Estimation of Carbon Dioxide Emissions from Passenger Cars in the United States

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Abstract

The purpose of this paper is to improve a model proposed by Agras and Chapman (1999). The paper estimates the fuel consumption of passenger cars in the U.S. using data from 1968-1999 and projects them to the year 2010. In addition, the paper also provides an analysis of two policies, CAFÉ standards and gasoline taxes that will lead to reduced carbon dioxide emissions by passenger cars. The sensitivity of the model will be evaluated using CAFÉ standards only, taxes only, and combinations of both policies. The contribution of this paper will be to add more variables that have been shown to be relevant elsewhere to test the sensitivity of the refined model to the policy instruments.

The results from the study indicate that carbon dioxide emissions from using passenger cars are predicted to be 169.90 million metric tons in 2010, which is an increase of 0.82% from 1999. The implementation of increased CAFÉ standards and higher gasoline taxes would result in reduce carbon dioxide emissions from passenger cars. The CAFÉ standards had more independent, statistically significant impact on fleet efficiency and the demand for gasoline than gasoline taxes through 1999. The study shows that the CAFÉ standards only case is the optimum solution in reducing carbon dioxide emissions and the worst case is when only gasoline tax is used.

1. Introduction

Global climate change is exemplified by an increase in atmospheric temperature attributable to the intensification of the greenhouse effect. One of the most important greenhouse gases is carbon dioxide. Thus, reducing carbon dioxide levels would help to remedy the problem of global climate change. In the U.S., transportation accounted for 27% of energy consumption and 32% of carbon dioxide emissions in 1998. Passenger cars accounted for 21% of the total energy used in the transportation sector. As more fuel is used by passenger cars, the greater is the amount of carbon dioxide emitted in the atmosphere. Therefore, it is important to understand how fuel consumption by cars will be affected by two policy instruments: Corporate Average Fuel Efficiency (CAFÉ) standards and gasoline taxes. CAFÉ standards mandated automotive manufacturers to meet sales-weighted minimum fuel efficiency standards on light-duty vehicles (passenger cars and light trucks). The objective is to improve the fuel efficiency in terms of increasing miles per gallon. Gasoline taxes would affect both car consumers and automotive producers. Gasoline taxes will encourage drivers to consume less gasoline and to buy fuel-efficient cars. They, in turn, will encourage car producers to improve fuel efficiency. These would result in the decrease

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of fuel consumption and carbon dioxide emissions.

2. Policy Control

2.1. CAFÉ standard

In 1974, the fuel efficiency of new U.S. passenger cars hit the lowest level in recent history with 14 miles per gallon. At the same time, there were world oil price shocks from the restriction of oil production by the Organization of Petroleum Exporting Countries (OPEC). Additionally, an oil embargo of the United States organized by the OPEC caused gasoline supply shortages. One response to these events was the passage of the Energy Policy and Conservation Act (EPCA) of 1975, which mandated automotive manufacturers to meet sales-weighted minimum fuel efficiency standards for all new light-duty passenger vehicles sold in the United States. The Act set passenger car standards at 18 miles per gallon (mpg) for the 1978 model year. The CAFÉ standard was slowly increased over the next 10 years, reaching 27.5 mpg in 1990 and has remained at 27.5 mpg to the present. The CAFÉ standards that have subsequently been established are given in Appendix *Table A*.

Initially, the CAFÉ program was used as a policy to prevent gasoline supply shortages. However, concern about global warming in the beginning of 1980s has resulted in new political pressures to raise CAFÉ standards to reduce the growth in U.S. emission of carbon dioxide.

The benefits of using CAFÉ standards would be to decrease fuel consumption and emissions, and to subsidize lower fuel economy car prices at the expense of higher fuel economy car prices. However, the drawbacks from using the CAFÉ standards would be to increase vehicle prices, vehicle miles traveled, and the number of older cars on the road. Moreover, CAFÉ may cause additional costs in the form of market distortions. With the increased number of big vehicles attributed to low gasoline prices and aggressive advertising by U.S. car producers, manufacturers will increase their sales of smaller, more fuel-efficient vehicles to counterbalance their increased sales of larger, less fuel-efficient vehicles. This could create a distribution of vehicles on the road that leads to more traffic fatalities.

