Spring 2010

What Factors Affect Average Fuel Economy of US Passenger Vehicles?

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<u>What factors affect average fuel economy of US passenger vehicles?</u>

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Abstract:

The auto industry consumes about 70 percent of total petroleum products used in the United States and is a major source of green house gas emissions. With the limited supply of traditional non-renewable energy and a slow growing renewable energy industry, it is important to increase energy efficiency to meet energy demand. Fuel economy, a measure of energy efficiency in automobiles, plays a vital role in reducing the consumption of limited energy and decreasing greenhouse gases. After reviewing past literatures, I find that factors such as, vehicle type, the price of fuel, CAFE standards, the weight of a vehicle, and engine performance have affected fleet fuel economy of automobiles in United States. In order to find the impacts on average fuel economy of passenger cars and light trucks (SUVs), I devise two empirical models. I find that among various attributes, technological factors such as, the weight of a vehicle and performance of a vehicles engine, affects the fuel economy of passenger vehicles significantly.

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I. <u>Introduction:</u>

Energy demand is projected to grow by 50% between 2003 and 2050 (Sadorsky, 2009). With a limited supply of traditional non-renewable energy and a slowly growing renewable energy industry, it is important to increase energy efficiency to meet energy demand. The U. S. transportation sector consumes 70 percent of the total petroleum used in the country as fuel (Energy Future, 2009). Burning petroleum products is a major source of green house gas emissions which are the main components causing global climate change (naturalgas.org). It has been hypothesized that fuel economy, a measure of energy efficiency in automobiles, could play a vital role in reducing the consumption of energy and in decreasing the production of greenhouse gases. Fuel economy of a vehicle depends on various attributes (i.e. the price of gas, technology, and government policies). The purpose of this research paper is to find and study some of these attributes to determine their effect upon energy efficiency in automobiles.

A considerable amount of energy is lost during the process of production, transmission, and consumption of energy (Energy Future, 2009). Energy efficiency is a way to reduce environmental costs of energy use without reducing the activities that energy needs to perform (Kanako, 2008). Energy efficiency in automobiles is measured in two different ways – fuel economy and fuel efficiency. Fuel economy determines how far a vehicle can run on a gallon of fuel, and is commonly measured in terms of mileage per gallon (*MPG*). Fuel efficiency relates

to the fraction of the energy content of the fuel used to move the vehicle (Wilcox, 1984). Improvements in fuel efficiency can increase fuel economy, but other factors like the weight and size of a vehicle can also affect fuel economy. So, fuel economy responds not only to changes in efficiency, but also to changes in weight and power. Thus, for this study, I consider fuel economy (*MPG*) as a desirable measure of energy efficiency in automobiles because of its comprehensive nature.

Vehicle manufacturing companies build a vehicle with certain fuel economy according to consumer demand, existing government policies, and available technology and innovation. Every vehicle needs energy in order to operate and different forms of fuel are used to provide energy to a vehicle's engine. Most vehicles use gasoline as a fuel (with some using diesel fuel), this makes the price of gasoline an important factor in determining the demand for vehicles. If the price of gasoline is increasing, consumers will demand automobiles with greater fuel economy placing pressure on manufacturing companies to produce automobiles with better fuel economy. Similarly, government regulations can also influence the fuel economy of automobiles through policies such as standards, tax credits, and subsidies. Moreover, improvements in technology such as lighter weight vehicles can also affect fuel economy (i.e. Crossover SUV's, an SUV engine on a car chassis creating a lighter weight vehicle).

II. <u>Literature Review:</u>

A number of studies have looked at different factors such as the price of petroleum, government mandates, technology, innovation, and taxes and subsidies that affect fuel economy. Some of these studies have shown that the increase in petroleum prices has helped improve fuel economy (Witt, 1997) (Green, 1990). The study of Witt (1997) looks at the effect of petrol price change on fuel efficiency in the UK market using the Atkinson-Halvorsen method. Atkinson-Halvorsen (1984) introduced a two-stage hypothesis consisting of two groups of consumers who look at different car attributes, those who look at their utility level and those who are constrained by a budget. The increase in fuel prices that makes owning a vehicle costly effects a consumer's decision, especially consumers who are constrained by a budget. Witt finds that consumers who are constrained by a budget tend to switch from low fuel economy automobiles to higher ones.

