Division of Economics
A.J. Palumbo School of Business Administration
Duquesne University
Pittsburgh, Pennsylvania

THE 2009 CAR ALLOWANCE REBATE SYSTEM: AN ANALYSIS OF THE CHANGE IN GASOLINE CONSUMPTION

Jason Vigneault

Submitted to the Economics Faculty
in partial fulfillment of requirements for the degree of
Bachelor of Science in Business Administration

December 2009

Faculty Advisor Signature Page

Matt Marlin, Ph.D. Date
Professor of Economics

Antony Davies, Ph.D. Date
Associate Professor of Economics

THE 2009 CAR ALLOWANCE REBATE SYSTEM: AN ANALYSIS OF THE CHANGE IN GASOLINE CONSUMPTION

Jason Vigneault

Duquesne University, 2009

Abstract

This thesis focuses on the effect of the 2009 Car Allowance Rebate System, an accelerated vehicle scrappage program, on gasoline consumption. The program raised the fuel economy of the vehicle fleet by replacing approximately 700,000 vehicles with newly purchased vehicles at a cost to taxpayers of $3 billion. The results indicate that the 2009 Car Allowance Rebate System will not significantly reduce gasoline consumption in the U.S. The estimates of change in gasoline consumption from this analysis form a basis for evaluating future policy and research regarding vehicle scrappage programs in the U.S.

JEL classifications: H50

Keywords: accelerated vehicle recycling, scrappage program, cash for clunkers, car allowance rebate system

Table of Contents

I. Introduction

During the summer of 2009, the National Highway Traffic Safety Administration (NHTSA), a division of the Department of Transportation (DOT), implemented the Car Allowance Rebate System (CARS), also known as the 2009 Cash for Clunkers program. CARS was an accelerated vehicle scrappage program, which replaced old vehicles on the road with new, more fuel-efficient vehicles. CARS encouraged individuals to scrap model-year 1984-2008 vehicles with fuel efficiencies below 18 mpg by offering $3,500 or $4,500 (dependent upon vehicle type) for the purchase of a new vehicle. The program replaced almost 700,000 vehicles over the summer of 2009 at a total cost of approximately $3 billion.

CARS was funded by the 2009 stimulus package as a program that would reduce foreign oil dependence and reduce the amount spent on fuel in the U.S. In this thesis, I estimate the change in gasoline consumption as a result of CARS. To complete this task, I perform an analysis on the annual vehicle miles traveled (VMT) of scrapped vehicles and the VMT of new vehicle purchases through CARS. Previous literature on scrappage programs focuses on the condition of scrapped vehicles, remaining life of scrapped vehicles and the associated costs and benefits of scrappage programs. This analysis adds to previous literature by focusing on the miles driven by vehicles involved in scrappage programs and may be used to estimate the costs and benefits from CARS as well as similar programs in the future.

II. Literature Review

A. Previous Scrappage Programs

Alberini, Harrington and McConnell (1996) find that vehicle scrappage programs attract vehicles in the poorest condition and with the lowest remaining vehicle life. Vehicle life is defined as the length of time that a vehicle continues to be useful before being retired from use. Further, they find that vehicles that are scrapped were driven the same number of miles as the average vehicle of the same model year. The authors use survey data collected from vehicle scrappage participants between 1992 and 1993 in Delaware. The Delaware scrappage program scrapped 125 pre-1980 vehicles for $500 each. The authors find that scrapped vehicles were driven, on average, between 6,000 and 8,000 miles annually. The authors survey both participants of the Delaware scrappage program and other vehicles owners; this survey questioned these individuals on the absolute minimum amount that they would need to be offered in order to scrap their vehicles. Alberini, Harrington and McConnell find that the relationship between the value of a vehicle and its expected remaining life is non-linear. A vehicle with an expected remaining lifetime of two years is valued at about $600, while a vehicle with an expected remaining life of four years is valued at approximately $1,600.

Hahn (1995) estimates pollution reduction benefits of a theoretical scrappage program in 1992, which scrapped pre-1980 vehicles in Los Angeles, CA. Following previous research, the author assumes that all scrapped vehicles have a remaining vehicle life of three years. To estimate the difference in emissions from scrapped vehicles and replacement vehicles, Hahn uses California’s EMFAC7E model[1] to estimate vehicle fleet

[1] The EMFAC7E, developed by California's Air Resource Board (CARB), was released in 1990 and used to model emissions of the vehicle fleet; EMFAC2007 is the most recent version of the model.

emissions of HC (hydrocarbons) and NO_x (nitrogen oxides), which are two pollutants that previous research suggests are major contributors to low-level ozone and smog. Hahn also uses the MOBILE4 model[2] to estimate odometer readings for different vehicle ages. Hahn finds that an increase in the offer price results in a decrease in the cost-effectiveness of a scrappage program. This relationship exists because an increase in the offer price results in two outcomes: (1) an increase in the overall cost of a scrappage program and (2) an increase in the scrappage of newer, less pollution-emitting vehicles that would otherwise not have been scrapped. Hahn compares the benefits of the theoretical program to estimates of external costs caused by pollution. He concludes that scrappage programs should be a strategy to remove only the highest pollution-emitting vehicles from the road. Scrapping any other vehicles reduces the marginal benefits of scrappage programs significantly.