2.2 Gasoline Taxes

Gasoline taxes have effects on energy consumption by increasing the marginal cost of operating all vehicles, thereby reducing the miles driven of both new and old cars. In addition, gasoline taxes would encourage drivers to purchase more fuel-efficient vehicles. Gasoline taxes would also encourage automotive manufacturers to produce cars with more fuel efficiency. As this result, gasoline taxes will accelerate the retirement of older, fuel-inefficient vehicles on the road. The benefits of using gasoline taxes would be a decrease in fuel consumption and carbon dioxide emissions, and increase government revenue and demand for fuel-efficient cars. However, the drawbacks of using gasoline taxes would be an increase in gasoline prices, placing a larger burden on lower-income drivers than on higher-income drivers. In addition, gasoline taxes are a politically unpopular policy.

The effectiveness of a fuel tax depends on the price elasticity of demand for fuel, which is equal to the difference between the elasticities of vehicle-miles traveled and of fuel efficiency with respect to fuel price. Previous empirical studies by Dahl (1986) found that short run elasticity of vehicle-miles traveled with respect to the fuel price is –0.32, but the elasticity of miles per gallon with respect to fuel prices is only about 0.17. In the long run, these elasticities rise to –0.55 and 0.57, respectively. Thus, the price elasticity of fuel demand is estimated to be –0.5 in the short run and unity in the long run.

In the U.S., consumers pay local, state and federal gasoline taxes at the pump. State gasoline taxes were increased gradually from an average of 6.1 cents per gallon in 1960 to 23.1 cents per gallon in 1999. Federal gasoline taxes were 4 cents per gallon from 1960 to 1982. Taxes rose to 9 cents per gallon by 1984 and remained at that level until 1991, when they increased again to 14.1 cents per gallon before they reached to 18.4 cents per gallon in 1994 and remain at that level until now. For every gallon of gasoline sold in the U.S. in 1999, the federal government collected 18.4 cents and state governments an additional 23.1 cents on average. Together these represented approximately 33.5% of the retail price of gasoline (API, 1999). *Figure A* in the Appendix shows the evolution of the real price of gasoline, and also indicates the proportion which is made up of state and federal taxes. After rising dramatically in the 1970s, the real price is back to the same level as 25 years ago. The real tax rates have not changed much over time, except for a modest fall in the early 1980.

3. Model specification

Fuel consumption during any given time period can be determined by two major factors, vehicle miles traveled (VMT) and fuel efficiency (MPG).

Vehicle miles traveled would depend upon the amount of resources available to the consumer, determined by his or her wealth or income and the cost of driving, which is simply given by the price per gallon of gasoline divided by a vehicle's mile per gallon. In addition to price and income, the number of consumers of travel and the number of registered cars per capita are also included in the model.

Fuel efficiency is a desirable attribute in the consumers' preference function and is likely to be sensitive to both the price of efficiency and the consumers' real income. The price of efficiency depends upon the price of gasoline. Moreover, the number of cars per capita could influence the demand for efficiency, since consumers who have more than one car might choose to have a small automobile for driving short distances around town and a larger car for longer trips. Whether the cars per capita variable affects fuel efficiency positively or negatively depends on the propensity of families to move from smaller to larger cars or vice versa as their per capita automobile consumption grows. Another factor, the CAFÉ standards, exerts an influence on the observed fuel efficiency.

By using the method of regression analysis, an econometric model is specified and estimated using pooled time-series from data on the passenger cars in the U.S. from 1968-1999. Based on the estimated equation, this paper projects vehicle miles traveled (VMT) and fuel efficiency (MPG) over the time period 2000-2010. Fuel consumption is calculated by dividing vehicle miles traveled by miles per gallon, and then the carbon dioxide emissions are determined by the linear relationship that one million gallons of gasoline emits 2424.88 metric tons of carbon dioxide (EIA, 1997).

