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THE TARGET MARKET FOR METHANOL FUEL

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Abstract — A survey of vehicle owners was conducted in New York State and California to explore the potential target market for methanol in the household sector. Data were colleted on revealed and reported premium gasoline purchase behavior and willingness to pay for cleaner fuels and more power. We found that drivers are willing to pay slightly more for cleaner fuels than for more power, although we do not interpret this to mean that when confronted at a fuel pump with two choices, one fuel cleaner but more expensive than the other, a motorist would select the more expensive cleaner-burning fuel. We found that income is not an important variable in predicting the purchase of cleaner fuels and that female drivers and Californians are willing to spend more on cleaner fuels than are male drivers and New Yorkers, respectively. Current premium gasoline users are willing to pay more for additional power and cleaner fuels than are regular gasoline users, indicating that premium gasoline users are likely to be initial buyers of methanol fuel and methanol-powered vehicles.

INTRODUCTION

This article is an exploration of the market for methanol fuel in the household vehicle market. The objective is to analyze the likely target market for methanol: those who use high-octane (premium) gasoline and value both power and low-polluting fuels. The article is based on a survey of vehicle owners in California and New York State.

The underlying hypothesis of this article is that a subset of premium gasoline buyers are the initial target market for methanol as a transportation fuel. We focused on premium gasoline because it is the closest analogy in the marketplace to methanol fuel. Although methanol and premium gasoline have two important attributes in common — high octane ratings and high prices — they also have dissimilar attributes, some superior, others inferior. Methanol's superior attributes from a user perspective include generally less air pollution and more engine power, whereas on the negative side it has half the energy per unit volume (resulting in shorter driving range per unit volume) and generally higher cost.

The analogy between methanol and premium gasoline is useful in that high-octane premium gasoline is priced substantially above regular gasoline, as methanol likely will be, and has gained a large and growing market share. Because methanol will also be more costly to the consumer than regular gasoline (unless it is subsidized), it will have to be viewed as a premium fuel if it is to gain market share. If methanol initially gains only a part of the premium gasoline market share, that will still be substantial because the premium gasoline market is so large. Thus, according to this premium fuel analogy, if methanol is perceived to be a superior fuel, we can expect a large number of people to be willing to purchase it, even if it is more expensive than regular gasoline.

In this study, revealed and reported premium gasoline purchase behavior are used to measure demand for octane, and a mixture of hypothetical choice questions are used to analyze demand for two other key attributes of methanol fuel — less pollution and extra power. Refueling frequency, the one major nonmonetary negative attribute associated with methanol, was tested using a stated preference question, but because many respondents seemed to be confused by the wording of the question, their responses could not be used.

BACKGROUND

Currently, the principal motive for introducing methanol as a transportation fuel is its superior emission characteristics: less airborne toxics and less reactive hydrocarbons. Methanol has two other important attributes from a consumer perspective (one positive, the other negative) that distinguish it from gasoline: (a) It provides about 10% greater power than gasoline in a comparably sized engine; and (b) because methanol has only half the energy content per unit of volume of gasoline, methanol vehicles must be refueled almost twice as often (or outfitted with larger fuel tanks). Methanol has other distinctive attributes, but they are either relatively unimportant in the vehicle and fuel purchase decision or they cannot be characterized readily as a clear advantage or disadvantage (Deluchi, *et al.*, 1988; OTA, 1990; Sperling, 1988).

Premium gasoline is distinguished from regular gasoline primarily by its higher octane rating and higher price. In recent years, regular unleaded gasoline in the United States had an octane rating ((R + M)/2) of 87, whereas premium grades generally had ratings of 91 or 92. In the late 1980s, gasoline marketers in the United States began selling a midgrade premium gasoline with ratings of 88 to 90, first on the East Coast and later elsewhere, to take advantage of what they saw as a greater willingness of consumers to pay extra for premium gasoline.

Virtually all of the premium gasoline sold in the United States since the early 1980s has been unleaded. Premium gasoline sales increased steadily from 12% of the total gasoline market in 1983 to 23% in 1989 (EIA, 1990b). The price differential between premium and regular unleaded gasoline increased from 7 cents per gallon in 1983 to 13 cents in 1989 (EIA, 1990b).

It is widely believed by oil and auto industry analysts that people are buying premium gasoline beyond what their vehicles need (GAO, 1991). In other words, consumer perceptions of the benefits of premium gasoline may not match the reality of those benefits. The major auto manufactures insist that virtually all their cars will run well on regular gasoline. The only systematic test of octane needs are those conducted annually by the Coordinating Research Council (CRC, 1989). Those studies tend to overstate octane requirements; if knocking is detected in a car, then that car is determined to need a higher octane, even though automotive engineers note that small amounts of knocking and pinging do not hurt the engine. In fact, an engine is considered to be operating most efficiently when it knocks on hills and during acceleration.