There is a considerable amount of research being done to analyze the effects of government policies on fuel economy (Goldberg, 1998) (Renshaw, 1990). Some of the important regulations are Corporate Average Fuel Economy (CAFE) standards, cash for clunkers, taxes and subsidies. The original goal of the CAFE regulation was to reduce fuel consumption by increasing fuel economy after the oil embargo of 1973. Pinelopi and Goldberg (1998) analyzed the effects of CAFE standards in US vehicles' fuel economy. The purpose of this paper was to estimate the affects of CAFE regulations on the US automobile industry after

controlling for automobile demand and supply parameters, (i.e. the elasticities' of substitution), and vehicle utilization parameters. They conclude that CAFE standards provide incentives for industries to build more fuel efficient cars.

CAFE opponents, however, claim fuel economy would have increased more if the government had not regulated fuel economy (Thorpe, 2007). Opponents say that CAFE standards do not provide incentives for the manufacturing industries to produce more fuel efficient cars as they have an option of just meeting the government's desired level. Thorpe (2007) uses a general equilibrium model and finds that CAFE standards lead to a decrease in average fuel economy. Thorpe concludes that CAFE standards may have contributed to decreasing average fuel economy by shifting automobile sales toward lower mileage vehicles.

Governments can also affect fuel economy by influencing the price of petroleum products through taxes and incentives. When a government imposes taxes on gasoline, it will increase the price of gasoline making driving more costly for consumers. Consumers may choose more fuel efficient vehicles as a result. Masayoshi *et. al* (2003). find that a fuel tax is an effective policy in increasing fuel economy. They also conclude that a tax break or incentive to car manufacturers to improve fuel economy may be effective.

Technology has also helped improve fuel economy over the years. Improvements such as the performance of the engine, advances in transmissions, aerodynamics, and the use of

lightweight materials in building vehicles are some examples of new technologies which have had a positive influence on fuel economy. Technological advances such as introducing fuel injection as opposed to carburetors has led to fuel efficiency being gained.

Past literatures have found that the weight of a vehicle is the most critical factor in increasing fuel economy (Executive summary- EPA, 2009) (Knittle, 2009). The American Physical Society's report on energy efficiency says that each 10 percent reduction in a vehicles weight translates to a 6 or 7 percent increase in fuel economy. Similarly, Knittel (2009) concludes that a ten percent decrease in passenger cars' weight is associated with a 4.26 percent increase in fuel economy. Knittle (2009) also finds that horse power, a measure on engine's performance, has a negative relationship with fuel economy.

III. Theoretical and Empirical Model:

In this paper, I treat fuel economy as a good, although it is not a physical object. For consumers, it is a desirable 'good' that seems to be a substitute to other vehicle attributes, such as power, comfort, and size of the vehicle. For manufactures, 'fuel economy' is an important factor because the demand for a vehicle depends on the fuel economy of a vehicle. For the government, 'fuel economy' is an important issue as energy independence and environmental impact have gained considerable attention in the public's eyes. The government's motive for increasing fuel economy is associated with the idea of internalizing negative externalities that are

caused by green house gas emission. Figure 1 displays the average fuel economy (*MPG*) of passenger cars and light trucks over time. In figure 1, we can see fuel economy increased rapidly until the mid 1980s, but slowed down considerably after. Fuel economy for light trucks also shows a similar trend as for passenger cars.