3.1. Estimating of fuel efficiency (MPG):

$$MPG = f(Price_G, Income, CAFE, \#Car / capita, MPG_{-1}, time)$$

$$\begin{aligned} ln\,MPG_t = A + \alpha_0 \, ln\,MPG_{t-1} + \alpha_1 \, ln(PG + tax)_t + \alpha_2 \, ln\,PCI_t \\ + \alpha_3 \, ln\,CAFE_t + \alpha_4 \, ln\,CPOP + \alpha_5 Time \ , \end{aligned} \quad (1)$$

where t = year from 1968-1999; *MPG* is the average fuel economy for passenger cars on the road; $(P + tax)$ is the pretax price of gasoline plus additional taxes; *PCI* is the personal income per capita; *CAFÉ* is the standard in year t; *CPOP* is number of registered cars per capita; *Time* is a trend capturing technological change. α_1 and α_2 a re the short-run price and income elasticities in fuel efficiency. $\alpha_1/(1-\alpha_0)$ and $\alpha_2/(1-\alpha_0)$ are the long-run price and income elasticities in fuel efficiency.

3.2. Estimating of vehicle miles traveled (VMT):

$$VMT = f(Cost / Mile, Income, VMT_{-1}, Population, \#Car / capita)$$

$$\begin{aligned} ln\,VMT_t = B + \beta_0 \, ln\,VMT_{t-1} + \beta_1 \, ln(PG + tax)_t + \beta_2 \, ln\,PCI_t \\ + \beta_3 \, ln\,POP_t + \beta_4 \, ln\,CPOP + \beta_5 \, ln\,MPG_t , \end{aligned} \quad (2)$$

where t = time period from 1968-1999; *VMT* is total vehicle miles traveled by passenger cars; *POP* = population; MPG_t is the average fuel economy obtained from the regression in (1). β_1 and β_2 are the short-run price and income elasticities in vehicle-miles traveled. $\beta_1/(1-\beta_0)$ and $\beta_2/(1-\beta_0)$ are the long-run price and income elasticities in vehicle-miles traveled.

3.3. Estimate the fuel consumption (Q_f) :

$$Q_f = \frac{VMT}{MPG} \quad (3)$$

where Q_f is fuel consumption in million gallons; *VMT* is total vehicle miles traveled in million miles; *MPG* is the average fuel economy in miles per gallon.

3.4 Calculate the amount of carbon dioxide emission :

$$CO_2 = 2424.88 \cdot (Q_f) \quad (4)$$

where CO_2 is the carbon emission in million metric tons.

3.5 Sensitivity of policy analysis

A base case with no new policies has been established by using data from 1968-1999. Then, equations for fuel efficiency and vehicle miles traveled are projected to the year 2010. EIA (1998) projects future energy use to the year 2020. For the transportation sector, they predict that vehicle miles traveled increases on average 1.5% annually and fuel consumption increases 2.0% annually on average. In addition, prices of gasoline increase annually at 0.8%. Economic Report of the President (1997) forecasts per capita personal income increases by 1.3% from 1996-2000 and by 1.5% from 2001-2010. Statistical Abstract of the United States (1998) predicts an annual increase of population by 0.8% from 1999-2010. Number of car registration is projected by using the model developed by Agras and Chapman (1999). The model and estimation results are indicated in Appendix *Table B*.

This paper will analyze the effect of a base case from using CAFÉ standards and gasoline taxes.

Case 1 : Only taxes used by increasing 10% from the year 1999 annually.

Case 2 : Only CAFE used by decreasing 10% from the year 1999 annually.

Case 3 : CAFÉ preference: Increasing taxes by 4% and decreasing CAFÉ by 6% from the year 1999

Case 4 : Tax preference : Increasing taxes by 6% and decreasing CAFÉ by 4% from the year 1999

4. Data Sources

The units of variables and data sources are used in this study shown in the following table. The prices of gasoline are measured in nominal term without taking account into inflation rate. Thus, the real prices of gasoline are calculated by dividing the nominal prices by the consumer price index (1992=100). The state and federal gasoline taxes and the data for per capita personal income are also measured in 1992 constant dollar.

