THE IMPACT OF GAS PRICE TRENDS ON VEHICLE TYPE CHOICE

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ABSTRACT

When shopping for cars, customers consider several factors, including comfort, safety, and cost. Due to recent fluctuations in gas prices, fuel economy has become increasingly critical among these factors. As a result, the auto industry is experiencing new demand patterns among their vehicle inventory: demand for high-consumption vehicles (i.e. SUVs) is down, and demand for gas-efficient cars (i.e. hybrids) is up.

Quantifying the impact of gas prices on vehicle choice is the subject of many studies in the literature. Those studies have typically investigated the short-term effects of gas price changes on customer behavior. This article addresses the impact of fuel cost fluctuations on customers' vehicle choice, a long-term decision, through the analysis of U.S. automobile sales data from 1990 to 2007.

KEYWORDS: Transportation Economics, Traveler Behavior, Gas Price, Demand Elasticity.

INTRODUCTION

The cost of energy is an important factor for all sectors of the economy — government, private sectors, and consumers. The recent fluctuations in energy cost have altered the decisions and behavior of many groups. Among all sectors, transportation accounts for nearly 67 percent of all petroleum consumption in the United States. From 1977-2002, the transportation sector's petroleum usage grew by 35 percent, but overall national petroleum use only increased by 7 percent (EIA, 2007). This indicates that overall non-transportation petroleum usage declined during this period while transportation usage more than doubled the net national increase. Additionally, transportation distillate use (highway, rail, and marine) constituted the fastest-growing element of national petroleum use. American passenger-miles have more than quadrupled since 1950, far exceeding the population growth rate.

Since transportation costs are dependent on fuel prices, the auto industry needs to study customer responses to fuel cost increases. Modeling customer choice and providing the vehicles consumers prefer helps the auto industry to improve their market share, and makes the economy less susceptible to the global oil market shocks. This in turn allows the economy to reduce the oil dependency and respond to fuel shortages more efficiently.

Two major oil price increases have occurred in the U.S. history: in the 1970s, and since 2004. After the first increase, people altered their shopping and recreational trips, but avoided altering their automobile trips to work. After oil prices dropped in the 1980s, household vehicle trips increased, primarily for non-work trips (Loeta, 2007).

While there are many studies about the long-term and short-term effects of oil price increase of the 1970s, few studies have been performed about recent fuel price fluctuations.

Haire and Machemehl (2006) analyzed five cities in the United States and found that most transit systems have experienced a ridership growth of approximately 0.09 percent for each additional cent of fuel price. In a 2005 survey of 500 residents of Austin, Texas, Bomberg and Kockelman (2007) found that travelers reduce their overall driving and/or chain their trips together to cope with high gas prices. They also reported that households drove their most fuel-efficient vehicles more when gasoline prices increased in 2005.

Goodwin et al. (2004) reviewed empirical studies since 1990 and found that a 10 percent increase in the real price of fuel produces:

a 1.0 percent reduction in vehicle miles traveled;
a 2.5 percent reduction in fuel consumption;
a 1.5 percent increase in the fuel efficiency of vehicles; and
a less than 1.0 percent decrease in net vehicle ownership.

Eltony (1993) attempted to model gasoline demand for Canada. He demonstrated through regression models that in response to a gas price increase, households planning to buy a new car either postpone their vehicle purchases or buy a more fuel-efficient car, and households that already own a car drive fewer miles.

Wadud et al. (2008) used a large household-level panel dataset to investigate the demand for gasoline in the United States. They concluded that the price and income elasticities of different households depend on income and other demographic and location characteristics. Income elasticity decreases as income increases, suggesting that multiple-car households consume more fuel as income increases than those with only one car. Also, multiple-wage-earner households drive more when their income increases than zero or single-wage-earner households. In response to an increase in income, there are not significant behavior differences between rural and urban households. They also concluded that multiple-vehicle households are more price elastic. This could be due to their ability to switch to a more fuel-efficient vehicle when gas prices increase. Multiple- wage-earner households have higher price elasticities than single-wage-earners, possibly because these households have higher flexibility in rearranging their travel patterns.