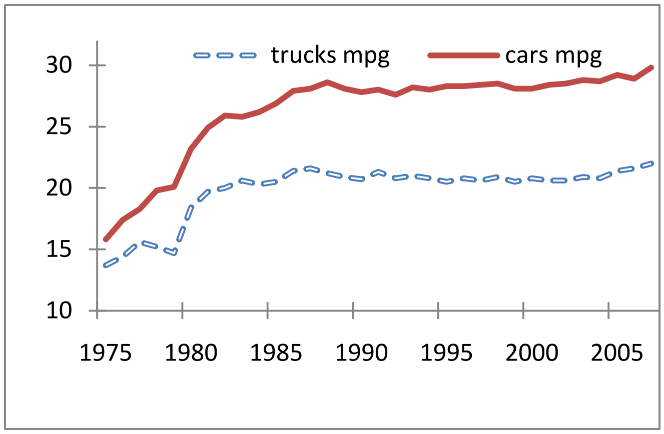

Figure 1: **MPG versus years for passenger cars and light trucks (*NHTSA, 2009*). Fuel economy**

The past research that I discussed in the previous section suggests that factors such as the price of gasoline, CAFE standards, and technological progress affects the fuel economy of a vehicle. In this section of the paper, I describe how these factors influence average fuel economy. With an increase in the price of gasoline, driving a vehicle becomes expensive (EPA, 2008). Assuming the demand curve for gasoline is downward sloping, the increase in the price of fuel decreases the quantity demanded for fuel. Because of this people will start looking for vehicles that are more fuel efficient. Consumers also consider other factors like size, safety, power, and comfort of vehicles in addition to fuel prices while buying a vehicle. So, with the

increase in fuel prices a consumer may substitute these other attributes with more fuel efficient vehicles. Moreover, automobiles are durable goods which last for a considerable amount of time and are expensive, so the short-term price increase of gasoline has less effect on the demand for fuel efficient vehicles than a long-term price increase. Figure 2 displays real fuel price (*gallons per dollar*) over the period of 1975-2008. The real fuel price has been fluctuating till 2004 and did not increase considerably, but it has started increasing since 2004.

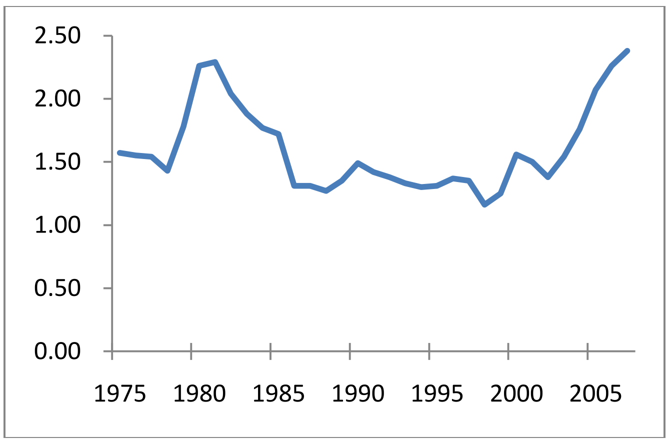

Figure 2: Average real fuel price per gallon ($) versus years *(EIA, 2009)*

The oil embargo and price shock of 1973 made US lawmakers think of ways to improve fuel efficiency. Because of this shock, CAFE standards were implemented in which vehicles produced in the United States have to achieve certain fuel economy standards. CAFE standards were set at higher limits during the period of 1978-1985, with less stringent standards since. Because of these standards the average miles per gallon (MPG) increased by 100% on cars from 1975-87 (APS, 2009) when the CAFE standards were set at higher limits, however after 1987,

standards have barely increased. Figure 3 displays CAFE standards for passenger cars and light trucks over time.