Variable	Units	Sources
Gasoline price	*cent/gal*	Energy Information Administration WebPages
State gasoline tax	*cent/gal*	American Petroleum Institute,Annual Review
Federal gasoline tax	*cent/gal*	American Petroleum Institute,Annual Review
Personal Income per capita	*dollar per capita*	Economic Report of President,1998
Number of registered cars	*total*	Highway Statistics
Number of drivers	*total*	Highway Statistics
Population	*total*	Statistical Abstract of the United States
CAFÉ	*limit in mpg*	American Automobile Manufacturers Association
VMT	*million miles*	AAMA, Motor Vehicle Facts & Figures
Fuel Consumption	*million gallons*	AAMA, Motor Vehicle Facts & Figures

5. Empirical Results

5.1. Base Case Results

Equation 1 and 2 are both formed to estimate the structure of the demand for gasoline. Logarithmic forms of the equations were estimated for the 1968-2010 period. The logarithmic specification is supported by Dahl (1982) who found that the various gasoline demand elasticities do not vary over price and income. Base case results are displayed in *Table 1* and *Table 2*. Overall, the results are quite encouraging. The adjusted R^2 in the fuel efficiency equation is 0.978. All the explanatory variable coefficients in the fuel efficiency equation are of the expected signs and are plausible. Moreover, both short-run price and income variables are significant at the level 0.1. The short-run average price elasticity for fuel efficiency (α_1) is 0.043. This result is a little bit lower than the previous studies but it is still in the relevant range. The long run price elasticity for fuel efficiency is ($\alpha_1/(1-\alpha_0)$), which in the base case equals 0.27. A short-run income elasticity for fuel efficiency (α_2) is –0.075. The result is consistent with the previous studies done by the others. The income elasticity for fuel efficiency is small and negative. This indicates a slight tendency of drivers to move from passenger cars to light trucks with lower fuel efficiency when their incomes increase. The coefficient of the number of registered cars per capita variable is negative and statistically significant at the level 0.1. This indicates that per capita growth in automobile consumption has been directed toward marginally less efficient automobiles.

In addition, the CAFÉ standards' coefficient is found to be positive and statistically significant at the level 0.05. These results indicate that while changes in gasoline prices and real incomes have significantly affected fleet efficiency for the period under study, the CAFÉ standards have had significant effect on fleet efficiency or the demand for gasoline. Interestingly, the results are inconsistent with the previous research of Crandall *et al.* (1986) and Mayo *et al.* (1988) which were estimated for the 1958-84 period and found that the CAFÉ standards had no independent, statistically significant impact on fleet efficiency or the demand for gasoline. They concluded that the CAFÉ standards were a less efficient mechanism to reduce greenhouse gases. However, the CAFÉ standards' coefficient is consistent with the study of Agras and Chapman (1999) who suggested that the CAFÉ standards were efficient to control carbon dioxide emissions for the 1982-95 period. Hence, the enforcement of the recently mandated standards becomes more efficient to the fuel economy constraints in reducing the demand for gasoline.

The coefficient for CAFÉ reflects the standard's impact on new cars on the road. A short-run elasticity, α_3, of 15% adequately reflects CAFÉ's impact on the stock of vehicles on the road. This also represents a long-run effect ,($\alpha_3/(1-\alpha_0)$), of 93.75%, which is a realistic estimate, especially as higher CAFÉ standards are imposed and possibly not met. The time trend variable has been excluded from the fuel efficiency equation because it shows small numbers of coefficients and is statistically significant.

The explanatory power of the vehicle miles traveled equation estimations is similarly high with coefficients of determination, 0.989. The coefficients used in the VMT equation are of the expected signs, plausible and have similar representations with the MPG equation. A short-run average price elasticity for the VMT equation, β_1, is –0.05, which results in a long-run elasticity, $(\beta_1/(1-\beta_o))$, of –0.08. This indicates higher gasoline prices would encourage people to drive less. A short-run income elasticity is 0.39, which results in a long-run elasticity of 0.65. Higher income would encourage people to drive more. In addition, the coefficient on the number of registered cars per capita and miles per gallon variables are positive and statistically significant.

The price elasticity of demand for fuel, which is calculated from the difference between the elasticities of vehicle-mile traveled and of fuel efficiency with respect to fuel price, is –0.1 in the short run and –0.35 in the long run. These numbers indicate the effectiveness of a fuel tax on the demand for fuel. An increase of 1% on price of gasoline plus fuel taxes would decrease the fuel consumption by 0.1% in the short run and 0.35% in the long run. Compared with the ranges of other estimates from –0.10 to –0.75, the short run price elasticity of fuel demand is a little bit low but it is still in the relevant range. In this study, fuel taxes have no strong effect on the demand for gasoline.