Hsu and Sperling (1994) examine the air quality impact of vehicle scrappage programs from 1993-1994. These scrappage programs do not require participants to purchase a new vehicle. Therefore, the authors assume participants replace scrapped vehicles with the average vehicle in the fleet. Hsu and Sperling find a very large standard deviation of the remaining life of scrapped vehicles and suggest it may be attributed to the various factors affecting vehicle life, such as differing weather conditions across the U.S. Using national vehicle scrappage data gathered by the Oak Ridge National Laboratory (ORNL) from 1978 to 1989, the authors estimate the average remaining life of scrapped vehicles to be between two and four years. The authors also reference a survey issued by Fairbank, Bregman and Maullin to participants of the 1990 Unocal

[2] MOBILE4 is a previous vehicle emissions modeling software created by the EPA; the most recent version is MOBILE6.2 and was released in 2004.

South Coast Recycled Auto Project (SCRAP).[3] From the data collected, the authors conclude that 9% of the vehicles scrapped by programs would have been scrapped regardless of the program because the remaining vehicle life of those vehicles was equal to zero. Hsu and Sperling also use the SCRAP survey to show that 13%, 35% and 38% of respondents were driving less, the same amount and more,[4] respectively, as compared to before retiring their vehicles. The authors estimate the average scrapped vehicle was driven 3,000-5,000 miles annually, while the average replacement vehicle is driven 9,800 miles annually.

Kavalec and Setiawan (1997) compare the outcome of two theoretical vehicle scrappage programs; one program scraps vehicles greater than 10-years-old (10+) and another scraps vehicles greater than 20-years-old (20+). The pair uses CALCARS, a vehicle choice-demand-usage model developed for California,[5] to estimate the average household response to a vehicle scrappage program. In the 10+ program, the authors find that vehicle ownership shifts to less fuel-efficient cars and light trucks. The shift in fuel efficiency occurs because a price floor is created by the offer price for scrappage vehicles. Therefore, consumers are encouraged to scrap less expensive vehicles, which historically have been more fuel-efficient mini and subcompact vehicles, and drive more expensive vehicles that are larger and less fuel-efficient. Alternatively, the fuel efficiency of the vehicle fleet[6] increases due to higher scrappage rates of light trucks in the 20+ program as compared to the 10+ program. Kavalec and Setiawan conclude that the 10+ program results in a larger increase in gasoline consumption than the 20+ program.

[3] Through SCRAP, Unocal Corporation scrapped 8,376 pre-1971 vehicles for $700 each.
[4] The survey did not ask respondents to quantify their change in driving.
[5] Refer to Kavalec (1996) for more information on the CALCARS model.
[6] The vehicle fleet includes all registered motor vehicles in the U.S. For the purpose of this thesis, the vehicle fleet includes only those vehicles that are cars or light trucks.

B. Rebound Effect

Small and Dender (2006) model the rebound effect, which suggests that better fuel economy, which decreases in the gasoline cost of driving, results in an increase in driving. Small and Dender use an OLS model to estimate the effect of the cost of driving due to gasoline on VMT. They find the OLS model overestimates the rebound effect. Instead, Small and Dender use a 3SLS model to account for the effect of the dependent variable, VMT, on the independent variable, cost of driving due to gasoline, using U.S. state-level data from 1966-2001. They conclude that the rebound effect exists but has diminished over time. The pair estimates a long-run rebound effect of 10.66%, given income levels and fuel prices for the period 1997-2001. A rebound effect of 10.66% suggests that a 50% decrease in cost of driving results in a 5.35% increase in VMT.

III. Methodology

A. CARS Data

The empirical section of this paper tests the hypothesis that CARS results in a net decrease in gasoline consumption. To perform this analysis, I collect data on scrapped vehicles and vehicles purchased through CARS, which was made available on September 26, 2009 on the cars.gov website. Vehicles with unlisted model, make or year were removed from the data set providing a total of 690,048 scrapped vehicles and 692,617 new vehicles that listed model, make and year. On the cars.gov website, the NHTSA also estimates the average miles per gallon for scrapped vehicles to be 15.8 and new vehicles to be 24.9. Figure 1 illustrates the distribution of scrapped vehicles by vehicle type (car or light truck) and model year.