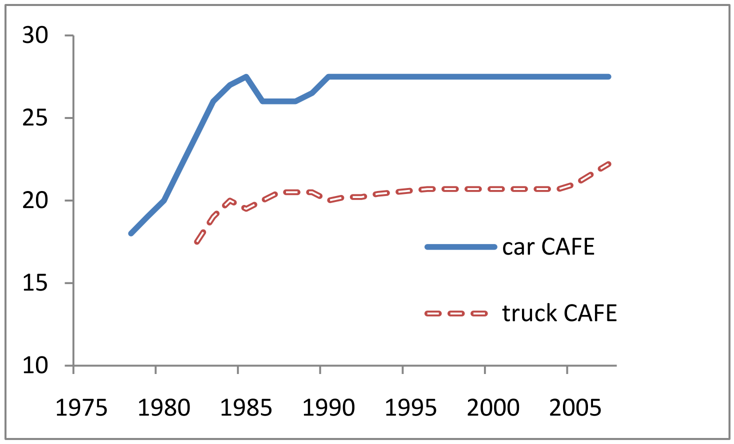

Figure 3: Average CAFE standards (*MPG*) versus year for cars and light trucks (*EPA, 2009)*

From past literatures, I came to the conclusion that weight of a vehicle and engine performance are two technological factors that could affect fuel economy. Controlling for other variables, it is assumed that vehicles with larger weights will be less fuel efficient than vehicles which are lighter in weight. The graph of the average weight for passenger cars and light trucks during the period of 1975-2008 is shown in figure 4. We can see that average vehicle weight decreased during 1978-1987 period; however it has increased since the mid 1980s. Similarly, the power of an engine, measured as horse power, should have a negative relationship with fuel economy as higher horsepower demands more fuel.

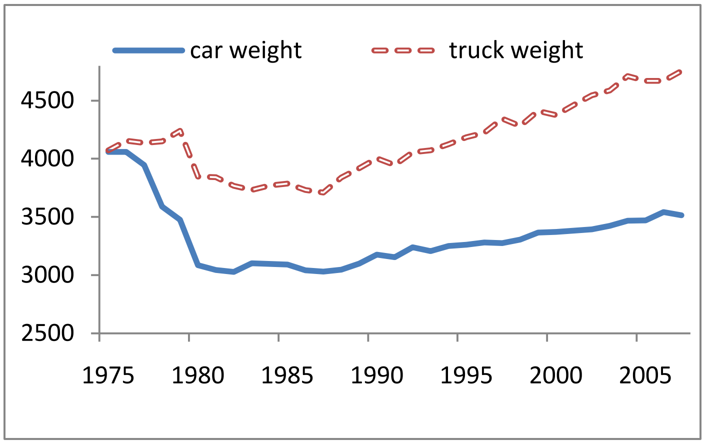

Figure 4: Average vehicle weight versus years for and light trucks (*EPA, 2009)*

The fuel economy of a passenger vehicle also depends on consumer's preferences. In a bulk part, we can divide passenger vehicles in two groups – passenger cars, and light trucks. Generally, the fuel economy of passenger cars is higher than the fuel economy of light trucks. If the purchase of light trucks is increasing over time, then manufacturers will focus on the production of light trucks more than the production of passenger cars. This is actually what has happened in The US automobile industry. The purchase of light trucks has increased ever since they were introduced in the late 1960's. In 1980 light trucks sales were roughly 20 percent of total passenger vehicles sales, where as this percentage increased to 51 in the year of 2004 (Knittle, 2009).

By considering all the factors discussed above, fuel economy of a vehicle can be described as a function of the following characteristics: type of passenger vehicle, fuel prices, government policies, vehicle weight, and engine power as shown in equation 1.

$FE = f\,(VT, FP, Policies, Wt, HP)$ --- (1)

where, FE = Fuel Economy
VT = Vehicle Type
FP = Real petroleum price per gallon
$Policies$ = Government policies
Wt = Weight of the automobiles
HP = Horse power of the engine

The empirical model follows the theoretical model developed above. The goal of the empirical model is to find appropriate ways to measure different characteristics that affect fuel economy as developed in the theoretical model in order to study their impact on the fuel economy of a vehicle. Fuel economy is measured as a vehicle's miles travelled per gallon of gasoline (*MPG*). The price of fuel per gallon is measured in real terms using 2000 as the base year. The US government's policy regarding improving fuel economy is based by setting standards rather than through taxes and incentives defined as CAFE standards. Similarly, the weight of a vehicle is an average weight of a newly produced vehicle for that year.