The demand for automobile transportation is determined jointly as the product of the decision of how many cars to own and how many miles to drive each car. The most important determinant of driving demand is income and its effect through automobile ownership rather than the number of miles driven. The elasticity of miles driven with respect to income, holding the number of cars constant, is less than 0.1, while the elasticity of automobile ownership with respect to income is 0.8. Many studies have concluded that in contrast to the responsiveness of automobile demand to income, the elasticity of auto driving to the cost of driving is very low. Drivers seem to adjust to higher gasoline prices not by driving less but by switching to more fuel-efficient automobiles. Therefore, while the elasticity of demand for gasoline to the gasoline price is significantly different from zero, the responsiveness of the number of miles driven to the gas price changes is close to zero (Boyer, 1997).

Consumers react differently to gas price increases in short-term than long-term. In short-term, they try to reduce the gas expenses by adjusting their daily behavior. They can use their fuel-efficient cars in the case of having multiple vehicles, use cheaper gas types, combine their trips, and reduce unnecessary trips. In long-term, however, they can change their transportation mode, their destinations, and finally their non-fuel-efficient vehicles.

This study investigates whether customers have changed their automobile-purchase behavior due to gas price increases since 2004. Using a model similar to the one described in Eltony's 1993 study, this study examines whether people have started to buy more fuel-efficient cars.

THE EMPIRICAL MODEL

A customer's binary choice between two types of vehicles is made based on household characteristics and the car features. Let the ratio of the probability of choosing car type *z* to type *x* by household *i* be *Piz/Pix*. K_i represents household characteristics, and L_t denotes characteristics of the alternative car type *t*.

$$P_{iz}/P_{ix} = (e^{A_z + B_Z K_i + CL_z})/(e^{A_x + B_x K_i + CL_x}) \qquad (1)$$

Where:

P_{iz}/P_{ix} = The ratio of the probability *y* of choosing car type *z* to car type *x* by household *i*

K_i = Characteristics of household *i*

L_t = Characteristics of car type *t*, ($t = z, x$)

A_t, B_t, C = Coefficients

Taking the logarithmic of the above equation yields

$$Ln(P_{iz}/P_{ix}) = (A_z - A_x) + (B_z - B_x)K_i + C(L_z - L_x) \quad \text{for } z = 1\text{-}5, z \# x \qquad (2)$$

Since the data on the household choice of the type of new car is unavailable, we substitute the probabilities by the relative frequencies of the households with the attributes Ki, choosing car type z as follows:

$$Ln(N_z/N_x) = (A_z - A_x) + (B_z - B_x)K + C(L_z - L_x) \quad \text{for } z = 1\text{-}5,\ z\#x \qquad (3)$$

Household disposable income and unemployment rate are the household characteristics (K) used in our estimation. The car characteristics (L) used in our estimation are the difference in car prices and the gasoline cost per mile for the current and two preceding years. In order to be able to use logit estimation (similar to the model used in Amemia, 1981), we assume that the coefficient of vehicle characteristics, L, are equal. Therefore, equation (3) can be rewritten as equation (4).

$$Ln(N_z/N_x) = A + B_1 .Income + B_2 .Un + C_1 .(P_{nz} - P_{nx}) + C_2 .P_g(1/en_z - 1/en_x) + C_3 .P_{g-1}(1/en_z - 1/en_x) + C_4 .P_{g-2}(1/en_z - 1/en_x) \quad \text{for } z = 1\text{-}5,\ z\#x \qquad (4)$$

Where:

$A = A_z - A_x$

$B_1 = B_{1z} - B_{1x}$

$B_2 = B_{2z} - B_{2x}$

C_1 , C_2 , C_3 , C_4 =Components of coefficient array C

Income = Household disposable income

Un = Unemployment rate

$P_{nz} - P_{nx}$= The difference in car type average prices

P_g = Price of gasoline per gallon

P_{g-1} = Price of gasoline per gallon one period back

P_{g-2} = Price of gasoline per gallon two periods back

en = Technical fuel economy in mile per galon

DATA AND EMPIRICAL APPROACH

We acquired the time series data from 1990-2007 for the United States from several sources. The population, unemployment rate, and the average household income were derived from the U.S. census. The average gas price, fuel efficiencies, and percentage of cars sold in each car type were obtained from the U.S. Department of Energy (Table1).

