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Analysis

Valuing climate protection through willingness to pay for biomass ethanol

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ABSTRACT

This study uses a multi-part, split-sample contingent valuation method (CVM) and fair share (FS) survey to better understand the public's valuation of mitigating global climate change through its willingness to pay for biomass or "cellulosic" ethanol. In addition to a basic CVM question, a related scenario was developed that asked half of the survey respondents to state their fair share cost to lessen a potential food shortage in the next decade, also through the expanded use of cellulosic ethanol. Three alternative biomass feedstocks were assessed: farming residues, forestry residues and paper mill wastes, and municipal solid wastes. Overall a slightly larger proportion of respondents were WTP extra for cellulosic ethanol in the basic CVM scenario than in the FS scenario, though no significant differences were found in the WTP for the different feedstocks. Bid curve lognormal regression results for the two models were similar, supporting the idea that asking a FS rather than a conventional WTP question may be justifiable in some circumstances, such as in cases of a national emergency.

1. Introduction

There is little remaining doubt that global climate change and climate disruption are not only serious and enduring problems, but also extremely urgent ones. A countless stream of studies at the national and international level have underscored this consensus, and the environmental, economic and social perils facing humanity if it fails to act in time (e.g., McKibben, 1989; Houghton, 2004; Lovejoy and Hannah, 2006; Parry et al., 2007; Metz et al., 2007; Stern, 2007). Indeed, if the pronouncements of leading climate scientists such as James Hansen and Steve Schneider are correct, the world has under a decade to dramatically lower its carbon dioxide (CO_2) and other major greenhouse gas emissions in order to stave off the worst effects of global climate change (e.g. Sheppard, 2007). Unfortunately, it may be a cruel irony that this most urgent of problems also appears to be one of the most difficult ones to solve. As noted by Hempel (2006, p. 299), "the economic implications of that fledgling consensus is inimical to the interests of powerful stakeholders. Uncertain, potentially catastrophic, complex beyond human comprehension, and susceptible to costly overreaction and underreaction by partisan policymakers, climate issues offer a revealing glimpse of what happens when probabilistic science meets the crystallized objectives of interest group politics."

It is natural for most citizens of a democracy to expect their government to not only warn them of major social and environmental problems, but also to enact timely policy responses. At the international level this has taken the form of the Kyoto Protocol to the Framework Convention on Climate Change, which entered into force on February 16, 2005 without U.S. participation. While little real progress toward emissions targets has been made thus far among the signatories, follow-up international discussions are continuing, most recently at the UN Climate Change Conference in Poznan, Poland in December 2008 (Toleffson, 2008). Although the U.S. Congress has yet to pass meaningful climate legislation, 17 U.S. states have developed their own CO_2 emissions reduction plans, most noticeably in California (Rabe, 2007). Similarly, over 900 U.S. mayors have committed to, among other things, strive to meet or beat the Kyoto Protocol targets in their own communities (Selin and Van Deever, 2007, pp. 6–7). These state and local actions are encouraging, but they have yet to have an appreciable effect on U.S. carbon-based energy consumption patterns, the primary contributor to rising emissions.

Even with inaction of the U.S. federal government on greenhouse gas control, individual citizens can play a constructive role in CO_2 emissions reduction. These responses are well known, and include such options as the purchase of hybrid gasoline-electric and high mileage vehicles, energy efficiency, renewable energy, recycling, and tree planting (Metz et al., 2007; Heiman and Solomon, 2007, pp. 14–16). Unfortunately, many of these technical options are beset by a variety of market failures and "public failures" or institutional biases that slow the rate of greenhouse gas reduction, or at a minimum make them unnecessarily expensive (Brown et al., 2008). Examples of these include the under pricing of carbon, as well as fiscal, regulatory, statutory and intellectual property barriers. This further underscores the need for government policy reform to reduce carbon emissions, which could act in concert with such responses from the public.

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One of the most readily available consumer options for lowering greenhouse gas emissions may be using biofuels in motor vehicles, such as ethanol or biodiesel. Research has clearly shown that the only sustainable option among these must be based on cellulosic material from crops, trees, grasses or wastes (Heiman and Solomon, 2007). Cellulosic ethanol also has the largest potential to reduce CO_2 emissions, by 90% or more. Almost all of current ethanol production, however, is based on corn, wheat, sugarcane, or other food crops. Not only is the production of these foodstuffs for fuel supply constrained and unsustainable, but it also has been implicated in the 2008 global food shortage and price increases (World Bank, 2008).