I assume a non-linear relationship for fuel economy of passenger vehicles and use a log-log model to derive the empirical model as shown in equation 2.

$$MPG = \beta_0\ e^{\beta_1(VT)}(FP)^{\beta_2}\ (CAFE)^{\beta_3}\ (Wt)^{\beta_4}\ (HP)^{\beta_5}e^{u} \quad \text{--- (2)}$$

In this paper, I study the effects on fuel economy of passenger vehicles in two different ways. The first model is developed by combining the data for passenger cars and light trucks

together. Since, both cars and light trucks are used as passenger vehicles, this model allows for a measure of the influence on fuel economy of passenger cars considering the factors affecting fuel economy of light trucks and vice versa. For this purpose, I introduce an explanatory variable, *VT*, in the theoretical model as a dummy variable to assign car type; 1 appearing for passenger cars and 0 for light trucks (Battese, 1997).

In the second empirical model, I study the effects of the explanatory variables on fuel economy for two types of vehicle - passenger cars and light trucks – separately. Doing so allows for a comparison of the impact of each explanatory variable on fuel economy for passenger cars and light trucks. Both of the models are obtained by using a log-log transform shown in equation 2 and are given below for each model respectively:

Empirical Model 1:

$$\ln(MPG) = \beta_0 + \beta_1\,(VT) + \beta_2\, ln\,(FP) \;\; +\beta_3\, ln(CAFE) \;\; + \beta_4\, ln\,(Wt) \;\; + \beta_5\, ln(HP) \;\; + u_{\,1} \quad \text{--- (3)}$$

Empirical Model 2:

$$\ln(MPG_{car}) = \beta_0 + \beta_2\, ln\,(FP) \;\; +\beta_3\, ln(CAFE_{car}) \;\; + \beta_4\, ln\,(Wt_{car}) \;\; + \beta_5\, ln(HP_{car}) \;\; + u_{\,2} \quad \text{--- (4)}$$

$$\ln(MPG_{tr}) = \beta_0 + \beta_2\, ln\,(FP) \;\; +\beta_3\, ln(CAFE_{tr}) \;\; + \beta_4\, ln\,(Wt_{tr}) \;\; + \beta_5\, ln(HP_{tr}) \;\; + u_{\,3} \quad \text{--- (5)}$$

Coefficients of the independent variables of a log-log model measure the percentage change in the dependent variable due to the equal percentage change in the independent variables. For example, β_2 measures the percentage change in fuel economy due to an equal percentage change in fuel prices, *ceteris paribus*. β_3 is the percentage impact on *MPG* of passenger vehicles due to same amount of percentage change in CAFE standards. Similarly, controlling for all other vehicles, β_4 gives percentage influence in *MPG* of passenger vehicle's with the same change in a vehicle weight. β_1 , the coefficient of vehicle type, gives the percentage change in fuel economy by switching from passenger cars to light trucks.

IV. Hypothesis:

Considering the previous literature and theoretical framework of this paper, it is my hypothesis that:

- Vehicle type (passenger cars versus light trucks), fuel prices, and CAFE standards will have a positive effect on fuel economy (i.e. $\beta_1 > 0$, $\beta_2 > 0$, and $\beta_3 > 0$).
- The weight of a vehicle and engine horsepower will have a negative effect on fuel economy (i.e. $\beta_4 < 0$ and $\beta_5 < 0$)

V. Data and Summary Statistics:

Data for all parameters are from the time period of 1975-2008. Fuel economy data is collected from online versions of annual statistics of the United States Environmental Agency

(EPA) for all the years[2]. The data reports a weighted average of city fuel economy and highway fuel economy. Data for fuel economy is collected in categories for passenger cars and light trucks. The light truck category originally included only pickup trucks (many used as passenger vehicles), but was expanded to include minivans and sport-utility vehicles when they were introduced. Data on fuel price is represented as the real price of gasoline per gallon using 2000 as the base year and is taken from Energy Information Agency's website[3]. Similarly, data on CAFE standards are taken from National Highway Traffic Safety Administration's (NHTSA) website[4]. Similarly, data on the average weight of each group of vehicle and average engine horsepower are retrieved from the EPA's website[1]. Table 1 provides summary statistics for each parameter used in the empirical models for both passenger cars and light trucks.