The U.S. population increased from 248,709,873 in 1990 to 303,162,947 in 2007. A larger population causes more car purchase and more trips. Average household income decreased from 1990 to 1993, and then increased from 1993 to 1999 due to the good economic situation and the Internet boom during this period.

The average income per household fluctuated from 1999 to 2002. The average income per household then increased from 2002 to 2007, following the economic pattern in the United States. The unemployment rate is the inverse of the income pattern: increasing from 1990 to

1992, decreasing from 1992 to 2000, increasing from 2000 to 2003, and decreasing again from 2003 to 2007.

The Environmental Protection Agency's (EPA) fuel economy standards have five different categories for passenger cars. Car Type 1 has a fuel efficiency of 5-20 miles per gallon, representing pickup trucks, SUVs, vans, and some large sedans. Car Type 2, which accounts for small SUVS and some large sedans, has a fuel efficiency of 20-25 miles per gallon. Car Type 3 has a fuel efficiency of 25-30 miles per gallon. This vehicle category includes mid-size cars. Car Types 4 has a fuel efficiency of 30-35 miles per gallon and represents small cars. Car Type 5 that represents hybrid cars has a fuel efficiency of 35-55 miles per gallon.

We utilized a linear regression, equation (4), for the car sales ratios of all car types (aggregate) relative to Car Type 1 (Van/SUV/Large Sedan). We then performed similar linear regression for each separate car type category.

Before performing regression analysis, we tested the co-linearity between income and unemployment rate. The co-linearity is -0.59, therefore, we use only one of the two variables.
We assumed that number of cars sold in each car type compare to car type 1 (Van/SUV/Large) is a function of income or unemployment, the difference of price of the car from Van/SUV/Large, and the gasoline cost per mile of the car compare to Van/SUV/Large.

Table 1
The National Socio-economic Data from 1990 to 2007

Year	Population	Income	Unemp	GasPrice	Van/SUV/Large	SmallSUV	Medium	Small	Hybrid
1990	248,709,873	38446	5.6	1.299	13.6	51.1	28.9	5.3	1.2
1991	252,153,092	37314	6.8	1.098	14.7	50.4	27.3	5.9	1.7
1992	255,029,699	36965	7.5	1.087	12	57.5	22.8	5.1	2.6
1993	257,782,608	36746	6.9	1.067	13.2	53.4	25.5	5.5	2.4
1994	260,327,021	37136	6.1	1.072	16.2	52.1	24.6	4.9	2.2
1995	262,803,276	38262	5.6	1.103	13.5	52.6	25.8	7.1	0.9
1996	265,228,572	38798	5.4	1.192	10.5	62.2	21.5	5.1	0.7
1997	267,783,607	39594	4.9	1.189	11	59.7	25.2	3.7	0.4
1998	270,248,003	41032	4.5	1.017	10	59.4	26.8	3.4	0.4
1999	272,690,813	42187	4.2	1.116	10	65.6	22.6	1.6	0.2
2000	281,421,906	42148	4	1.462	9.2	69.8	19	1.6	0.5
2001	285,226,284	42900	4.7	1.384	11.8	60.7	19.9	7	0.4
2002	288,125,973	42409	5.8	1.313	10.2	65.8	17.5	5.9	0.6
2003	290,796,023	43318	6	1.516	10.8	60.1	24.1	4.1	0.8
2004	293,638,158	44389	5.5	1.812	13.2	56.3	27.2	2.2	1.1
2005	296,507,061	47845	5.1	2.240	13.7	47.7	30.3	6.4	1.9
2006	299,398,484	48201	4.8	2.533	14.7	49.8	25.1	8.9	1.5
2007	303,162,947	48557	4.6	2.700	16	46.8	29.3	5.7	2.3

GAS PRICES AND CAR SALES: A FIRST LOOK

Figure 1 charts the trend in gas prices in the U.S. Gas price fluctuated from 1990 to 1999 but remained below \$1.20 per gallon. From 2000-2003, it was less than \$1.50 per gallon. Gas prices began to rise in 2004, and reached an average price of \$2.70 per gallon in 2007.