The U.S. Congress recognized the great potential of cellulosic ethanol by passing the Energy Independence and Security Act in December 2007 (EISA). The EISA established a Renewable Fuel Standard (RFS) for U.S. transportation fuels of 36 billion gallons by 2022. No more than 15 billion gallons per year of this total will come from cornstarch, with the remaining 21 billion to come from advanced biofuels with greatly reduced greenhouse gas emissions (including biodiesel). Over three fourths of the advanced biofuels portion will eventually come from cellulosic materials, and this part of the mandate could be met with any combination of ethanol and other alcohols (Sissine, 2007). While as of early 2009 a commercial market for cellulosic biofuels in the U.S. had yet to develop, several demonstration plants were operating while a half dozen commercial plants were slated to open in 2009–10 (Solomon et al., 2008).

The purpose of this paper is to determine how the public values climate protection through the potential purchase and consumption of cellulosic ethanol. A case study of Michigan, Minnesota and Wisconsin residents will explore this issue in the U.S. context through a stated preference survey. In the next section of the paper we will review the pertinent previous research on this subject. This will be followed by an overview of our methodology. In particular, we will describe a willingness to pay contingent valuation method (CVM) survey and scenario, and a related "fair share" scenario of a food shortage emergency that was given to half of the survey recipients. The CVM and fair share scenarios are part of a larger survey to investigate the viability of large-scale development of cellulosic ethanol in the regional context. We will then present our main statistical results and analyses, and end the paper with a summary and some conclusions.

2. Previous research

Since a commercial cellulosic ethanol industry was not considered feasible until recently, no previous stated preference research has examined the willingness to pay for this motor vehicle fuel. Alternatively, since grain and sugarcane-based ethanol have been produced and marketed for decades, revealed preference data can be collected on these fuels. However, as noted earlier, ethanol production from these feedstocks is unsustainable and does not significantly reduce CO_2 emissions. There have been several studies of consumer preferences or support for climate change mitigation policies and related environmental values that are instructive for a market assessment of cellulosic ethanol. In addition, several other studies have examined consumer willingness to pay for renewable electricity generation, with biomass energy being among the fuel options. These studies will be reviewed in turn.

Dietz et al. (2007) used mail surveys to assess the preferences of Michigan and Virginia residents for policies designed to reduce the burning of fossil fuels and to mitigate climate change. Policies with the most direct economic impact on consumers received the least support, such as an increase in taxes on gasoline and large vehicles. In contrast the most support was expressed for shifting government subsidies away from fossil fuels and toward cleaner forms of energy, and to increase automobile fuel efficiency (which was finally enacted under the EISA in 2007). The authors found that political affiliation, age, income, and state of resident were significant determinants of policy support, while gender and education were insignificant.

More directly relevant to our own research is the CVM study of Berrens et al. (2004) and the related, follow-up study by Li et al. (2009). Berrens et al. (2004) used a split-sample treatment referendum design to examine willingness to pay (WTP) for greenhouse gas emissions reduction under the Kyoto Protocol. Three very large national internet-based samples were compared to a national telephone sample baseline. Li et al. (2009), in turn, used national telephone and internet-based samples to examine WTP to support energy research and development to reduce U.S. reliance on fossil fuels. Berrens et al. (2004) found a conservative mean estimator of $191.70 in annual WTP, and conditional on households having a positive value, WTP rose to $816 per year. Several models were assessed. Significant explanatory variables included political ideology, education, age, gender, respondent assessments of the effectiveness and fairness of the Kyoto Protocol, and belief in the greenhouse effect. The respondent region was insignificant. As for the split-sample effect, respondent use of enhanced information on global climate change was modest and highly variable, though some of this effort (objectively measured page count) positively and significantly influenced WTP. In the study by Li et al. (2009), WTP was significantly related to gender, political ideology, income, perceived importance of crop-based energy, and expressed importance of reducing U.S. reliance on foreign energy sources.

Hidano et al. (2005) conducted a CVM study of Japan's anti-global warming policies, focusing on the amount of effort needed to complete the survey. In particular, the authors split their sample into two groups to determine the effect of different levels of survey load (i.e. extensive additional attached information on global warming and policy) and fringe benefits (i.e., whether respondents believed the survey was a good cause and provided useful information), and used a payment card approach to determine respondents' WTP additional taxes to reduce CO_2 emissions. The findings were that participation rate was higher if the survey fringe benefit factor scored higher and, as expected, lower for the recipients of the survey with the heavier load.

Another study of indirect relevance to the cellulosic ethanol case was conducted by Lewandowski et al. (2006). The authors attempted to quantify value of the phytoremediation function (cleaning of the soil by plants, e.g. cadmium removal) among farmers in the Rhine Valley of Germany who faced the option of switching from vegetable or cereal production to willow (*Salix* spp.). Replacement cost and hedonic price analyses were conducted and compared to CVM results applied to the farmers. While the first two methods yielded similar results, the WTP results were much lower because the farmers considered remediation as the government's responsibility.

