Automobile Fuel Economy: What is it Worth?

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Key Words:

Hedonic pricing
Automobiles
Fuel Economy
CAFE Standards
Fuel Taxes

Paper presented at the Annual Meetings of the American Agricultural Economics Association, Denver, August 1-4, 2004

Abstract

The marginal value of increased automobile fuel economy is estimated using a hedonic model of 2001 model year automobiles sold in the United States. This value is then compared to the average expected lifetime fuel savings attributable to increased fuel economy. Results indicate that automobile buyers fully internalize fuel cost savings attributable to improved fuel economy at low discount rates, and may partially internalize other perceived benefits of improved fuel economy such as reduction in global warming and fossil fuel dependence.

1. Introduction

Concern about energy efficiency touches a broad cross section of the populace. Supporters of increased automobile fuel economy cite global warming and air quality concerns, desire to conserve fossil fuels, and enhancement of domestic energy security. Organization of Petroleum Exporting Countries' announcement of a quota cutback in February of 2004 rattled world oil markets, leading almost immediately to increased market prices, proving its continuing ability to significantly influence world oil markets. Government interventions in automobile markets include mandated fleet average fuel economy standards, gas guzzler vehicle taxes, gas taxes, and tailpipe emissions regulations.

In spite of the increased share of sport utility vehicles and light trucks as a percentage of new passenger vehicle sales, average fuel economy is virtually unchanged since 1981 (reference EPA), yet vehicle weight has increased by 24%, horsepower 93%, and 0 to 60 acceleration has improved by 29%. In other words, consumers are buying more size and performance without sacrificing in terms of operating costs. Since 1987, however, fleet average fuel economy for cars and light trucks has declined by about 6%.

But does this lack of improvement in fuel economy mean that consumers don't value fuel savings? In light of legislation proposed to mandate increases in fuel economy and subsidize research into alternative fuel vehicles and hybrid vehicles, an understanding of consumers' valuation of fuel economy can aid in anticipating market reaction to such legislation and the potential impact on consumer well being. This research estimates the value consumers place on fuel economy through a hedonic analysis of model year 2001 new car sales in the United States to determine if consumers accurately value the fuel savings of improved fuel economy. In addition, the gas guzzler tax is considered explicitly to determine to what extent consumers internalize this potential added cost and to what extent it influences consumers' valuation of fuel economy.

2. Previous Literature

Surprisingly few economic studies have attempted to determine consumers' willingness to pay for improvements in automobile fuel economy. The earliest hedonic studies of automobiles were concerned with estimation of quality adjusted prices, for example Court (1939), Griliches (1971), Cowling and Cubbin (1972), Ohta and Griliches (1976), and Triplett (1969, 1986). Other researchers focused on valuation of safety features and associated implications for the value of life (Atkinson and Halvorsen 1984, Dreyfus and Viscusi 1995, Dunham 1997). Douglas, Glennon, and Lane (1993) considered the relationship between vehicle warranties and vehicle quality, while several others attempted to measure market power exerted by producers in different locations (Mertens and Ginsburgh 1985, Thompson 1987).

As fuel economy was not an explicit focus of most of these studies, it was omitted by some and often found to be insignificant due to high correlation with other included variables. Arguea and Hsiao (1993) and Thompson (1987) included fuel economy measured in miles per gallon linearly and found inconsistent and insignificant results. Since fuel economy would be expected to be valued by consumers for the fuel savings it provides, "miles per gallon" would more accurately have an inverse relationship with automobile price, since fuel cost equals price per gallon times miles driven divided by miles per gallon.

Atkinson and Halvorsen (1990) and Dreyfus and Viscusi (1995) appropriately use the inverse of "miles per gallon" in their analyses, but derive a fuel cost variable by assuming a fuel price and average miles driven. This study does not presuppose fuel price or miles driven, in particular because miles driven may either influence a consumer's choice of fuel economy or be influenced by the fuel economy of the vehicle purchased. In either case, the implicit price of fuel economy would be expected to reflect the consumer's fuel cost savings which would be a function of their expectation of future fuel prices and vehicle miles to be driven.