Table 1: Variable Definitions and Summary Statistics

Definition		Passenger cars		Light Trucks	
		Mean	St. Dev.	Mean	St. Dev.
MPG	mileage per gallon	26.4	3.7	19.9	2.3
FP	Fuel Price	1.6	0.4	1.6	0.4
CAFE	CAFE standard (mpg)	23.8	7.9	20.5	0.9
Wt	Average weight of vehicle/lb	3335	276	4171	328
HP	Average power of the engine	142.3	30.2	167	42

Table 1 shows that average fuel economy for passenger cars is around 26 MPG where as that of light trucks is just under 20 MPG. The average fuel economy of passenger cars offered in

[2] http://www.epa.gov/otaq/fetrends.htm

[3] http://www.eia.doe.gov/emeu/aer/txt/ptb0524.html

[4] http://www.nhtsa.dot.gov/CARS/rules/CAFE/CAFEData.htm

2008 is 30 MPG while it was 15.8 MPG in 1975. This represents an increase in roughly 90 percent. However, fuel economy for passenger cars has leveled off since. If we compare fuel economy between 1988 (28.6 MPG) and 2008 (30 MPG), the increase is only about 5 percent. Similarly, CAFE standards increased more rapidly for both types of vehicles during 1978-1985 but they have almost remained constant since then. CAFE standard for passenger cars was 18 MPG in 1978 and increased by 52 percent by 1985, and has barely increased since then. Surprisingly, the standard for passenger cars is at the same level in 2008 as it was in 1985. CAFE standards for light trucks also show a similar trend. The average passenger car has a curb weight of around 3300 pounds in the period of 1975-2008. Overall, average weight has decreased by 13 percent over the sample. The average weight of light trucks has increased by almost 16 percent over the data period.

VI. Results:

I use an Ordinary Least Squares (OLS) regression to determine the effects of these explanatory variables on fuel economy. I ran separate regressions for the different models. Before analyzing results, I tested for any statistical diseases that my data may have. Since, the data are in time series, there is a high possibility of having autocorrelation in the model (Ramu, 1998). I used a Durbin-Watson test to figure out whether autocorrelation exists or not on both models. Comparing the Durbin-Watson values of each regression models with the Upper and

lower limits from the Durbin-Watson table, I found that autocorrelation could exist in model 1 and in model 2 for passenger cars. Because of this, I used the Prais-Winsten technique in order to correct for autocorrelation[5]. Besides correcting for autocorrelation, I also acknowledge that my model may have non-stationary properties since I have time-series data. Testing for non-stationary series with the help of spurious regression is out of my area of expertise and is a means of future research.

Table 2: Regression results for both empirical models

Independent Variables	**Model 1**	**Model 2**	
		Passenger cars *MPG*	**Light trucks *MPG***
lnFP	0.042** (0.013)	0.024 (0.020)	0.067** (0.010)
lnCAFE	0.37** (0.052)	0.281** (0.074)	0.391** (0.072)
lnWt	-1.44** (0.138)	-1.75** (0.207)	-1.28** (0.216)
lnHP	0.451** (0.049)	0.517** (0.066)	0.402** (0.078)
VT	-0.091** (0.020)		
F value	1127**	237**	39.8**
R^2 (adjusted)	0.976	0.934	0.857
Durbin-Watson value (Autocorrelation corrected)	1.820	1.683	1.797

** indicates significance at the 1% level   Numbers in parentheses indicate standard errors

The results from the three regressions on both empirical models are given in table 2. The adjusted R^2 values are relatively high for all three regressions varying from 0.857 to 0.976. R^2 is a measure of how well the regression line approximates the data points. Since, the R^2 is high; the

[5] See appendix for explanation in Durbin-Watson test and Prais-Winsten technique

regression lines fit the data. F values of both models are significant at 1% level which suggests that the explanatory variables combined are significant in explaining fuel economy.