Several studies of consumer WTP for "green" electricity, including electricity generated from biomass energy sources, have been conducted since the late 1990s (e.g., Ethier et al., 2000; Zarnikau, 2003; Bergmann et al., 2006; Hansla et al., 2008; Longo et al., 2008). Byrnes et al. (1999) tested the criterion validity of CVM in this context by conducting telephone interviews of Colorado and Wisconsin ratepayers who previously expressed a willingness to make a voluntary premium payment on their utility bills to purchase electricity from renewable sources with actual payment commitments. Only the Colorado program included biomass energy as one of the fuel options (the Wisconsin program used photovoltaic solar cells). The authors concluded that while mean WTP across respondents varied greatly between the CVMs and market simulations, the CVM is capable of reliably estimating WTP of people who would make payments, though not of predicting who would actually pay. They also emphasized the importance of attributing zero valuations to non-respondents. Contrary findings were reported by Roe et al. (2001). These authors compared the results of a conjoint analysis of hypothetical WTP to actual price premiums for green electricity, and the latter were roughly half the former.

A recent CVM study of renewable electricity provision was reported by Wiser (2007). This study, like ours, was not a "standard" CVM in that higher bid levels corresponded to more renewable energy being supplied and environmental improvement. Thus, valuation of the good was not possible in the usual sense. Wiser mailed a dichomotous choice, split-sample CVM and more limited opinion survey to a large national sample. In particular, this study crossed payment method (voluntary vs. collective) and provision arrangement (government vs. private). Responses were somewhat sensitive to the context, with higher values found under the collective payment and private provision arrangements. WTP rates varied from 36–80%, depending on the scenario. In logit analyses of the bid curves, Wiser found the most significant explanatory variables to include the bid amount respondents were asked to pay, income, political liberalism, gender, and some attitudinal variables. A contemporaneous study used a choice experiment to determine if preference for green energy differs by source, and was applied to one county in Delaware (Borchers et al., 2007). The greatest preference found was for solar energy, and the least preferred option was biomass energy and farm methane. Longo et al. (2008) found similar results in a choice experiment applied in Bath, England. In addition, WTP in Delaware was greater for a voluntary green energy program than for a mandatory one, in contrast to Wiser (2007).

3. Methodology

The goal of this study was to estimate the WTP for cellulosic ethanol in the upper Midwestern U.S. as a means to assess environmental non-market values for mitigating global climate change. We accomplished this by conducting a large, multi-part survey of residents in our three-state region (Michigan, Minnesota and Wisconsin), following pre-testing, which was then subjected to statistical analyses. While our CVM methodology is fairly conventional, this particular valuation application is atypical since cellulosic ethanol is a pre-market commodity (for a pre-market good application of CVM to salmon fishing, see Cameron and James, 1987).

3.1. Problem framing

We began our CVM study by determining that the future consumption of cellulosic ethanol could be a critical means to achieve the environmental outcome of a reduction in CO_2 emissions and thus climate change mitigation. A plethora of studies supports this conclusion (see, e.g., Farrell et al., 2006; Hill et al., 2006; Hammerschlag, 2006), though it may be challenging for consumers to understand given the controversies surrounding ethanol consumption from corn in the U.S. The latter includes long-standing debates about net energy yield, water pollution, and soil erosion problems associated with corn crops, and most recently concerns about net greenhouse gas emissions and food price increases (Pimentel et al., 2007; Runge and Senauer, 2007; Fargione et al., 2008). Nonetheless, we hypothesized that once the word got out about the greater benefits of biofuels from cellulosic materials, including a more effective reduction in oil consumption requirements, public support would be strong. We therefore set up a hypothetical market for cellulosic ethanol as a means to our environmental valuation.

While the use of cellulosic ethanol could greatly lower dependence on foreign oil, a more urgent problem for many people may be the increase in food prices that is due, in part, from the rapidly growing domestic use of biofuels made from corn and soybeans. This concern has been raised for a few years, and has been even linked with recent food shortages and riots around the world (World Bank, 2008). While several complex factors affect food supply and prices, the diversion of cropland for fuel generally means less cropland for food. We therefore noted on our survey that it has been suggested that greater ethanol use has caused increases in the prices of corn, beef and dairy products. Given these concerns, we also framed some WTP questions in the context of a potential food shortage within the next decade and continuing increases in corn prices. Because of the emergency nature of the food concern, however, we decided to ask survey recipients what they believed their "fair share" charge should be for cellulosic ethanol. Half of the surveys were provided with this WTP scenario, and the results will be compared with the other half that were given the basic CVM survey.