3. Estimation

a. Model

Automobiles are purchased for the travel services they provide. The utility that a consumer derives from travel services depends, in part, on vehicle characteristics such as comfort, size, safety, and performance, with fuel economy being but one characteristic to consider. Fuel economy is often, although not always, negatively correlated with these other vehicle characteristics. Thus the consumer must balance potential savings in fuel costs due to higher fuel efficiency against a preference for larger, safer, or faster vehicles. Over time, technological improvements have led to increases in fuel efficiency with fewer sacrifices in terms of size, safety, and performance, thus reducing consumer aversion to vehicles with higher fuel economy.

This analysis follows the methodology developed by Rosen (1974) for hedonic price analysis. Each automobile is a differentiated bundle of characteristics. In a competitive equilibrium, the price of an automobile will result from the interaction of producers and consumers for different bundles of these characteristics. The price of an automobile can be represented as $P_{auto} = P(A_1, A_2, A_3, \ldots A_n)$ where each A_i is a characteristic or attribute of the vehicle. The implicit marginal price of any one attribute is the partial derivative of the equilibrium hedonic price function with respect to that attribute:

$$p(A_k) = \partial P_{auto} / \partial A_k = P_{Ak}(A_1, A_2, A_3, \ldots A_n)$$

Given an equilibrium market, this value reflects both the consumers' marginal willingness to pay for an additional unit of that attribute and the producer's marginal cost of providing another unit of that attribute in that vehicle.

b. Data and Vehicle Characteristics

The data used in this analysis was obtained from Consumer Reports and Ward's Automotive Report websites and includes 130 automobile models, list price, vehicle attributes, and sales quantities for model year 2001 automobiles. In addition to fuel economy, this study considers seven general categories of desired vehicle characteristics: size, power, performance, safety, comfort, reliability, and whether or not the vehicle is classified as a luxury automobile. Because different regulations apply to sport utility vehicles, vans, and light trucks, and because many of these vehicles are used for commercial purposes, these types of vehicles are not included in this analysis. Table 1 shows the summary statistics for the variables included in this hedonic analysis.

Length, width, wheelbase, and curb weight are all indications of vehicle size. Curb weight, however, is likely the best indicator of size as both length and width are one dimensional and wheelbase can vary across similar size vehicles depending on vehicle design. Further, among these variables, curb weight has the highest average correlation with the other three size indicators so it is used in this model as the indicator of vehicle size.

Power has most commonly been measured by horsepower or horsepower divided by curb weight. Zero to sixty miles per hour acceleration time has also often been used as a measure of vehicle power. Since acceleration is highly correlated with horsepower (-0.64) but less highly correlated with curb weight than is horsepower (-0.43 versus 0.71), zero to sixty acceleration is included as the indicator of power. Performance is measured by turning circle which is the bumper clearance needed to make a 'U' turn recorded in feet.

Two safety attributes are included, braking distance and crash test results. Braking is the distance in feet needed for the vehicle to come to a standstill from a speed of sixty miles an hour on dry pavement. The National Highway Traffic Safety Administration administers crash tests and scores vehicles on a scale of 1 to 5, with 5 being the best rating, for both a front crash test and a side crash test. This hedonic analysis uses the sum of these two ratings as a measure of vehicle safety.

Comfort rating is based on reported front seat comfort rating on a scale of 1 to 5 with 5 being the best. The comfort score assesses noise under normal driving conditions and ergonomic factors such as legroom, headroom, and driving position comfort. Reliability is similarly based on reported rating that ranges from 1 to 5 with 5 being the most reliable. This test is based on the rate of problems with vital vehicle components such as brakes and transmission.

