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Consumers Willingness to Purchase Factory Production Ethanol Cars: A Contingent Valuation Approach

by

Vishal P. Singh
Graduate Research Assistant,
Department of Economics,
Iowa State University, Ames, IA, 50011

Jean-Philippe Gervais
Graduate Research Assistant,
Department of Economics,
Iowa State University, Ames, IA, 50011

and

C. Phillip Baumel
Charles F. Curtiss Distinguished
Professor in Agriculture,
Department of Economics,
Iowa State University, Ames, IA, 50011
Phone: 515-294-6263
Fax: 515-294-1700

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Summary: This study uses data from a survey conducted in Iowa and a contingent valuation approach to evaluate the willingness of consumers to pay (WTP) for ethanol fuel (E-85) powered vehicles. E-85 fuel is a combination of 85 percent ethanol and 15 percent gasoline and is environmentally cleaner than regular gasoline. The average willingness to pay for respondents who are willing to pay a premium for E-85 powered vehicles is estimated to be $846.55. The mean WTP is inversely related to the age of the respondents. However, confidence intervals for the WTP estimates overlap different age group, thus tempering the conclusion that age is a significant factor in the WTP. When the respondents not willing to pay a premium for E-85 vehicles are included in the analysis, the average WTP drops to $503.29. For the entire population, there is an inverse relationship between the willingness to pay and the age of the respondents. There also a positive relationship between the mean WTP and the respondents' education level.

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Consumers willingness to Purchase Factory

Production Ethanol Cars: A Contingent Valuation Approach

I - Introduction

Subsidization of ethanol production for use as an alternate source of fuel is a heavily debated topic in the U.S. Proponents of ethanol subsidies claim ethanol fuel is the "renewable" fuel of the future. Opponents of ethanol claim the ethanol industry to be one of the most artificially sustained industries today; for the industry to survive at all, critics say that massive trade protection, tax reductions, government mandates for its use, and production subsidies are crucial. Despite this opposition, the ethanol industry has received support from recent presidential administrations as well as Midwest Republican and Democrat leaders.

There is little factual available information on how much people value the perceived environment quality improvement from the use of ethanol. Federal regulations requiring fleet operators in certain locations to purchase alternative fuel vehicles (AVFs) and use alternative fuel, will not, in themselves, enable the ethanol industry to survive. In the long run, the ultimate demand for both ethanol fuel and vehicles must come directly from consumers. However, measuring consumer willingness to switch to these alternative vehicles poses several problems. It is well known in marketing literature that adoption of new products entails a number of variables other than just cost. These other variables include the new products relative advantages, complexity of the new product, compatibility with the existing products, risk and rates of adoption. The main problem with AFV's is that the principal advantage of cleaner environment is like a public good; that is, consumers who are willing to switch are not distinguishable from the consumers who are unwilling to switch. This paper uses a consumer survey conducted in Iowa about consumers current usage of ethanol, their perceptions about ethanol as an environmentally cleaner fuel, and their willingness to buy and pay a premium for cars designed to run on E-85 fuel. The purpose of this paper is to quantify the value that automobile users place on these environmental benefits by estimating their willingness to pay for cars designed to run on E-85 fuel.

II - Air Pollution and Comparisons of Ethanol and Gasoline on Air Pollution

While the US population has grown slowly over the last two decades, the number of automobiles and vehicle miles traveled have grown rapidly. Vehicle miles traveled has grown at an average annual rate of about 3.2 percent, while the population has grown at an annual rate of one percent (US Department of Commerce, Highway Statistics, 1970-1992).

Nearly 18 percent of the U.S. Gross National Product (GNP) is spent on transportation, with about one-half of that amount accounted for by cars, related equipment and infrastructure [Barde, (1990)]. The impacts of this transportation on the natural, social, and economic environments are both direct and indirect, and positive and negative. Positive effects include the increased mobility, accessibility and the low cost of transportation. Negative effects of transport activities include accidents, congestion, air pollution, noise pollution, and the consumption of energy, land and natural resources.