3.2. Description of the payment method

While a market for cellulosic ethanol did not exist at the time of our survey, it is expected to begin in the next few years. Moreover, once the fuel is sold it is unlikely to be labeled as such, and will probably appear in an ethanol blend such as E10 or E85. As a result, we decided to use retail gasoline service stations as the payment vehicle. Our hypothesis is that commercial purchase of cellulosic ethanol, when it is available, will become an important way for consumers to express their concern for and valuation of global climate change, similar to the current purchase and use of hybrid gasoline-electric vehicles (Heiman and Solomon, 2007). To prep survey recipients for the WTP question, we asked them if they purchased any (corn) ethanol in the past year and if so how much.

3.3. WTP and fair share elicitation formats

Draft surveys were pre-tested in September 2007 by face-to-face administration to ten residents of Houghton, Michigan. During the tests, at the end of each section of the survey respondents were asked for an opinion about the survey structure, the nature of the questions, clarity of questions, and so forth. Both payment card and dichotomous choice formats were pre-tested for determining WTP, and several respondents found the latter method confusing. The final elicitation format chosen therefore was a single-bounded payment card with a non-linear bid curve of higher prices per gallon for cellulosic ethanol in various increments ($0.00, $0.01, $0.02, $0.03, $0.04, $0.05, $0.10, $0.25, $0.40, $0.65, $1.00, $1.00+). Following the scenario descriptions, the valuation questions read:

> Under these conditions and keeping in mind your family income and other expenses, what is the most [that you think] your household would be willing to pay [should be charged] extra per gallon [as its "fair share"] to purchase cellulosic ethanol from farming residues (or solid wastes, or forestry residues and paper mill wastes) if the fuel becomes available in your area? Circle the maximum amount.

Following the WTP and fair share (FS) questions in the two sets of surveys, two related questions were asked. The first asked how much respondents would drive, compared with how much they currently drive, given the higher price they would be willing to pay for cellulosic ethanol fuel. The second question asked what percentage of their total motor vehicle fuel consumption would be cellulosic ethanol. Because of the potential for preference of feedstocks, respondents were asked to bid separately for farming residues, forestry residues and paper mill wastes, and solid wastes.

3.4. Survey structure

The survey questions were combined with a set of questions on global climate change that are being used in a larger study. There were two main sections. The first section, on global climate change, measured agreement/disagreement using an ordinal scale with 44 statements. These questions were divided into background, "your concerns and climate change", causes of climate change, climate change solutions, energy and America's future, and environment. The second section, on ethanol fuel, had four parts — it began by

introducing respondents to ethanol by way of background information, and asked for their familiarity with the subject as well as consumption of ethanol in the past year. This was followed by part three, with the WTP/FS scenarios. The final part of the section asked demographic questions. An average time of 30 min was required to complete the survey. In order to ensure an equal distribution between female and male respondents the person in the household with the next birthday was asked to complete the survey. Part three, the WTP/FS scenarios, were presented as follows:

- Issue framing: lowering of the states CO_2 emissions and pressure on food prices, and the possible siting of cellulosic ethanol plants in the state, potential smell, possible costs (higher fuel prices) and benefits (lower CO_2 emissions);
- CVM scenario (given to a random half of the survey recipients): Three sets of CVM questions seeking to determine WTP (one for farming residues, one for forestry residues and paper mill wastes, and one for solid wastes); and
- FS scenario (given to the other half of the survey recipients): a statement reading "assume that corn prices continue to rise and a food shortage occurs within the next decade" and "state and federal governments are considering requiring that all gasoline stations much sell a high percentage of cellulosic ethanol (e.g., half of the pumps) once the fuel becomes commercially available".

After mailing a pre-notification letter in October 2007 we sent the survey as a mail questionnaire to 1500 households throughout Michigan, Minnesota, and Wisconsin in three rounds from November 2007 thru January 2008. Nine hundred of the recipients were rural households and 600 were urban. We greatly over-sampled rural households for two reasons — to increase the number of respondents who own or manage farmland or forests that could potentially be used for ethanol feedstock, and because we hypothesized that rural households would be more likely to complete the survey for this reason (cf. Bergmann et al., 2008). The names and addresses were provided by the Survey Sampling International (SSI), which used population densities (by address) to determine if a household was urban or rural. After accounting for bad addresses, the final survey pool was reduced to 1432. We followed an expanded version of Dillman's tailored design method of survey administration, which used several steps to increase the response rate (Clendenning et al., 2004). These steps included personalizing the surveys, sending out pre-notification letters, using a memorable and retrievable survey cover design (e.g., in our case a glossy color photograph of the autumn North Woods and a pristine lake), using university letterhead, using three rounds of surveys plus reminder post cards, enclosing a $2 bill with the first survey as a response incentive to recipients, and distinctive packaging.