The retrieved data on the percentages of cars sold in the U.S. in each category suggests that people buy more fuel-efficient cars when gas prices increase (Figure 2). The percentage sold of Car Type 1 (pickup trucks, SUVs, vans, and some large sedans) with fuel efficiency of 5-20 miles per gallon, fluctuates from 1990 to 2007, with a minimum of 9.2 percent in 2000 and maximum of 16.2 percent in 1994.

Car Type 2 (small SUVs and some large sedans) has a fuel efficiency of 20-25 miles per gallon. While it is the bestseller of all car types — ranging from 46.8 percent of all cars sold in 2007 to 69.8 percent in 2000 — sales dramatically decreased after 2005. That drop in sales coincides with the rise in gas prices (Figure 2).

Car Type 3 (mid-size cars) with a fuel efficiency of 25-30 miles per gallon, made up 28.9 percent of cars sold in 1990. That number fell to 17.5 percent in 2002, with smaller subsequent fluctuations.

Until 2000, Car Types 4 (small cars) and 5 (hybrids) represented a very small share of total car sales. However, by 2007, Car Type 5 sales were ten times bigger than they were seven years earlier. Figure 3 shows that hybrid cars have the same trend as gas price.

Figure 1
Gas price (Dollar per Gallon) Trend in the U.S. from 1990 to 2007

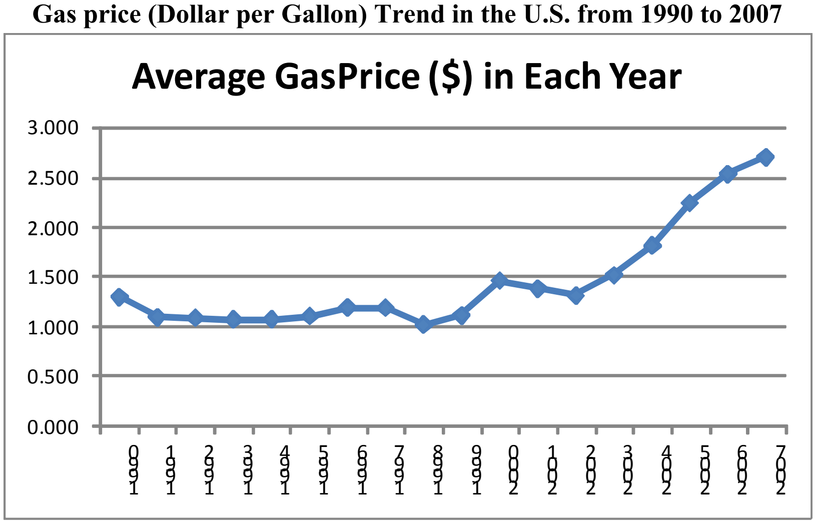


Figure 2
Percentage Car Sale Trend in the U.S. from 1990 to 2007

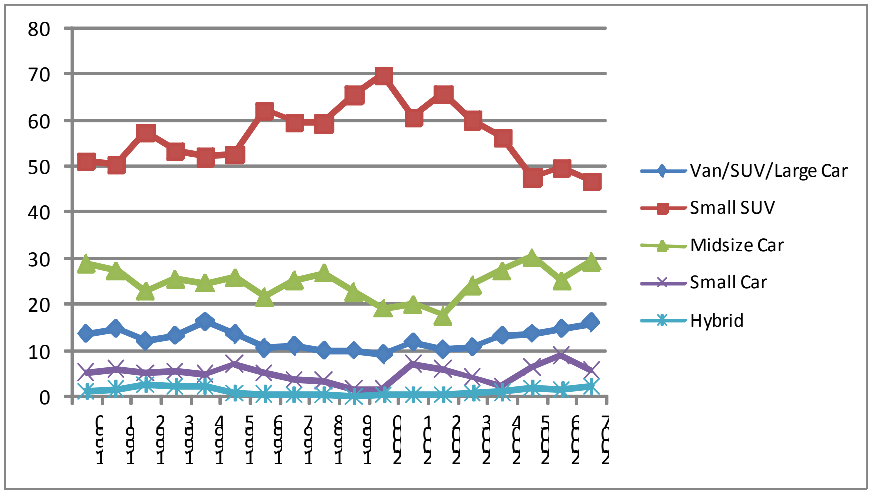
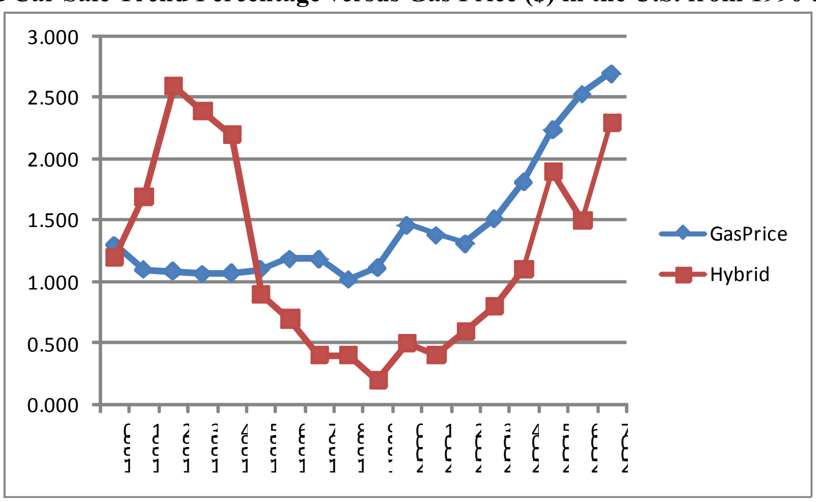


Figure 3
Hybrid Car Sale Trend Percentage versus Gas Price ($) in the U.S. from 1990 to 2007



EMPIRICAL RESULTS

The regression estimation results of all car types (aggregate) relative to Car Type 1 (Van/SUV/Large Sedan) are presented in Table 2. The results indicate that people begin purchasing more fuel- efficient cars when gas prices have increased for two periods.

There is a negative relationship between the difference in car type average prices and number of other cars sold compare to Van/SUV/Large Sedans. In another words, when the price of other cars increases, people buy more of Van/SUV/ Large Sedan. This by itself explains 70%