Even so, using its more conservative approach, CRC determined that 73% of new cars needed up to 87 octane in 1985; 82% in 1986; 73% in 1987; and 88% in 1988. Taking into account octane "creep" in aging cars, CRC estimated that 15 to 16% of all cars in 1987 and 1988 required greater than 90 octane. Because sales of gasoline rated at over 90 octane accounted for 23.5% of sales in 1988, one concludes that at least one third of all premium gasoline sales are unneeded. This figure is consistent with estimates by Energy Information Administration (EIA, 1990a) that 15% of all cars (excluding vans and light-duty trucks) required premium gasoline. However, a study by General Motors (GM, 1989) found that only 3% of the automotive fleet (including cars, vans and light trucks) needed premium gasoline. One reason these studies differed is that GM used untrained raters in estimating premium gasoline needs, whereas the EIA and CRC estimates are based on tests with trained raters, who presumably are more sensitive to knocking and pinging (GAO, 1991).

Given that many, if not most, buyers of premium gasoline do not need to use premium gasoline, we examine in this article whether premium gasoline buyers would be likely to switch to methanol, also a high-octane, high-priced fuel.

RESEARCH APPROACH

Respondents in two very different regions—California and New York State—were interviewed by mail to determine their willingness to pay for methanol fuel. Methanol was never specifically mentioned in the survey to assure that respondents' superficial and perhaps inaccurate knowledge of methanol would not contaminate their fundamental valuations of attributes. Current attitudes toward methanol are not stable or strongly felt and are likely to change over time as information regarding methanol is more widely disseminated.

A two-step analysis was conducted. First, demand for the principal methanol attributes was analyzed; then the attribute analyses were synthesized to gain a sense of the potential magnitude of the methanol market.

The three principal positive attributes of methanol, not directly measurable in monetary terms, were tested to determine the upper level of demand for methanol: high octane, low air pollution, and greater engine power. Demand for a less polluting fuel and a more powerful fuel (i.e., methanol) was tested using two stated preference questions. Demand for high octane was tested using a revealed preference question.

In the second and last analytical activity, the potential size of the methanol market was explored by identifying groups of individuals that value multiple positive attributes of methanol.

DATA COLLECTION AND MEASUREMENT OF VARIABLES

Sample size

In late February 1989, 5000 questionnaires were mailed to registered owners of a random sample of automobiles in New York and California. The mailing lists were purchased from R. L. Polk, Inc. and included the name and address of the owners and the year, make and model of the vehicle. The list included 1974 or later model year vehicles. Each respondent was asked in the cover letter to respond with respect to the identified vehicle or, if that vehicle had been replaced, for the vehicle which had replaced it. Each survey was numbered and coded so that we could monitor whether the responses were for the vehicle specified in the R. L. Polk sample. Of the 5000 individual sampled, 1876 usable surveys were returned. Another 505 were returned as "undeliverable," 11 were returned from diesel owners, and 6 were returned blank without comment. Therefore, the final response rate is 42%. Of the 1876 usable responses, 1504 (80.2%) were for the specified vehicle. The returned questionnaires were weighted heavily toward males (approximately 69%), as are automobile registrations.

Dichotomous choice with contingent valuation method

The contingent valuation method (CVM) was selected for this study to derive estimates of consumer willingness to pay for typical attributes of methanol fuel that differ from gasoline. CVM is widely accepted as a method of generating willingness-to-pay (WTP) functions for a wide variety of market and nonmarket goods, including environmental benefits. For further discussion of CVM, see Cummings and Brookshire (1986).

The basic premise of CVM is that a good, market and payment technique are described to a respondent, who then bids how much he or she is willing to pay for that good under those conditions. Traditionally, each respondent's WTP is determined with open-ended questions, in which respondents are allowed to bid their own amount, or with iterative bidding, in which an interviewer presents a series of possible bids, usually in increasing order, to a respondent until a "no, I would not pay that amount" response is elicited. These two methods do not represent how individuals actually make decisions. To give respondents a more marketlike setting, we used dichotomous choice CVM. In dichotomous choice CVM, each respondent is asked to accept or reject one particular good at a specified price (bid).

In dichotomous choice CVM, the sample is divided into subsamples, each of which is presented a different bid amount with a dichotomous choice: "Yes, I would pay that amount" or "No, I would not pay that amount." Each subsample has an associated frequency distribution of yes responses which can be inferred to be valid for the entire sample. These frequency distributions yield a willingness-to-pay curve analogous to a demand curve.