A report by the Natural Resources Defense Council concludes that federal air pollution laws and regulations do not take into account "compelling medical evidence" of the increased vulnerability of children to ozone and other forms of air pollution. As a result of this, the Environmental Protection Agency (EPA) is reassessing many of its clean-air policies and assumptions, including the relative impact of vehicle pollution in various metropolitan areas (Wall Street Journal, October 28, 1993).

The Environmental Impacts and Costs of Air Pollution

The most prevalent air pollutants emitted from transport sources include carbon monoxide (CO), particular matter (PM-10) and ozone (O3). The EPA has established National Ambient Air Quality Standards (NAAQS) for these pollutants.

Transport (primarily cars) is the source of about 90 percent of the total emissions of carbon monoxide (CO). It is a poisonous gas produced by incomplete combustion. Although modern automobile emission control systems have reduced the hazard from this gas, carbon monoxide levels still occasionally exceed the maximum acceptable level in some urban locations in the United States and Canada. U.S. data show that transportation sources account for over two-thirds of this pollutant. Carbon monoxide interferes with the delivery of oxygen to the body's organs and tissues. The health effects of CO vary depending upon the length and intensity of the exposure and the individual's health. The NAAQS for CO require an area's near-peak average eight hour concentration to be less than 9.0 parts PPM. As a result, many U.S. cities have mandated the use of "oxygenated" gasoline, such as ethanol blends, to reduce carbon monoxide emissions.

Ground-level ozone, the main component of smog, is formed by the reaction of nitrogen oxides (NOx) and volatile organic compounds (VOC) with heat and sunlight. Ozone irritates the mucus membranes of the respiratory system. Exposure can result in coughing, choking, headaches, and eye irritation. Ozone can also reduce resistance to colds and pneumonia as well as aggravate existing respiratory conditions such as asthma, bronchitis, and emphysema. The NAAQS for ozone requires that the second highest hourly concentration per year in an area does not exceed 0.12 PPM. Ground level ozone does nothing to increase ozone concentration in the stratosphere, which protects the earth from the sun's harmful ultraviolet radiation. Burning gasoline emits significant quantities of a wide range of hydrocarbons, whereas burning ethanol yields mainly unburned ethanol and aldehydes. Alcohol has much lower reactivities than gasoline hydrocarbons, whereas aldehydes are highly reactive. Several U.S.-based studies conclude that the overall ozone forming potential of ethanol-gasoline blends (with their higher volatility) is the same or lower than that of gasoline.

Ethanol is a liquid alcohol that is manufactured by the fermentation of grains such as wheat, barley, corn, wood, and sugar cane. Although it has been traditionally used as a beverage product for use in spirits, beer and wine, ethanol is an important, viable alternative to unleaded gasoline fuel. It is a high-octane fuel with high oxygen content (35% oxygen by weight) and when blended properly in gasoline produces a cleaner, and more complete combustion.

Environmental Benefits

The ethanol industry is promoting the use of E-85 as a cleaner fuel, citing many environmental advantages from using ethanol as a fuel. A 10 percent ethanol blends reduce carbon monoxide 25 percent more than any other reformulated gasoline blend according to the American Coalition for Ethanol. Moreover, ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution. Because it is produced from renewable agricultural feedstocks, ethanol reduces greenhouse gas emissions. However, there are some disadvantages related to that technology. Ethanol has fewer Btu's per gallon and it requires the purchase of special alternative-fuel-vehicles (AFVs). Also, adequate training is required for those who repair and maintain AFV's. Ethanol is corrosive and requires special lubricants and different oil change schedule; due to the corrosive properties of ethanol, lines, hoses and valves in ethanol powered cars require special materials. Refueling infrastructure needs to be increased. That means adding locations to the already existing fueling sites and making drivers aware of them.

III - Contingent Valuation Methodology

The Contingent Valuation (CV) is a method of estimating the value of a nonmarket good. The CV method has been used extensively in valuing nonmarketed goods such as forests, wildlife, recreation, air water and other resources which are not directly traded in the traditional market place. The CV method sets up a hypothetical market to elicit an individual's economic valuation of a natural resource. CV involves asking individuals, in a survey or an experimental setting, what he/she would be willing to pay for that resource or what he/she would be willing to accept as compensation if this resource was lost or made unavailable. The dollar value estimated are those values that are contingent upon the existence of a market. CV methods thus involves asking individuals to reveal their personal valuation of increments or decrements of unpriced goods by using contingent markets. These values for nonmarket goods are then compared to market values to produce more informed choices. Therefore, the ultimate aim of a CV study is to obtain an accurate estimate of benefits of a change in the level of provision of a public good. For a detailed discussion on CV methodology, see Mitchell and Carlson (1989).