A base case with no new policies controlled has been established by projection of estimated equations from 2000 to 2010. CAFÉ standards remain at 27.5 for passenger cars and gasoline taxes remain at the 1999 level. Fuel consumption can be calculated by dividing vehicle miles traveled by miles per gallon. The fuel consumptions of passenger cars are predicted to be 70.88, 70.47 and 70.07 billion gallons in 2000, 2005 and 2010, respectively. The estimation for carbon dioxide emissions can be directly derived from estimates of fuel consumption through the identity $CO_2 = 2424.88*Q_f$, where 2424.88 metric tons carbon dioxide per million gallons of gasoline are emitted. Carbon dioxide emissions from passenger cars are predicted to be 171.87, 170.88 and 169.90 million metric tons in 2000, 2005 and 2010, respectively. Therefore, carbon dioxide emissions are increased by 0.82% in 2010. *Figure 1* presents carbon dioxide emissions from the base case results for passenger cars. The level of carbon dioxide emissions from passenger cars in the past is 155 million metric tons on average and they are predicted to be 169.9 million metric tons by 2010. There were two dips of carbon dioxide emissions from using passenger cars in the beginning of 80's and 90's. Two plausible explanations, which are not mutually exclusive, emerge. First are the higher gasoline prices due to the output restriction of OPEC in the beginning of 80's. Second are the lower fuel consumptions from passenger cars because of switching to the light trucks in the beginning of 90's. The EPA predicts a level of 150 million metric tons in 2010 for passenger cars. (Bradsher, 1997)

5.2. Policy Results

In the previous section, the base case without policy control has been established. This section will study how fuel consumption by passenger cars will be affected by two policy instruments: CAFÉ and gasoline taxes. *Figure 2* shows the reduction of carbon dioxide emissions from base case through policy control from 1990 to 2010, and the numerical results of the effect of change in gasoline taxes and CAFÉ on fuel consumption are presented in *Table 3*. The first step of study is to increase gasoline taxes annually from 1990 to 2010. The results from *Table 3* show that carbon dioxide emissions are reduced from the base case by 0.5%, 1.18% and 1.71% in 2000, 2005 and 2010, respectively. Next, the CAFÉ standards are increased by 10% from 1999 to 2010. These would reduce carbon dioxide emissions by 1.42%, 6.81% and 10.53% in 2000, 2005 and 2010, respectively. Then, the study uses combinations of gasoline taxes and CAFÉ standards. Tax preferred case with an increase of taxes by 6% and CAFÉ by 4% would reduce carbon dioxide emissions by 1.95%, 4.71% and 7%, respectively. In addition, CAFÉ preferred case, with an increase of taxes by 4% and CAFÉ by 6%, shows that carbon dioxide emissions can be reduced from the base case by 1.02%, 4.86% and 7.83%, respectively.

From the overall results, the study shows that the CAFÉ only case is the optimum solution in reducing carbon dioxide emissions. The worst case is when only tax is used. These results agree with the empirical studies mentioned in the previous section. The study shows that the CAFÉ standards' coefficient is statistically significant at the level 0.05 and has a higher coefficient than the prices of gasoline's coefficient for the period 1968-2010. The results from the tax preferred and CAFÉ preferred cases are ambiguous. The reduction of carbon dioxide emissions, however, is very close from both cases. *Figure 2* shows that around 2004, carbon dioxide emissions from the tax preferred case would be equal to the CAFÉ preferred case at 163.9 million metric tons. The tax preferred case becomes more efficient in reducing carbon dioxide emission until 2004.

The paper further suggests that if both taxes and CAFÉ standards are increased annually by 10% from the year 1999, carbon dioxide emissions from passenger cars are predicted to be 149.42 million metric tons by 2010, which are below the average levels of carbon dioxide emissions in the past. These policies will help the U.S. government to overcome the problem of carbon dioxide emissions from using passenger cars in the future.