Logistic regression (discrete choice analysis) can be applied using the frequency distribution of yes and no responses for each question as the dependent variable. The effects of independent variables—such as income, education level and type and characteristic of vehicle—are interpreted as an individual's willingness to pay. For dichotomous choice with CVM, see Hanemann (1984) and Loomis (1988).

Sampling procedure

For our study, eight different bid amounts were specified for each question. Individual respondents were randomly assigned to a survey version resulting in eight subsamples. Because there were six different questions which employed this technique, each version had the same st of bid amounts on those six questions. The implicit pattern created, that of similar bid values for each attribute, avoids signaling the respondent that one characteristic should be valued more or less than another. Appropriate bid amounts were determined by pretesting to cover the largest range of possible WTP responses while remaining sensitive to the critical portion of the range.

Because respondents were selected randomly, it was expected that each subsample would be representative of the larger sample and therefore that results from those subsamples could be extended to the larger sample. Indeed, response rates (see Appendix Table A-1) were not significantly different for the eight subsamples, ranging from 11.9% to 13.2% of the total sample; nor were differences in the basic demographic variables (sex, income or education level) statistically significant between subsamples.

Variable specification

The measurement and specification of variables used in this article are presented in Table 1. To analyze demand for methanol, we identified two indicators that are treated as distinct dependent variables: (a) willingness to pay for cleaner fuel, and (b) willingness to pay for extra power. These variables are binary variables. They were coded as zero if the respondent was not willing to pay at a given price (bid amount) and one if the respondent was willing.

Data for seven independent explanatory variables were collected in the survey; we grouped these variables as shown in Table 1. The first subgroup includes socioeconomic and demographic attributes. Data on total annual household income (before taxes) were collected as a 12-interval-scale variable and recoded into three categories: $24,999 or less, $25,000 to $59,999 and more than $59,999. Education level was then collapsed into three groups: those with up to 12 years of school, those who attended up to 4 years of college and those with more than 17 years of schooling. The rest of variables in the first subgroup—sex and state of residence—are binary variables.

Other independent variables are engine size, measured as number of cylinders; and type of fuel "mostly used by driver," classified as unleaded regular, midgrade and premium. Only 78 respondents used regular leaded gasoline, and therefore they were deleted from the analysis.

Variables with missing values

In mail or telephone surveys some questions are not answered. These missing values will reduce the usable sample size considerably, especially when the missing value pattern is scattered. Consequently, the reduced data may lead to less efficient estimates. Moreover, possible biases may arise when missing value cases are deleted (Little and Rubin, 1987). In our case, the sample size would be reduced from 1876 to approximately 1563 (a reduction of almost 17%) if questionnaires that contained missing values were deleted. An attempt has been made to impute those missing values. Five of the seven independent variables have at least one missing value (see Appendix Table A-2).

Single imputation

Single imputation—assigning values to missing observations—is the easiest and most commonly used technique for handling nonresponse. However, this technique for handling nonresponse has a drawback. Single imputation may lead to underestimation of

Table 1. Variables used in the model

No.	Variable	Definition	Values
A.	*Dependent Variables*		
1.	WTPAQ	Willingness to pay for cleaner fuel	0 = no 1 = yes
2.	WTPXP	Willingness to pay for more powerful fuel	0 = no 1 = yes
B.	*Independent Variables*		
3.	Log of bid	Log of bid amount (in dollars)	log(0.02)[a], (0.03)[b] log(0.05), (0.06) log(0.10), (0.09) log(0.15), (0.12) log(0.20), (0.15) log(0.25), (0.20) log(0.35), (0.30) log(0.45), (0.40)
	Socioeconomic & Demographic Attributes		
4.	Income	Annual household income before tax	1 = less than $25,000 2 = $25,000-$59,999 3 = more than $59,999
5.	Education level	Number of years of formal education	1 = 12 yrs. or less 2 = 13-16 yrs. 3 = 17 yrs. or more
6.	Sex	Sex of respondent	0 = female 1 = male
7.	State	Respondent's domicile state	1 = New York 2 = California
	Vehicle Attributes		
8.	No. of cylinders	Number of cylinders	1 = 4 cylinders 2 = 6 cylinders 3 = 8 cylinders or more
	Behavioral Attributes		
9.	Fuel grade	Type of fuel mostly used	1 = unleaded regular 2 = unleaded midgrade 3 = unleaded premium

[a]Bid amounts associated with willingness to pay for cleaner fuel
[b]Bid amounts associated with willingness to pay for more powerful fuel

variance and therefore a tendency to accept a hypothesis when it should be rejected; in general, though, single imputation is adequate and has been utilized widely (Rubin, 1987). To minimize the loss of information, original values or codes were used if possible.