Two of the most common approaches used to obtain CV estimates are Hanemann's (1984) random utility model and Cameron and James' (1987) alternative bid function approach for referendum data with logistic errors. The approach used in this paper is the one suggested by Hanemann, which implicitly recognizes the utility-maximizing choice underlying the individuals' responses.

From the utility theoretic standpoint, an individual is willing to pay $C for, say, an increase in the quality of environment if the individual's utility at the new level of cleaner environment and lower income is at least as great as at the initial state, *i.e.* if

$$U(E^0, Y; S) \leq U(E^1, Y\text{-}C; S) \qquad (1)$$

where E^0 is the current environmental conditions, E^1 is the environmental conditions that will result from switching to E-85 fuel, Y is the individual full income, and S is a vector of other attributes of the individual that may affect the WTP decision. The individual's utility function $U(E^i, Y; S)$ is unknown because of components that are unobservable. Thus, the utility function can be considered a random variable. The observable portion is V(E,Y;S), so the utility function can be rewritten as:

$$U(E, Y; S) = V(E, Y; S) + \varepsilon \qquad (2)$$

where ε is an identically and independently distributed random variable with mean zero. Using Hanemann's derivation, an individual's willingness to pay for the change in E from E^0 to E^1 is defined as the equivalent surplus solving $U(E^0, Y; S) = U(E^1, Y\text{-}C; S)$. Using equation (2) and rearranging, WTP is implicitly defined by

$$\{V(E^1, Y\text{-}WTP; S) - V(E^0, Y; S)\} + \eta = 0 \qquad (3)$$

where $\eta = \varepsilon_1 - \varepsilon_0$. Following Johansson and Kristrom (1988), an explicit equation of the WTP is then found using a linear approximation of V around $(E^0, Y; S)$, with

$$V(E^1, Y\text{-}C; S) - V(E^0, Y; S) \approx \alpha - \beta\, WTP \qquad (4)$$

where $\alpha = \partial V(E^0, Y; S)/\partial E$ and $\beta = \partial V(E^0,Y;S)/\partial Y$. Substituting equation (4) into equation (3) and solving for WTP yields:

$$WTP = \alpha/\beta + \eta/\beta \quad (5)$$

Taking the expectation of (5) yields the average WTP for the proposed change in the provision of nonmarket good E:

$$E(WTP) = \alpha/\beta \quad (5')$$

IV - Survey Methodology

Data on attitudes and preferences toward the use of E-85 vehicles and fuel were obtained from individual consumers in Iowa. Stratified random samples were selected from the metropolitan areas of Des Moines, Cedar Rapids, and Davenport, the general public, and from the Iowa farm sector. The acceptance of and potential use of E-85 fuel was hypothesized to be different among these three populations. Corn producers have a vested interest in seeing more corn used in the production of ethanol and they could potentially respond differently to the questions than the population as a whole. Des Moines, Cedar Rapids, and Davenport residents were hypothesized to have concerns about the environment that could be different from the population as a whole.

Iowa Agricultural Statistics Service (IASS) conducted the E-85 attitude, willingness to pay, and preference surveys. Random samples of telephone numbers were purchased from Survey Sampling Incorporated (SSI) in Fairfield, CT for the rural Iowa and the three metropolitan cities. A sample of 1,200 telephone numbers was purchased for the rural Iowa survey. These telephone numbers were processed to remove the numbers assigned to businesses and disconnects. A total of 265 interviews were completed from this sample.

Samples of 500 telephone numbers were selected for each of the three metropolitan areas. Then, the numbers were processed to remove the numbers assigned to businesses and disconnects. The number of completed interviews for each of the population centers were 94 for Des Moines, 103 for Cedar Rapids, and 100 for Davenport.