of the model (R^2=.70 when the dependent variable is only the price difference) and is the most important factor in people's car purchase behavior. People also buy more fuel- efficient cars when the unemployment rate increases. The coefficient of this variable is rejected to be zero in 90% confidence interval. Also, when population increases, people buy more of other cars compared to Van/SUV/Large sedans. When gas price increases, the difference in gasoline cost per mile increases. Therefore, people buy more of other cars compare to Car Type 1 (Van/SUV/Large Sedans), which has the lowest efficiency. The effect of gas price goes back to two years, meaning that when gas price keeps increasing for two years, people will start buying more fuel efficient cars. The difference in gas cost per mile in two years back explains around 42% of the model. We checked the effect of gas price in three or more years back, but it did not explain the model better and it decreased R^2.

We also performed a similar regression analysis for each car type to Car Type 1 (Van/SUV/Large Sedans) separately. The results, presented in Table 3, verify that, people tend to buy smaller cars when employment rate decreases. The results also verify the previous conclusion that people buy smaller cars when gas prices increase, after two years. However, most of the coefficients are not significant, and the adjusted R2 is very low due to having few data points and many variables for each car type.

From Plunkett Research, we acquired data on the percentages of only new cars sold in each category in the U.S. from 2000 to 2005. Plunkett Research has a different category for cars. It separates vans, SUVs, and large sedans. Also it does not have a category for hybrid cars. Category 1 is small cars with fuel efficiency of 33.7 miles per gallon (mpg). Category 2 represents mid-size sedan with fuel efficiency of 26.8 mpg. Category 3, large sedan, has a fuel efficiency of 18.7 mpg. Category 4 represents SUVs with fuel efficiency of 16.6 mpg and category 5, van, has a fuel efficiency of 15 mpg.

We performed a similar regression model for the new car sales ratios of each car type relative to category 1 (small cars). Table 4 presents the results. R2 and adjusted R2 are low due to few data points. However, all the coefficients are different from zero and the results verify the results acquired from previous model.