We used several techniques to impute values, including logistic regression, multiple regression and mean value method. Logistic regression was used for dichotomous independent variables and multiple regression for continuous variables such as income. The last technique, mean value method, was used for variables which are weakly correlated to other independent variables – such as sex.

RESULTS

Demand for cleaner fuel

In our surveys, we asked, "Would you switch to a fuel that produced less air pollution if it were priced (bid amount) higher than the gasoline you normally buy?" We defined cleaner fuels as those that produce less air pollution, but we did not quantify the difference because of controversy (and therefore confusion to the consumer) over the likely expected pollution impact of methanol (OTA, 1990). From the response, we found that almost 85% of the respondents were willing to pay 2 cents more per gallon and approximately 24% were willing to pay 45 cents more.

Before estimating the coefficients for the cleaner fuel demand function using a maximum likelihood estimator, it is important to choose the appropriate functional form for relating each variable to logit function (Boyle & Bishop, 1989). Based on univarate analysis (using only one independent variable, such as bid amount), the logit function is not linearly related to bid amount; therefore, in multivariate analysis we decided to use the logarithm of the bid amount, which will provide declining marginal utility with price or bid amount. Because bid amount was assumed to be a continuous variable, no design variable was considered. However, design variables were then developed for categorical variables using the partial method (Dixon, 1983). This method has been widely used in epidemiology research, whereby one group in the sample is treated as the reference group and the other as the exposed group(s). The ease of interpreting the result makes it a more popular technique than its counterpart, the marginal method (deviation from mean parameterization). For example, in our case, all else being equal, if we want to know how much the willingness to pay for cleaner fuels differs between females and that of males, the partial method assigns a zero value to the lowest code for sex and value of one to the highest value. Then the resulting design variable under this method would be zero for females and one for males.

The likelihood ratio test leads to reject the null hypothesis that all variables have zero slopes with 5% level of significance. (This is shown in Table 2, in which the calculated likelihood ratio equals 432.53 asymptotically distributed as chi square, with df = 9, which is significantly larger than 16.92.)

Results indicate that, as expected, the log of bid amount was strongly correlated with willingness to pay. The minus sign in this variable shows that as bid amount increases, the willingness to pay decreases. The last column in Table 2 is the odds ratio, which can be interpreted as the likelihood of a consumer to buy cleaner fuels for unit change in the log bid variable.

Surprisingly, income is not related to willingness to pay for cleaner fuels. One explanation is that environmental concern indeed cuts across all socioeconomic groups. A second explanation is that individuals are not being called on to make actual cash payments and thus may overstate their willingness to pay (especially less affluent individuals). Level of education is only marginally significant, with the most educated people (those with more than 16 years of schooling) being 27% more likely to pay (i.e. odds ratio of education level 2 equals 1.274) for less polluting fuels than the least educated people (those with less than 12 years of formal education).

Overall, our findings regarding income, education and valuation of clean fuels are in agreement with those of Kurani and Sperling (1988) regarding diesel car owners, and to some extent with those of Calfee (1985) regarding demand for electric cars.

Table 2. Estimation results for cleaner fuel choice model

No.	Variable	Estimated Coefficient	Standard Error	*t* Statistic	Odds Ratio
1.	Constant	−2.0326	0.3171	−6.409	0.131
2.	Log of bid[a]	−2.0636	0.1399	−14.753	0.127
A.	*Socioeconomic & Demographic Attributes*				
3.	Income (1)[b]	−0.0222	0.0168	−1.321	0.978
	(2)	0.1213	0.0723	1.678	1.129
4.	Education level (1)	0.1706	0.1002	1.702	1.186
	(2)	0.2422	0.1202	2.015	1.274
5.	Sex	−0.2070	0.0964	−2.147	0.813
6.	State	0.4395	0.1021	4.305	1.552
B.	*Behavioral Attributes*				
7.	Fuel grade (1)	0.5568	0.2618	2.127	1.745
	(2)	1.0637	0.2671	3.982	2.897

Summary Statistics:
Number of observations = 1964
Number of cases = 1799
$L(0) = -1213.310$
$L(\hat{\beta}) = -997.045$

[a]In dollars.
[b]Number in parentheses corresponds to design variables.

Male drivers are approximately 0.8 times more likely to pay for cleaner fuels than female drivers, as shown in Table 2 (see also Fig. 1). Other surveys generally support this finding (McStay and Dunlap, 1983; Passino and Lounsburry, 1976).