3.5. Anticipating potential biases

In CVM and related surveys it is critical to think about and anticipate potential biases (Mitchell and Carson, 1989, pp. 231–59). Given the payment card format's large price range and the payment method chosen it was unlikely that there was vehicle, starting point, or anchoring bias (although some respondents may only purchase ethanol or other biofuels if they are cheaper than gasoline, the spike in gasoline prices did not occur until spring/summer 2008). In addition, since we used the actual bid prices provided by respondents and not the mean of the response and the next highest value, it was unlikely that there was range bias. Similarly, there was no reason to believe there would be strategic bias since the survey stated that a cellulosic ethanol demonstration plant has operated in Ottawa, Canada since 2004 and several refineries are being built.

A more important concern in our survey was sample selection bias, given its administration by mail. As noted by Mitchell and Carson (1989, p. 277), sample selection bias cannot generally be compensated for by weighting and imputation procedures. We addressed this bias in several ways: we following an expanded version of Dillman's "tailored design method" in administering the survey (Clendenning et al., 2004); conducted telephone interviews with non-respondents; compared the socioeconomic characteristics of the respondents to those of the general population; and made the conservative assumption that the non-respondents for whom we had a correct address would not purchase cellulosic ethanol at any price.

3.6. Data analysis

Our analysis required calculation of the true WTP or FS variable from the survey results since interpretation of the payment card responses is not straightforward. This is because we asked respondents either what is their WTP or FS extra per gallon to purchase cellulosic ethanol from each of three feedstocks (forestry residues and paper mill wastes, farming residues, and solid wastes), which is the most realistic future choice that would present itself. To this figure we must multiply by the change in total fuel consumption (most likely downward) after determining the respondent's expected cellulosic ethanol/gasoline fuel use mix to compute the total additional amount that would be paid. These calculations were done in a spreadsheet and assumed average fuel use expenditures for each of the three states (EIA, 2008). If the change in spending on all fuels is positive for a household, this will be a lower bound estimate of non-market consumer surplus from cellulosic ethanol consumption; if the change in spending on all fuels is negative for a household, then zero is a lower bound estimate of non-market consumer surplus. Given the need for several data items to calculate the dependent variable, we conservatively omitted all observations with missing data items required for the regression analyses. We also dropped observations with logically inconsistent results, such as a respondent WTP for cellulosic ethanol but not willing to buy it.

In order to better understand the determinants of consumer demand for cellulosic ethanol as a proxy for valuation of climate change mitigation, we subjected the WTP and FS variables to a series of multivariate analyses. Before doing so, we converted these variables from marginal to total WTP and FS (see below). As is usually the case, we will determine the theoretical validity of these dependent variables based on consumer demand theory and analyze their respective bid curves. We selected lognormal regression for the analyses since the distributions of the total WTP and FS values are right skewed:

$$\text{Ln WTP} = X'ß + \mu \quad (1)$$

where X' are the characteristics of the respondents and μ is normally distributed with 0 mean and standard deviation σ, and $ß$ are regression coefficients.

4. Results and discussion

4.1. Response rate, demographics, and attitudes regarding global climate change

A total of 745 households responded to the multiple mailings of the survey for an overall response rate of 52%. The response rates did not vary much based on state, though the rural return rates, as expected, were always higher than the urban ones (Table 1). Given the similarity of the response rates from the three states, adjustments for non-respondents were not made. The first mailings of the survey and reminder post cards generated a 38.9% response rate. The mailings of the second survey and reminder post cards raised this rate to 47.8%, and thus the third round of the survey generated few additional respondents. These results contrast with Clendenning et al. (2004), who received a 63.4% response rate from their first mailings of a

Table 1
Survey response rate by state.

	Percentage of state population	Percentage of surveys mailed	Response rate	Sampling weight
Michigan				
Rural	25.3%	60%	54.9%	0.40
Urban	74.7%	40%	46.0%	2.07
Total			51.3%	
Wisconsin				
Rural	31.7%	60%	56.5%	0.50
Urban	68.3%	40%	47.5%	1.86
Total			52.8%	
Minnesota				
Rural	29.1%	60%	56.7%	0.45
Urban	70.9%	40%	45.8%	2.03
Total			52.4%	

general population survey of landowners and reminder post cards, and an impressive 82.8% overall response rate.

As noted earlier we intentionally over-sampled rural voters in our survey, who received 60% of the total questionnaires. Sampling weights were used to normalize the responses to the actual rural/urban mix of the populations in the three states, i.e., for six sub-populations (Census Bureau, 2000a). While there were no protest values in this survey, results from 78 respondents were eliminated from further analysis because the respondents did not completely fill out at least one WTP set of questions.