The signs of the coefficients of explanatory variables for model 1 are as hypothesized except for horse power and vehicle type. All coefficient values are statistically significant at 1% level using a Student t-test. Fuel price has a positive effect on fuel economy however its impact is not significant - fuel economy for passenger vehicles increases by 0.4 percent with a 10 percent increase in gasoline price. This may be because of the low amount of variation in real fuel prices over the time period studied. Since, price did not change much (as shown in figure 2), fuel prices may not have much of an impact on *MPG*. According to the regression results, fuel economy gains in passenger vehicles are associated with increasing CAFE standards; all else equal, a ten percent increase in CAFE standard is associated with a 3.7 percent increase in fuel economy.

Results from model 1 suggest that large gains in fuel economy are associated with technological factors - vehicle's weight and horse power. The regression results of model 1 imply that, *ceteris paribus*, a ten percent decrease in the weight of passenger cars is associated with 14.4 percent increase in fuel economy**.** The relationship between horse power and fuel economy is positive- a 10 percent increase in horse power results in 4.51 percent increase in fuel economy- which in reality has a negative impact on fuel economy. The positive relationship

between fuel economy and horse power could have been observed because other technological factors that affect fuel economy in my model, such as torque, fuel injection technology over carburetors, and automatic transmissions were not included. Similarly, the regression results suggest that choosing cars over light trucks did not improve the fuel economy of passenger cars; rather the results show that choosing cars over light trucks has a negative impact on fuel economy. However, this effect (β_1) is small which may suggest that fuel economy is not a deciding factor while choosing between passenger cars over light trucks.

Empirical model 2 estimates the relationship of fuel economy for passenger cars and fuel economy for light trucks separately. The regression results for passenger cars (equation 4) show that relationship between fuel prices and fuel economy for passenger cars is insignificant. This result suggests that the fuel economy of cars can be improved greatly by decreasing its weight. A 10 percent decrease in the weight of cars is associated with 17.5 percent increase in fuel economy. Similarly, results show that the fuel economy of passenger cars increases by 2.8 percent by an increase in CAFE standards for cars by 10 percent. The regression analysis predicts the effect of horse power on fuel economy as a negative relationship for passenger cars as well. This result suggests that a 10 percent increase in horse power improves fuel economy by 5.2 percent.

The results for light duty trucks are similar to passenger cars. The key difference between their results is the impact of a vehicle weight on its fuel economy. A ten percent increase in light trucks weight is related with a 12.8 percent increase in fuel economy where as fuel economy for passenger cars increases by 17.5 percent with 10 percent decrease in its weight. Fuel prices have a positive effect on fuel economy of light trucks; however this effect is fairly low as compared with other explanatory variables. CAFE standards have a higher impact on fuel economy for light duty trucks than that of passenger cars. Results suggest that fuel economy decreases by 3.9 percent with lowering CAFE standards by 10 percent. There is a positive relationship between engine power and light trucks fuel economy- an increase of 4 percent in fuel economy with a 10 percent increase in horse power.

VII. Conclusion:

In this paper, I studied factors affecting the fuel economy of passenger vehicles in the U. S. by analyzing relevant literatures and statistics. After going through related past research, I found that the vehicle type, fuel prices, CAFE standards, average vehicle weight, and engine horsepower are determinants in fuel economy for both passenger cars and light trucks. I first pooled the data for passenger cars and light trucks to see the overall impact on fuel economy. In the second model, I looked at impacts on fuel economy of passenger cars and light trucks separately.