All else being equal, Californians are 1.5 times more likely to pay for cleaner fuels than New Yorkers (Table 2). This finding is consistent with the hypothesis that Californians are more environmentally concerned, in part because of severe air quality problems in that state. Finally, those who use unleaded premium gasoline (variable 7 in Table 2) are almost three times more likely to be willing to pay more for cleaner fuel than unleaded regular gasoline users.

In summary, several conclusions can be noted so far: Income is not an important variable and education is a weak variable in predicting the purchase of cleaner fuels; female drivers are willing to spend more on cleaner fuels; and premium gasoline buyers are more willing to pay for cleaner fuel than nonpremium buyers, and Californians more than New Yorkers.

Demand for more power

Because methanol potentially provides about 10% more power than an energy-equivalent amount of gasoline, the willingness of consumers to pay for additional power is an important variable in predicting future demand for methanol (especially in multi-fuel vehicles). The greater power is obtained by raising the effective compression ratio to take advantage of methanol's higher octane rating and cooling effect.

With this in mind, we tried to determine which people are more willing to pay for more powerful fuels. The question posed in the survey was, "Would you switch to a fuel that gave your car about 10% more power if it was priced higher than the gasoline you normally buy?" About 65% of the respondents stated they were willing to pay an additional 3 cents per gallon, and 18% were willing to pay 40 cents more.

Using a model similar to that for predicting demand for cleaner fuels, we tested the relationship of several explanatory variables with willingness to pay for more power. We found that income is associated with demand for power. As shown in Table 3, the highest income group (more than $59,999/year) is about 40% more willing to pay for power than the lowest income group (less than $25,000/year), whereas the middle-income group ($25,000 to $59,999/year) is 20% more willing than the lowest income group.

As expected, male drivers are more willing to pay for power than female drivers (see also Fig. 2), and there is virtually no difference between Californians and New Yorkers. Owners of vehicles with larger engines (more cylinders) tended to be willing to pay more for power, but the relationship was much weaker than we expected. Unleaded premium

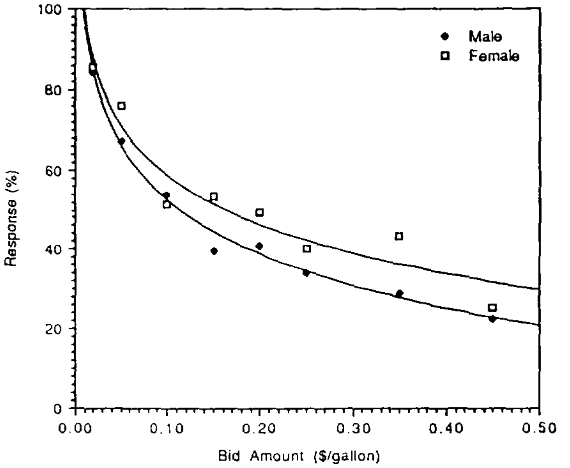

Fig. 1. Willingness to pay for cleaner fuel by male and female drivers.

Table 3. Estimation results for more power fuel choice model

No.	Variable	Estimated Coefficient	Standard Error	t Statistic	Odds Ratio
1.	Constant	−3.5405	0.3498	−10.121	0.029
2.	Log of bid[a]	−2.1982	0.1704	−12.897	0.111
A.	*Socioeconomic & Demographic Attributes*				
3.	Income (1)[b]	0.1873	0.1038	1.805	1.206
	(2)	0.3315	0.1502	2.207	1.393
4.	Sex	0.2829	0.1126	2.512	1.327
5.	State	0.0545	0.0407	1.340	1.056
B.	*Vehicle Attributes*				
6.	Number of cylinders (1)	0.1458	0.1320	1.105	1.157
	(2)	0.2784	0.1613	1.726	1.321
C.	*Behavioral Attributes*				
7.	Fuel grade (1)	0.3784	0.2235	1.693	1.460
	(2)	0.7812	0.2593	3.012	2.184

Summary Statistics:
Number of observations = 1964
Number of cases = 1580
$L(0) = -1107.890$
$L(\beta) = -901.078$

[a]In dollars.
[b]Number in parentheses corresponds to design variables.

gasoline buyers were much more willing to pay (two times more) for more powerful fuels than buyers of unleaded regular gasoline.

Most instructive, as shown by comparing the odds ratio of bid amounts in Tables 2 and 3, drivers generally perceive power as slightly less valuable than lower pollution.