In the data source, all vehicles were classified as small, coupe, family, wagon, large, sport, upscale, and luxury. Categorizations based on vehicle size (small and large) should be captured in the vehicle size variable discussed above. Sports cars and coupes are generally smaller than average, but typically differentiated from small cars due to power and performance, hence power and performance variables would be expected to pick up the differential value of sports cars and coupes more explicitly in terms of what differentiates them from other vehicles. Tests of significance of the other vehicle categories found only the luxury classification, representing six percent of the vehicles, to be statistically significant so it is the only classification included in the final analyses.

The fuel cost of operating an automobile is fuel price per gallon multiplied by miles driven divided by miles per gallon. Higher fuel costs would be expected to reduce vehicle price, all else constant. Since fuel economy is expected to be valued by automobile consumers in relation to the fuel cost savings provided, fuel economy, measured in miles per gallon, should be inversely related to automobile price.

Fuel economy numbers are based on U.S. Environmental Protection Agency (EPA) tests. Both city mileage and highway mileage are considered, as well as a weighted average as calculated by the EPA. The weighted average is based on an assumption of 45% highway driving and 55% city driving. It is not adjusted for in-use shortfall. It is approximated as (1/(0.495/city MPG + 0.351/highway MPG))+0.15 (US EPA). This is also the equation used to determine the Gas Guzzler Tax. The Energy Act of 1978 (Public Law 95-618) established the Gas Guzzler Tax on the sale of new model year vehicles for which the weighted average fuel economy was less than 22.5 miles a gallon. It increases as fuel economy declines for every one mile per gallon decrease down to 12.5 miles per gallon, as shown in Table 2. Among the 2001 model year vehicles included in this analysis, none averaged less than 18.5 miles per gallon.

Curb weight, comfort, safety, reliability, and luxury status are all expected to contribute positively to vehicle price. Since acceleration is measured in seconds to achieve a given speed, and turning circle and braking distance and measured in feet to accomplish the task of turning or braking, these variables are expected to have a negative relationship to vehicle price. Ceteris paribus, vehicles subject to the gas guzzler tax would also be expected to sell for less, as consumers consider the added cost as part of their total cost of acquiring the vehicle, reducing their willingness to pay for the vehicle. Finally, the coefficient on the inverse of miles per gallon is expected to be negative, indicating that lower levels of fuel economy increase fuel costs, resulting in a lower willingness to pay.

4. Empirical Results

Four linear models are estimated using White's heteroskedastic consistent standard error correction, with fuel economy entered inversely in all. The first model includes city fuel economy, the second includes highway fuel economy, the third includes both city and highway fuel economy, and the last includes the weighted fuel economy. Automobile consumers most likely consider both city and highway fuel economy, so models 3 and 4 are likely more representative, but the others are included for comparison.

All coefficients are of the expected sign and are fairly consistent across the models. Only the reliability rating and the third tier of the gas guzzler tax were not statistically significant across all the models. The coefficient values for the gas guzzler taxes, particularly the first and fourth tier, are generally higher than expected. Since these variables are dummy variables, the coefficient is expected to be close to the negative of the actual value of the tax, yet "Tax 1" is about two and a half times the $1000 tax and "Tax 4" is at least 60% higher than the actual $2100 tax across the four models.

Table 4 compares the estimated value of a one mile per gallon increase in fuel economy to the actually value of fuel savings of such an increase. The actual value of fuel savings are based on a U.S. Department of Transportation (DOT) report of an average final vehicle mileage of 145,000 miles and the EPA assumption of 45%/55% split on highway versus city driving mileage. Three calculations were made using different fuel prices: $1.50 per gallon, $1.75 per gallon, and $2.00 per gallon. The average retail gasoline price per gallon from September 2000 through November 2001, the time period over which most model year 2001 vehicles were sold, was $1.51 per gallon. The DOT reports the average lifespan of a vehicle is just over 13 years, but the estimation results indicate consumers value increases in fuel economy by more than the expected undiscounted value of fuel savings based on 145,000 miles driven and a price of $1.50 per gallon, so the fuel saving values reported in Table 4 are not discounted.