Summary demographic data on the survey respondents are shown in Table 2. A noticeable finding is that males comprised three fourths of the respondents, which makes the gender variable in the regression results especially important. Overall respondents were moderate to conservative in their political orientation, older (65.6% were aged 51 or higher), well educated, with a mix of moderate to higher incomes, and a mix between employed and retired. About a quarter of the respondents had children under 18 in their household and less than 10% belonged to an environmental or conservation group.

We compared our respondent sample with 62 non-respondents reached for telephone interviews, as well as to the general population (Census Bureau, 200b). Not too surprisingly, less than half of the non-respondents were WTP more for cellulosic ethanol (45%). Census data confirmed that our sample was different from the general population of the three states in several ways. In addition to having 74.7% males and an inflated rural/urban mix, our sample was older, wealthier, and less well educated. Because of these differences we will conservatively assume a zero WTP for non-respondents.

Attitudes about global climate change amongst the 667 useable responses indicated that most people in the sample think that climate change is happening, while at the same time they believed that the causes are unclear (Table 3). For instance, half of the respondents thought that climate change was "part of a natural cycle beyond human control." Dirty fuel was identified as causing climate change, which indicates confusion about air pollution's role in the greenhouse effect (rather, lack thereof) in climate change. On the other hand, both CO_2 and greenhouse gasses were identified as causes as well. There was a weak preference not to pay 40 cents more per gallon for gasoline, even if the money went to help stop climate change, while at the same time there was a stronger agreement that it is reasonable for people to use less energy. These findings are similar to those of Dietz et al. (2007), discussed earlier. Finally, there is indication of an interest in a biofuels market. The preference for this market is slightly stronger in the rural communities, and there is virtually no difference in this view between the three states.

4.2. Payment card results

Five types of WTP and FS distributions were analyzed: by type of feedstock, state of response, rural/urban distribution, gender, and WTP/fair share. The first three distributions showed insignificant variation, and were dropped from further analysis; the latter two

Table 2
Demographic characteristics of the survey respondents.

Survey question	Percent of respondents	State averages
Gender		
Male	74.7%	49%
Female	25.3%	51%
Age		
18–30	4.3%	24%
31–40	9.8%	20%
41–50	20.2%	20%
51–64	32.8%	19%
65+	32.8%	17%
Income		
Less than $15,000	6.8%	15%
$15,000–$24,999	12.7%	32%
$25,000–$34,999	13.8%	7%
$35,000–$49,000	18.3%	23%
$50,000–$69,000	19.3%	15%
Above $70,000	29.1%	8%
Education		
Some high school	4.5%	13%
High school degree	28.2%	12%
2 year trade/technical school	21.7%	13%
Attended a 4-year college	12.0%	17%
Graduated from college	18.3%	22%
Advanced degree	15.3%	23%
Political views		
Very conservative	9.0%	
Conservative	27.8%	
Moderate	45.8%	
Liberal	14.2%	
Very liberal	3.3%	
Children < 18 in household	24.9%	
Member of household in an environ. or conservation group	8.1%	
Felt survey gave enough information	79.2%	

Source of state averages: Census Bureau (2000b).

Table 3
Survey responses to global climate change questions (section A).

Survey statement	Percent who don't know	Mean on the Likert scale*
Climate change is *not* going to happen	3.0	1.8
The so-called ecological crisis facing humans has been greatly exaggerated	7.2	2.5
We can't stop climate change because it is not happening	1.6	1.9
Climate change is part of a natural cycle beyond human control	3.6	2.9
Rapid increases in greenhouse gases are causing climate change	10.5	3.8
Climate change is caused by burning dirty fuel	8.3	3.6
Carbon dioxide emissions are one of the major causes of climate change	9.1	3.7
Saving energy is a way to stop climate change	7.5	3.9
Using too much energy is causing climate change	11.0	3.5
It is unreasonable to expect people to use less energy than they do now	1.4	2.3
I would be willing to pay 40 cents more per gallons of gasoline if the money was used to stop climate change	4.1	2.7
I can afford to pay more for gasoline and other fossil fuels if the increases are used to stop climate change	1.6	2.8
I don't support increasing gasoline prices in order to stop climate change because may people can't afford the increases	2.1	3.6
Making biofuels, like corn ethanol, would be good for my area's economy	4.5	3.7

*1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

showed significant variation. In the case of gender, women respondents bid higher than men. To be conservative we did not adjust for this difference even though there were many more male respondents. The most striking WTP distribution difference is the one between the two scenarios (Fig. 1). Fig. 1 values average the respondent WTP for the three feedstocks and dropped those who gave logically inconsistent answers (e.g., if a respondent was WTP a positive amount for cellulosic ethanol but not purchase any). Clearly, the FS bids are lower, and we hypothesize this is because respondents assume that the burden for creating the market in this case is placed on the government, not the public. Overall 83.8% of the survey respondents were WTP extra for cellulosic ethanol, though only 76.2% were under the FS emergency scenario.