From the regression analysis of both empirical models, we can conclude that the weight of a vehicle is a significant factor affecting fuel economy. This result coincides with trends of fuel economy and vehicle weight seen as in the US automobile industry. When CAFE standards were increasing rapidly during the early 1980s, manufacturers decreased the weight of vehicles considerably in order to meet fuel economy standards. In figure 2 and figure 3, we can see that the decrease in the weight of passenger cars and light trucks correlates with the rapid increase in CAFE standards during 1978-1985 period. The results of model 2 show that the impact of a vehicles weight is larger for passenger cars than for light trucks.

The results suggest that CAFE standards have a positive impact on fuel economy. This result is welcoming as more stringent CAFE standards have been announced recently that call for a 35.5 *MPG* average by 2016 (Knittle, 2009). Using the results that I obtained, I can conclude that the fuel economy of 35.5 *MPG* for passenger cars is easily achievable if we decrease a vehicle's weight by about 8 percent from the average weight of passenger cars in 2008. Similarly, by decreasing the average weight of light trucks by 15 percent, average fuel economy may reach 30 *MPG*. However, we need to note the trends of CAFE standards over the years before accepting the results from this study. CAFE standards increased considerably during the first ten years (1978-1987) without a further change since. Therefore, CAFE standards may have

different affects on fuel economy when they were increasing rapidly than in the post 1987 period where they did not change a lot.

The sign for the coefficient of engine horsepower (β_5) in both empirical models is positive which is opposite from the hypothesis. Finding a better approach to measure engine performance may be an area of interest for further study. There are other factors such as torque, use of fuel injection technology over carburetors, acceleration time, supercharger, and turbocharger that also determine engine performance (Knittle, 2009). These factors are a means for further research. Similarly, including the interaction effect of horse power and fuel efficiency in the empirical model could be a good measure for an engine's performance. Fuel efficiency is solely based on engine's performance and has increased throughout the years and horse power is also another measure of engine's performance. So, an interaction term of fuel efficiency and horse power may capture technological advances in a vehicle's engine.

Similarly, another area of future study could be looking at the impact of a vehicle's weight on its fuel economy. This study suggest that a ten percent decrease in a vehicles weight increases fuel economy by 14 percent, whereas past studies have concluded that a vehicles weight impact is lower than what I found. An energy report from APS writes that a ten percent decrease in vehicle weight increases fuel economy by 6 or 7 percent where as a study by Knittle

finds that fuel economy only increases by 4.26 percent by decreasing vehicle weight by 10 percent.

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Appendix:

Durbin-Watson test:

For my study, I assume that there is first-order autocorrelation.

So, the error term is defined as: $u_t = \rho\, u_{t-1} + \varepsilon_t$

where, u_{t-1} = previous period's error

ρ = first order autocorrelation coefficient whose value is in between 0 and 1

Then, hypothesis for autocorrelation becomes, H_o: $\rho = 0$ ($\alpha = 0.05$); and H_a: $\rho > 0$

For empirical model 1,

Reject H_o if $d < d_l = 1.248$($\alpha = 0.05$, 57 observations, and 3 explanatory variables)

Accept H_o if $d > d_u = 1.598$

From regression analysis, Durbin-Watson values for fuel economy of empirical model 1, d, is 1.178 which is smaller than $d_l = 1.248$. So, Reject $H_{o.}$ So, there is autocorrelation in the data set. To find the value of first order autocorrelation coefficient for passenger cars fuel economy, we have, $d = 2(1- \rho) = 1.178$, so $\rho = 0.411$.

Similarly, following the similar procedure, I found that there is autocorrelation in the empirical model 2 for passenger cars.

Prais-Winsten Technique:

In order to correct autocorrelation that is present on my model, I used Prais-Winsten technique. For this purpose, I wrote syntax on SPSS and ran OLS regression. The syntax to correct autocorrelation for Empirical Model 1 is as follows:

```
TSET

/CNVERGE = 0.0001

areg VARIABLES lnMPG with lnFP lnCAFE lnWT lnHP

/method=PW

/RHO = 0

/MXITER = 100
```