The estimated values derived from Models 1 and 2 clearly suggest overvaluation of fuel savings, but since each of these models excludes one measure of fuel economy, the other is likely picking up some of the influence of the omitted variable, biasing the estimate upward. For model 3, city mileage is fairly close to the actual undiscounted fuel savings at an assumed fuel price of $1.50 per gallon, suggesting a discount rate of about 1% if these mileage and fuel price estimates are accurate. To the extent that consumers expect new vehicles to last longer or fuel prices to be higher, the estimated fuel economy value reflects moderate discounting by consumers, at a rate of 4% for a price of $1.75 and 7% for a price of $2.00 per gallon. These calculations are based on the DOT estimates that the average new-car buyer trades in at 55,000 miles, approximately every four years. The vehicle is then assumed to be driven gradually fewer miles until the average final mileage of 145,000 is met at 13 years.

In contrast to city mileage estimates, the estimated marginal value of highway fuel economy is significantly greater than actual fuel savings, again based on EPA estimates of 45% of total mileage being highway driving and the DOT estimate of 145,000 total miles. If automobile consumers are overestimating fuel cost savings from improvements in highway mileage, it makes sense that average mileage improvements would also be overvalued, especially if consumers are "guesstimating" average fuel economy based on new car sticker information of city and highway fuel economy. It is also possible that consumers don't have an accurate idea of the potential fuel savings associated with improvements in fuel economy, particularly as most proponents of fuel economy improvements cite fuel cost savings (see, for example, Emert 2002 or Sierra Club 2002), while most opponents focus on safety and freedom of choice issues, rather than the declining value of fuel economy improvements as average fuel economy increases (see, for example, Competitive Enterprise Institute 2003 or Crandall et al. 2002). On the other hand, consumers may be valuing something they perceive to be associated with improvements in fuel economy, such as lower vehicle emissions, reduction in global warming, or decreasing dependency on fossil fuels. Finally, there may be a bias in the sample since sport utility vehicles, minivans, and light trucks are not included.

5. Conclusions

In contrast to most past studies, this research finds a positive and significant value for fuel economy reflected in automobile prices, possibly even greater than undiscounted fuel savings associated with such increases, reflecting possible internalization of social values for reduced global warming or reduced energy dependency.

Between 1960 and 2001, highway travel in the United States grew about 3.4 percent a year, a 139 percent increase overall, an increase that many attribute to low fuel prices. Yet improvements in fuel economy of automobiles have nearly offset this increase in terms of overall fuel consumption. Yet, many continue to push for higher fuel economy standards and higher gasoline taxes. Portney (2002) recently concluded that the federal CAFE standards require automobile manufacturers "to produce more fuel efficient cars than large segments of the public appear to want - at least at current gasoline prices."

Mandating higher fuel economy limits consumers' choices in the marketplace and, many argue, costs lives in terms of reduced vehicle safety. If there are externalities associated with current levels of fuel consumption that are not adequately addressed by existing regulations and taxes, then further increasing the price of fuel would give consumers the incentive to improve fuel economy and drive less while retaining choice of vehicles in the marketplace. Whether or not the government should attempt to increase average fuel economy is beyond the scope of this study, however. Rather, this research can help inform policy makers regarding the value consumers place on improving fuel economy and how the demand for fuel economy might change in response to changes in future expected fuel prices, and hence the effectiveness of fuel taxes or standards in achieving changes in fuel economy over time.

Consumers appear to fully internalize the value of fuel savings associated with increases in fuel economy at low discount rates. This indicates that they are behaving rationally, contrary to the findings of earlier studies. To the extent they appear to overvalue fuel economy, they may be internalizing what are generally considered to be externalities, for example, global warming impacts and fossil fuel dependence. Hence, further government regulation would only be warranted under social efficiency considerations to the extent that they are still undervalued.