The marginal WTP and FS values were converted into total future expenditures before subjecting them to multiple regression analyses. We determined this by multiplying the average WTP bid for the three feedstocks by the quantity Q of cellulosic ethanol e that each respondent i would consume as a proportion of their total fuel consumption in gallons in the next time period (based on each respondent's stated price elasticity of demand for total fuel assuming a higher price for e blends) compared to the last one. Because Q_g was unknown for each respondent, the past year state average per capita gasoline expenditures were used to determine annual average expenditures for fuel consumption: $1500 in Minnesota, $1400 in Michigan, and $1375 in Wisconsin (EIA, 2008). An average price of $3.00 per gallon of gasoline g in all cases was assumed for late 2007 (the time of the survey). Finally, the price elasticity of demand (Ed_{git}) was provided by the survey responses, viz:

$$\mathrm{WTP}_{ei,t+1} = \left(\$3/\mathrm{gal}_{g,t-1} + \mathrm{WTP}/\mathrm{gal}_{eit}\right) Q_{gi,t-1}\, Ed_{git}. \quad (2)$$

This calculation was performed for each feedstock, averaged for each respondent, and weighted. To ensure a conservative estimate, the actual bid prices were used and not the average of the payment card responses and the next highest values. The mean total WTP was found to be $556 per capita per year and the mean total FS was $472 per capita per year. As noted earlier, to be conservative we assumed that all survey non-respondents were willing to pay zero. In this case the population averages become $252 and $192 for total WTP and total FS, respectively.

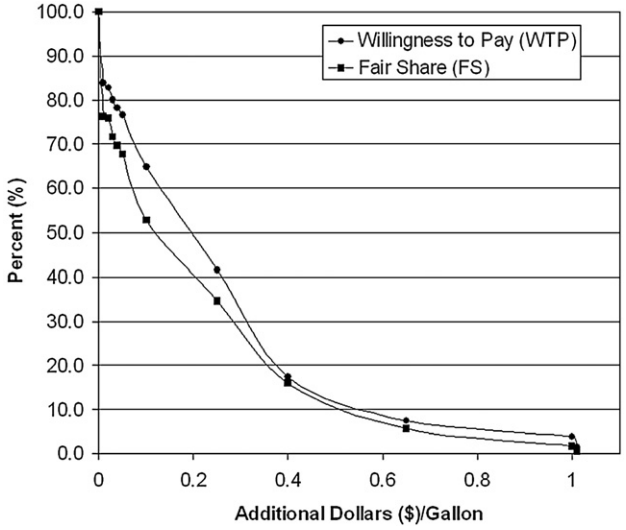

Fig. 1. WTP and FS distributions for cellulosic ethanol.

Table 4
Independent variables in the regression models.

Variable	Description
Geographic dummy variables	
Minnesota	1 if Minnesota resident; 0 if Michigan or Wisconsin resident
Rural/urban	1 if rural resident; 0 if urban or suburban resident
Demographic and socioeconomic variables	
Age	1–5 scale (1 = 18–30; 2 = 31–40; 3 = 41–50; 4 = 51–64; 5 = 65 and over)
Gender	1 if female; 0 if male
Income	1–6 scale (1 = less than $15 k/yr; 6 = $70 k/yr+; intermediate gradations)
Political views	1–5 scale (1 = very conservative; 2 = conservative; 3 = moderate; 4 = liberal; 5 = very liberal)
Attitudinal questions on global climate change:	*1–5 agreement scales; 1 = strongly disagree; 5 = strongly agree; 6 = don't know*
Climate change concerns and beliefs: "Climate change will cause problems for people"	
Climate change solutions: "I would be willing to pay 40 cents more per gallon of gasoline if the money was used to stop climate change"	

4.3. Bid curve analyses

Based on the findings of previous research and creation of our total WTP and FS dependent variables, we analyzed the effects of a variety of independent variables as determinants (Table 4). Two types of geographic dummy variables were defined. One was for state of residence, with the hypothesis that only Minnesota residence would be found as significant since the state has a much further developed ethanol industry than the other two and thus its consumers may be more familiar with and comfortable with the fuel. State of residence was tested and consistently found to be insignificant, and consequently was dropped from the final models. The other dummy variable was for rural vs. urban or suburban residence, with the hypothesis that rural residents would have a greater WTP because of the potential to profit off of rural resources and to increase employment opportunities (Bergmann et al., 2008, pp. 622–623). We also analyzed age but dropped this variable as insignificant.