The farm sector sample was selected randomly from the universe of farm operators maintained by the IASS. The random sample of farm operators was selected proportional to the number of farms in each county across the state. A total of 1,000 farms was selected from the list universe maintained by IASS. A total of 276 farm interviews were completed by telephone.

There are a number of ways to elicit individuals willingness to pay. Closed-ended questions are easier for the respondents to answer than open-ended questions because the respondents do not have to reveal their exact WTP. In a closed-ended survey, individuals are asked whether or not he or she would accept or pay a single specified amount (C).

The advantage of closed-ended format is that it approximates the situation that most consumers face in the usual market transaction: "take it or leave it" at the posted price. In addition, the closed-ended approach avoids asking the respondent to provide a 'true' value of the good. However, the single closed-ended question limits the information revealed about an individual's willingness to pay, indicating whether it is above or below a specified bid level (C). This, in turn, reduces the precision with which an analyst can measure and characterize the distribution of WTP in the target population.

The approach used in this analysis increases the information available from each respondent by posing an increasing series of closed-ended questions. In general, this 'one-way n-chotomous' choice approach begins by offering the individual a compensation level C_1. If the individual responds yes, the questioning ends and the individual's maximum WTP is presumed to lie at or above that amount C_1. If the answer is no, a lower compensation level ($C_2 < C_1$) is offered. Again, if the answer is yes, the questioning ends (with $C_2 \leq$ WTP$< C_1$), whereas a no response leads to a new and lower bid. The process continues until either the respondent has accepted a bid or the lowest bid (C_n) has not been accepted (with WTP $\leq C_n$). In this study, bids of $1,500, $1,200, $1,000, and $500 were used.

V - Estimation Procedure

The series of discrete choice questions in the survey allow respondents to be classified into the following mutually exclusive willingness to pay categories:

D_{1i} = 1 if respondents WTP ≥ \$1500

= 0 otherwise

D_{2i} = 1 if respondents \$1200 ≤ WTP < \$1500

= 0 otherwise

D_{3i} = 1 if respondents \$1000 ≤ WTP < \$1200

= 0 otherwise

D_{4i} = 1 if respondents \$500 ≤ WTP < \$1000

= 0 otherwise

D_{5i} = 1 if respondents WTP < \$500

= 0 otherwise

Table 1 contains the number of respondents falling into each of these categories. These numbers only include the respondents who were willing to pay a premium to buy a vehicle designed to run on E-85 fuel. The totals for each category do not necessarily add up to 597 observations since some of the persons did not report their age or education level. In those cases, the unusable observations were eliminated for the empirical analysis. For the entire sample, 597 out of the 834 usable questionnaires (72%) were willing to spend an additional amount of money to buy an E-85 powered vehicle.

Table 1. Number of people willing to spend an additional amount of money to buy an E-85 powered vehicles by age and education level.

Sample	D_{1i}	D_{2i}	D_{3i}	D_{4i}	D_{5i}	Total
Total	99	29	145	144	180	597
Age group						
Under 30	21	11	19	13	23	87
30-50	49	10	68	60	67	254
Over 50	29	9	59	72	77	243
Education						
No college	36	11	61	57	52	214
Some college	31	10	43	51	71	206
College graduate	32	9	42	37	44	164

Using equation (3) and definitions of D_{ij}, we can identify the range of values that η_i can take and form the set of equations (6):

$\eta_i \geq V(E^0, Y; S) - V(E^1, Y\text{-}1500; S)$ for $D_{1i} = 1$

$V(E^0, Y; S) - V(E^1, Y\text{-}1200; S) \leq \eta_i < V(E^0, Y; S) - V(E^1, Y\text{-}1500; S)$ for $D_{2i} = 1$

$V(E^0, Y; S) - V(E^1, Y\text{-}1000; S) \leq \eta_i < V(E^0, Y; S) - V(E^1, Y\text{-}1200; S)$ for $D_{3i} = 1$

$V(E^0, Y; S) - V(E^1, Y\text{-}500; S) \leq \eta_i < V(E^0, Y; S) - V(E^1, Y\text{-}1000; S)$ for $D_{4i} = 1$

$\eta_i < V(E^0, Y; S) - V(E^1, Y\text{-}500; S)$ for $D_{5i} = 1$

Now substituting equation (4) into the above equations yields:

$\eta_i \geq -\alpha + \beta\,(1500)$ for $D_{1i} = 1$

$-\alpha + \beta\,(1200) \leq \eta_i < -\alpha + \beta\,(1500)$ for $D_{2i} = 1$

$-\alpha + \beta\,(1000) \leq \eta_i < -\alpha + \beta\,(1200)$ for $D_{3i} = 1$ (7)

$-\alpha + \beta\,(500) \leq \eta_i < -\alpha + \beta\,(1000)$ for $D_{4i} = 1$

$\eta_i < -\alpha + \beta\,(500)$ for $D_{5i} = 1$

Assuming that η is normally distributed, the corresponding log likelihood function is a generalization of the traditional probit specification,

$$L = \Sigma_i\{D_{1i}\,[\,1 - (\Phi[-\alpha + \beta\,(1500)] + D_{2i}\,\{\Phi[-\alpha + \beta\,(1200)] - \Phi[-\alpha + \beta\,(1500)]\} + D_{3i}\,\{\Phi[-\alpha + \beta\,(1000)] - \Phi[-\alpha + \beta\,(1200)]\} + D_{4i}\,\{\Phi[-\alpha + \beta\,(500)] - \Phi[-\alpha + \beta\,(1000)]\} + D_{5i}\,\{\Phi[-\alpha + \beta\,(500)]\} \quad (8)$$

where $\Phi(x)$ is the cumulative distribution function of a standard normal variate. As was shown in section III, the mean willingness to pay is α/β. For a detailed derivation of (8), refer to Combs *et al.* (1993).

VI - Results

Table 2 presents the estimated average willingness to pay, their respective standard error and the confidence interval for the estimate at the 95 percent significance level, rounded up to the nearest dollar. A Wald test produces a *p-value* of zero for the null hypothesis that both coefficients α and β in (8) are jointly equal to zero. The mean willingness to pay was estimated to be $846.55 for the respondents willing to pay a premium to buy E-85 powered vehicles.

Table 2. Estimated average willingness of respondents willing to pay a premium to buy E-85 powered vehicles.

Model	Mean willingness to pay	Standard error	Confidence interval
All respondents	$846.55	28.46	(791 ; 902)
Age group			
Under 30	1,009.04	84.93	(843 ; 1,176)
Between 30 and 50	912.37	42.76	(829 ; 996)
Over 50	793.74	38.99	(717 ; 870)
Education level			
No college	926.87	40.44	(848 ; 1,006)
Some college	775.39	51.52	(674 ; 877)
College graduate	916.58	54.37	(810 ; 1,023)

The same procedure was applied to the responses by different age groups. It was hypothesized that younger people are willing to spend a higher amount of money on E-85 powered vehicles than older persons since they are assumed to be more environmentally conscious. That hypothesis seems to be verified. Table 2 shows that the average willingness to pay is $1,009.04, $912.37 and, $793.74 for the respondents under the age of 30, respondents in the age group 30-50, and for the respondents over 50 years old respectively. A formal test that the difference of willingness to pay between two different group is not zero would require Monte-Carlo experiments to obtain the covariance of the WTP estimates between the two groups. But this is beyond the scope of this paper. However, the Delta method allows to approximate the distribution of α/β in large samples [Greene (1991)]. To do so, we take a first-order Taylor approximation of α/β around $\hat{\alpha}/\hat{\beta}$:

$$\sqrt{n}\left(\alpha/\beta - \hat{\alpha}/\hat{\beta}\right) \approx \sqrt{n}\frac{1}{\beta}\left(\alpha - \hat{\alpha}\right) - \sqrt{n}\frac{\alpha}{\beta^2}\left(\beta - \hat{\beta}\right) \tag{9}$$

A well known property of maximum likelihood is that $\sqrt{n}\left(\alpha - \hat{\alpha}\right) \xrightarrow{d} N\left(0, V(\alpha)\right)$ and $\sqrt{n}\left(\beta - \hat{\beta}\right) \xrightarrow{d} N\left(0, V(\beta)\right)$, *i.e.* α and β will be normally distributed in large samples [Greene (1991)]. In that case,

$$\sqrt{n}\left(\alpha/\beta - \hat{\alpha}/\hat{\beta}\right) \xrightarrow{d} N\left(0, \left(\frac{1}{\beta}\right)^2 V(\alpha) + \left(\frac{\alpha}{\beta^2}\right)^2 V(\beta) - \left(\frac{\alpha}{\beta^3}\right) Cov(\beta, \alpha)\right) \tag{10}$$