As technology continues to improve, cars become less polluting and more fuel efficient, yet just as comfortable, powerful, and safe. As our desire for such attributes as size and power reach saturation, perhaps improvements in fuel economy will catch up, finally increasing fleet average fuel economy with less government regulation.

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Table 1: Summary Statistics

Variable	Mean	Std Dev	Min	Max
Price ($)	23,098	10,217	9095	95,400
Curb Weight (pounds)	3173.3	432.92	1875	4420
Acceleration (seconds)	9.0	1.34	5	12.6
Turning Circle (feet)	39.2	2.32	33	45
Braking (feet)	139.4	6.26	117	153
Crash Test Rating	7.6	1.2	2	10
Comfort Rating	3.8	0.64	2	5
Reliability Rating	3.3	1.18	1	5
Luxury	0.06	0.23	0	1
City Mileage	15.6	2.86	12	36
Highway Mileage	33.3	4.10	23	66
Average MPG	23.7	3.73	18.6	52.6

Table 2: Gas Guzzler Tax

Average MPG	Tax	Percent of Vehicles
At least 22.5	0	59.5
At least 21.5 but less than 22.5	$1000	9.9
At least 20.5 but less than 21.5	$1300	14.3
At least 19.5 but less than 20.5	$1700	3.7
At least 18.5 but less than 19.5	$2100	12.6

Table 3: Empirical Results Using Actual Gas Guzzler Tax Dummy Variables

Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Curb Weight (pounds)	17.94	17.62	18.66	18.45
	(29.53)	(37.52)	(31.27)	(30.13)
Acceleration (seconds)	-1541.5	-1836.0	-1784.0	-1630.0
	(-17.82)	(-19.56)	(-19.79)	(-18.08
Turning Circle (feet)	-902.5	-957.7	-917.6	-900.4
	(-17.97)	(-18.14)	(-18.33)	(-17.96)
Braking (feet)	-110.34	-137.77	-127.10	-114.97
	(-10.38)	(-12.02)	(-11.65)	(-10.59)
Crash Test Rating	218.12	388.51	232.24	191.77
	(3.01)	(6.31)	(3.23)	(2.71)
Comfort Rating	1103.0	498.42	796.87	1039.1
	(7.30)	(3.38)	(5.34)	(6.97)
Reliability Rating	133.26	181.66	105.40	106.22
	(1.73)	(2.46)	(1.37)	(1.38)
Luxury	15,866	16,963	16,192	15,840
	(26.53)	(28.78)	(27.17)	(26.68)
City gallons per mile	-129,020		-107,000	
	(-6.26)		(-5.05)	
Highway gallons per mile		-313,950	-269,070	
		(-8.55)	(-7.15)	
Average gallons per mile				-290,150
				(-7.84)
Tax 1 ($1000)	-2683.6	-3032.2	-2561.9	-2539.0
	(-6.87)	(-7.18)	(-6.52)	(-6.46)
Tax 2 ($1300)	-1808.0	-1866.4	-1357.3	-1522.6
	(-6.58)	(-5.78)	(-4.57)	(-5.37)
Tax 3 ($1700)	-43.60	-1531.6	-174.83	176.50
	(-0.14)	(-4.52)	(-0.57)	(0.57)
Tax 4 ($2100)	-3677.6	-5702.3	-4020.7	-3480.9
	(-8.67)	(-12.25)	(-9.45)	(-8.04)
Adjusted R-squared	0.85	0.85	0.85	0.85

T-statistics are in parentheses.

Table 4: Actual Versus Estimated Value of Fuel Economy

	for a one mile per gallon increase in:		
	City MPG	**Highway MPG**	**Average MPG**
Model 1	$531		
Model 2		$282	
Model 3	$440	$242	
Model 4			$517
Actual undiscounted fuel savings assuming:			
145,000 miles, $1.50/g	$463	$85	$372
145,000 miles, $1.75/g	$540	$100	$433
145,000 miles, $2.00/g	$617	$114	$495