The final models had six independent variables: household yearly income, political views, gender, rural residence, concern with and belief in climate change ("climate change will cause problems for people", which is a proxy for knowledge or education), and willingness to pay 40 cents more per gallon of gasoline if the money was used to stop climate change. The expected sign on all of the variables is positive. In the case of gender, being female is expected to result in greater WTP to lower CO_2 emissions and pressure on food prices (Davidson and Freudenburg, 1996).

The WTP and FS results are reported separately. In the case of the CVM (WTP) analysis, as Table 5 shows three of the variables are significant at the 0.01 level, one at the 0.05 level, and one at the 0.10

Table 5
Bid curve analysis: estimated WTP lognormal regression model.

Variable	Estimated coefficient	*t*-statistic
Constant	0.029	0.104
Income	0.270	4.825***
Gender	−0.008	−0.142
Political views	0.118	2.146**
Rural or urban	0.090	1.671*
Climate change beliefs	0.186	3.326***
Climate change solutions	0.197	3.472***
F statistic	14.030***	
Adjusted R^2	0.21	
N	297	

***Significant at the 0.01 level.
**Significant at the 0.05 level.
*Significant at the 0.10 level.

Table 6
Bid curve analysis: estimated FS lognormal regression model.

Variable		Estimated coefficient	*t*-statistic
Constant		0.042	0.135
Income		0.148	2.598***
Gender		0.142	2.526***
Political views		0.075	1.273
Rural or urban		0.082	1.488
Climate change beliefs		0.199	3.278***
Climate change solutions		0.343	5.519***
F statistic	15.848***		
Adjusted R^2	0.26		
N	261		

***Significant at the 0.01 level.

level. Only the gender variable is insignificant. For the FS model (Table 6), four of the independent variables are significant at the 0.01 level while the political views and rural residence variables are insignificant. The latter variable was the least significant variable in the CVM model. All of the signs on the coefficients of the significant independent variables were as expected. There were no multi-colinearity problems (the Variance Inflation Factor was always under 2.0). Overall the results of the two models are similar, giving credence to the idea that asking a fair share rather than a traditional WTP question may be reasonable in some cases. As shown by Bohara et al. (1998), some CVM elicitation formats, especially open ended questions, may be susceptible to "fair share" and lower value responses (as found here) if program cost information is provided. In our surveys, we simply stated that "cellulosic ethanol initially may cost more than corn ethanol".

We also conducted a Chow test to determine if there are any differences between the WTP and FS results for the base set of common responses ($n=261$). We found that the results were significant at the 0.10 level ($F=1.81$).

5. Summary and conclusions

A large multi-part survey was developed and implemented to better understand the non-market valuation of mitigating global climate change by the public in the states of Michigan, Minnesota and Wisconsin. In particular, these environmental values were directly linked with the possibility of purchasing and using cellulosic ethanol, a new and potentially sustainable fuel that is expected to be commercialized in the near future. While we used a WTP question format, the survey was not a standard CVM since higher bid levels represented more fuel being consumed as well as environmental improvement (i.e., reduction in CO_2 emissions). In addition, half of the surveys asked a "fair share" payment question under a scenario of a potential food shortage in the next decade, with the link between conventional ethanol and corn supply being noted.

Payment card formats were used to implement the WTP surveys, asking respondents if they would be willing to pay extra for cellulosic ethanol. No significant differences were found between the results for the three states or three feedstocks, though the FS scenario bids were lower than in the basic CVM scenario of WTP. Overall a larger proportion of respondents were WTP extra for cellulosic ethanol in the basic CVM scenario than in the FS scenario (83.8% vs. 76.2%). This may be because respondents assumed that the burden for creating the new fuel market should be placed on the government in the case of a food emergency. The marginal WTP/FS values were converted into total expenditure by multiplying bids by the quantity of cellulosic ethanol that would be consumed as a proportion of total gallons of fuel use, after accounting for potentially higher prices. We found the population averages of total WTP to be similar to those of the conservative scenario of Berrens et al. (2004).

In order to assess the theoretical validity of the CVM and FS models we analyzed our findings with lognormal regression. Five explanatory variables were found to be significant determinants of total WTP in at least one of the models and always with the correct sign. These included household yearly income, political views, gender, climate change concerns and beliefs, and WTP 40 cents more per gallon of gasoline if the money is used to stop climate change. The regression results for the two models were similar, supporting the idea that asking a FS rather than a conventional WTP question may be justifiable in some circumstances, such as in cases of a national emergency.

There are many ways for people to respond to concerns about global climate change and to lower emissions of CO_2 and other greenhouse gases to help mitigate it. Given the sluggish response of the U.S. federal government to this major world problem, and the incomplete response by states and local governments, it is especially important that citizens help to lower emissions at an individual level. This study shows that at least in one region of the country the public is ready to begin the long process of converting its energy system to non-carbon sources, action that will reinforce recent federal energy policy initiatives to accelerate this transition.

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