Demand for high octane fuel

As indicated earlier, demand for premium gasoline is high. In 1989, when our questionnaire was administered, premium gasoline, priced at an average of 13 cents per gallon more than regular (unleaded) gasoline, accounted for 23% of sales (EIA, 1990b). In our survey, we asked respondents what type of gasoline they usually purchase and, elsewhere in the questionnaire, what octane level they seek. We found that 24% reported seeking high octane (91 +) gasoline on a regular basis, and 26% reported using premium gasoline (excluding midgrade) on a regular basis. These self-reported results seem consistent with statistics of premium gasoline sales figures.

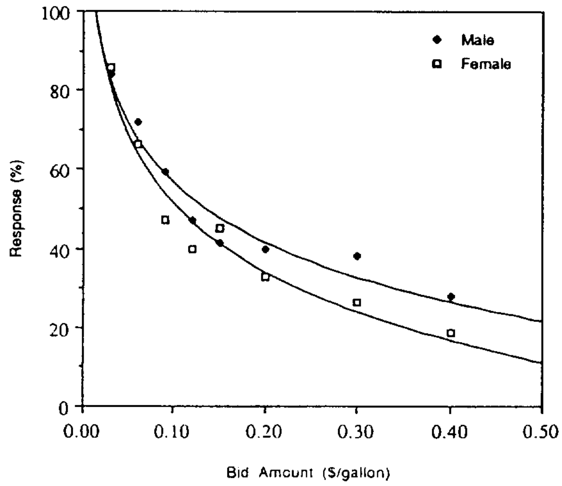

Fig. 2. Willingness to pay for more powerful fuel by male and female drivers.

But drivers do not purchase premium gasoline only, or even mostly, because of its high octane. In our survey, when respondents were given a list of reasons for purchasing premium gasoline, they ranked them as follows: "based on my own experience" (39%), "car knocks or pings" (16%), "owner's manual recommendation" (12%), "higher octane number" (9%), "mechanic's recommendation" (5%), "prefer higher grade unleaded" (5%), "contains detergent additive" (5%), "car runs poorly on unleaded regular" (5%) and three other miscellaneous reasons (4%). In another set of questions, 90% of those who said they seek 91 or higher octane reported that they purchased premium gasoline, whereas of those who purchase premium, only 51% said they seek 91 or higher octane.

Thus, octane is important, but fuel purchasers seem to think (for the most part mistakenly) that premium gasoline has other important attributes. In any case, we posit that these other positive perceptions associated with premium gasoline could be captured by methanol.

The demand for high-octane fuel varies somewhat across the driver population. Although no significant difference in those seeking higher octane fuel was observed among different income groups, we observed that male drivers were more likely to seek high-octane gasoline then female drivers (25% vs. 13%), and New Yorkers were more likely to seek high-octane fuel than Californians, possibly because New Yorkers reported driving cars with bigger engines than did Californians.

VALIDITY AND INTERPRETATION OF STATED CHOICE RESPONSES

Hypothetical choice questions may not accurately measure intended behavior or attitudes. The problem is that if respondents know that they will not be bound by an expression to pay a certain amount for a particular good or service, then they will tend to overstate their willingness to pay. (For instance, a simple 1990 opinion poll in the San Francisco Bay Area found that 94% of individuals stated they would be willing to pay 5 cents more per gallon for a cleaner fuel, much more than that of respondents in our more careful study) (MTC, 1991). We reduced the overstatement bias of WTP estimates somewhat by using bid amounts.

We were most concerned about the validity of the WTP for cleaner fuels, because clean air is a "motherhood" issue when treated in isolation of costs and other trade-offs. Because the stated willingness to pay for cleaner fuel as estimated from our survey is comparable to the stated willingness to pay for extra power—and because we know, as revealed in the marketplace, that actual willingness to pay for power is large—we conclude that our estimates of willingness to pay for cleaner fuel are not greatly overstated.

This willingness to pay for cleaner fuels does not mean, however, that when confronted at a fuel pump with two fuels, one cleaner but more expensive than the other, that a motorist would select the more expensive cleaner-burning fuel. For example, in 1970 when environmental consciousness was at its zenith, most of the major oil companies began marketing low-lead or no-lead gasoline primarily on the basis of the air quality benefit of eliminating lead. The unleaded gasoline sold for only 1 to 4 cents per gallon more than leaded gasoline, and yet sales were less than 3% of gasoline sales in 1971 and did not exceed 5% until catalytic converters were widely introduced on vehicles in 1975 (Sperling and Dill, 1988).