6. CONCLUSIONS

This paper has shown that the U.S. could achieve to reduce carbon dioxide emissions from passenger cars. An implementation of increased CAFÉ standards and higher gasoline taxes would significantly reduce carbon dioxide emissions from passenger cars. The paper finds that the CAFÉ standards had more independent, statistically significant impact on fleet efficiency and the demand for gasoline than gasoline taxes through 1999, while the estimations done by Mayo *et al.* (1988) clearly indicated that the CAFÉ standards were ineffective over the 1977-83 period. One plausible explanation is the CAFÉ standards for passenger cars were 18 miles per gallon on average before 1983 but the U.S. has increased the CAFÉ standards to 27 miles per gallon on average and remained at 27.5 miles per gallon to the present. The enforcement of the recently mandated standards may affect the fuel economy constraints and, hence, be effective in reducing the demand for gasoline. In addition, the effects of non-regulatory factors may have simply the demand for gasoline than gasoline taxes through 1999, while the estimations done by Mayo *et al.* (1988) clearly indicated that the CAFÉ standards were ineffective over the 1977-83 period. One plausible explanation is the CAFÉ standards for passenger cars were 18 miles per gallon on average before 1983 but the U.S. has increased the CAFÉ standards to 27 miles per gallon on average and remained at 27.5 miles per gallon to the present. The enforcement of the recently mandated standards may affect the fuel economy constraints and, hence, be effective in reducing the demand for gasoline. In addition, the effects of non-regulatory factors may have simply dominated whatever impacts the fuel efficiency standards would have had in the absence of these effects in the first six years of their implementation.

Using the combination of gasoline taxes and CAFÉ standards, the CAFÉ standards become more efficient in reducing carbon dioxide emissions in the long run. On the other hand, gasoline taxes would affect to lower the demand for gasoline in the short run. Increasing gasoline taxes will discourage people from consuming more fuel in the short run, while it would take some periods to encourage the people to buy passenger cars with more fuel efficiency.

Table 1 : Coefficients Used in Base Case Fuel Efficiency Equation (MPG)

Independent Variables	**Parameter Estimates**	**Supawat (2001)**	**Agras and Chapman (1999)**	**Mayo and Mathis (1988)**	**Dahl (1986)**	**Haughton and Sarkar (1996)**
MPG_{-1}	α_0	0.84** *(9.92)*	0.8			
Price-SR	α_1	0.043* *(1.97)*	0.12	0.213	0.17	0.09
Price-LR	$\alpha_1/(1-\alpha_0)$	0.27	0.60		0.57	0.51
Income-SR	α_2	-0.075* *(-1.88)*	-0.07	0.898	-0.07	-0.03
Income-LR	$\alpha_2/(1-\alpha_0)$	-0.46	-0.35		-0.32	-0.29
CAFE	α_3	0.15** *(2.69)*	0.175	0.003		
CPOP	α_4	-0.045* *(-1.80)*		-1.30		
R^2		0.978				
Durbin-Watson		1.39				

Note : t-statistics in parentheses,
** indicates statistically significant at 10% level,*
*** indicates 5% significance.*

Table 2 : Coefficients Used in Base Case Vehicle Miles Traveled Equation (VMT)

Independent Variables	Parameter Estimates	Supawat (2001)	Agras and Chapman (1999)	Mayo and Mathis (1988)	Dahl (1986)	Haughton and Sarkar (1996)
VMT_{-1}	β_0	0.40^{**} *(2.51)*	0.53	0.152		
Price-SR	β_1	-0.05^{*} *(1.98)*	-0.15	-0.22^{***}	[-0.1,-0.5]	$[-.07,-.17]^{***}$
Price-LR	$\beta_1/(1-\beta_0)$	-0.08	-0.32	-0.26^{***}	[0,-1.8]	$[-.22,-.58]^{***}$
Income-SR	β_2	0.39 *(2.57)*	0.26	0.25	[0.06,0.98]	[.23,.33]
Income-LR	$\beta_2/(1-\beta_0)$	0.65	0.55	0.30	[.54,4.9]	[.43,.58]
CPOP	β_3	0.09^{*} *(1.81)*		0.673		
MPG	β_4	0.07^{*} *(1.94)*	0.15		[.06,.50]	
R^2		0.989				
Durbin-Watson		1.49				

Note : t-statistics in parentheses,
** indicates statistically significant at 10% level,*
*** indicates 5% significance,*
**** reports the price (P) and income (I) elasticities of demand for the cost per mile (CPM).*

