				(10.993)	(11.888)	(11.769)
Global warming "yes"	–	–	–	19.117*	9.934	16.054
				(10.029)	(10.196)	(10.599)
Global warming "yes, very sure"	–	–	–	35.726***	43.636***	43.604***
				(8.705)	(8.764)	(9.206)
Year 2011	3.396	6.615	4.682	−1.070	4.993	7.270
	(7.261)	(7.111)	(7.413)	(6.808)	(6.884)	(7.144)
Constant	−25.939	4.629	77.951***	−50.071*	−14.303	51.986*
	(27.027)	(26.603)	(27.833)	(25.924)	(26.246)	(27.725)
Observations	698	688	648	692	686	641

Notes: The dependent variable is the censored responses to the valuation question including the "don't know" and missing responses as indicating a willingness-to-pay of zero. All regressions are weighted for sample representativeness. Standard errors are reported in parentheses. Democrat is the omitted category for political party, and "global warming 'don't know'" is the omitted category for the global warming question. *, **, *** indicate statistical significance at the 90, 95 and 99% levels, respectively.

a 17% reduction of GHG emissions by 2020 does not vary in a substantial way among the policy instruments of a cap-and-trade-program, a carbon tax, or a GHG regulation. But the socio-demographic characteristics of who is willing to pay, and how much, does differ by the instrument choice. Combined, the empirical results of this paper support the notion of an economic justification for controlling domestic GHG emissions, but they illuminate the ways in which policy-instrument choice can significantly affect public support.

Appendix A

See Appendix Table A1.

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