We therefore interpret the high willingness to pay for cleaner fuels as a willingness to pay if the cost burden is shared by all. It is a textbook "free-rider" problem. One approach for transforming this high willingness to pay into a politically acceptable initiative might be to place a surcharge on dirtier fuels (e.g. gasoline) as a means of subsidizing cleaner fuels (e.g. methanol) (Sperling, 1991); it would be most acceptable if that surcharge was specifically targeted to supporting cleaner fuels and clean air.

TARGET MARKET FOR METHANOL

For methanol to gain significant market penetration, it must be perceived as a premium fuel. Because methanol can legitimately be marketed as a high-octane, cleaner fuel that provides more power, it indeed could be positioned as a premium fuel.

In exploring the potential (hypothetical) willingness to pay for methanol, we have identified three attributes of methanol that differ from those of gasoline: higher octane, cleaner burning and more power. The three attributes have been analyzed qualitatively and quantitatively to establish WTP estimates for each attribute.

We define the target market for methanol – the likely early adopters – as those who regularly seek high-octane (premium) gasoline and who are willing to pay for fuels that are both cleaner and provide more power. We estimate the size of this target market by identifying high-octane seekers (who currently pay an average of 13 cents extra for premium gasoline) who are willing to pay even more for cleaner and more powerful fuels. Indeed, we found a significant proportion of drivers willing to pay more for these attributes of methanol. (It must be emphasized that these WTP figures cannot be added together to arrive at one curve for methanol.)

Combining the attributes, 68% of high-octane gasoline buyers were willing to pay an additional 2 cents per gallon for fuel that was cleaner and provided more power, and 26% were willing to pay 40 cents more per gallon for the two attributes (Fig. 3). High-octane seekers willing to pay at least 2 cents more for cleaner fuels and extra power account for approximately 10% of the total sample (39% of high-octane seekers). The target market, as defined in this manner, included 23% (165 of 707) of those willing to pay more for extra power and 18% (165 of 881) of those willing to pay more for less pollution. The target market has a higher average income than the sample population ($59,000 vs. $42,000), included slightly more men (75% vs 70%), drove slightly newer and bigger cars but was just as likely to live in California as New York State.

Following a similar analytic procedure but using premium gasoline users instead of high-octane seekers to estimate the target market, we arrived at similar results: In this case, 65% of premium gasoline buyers (Fig. 4) were willing to pay 2 cents more for cleaner and more power fuel (versus 68% of high-octane seekers), and 19% were willing to pay 40 cents more per gallon (versus 26% of high-octane seekers).

The magnitude of the target market for methanol could be defined by specifying different combinations of the three attributes. For instance, one could pool drivers willing to pay extra for different combinations of two of the three attributes at different bid amounts. A review of Figs. 3 and 4 provides a sense of how the target market would grow or shrink by using different attributes and bid amounts as criteria. No matter how one defines the target market, it appears to be fairly large as long as methanol fuel prices and methanol car prices are close to those of gasoline fuels and cars. What is most attractive from a methanol marketing perspective is that there is a large overlap between people who place a high value on clean fuels and greater power, a finding that surprised us.

The estimates of market potential derived in this study, based on willingness to pay for positive attributes, should be seen as upper bounds for two reasons. First, as indicated

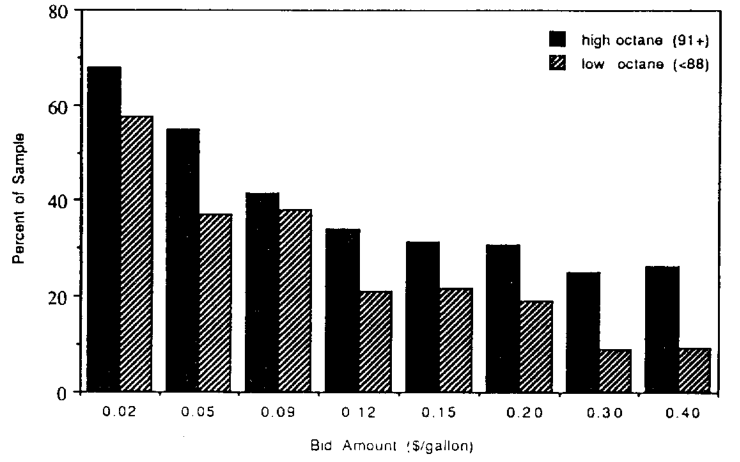

Fig. 3. Willingness to pay for less-polluting and more powerful fuels by high- and low-octane seekers.