Figure 1 : CO_2 Emissions of Passenger Cars for 1979-2010

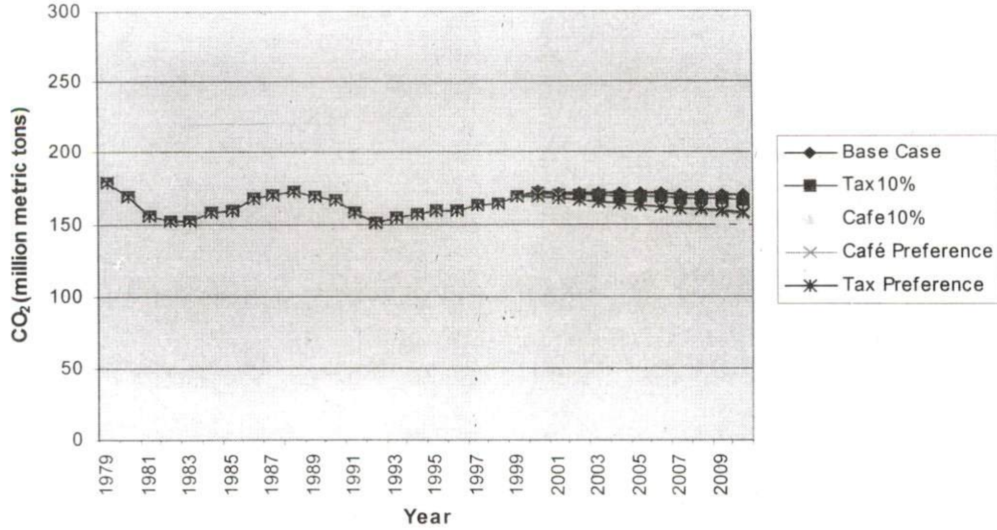

Figure 2 : The reduction of CO_2 emissions through policy control from 1999 to 2010