Equation (10) gives the limiting distribution of α/β. Then, using the standard errors in table 2, a confidence interval can be constructed for each estimated WTP. It is straightforward to see that the different confidence intervals are not completely disjoint, *i.e.* they overlap each other. This suggests that the difference among the WTPs may not be statistically different from zero. Moreover, there seems to be no correlation between the WTP and the education level of the respondents in table 2.

In table 2, we eliminated the observations for respondents who indicated that they were unwilling to spend any additional amount of money to buy an E-85 vehicle. In an alternative analysis, we have included the 234 respondents who were unwilling to pay any premium for an E-85 vehicle. Those individuals are assumed to have a negative WTP in the sense that some additional incentive need to be given to them in order to make them buy an E-85 car. The estimation procedure is however the same as in equation (8). Only a few adjustments are needed. The variable D_{5i} was redefined and D_{6i} was created so that:

$D_{5i} = 1$ if respondents $0 \leq WTP < \$500$

$= 0$ otherwise

$D_{6i} = 1$ if respondents $WTP < \$0$

$= 0$ otherwise

Table 3 presents the estimated average willingness to pay when all the sampled people are nested into one single group along with their respective standard errors. Confidence intervals at the 95 percent significance level were also calculated following equation (10). Willingness to pay is also estimated by different individual characteristics. The average willingness to pay for all respondents is \$503.29. This is \$342.29 lower than the estimated WTP for those who were willing to pay a premium for E-85 vehicles. The respondents not willing to spend any additional money to buy E-85 powered vehicle have a negative bid, meaning they have to be compensated in order to own an E-85 vehicle.

The average willingness to pay is $718.04 for the respondents under the age of 30. The two older group were willing to pay $573.38 and $391.65 for the age group 30-50 and for the over 50 years of age respectively. The hypothesis that younger people will be more disposed to pay a premium for E-85 powered vehicles has stronger statistical support here than in table 2. The reason is that the confidence intervals for respondents under the age of 30 and over the age of 50 are disjointed. Moreover, the same seems to be true between the respondents with no college education and with a college degree.

Table 3. Estimated average willingness of all respondents to purchase E-85 powered vehicles.

Model	Mean willingness to pay	Standard error	Confidence interval
All respondents	$503.29	31.11	$(442 ; 564)
Age group			
Under 30	718.76	92.22	(538 ; 900)
Between 30 and 50	573.65	49.55	(477 ; 671)
Over 50	391.38	45.69	(302 ; 481)
Education level			
No college	376.55	56.58	(266 ; 487)
Some college	566.20	49.02	(470 ; 662)
College graduate	618.06	61.01	(498 ; 738)

VII - Conclusion

This study uses a contingent valuation approach and data from a survey conducted in Iowa to evaluate consumers willingness to pay (WTP) a premium for E-85 powered vehicles. E-85 fuel is a combination of 85 percent ethanol and 15 percent gasoline. The average consumer willingness to pay a premium for E-85 powered vehicles is found to be $846.55. When the respondents not willing to spend any additional amount of money are included in the sample, the average WTP drops to $503.29. Younger respondents have a stronger awareness of the benefits to environment of a cleaner fuel because they are willing to spend a higher premium to buy an E-85 powered vehicle. There is also some evidence that more educated individuals will also pay an higher amount of money.

This study represents a first step in estimating the economic viability of E-85 fuel. Our analysis clearly shows that there is a market for E-85 vehicles. This, however, is only a first step. Estimates of the consumers willingness to buy E-85 fuel and of the environmental and economic benefits from the use of this fuel are needed to provide the basis for rational economic decisions on if and how much the ethanol industry and government should promote the production of such a fuel. The procedures used in this analysis can be used to evaluate the willingness of consumers to buy other alternative fuels and vehicles.

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