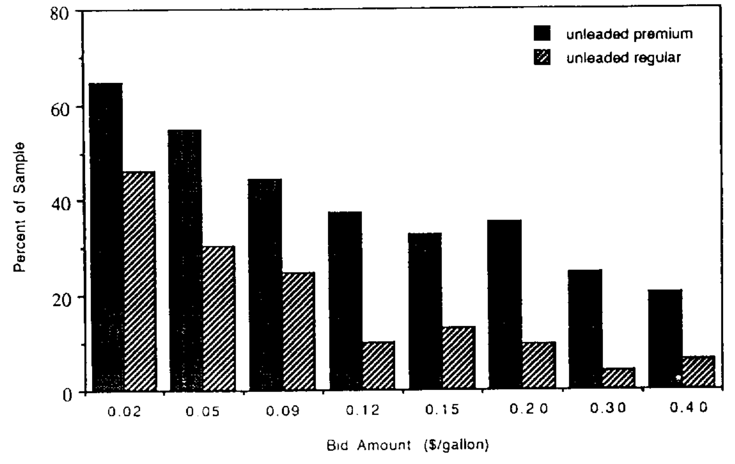

Fig. 4. Willingness to pay for less-polluting and more powerful fuels by unleaded regular and unleaded premium gasoline buyers.

earlier, although we have confidence in the estimates of willingness to pay for power and less-polluting fuels, all else being equal, the extra costs are probably larger than individuals would pay in actual transactions. Second, to the extent that the driving range associated with methanol is less than that of equivalent volumes of gasoline, drivers' overall willingness to pay for the fuel will shrink.

Other factors—such as safety, reliability and national interests—could also affect, negatively and positively, the market potential of methanol, but these factors are more tied to perceptions and social messages than quantifiable attributes. Further research is needed to determine the importance of these factors in methanol fuel and vehicle purchase decisions.

CONCLUSIONS

The results presented here may be applied—with caveats, and with caution—to both methanol fuel and vehicle purchase decisions. The demand for methanol fuel by owners of multi-fuel vehicles is characterized by the analysis in this article of the demand for higher octane (premium gasoline), extra power and less pollution. The principal other attribute whose effect is strong and (in principle) measurable is driving range. The driver of a multi-fuel vehicle will have a very clear range choice, with a tank filled with gasoline always providing considerably greater range than M85 (85% methanol blended with 15% gasoline, the likely methanol formulation to be marketed commercially)—about 50 to 80% more. The effect of reduced range on fuel purchase choices has not been quantified reliably (Greene, 1985, 1990; Sperling & Kitamura, 1986; Sperling & Kurani, 1987; Sperling, *et al.*, 1990) but is likely to be important especially if methanol refueling stations are not ubiquitous, as will be the case initially.

The effect of driving range limitations will be less important in the vehicle purchase decision than in the fuel purchase decision, even if the vehicle is dedicated to methanol, for the following reasons: (a) The driver is not confronted with the range-constraining choice at each refueling, (b) the vehicle will likely be designed to provide larger fuel tanks and therefore driving range comparable to gasoline vehicles and (c) other factors play a relatively greater role in the purchase decision. The decision to purchase a dedicated methanol vehicle will be based not only on considerations of power and pollution, but also on perceptions of future fuel availability and fuel prices, safety in handling methanol, engine reliability and life, maintenance cost and resale value of the vehicle, all of which are either subjective or unknown at this point.

If multi-fuel and dedicated methanol vehicles cost about the same as comparable gasoline vehicles, and methanol fuel costs the same as or slightly more than premium gasoline, as generally expected (especially where more expensive reformulated gasoline is required), then methanol could be competitive with gasoline in the transportation fuels market.

The central finding of this article, however, is that there is a large overlap among vehicle owners who highly value octane, power and low pollution and that this population is fairly large. The challenge for methanol marketers and proponents is to create marketing strategies which target that market segment and regulatory incentives that reward methanol's superior pollution characteristics.

In the larger context, however, the future of a methanol market is uncertain. Given the relatively modest advantages offered by methanol, the existence of initial refueling disadvantages and the lack of a strong industry advocate, methanol's future will be largely determined by government rules and regulations and how it is treated by the media.

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APPENDIX

Table A-1. Response rate by bid amounts

Bid Amount ($)	Response Frequency	Relative Frequency (%)	Cumulative Frequency (%)
0.02	243	12.1	12.1
0.05	240	11.9	24.0
0.10	243	12.1	36.1
0.15	252	12.5	48.7
0.20	266	13.2	61.9
0.25	261	13.0	74.9
0.35	255	12.7	87.6
0.45	249	12.4	100.0

Table A-2. Number of missing values in survey data

Variable[a]	Number of Cases
1. Income	174
2. Education level	72
3. Sex	43
4. No. of cylinders	81
5. Fuel grade	134

[a]See Table 1 for definition.