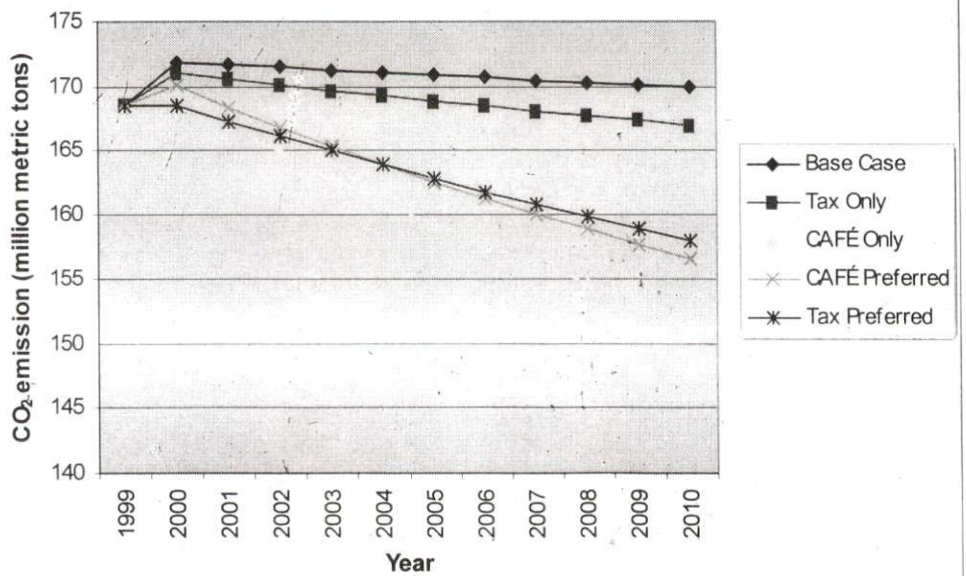

Table 3 : Effects of Change in Gasoline Tax and CAFÉ on Fuel Consumption

	2000	2005	2010	2000	2005	2010
	Absolute values			Percentage change relative to base case		
Base Case:						
Tax/gallon (cents/gal)	41.50	41.50	41.50			
Price of gasoline (cents/gal)	125.00	137.70	138.00			
CAFÉ (limit in MPG)	27.50	27.50	27.50			
Fuel consumption (billion gallons)	70.88	70.47	70.07			
Carbon emission (million metric tons)	171.87	170.88	169.90			
Only tax increased annually by 10% from the year 1999						
Tax/gallon (cents/gal)	45.65	66.40	87.15	10.00	60.00	110.00
Price of gasoline (cents/gal)	129.15	162.60	183.65	3.32	18.08	33.08
CAFÉ (limit in MPG)	27.50	27.50	27.50	0.00	0.00	0.00
Fuel consumption (billion gallons)	70.52	69.64	68.87	-0.51	-1.18	-1.71
Carbon emission (million metric tons)	171.01	168.87	167.00	-0.50	-1.18	-1.71
Only CAFE increased annually by 10% from the year 1999						
Tax/gallon (cents/gal)	41.50	41.50	41.50	0.00	0.00	0.00
Price of gasoline (cents/gal)	125.00	137.70	138.00	0.00	0.00	0.00
CAFÉ (limit in MPG)	30.25	44.00	57.75	10.00	60.00	110.00
Fuel consumption (billion gallons)	69.87	65.67	62.69	-1.42	-6.81	-10.53
Carbon emission (million metric tons)	169.43	159.25	152.01	-1.42	-6.81	-10.53
Tax preferred (increased tax by 6% and CAFÉ by 4%)						
Tax/gallon (cents/gal)	43.99	56.44	68.89	6.00	36.00	66.00
Price of gasoline (cents/gal)	127.49	156.00	169.85	1.99	13.29	23.08
CAFÉ (limit in MPG)	28.60	34.10	39.60	4.00	24.00	44.00
Fuel consumption (billion gallons)	69.50	67.15	65.16	-1.95	-4.71	-7.01
Carbon emission (million metric tons)	168.52	162.84	158.01	-1.95	-4.71	-7.00
CAFÉ preferred (increased tax by 4% and CAFÉ by 6%)						
Tax/gallon (cents/gal)	43.16	51 46	59.76	4.00	24.00	44.00
Price of gasoline (cents/gal)	126.66	147.66	156.26	1.33	7.23	13.23
CAFÉ (limit in MPG)	29.15	34.65	40.15	6.00	26.00	46.00
Fuel consumption (billion gallons)	70.15	67.05	64.58	-1.03	-4.85	-7.84
Carbon emission (million metric tons)	170.12	162.58	156.59	-1.02	-4.86	-7.83
Both tax and CAFÉ increased annually by 10% from the year 1999						
Tax/gallon (cents/gal)	45.65	66.40	87.15	10.00	60.00	110.00
Price of gasoline (cents/gal)	129.15	162.60	183.65	3.32	18.08	33.08
CAFÉ (limit in MPG)	30.25	44.00	57.75	10.00	60.00	110.00
Fuel consumption (billion gallons)	69.52	64.90	61.62	-1.92	-7.90	-12.06
Carbon emission (million metric tons)	168.58	157.38	149.42	-1.91	-7.90	-12.05

APPENDIX

Table A : Corporate Average Fuel Economy Standards (CAFÉ)

Model year	Mileage Standard
1978	18.7
1979	19.0
1980	20.0
1981	22.0
1982	24.0
1983	26.0
1984	27.0
1985	27.5
1986	26.0
1987	26.0
1988	26.0
1989	26.5
1990	27.5
1991 to 1999	27.5

APPENDIX

***Table B*:** Estimation and projection of the CPOP variable from model developed by Agras and Chapman (1999)

$$\ln CPOP_{i,t} = A + \alpha_0 \ln CPOP_{i,t-1} + \alpha_1 \ln(P + tax)_{i,t} + \alpha_2 \ln PCI_{i,t} + u_{i,t}$$

where i = passenger cars, t = 1968-1999, $P + tax$ is the average retail price of gasoline (all types) plus federal and state gasoline taxes, *PCI* is per capita personal income, *CPOP* is the number of registered cars per capita

Year	CPOP Estimation
1999	0.496
2000	0.495
2001	0.493
2002	0.492
2003	0.491
2004	0.489
2005	0.488
2006	0.486
2007	0.485
2008	0.483
2009	0.482
2010	0.480

REFERENCE

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ใบบอกรับเป็นสมาชิก

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