The coefficient of the difference in car type average prices is negative and it is rejected to be zero with 95% confidence interval. It means that, when the price of other cars increases compare to small cars, people buy less of other cars compare to small cars. The coefficient of income is positive and it is rejected to be zero with 90% confidence interval, meaning that when income increases, people buy more of larger cars. The coefficient of the difference in gasoline cost per mile is negative and is rejected to be zero with 95% confidence interval. In other words, when gas price increases, people buy more of small cars. However, adding the difference in gasoline cost per miles for previous years decreased R2 and the hypothesis that the coefficients are zero, could not be rejected. Therefore, we did not include them in the regression.

Table 2
Car Sales Ratios to Car Type1 (Van/SUV/Large Sedans)

Variables	Coefficient	T-Stat	P-Value
The difference in car type average prices	-.377	-6.46	0.000
Unemployment	0.236	2.43	0.018
The difference in gasoline cost per mile in the same year ($P_g(1/en_z - 1/en_x)$)	4.627	0.20	0.839
The difference in gasoline cost per mile in one year earlier ($P_{g-1}(1/en_z - 1/en_x)$)	-16.939	-0.50	0.617
The difference in gasoline cost per mile in two year back ($P_{g-2}(1/en_z - 1/en_x)$)	47.493	1.71	0.092
Population	0.184	1.75	0.085
Constant	-2.96	-0.95	0.348
R^2	0.76		
Adjusted R^2	0.74		

Table 3
Car Sale Ratios by Car Type to Car Type1 (Van/SUV/Large Sedans)

Variables/Car Type	Small SUV	Midsize	Small	Hybrid
P_{nz} -P_{nx}	--	--	--	--
Unemployment	0.103 (3.88)	-0.068.576)	.173 (1.381)	0.529 (5.658)
$P_g(1/en_z - 1/en_x)$	18.349 (1.089)	-6.840 (-0.81)	25.387 (1.250)	-37.016 (-3.038)
$P_{g-1}(1/en_z - 1/en_x)$	36.262 (1.41)	18.296 (1.485)	-28.669 (-1.965)	11.818 (0.669)
$P_{g-2}(1/en_z - 1/en_x)$	-18.559 (-0.829)	-10.504 (-0.967)	27.166 (1.031)	-4.301 (-0.270)
Population	0.130 (2.563)	-0.150 (-0.401)	0.011 (0.101)	-0.158 (-1.937)
Constant	-0.595 (-0.433)	1.511 (1.486)	-2.512 (-0.851)	-2.718 (-1.233)
R^2	0.72	0.31	0.37	0.85
Adj. R^2	0.60	0.02	0.11	0.79

Table 4
Car Sale Ratios for the New Cars

Variables	Coefficient	T-Stat	P-Value
$P_g(1/en_z - 1/en_x)$	-0.334	-5.08	0.000
P_{nz} -P_{nx}	-0.176	-4.70	0.000
Unemployment	-0.125	-2.69	0.014
Constant	-5.632	-2.81	0.011
R^2	0.58		
Adjusted R^2	0.51		

We also calculated the elasticities of car sale ratio of each car type to car type 1 (Van/SUV/Large sedans) to gas price using the above data. We found that if gas price increases by 10%, the ratio of small SUV's to Van/SUV/Large sedan's sale decreases by 13.7%. This ratio increases by 1.5% for mid size car, increases by 2.8% for small cars, and increases by 9.1% for hybrid cars.

CONCLUSION

Gas price has a direct impact on vehicle choice customers. Customers tend to purchase more fuel efficient vehicles as the gas price gets higher. However, this impact is not immediate and there is a time lag between price changes and vehicle choice. Regression modeling shows that an up tick in the purchase of fuel-efficient vehicles starts about two years after significant increases in gas price. Our results also indicates that a 10% increase in gas price, decreases the SUV demand by 13.7% and increases the demand for Hybrid cars by 9.1%.

Several studies had concluded that households with several cars would switch to more fuel efficient cars when gas price increases. Some other studies indicated that people would not reduce their trips but they would switch to more fuel efficient cars when gas price increases. Our study verifies their finding.

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