Figure 1: Scrapped Vehicles by Vehicle Type and Model Year

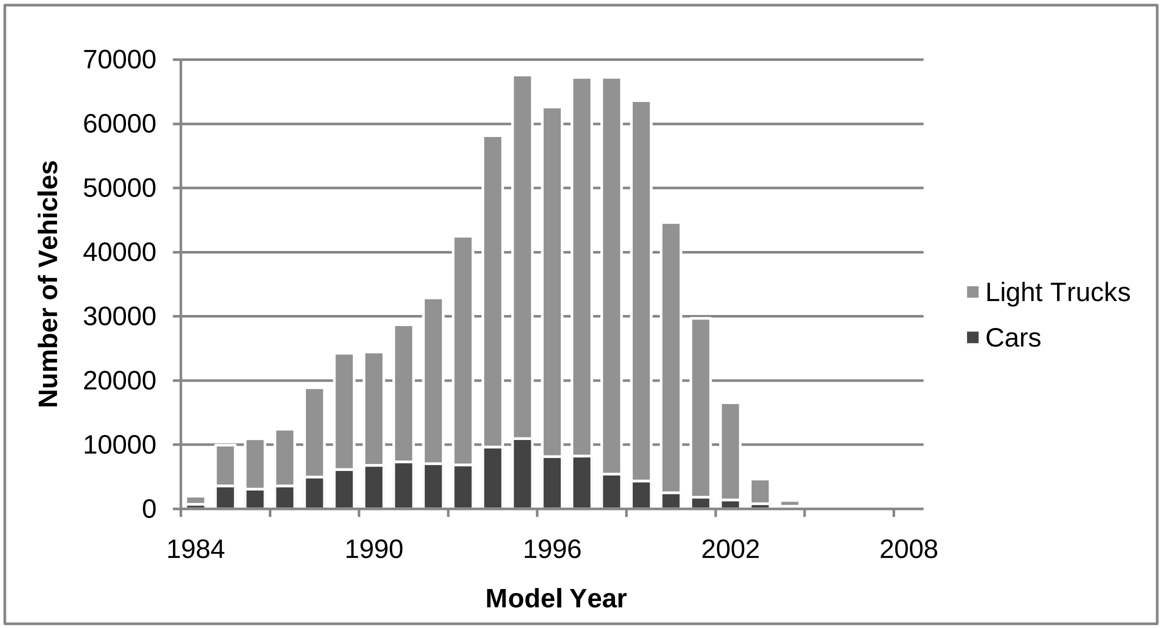


Figure 1 shows that significantly more light trucks were scrapped than cars. On average, light trucks have lower fuel efficiency than cars and as such more light trucks qualified for CARS than cars.

B. Assumptions

When calculating the total change in gasoline consumption due to CARS, it is necessary to compute the change in consumption over the remaining vehicle life. The remaining vehicle life is the number of years that a scrapped vehicle would have been driven had it not been scrapped. It is therefore assumed that, if the vehicle had not been scrapped through CARS it would be replaced at the end of its remaining life with a vehicle identical to that which was purchased through CARS.[7]

Alberini, Harrington and McConnell (1996) estimate expected remaining life of the average pre-1980 vehicle attracted to a 1992-1993 scrappage program by modeling a

[7] It is necessary to note that this situation may actually result in an instance where the replacement vehicle today is more or less fuel-efficient than a possible future replacement vehicle, depending on future fuel efficiency trends.

vehicle owner's willingness to accept different offer prices. The authors estimate remaining life to be 3.9 years, given an offer price during the 1992-1993 Delaware scrappage program of approximately $4,500 (2009 dollars), while the average amount offered during CARS was approximately $4,200. Alternatively, Hahn (1995) and UNOCAL's 1991 SCRAP program[8] in California each use three years as the estimate for remaining vehicle life. Hsu and Sperling (1994) use estimates between one and five years, but mainly focus on a remaining life of three years. Due to lack of agreement on the estimate for remaining vehicle life in previous literature, I carry out this analysis of CARS using remaining vehicle life estimates of two, three, four and five years.

Previous research does not agree on a method to calculate VMT of scrapped and replacement vehicles from vehicle scrappage programs. To calculate change in gasoline consumption, I first estimate change in VMT using three different assumptions about VMT estimates: (1) base, (2) rebound effect and (3) vehicle age.

(1) Base VMT Assumption

The EPA (2005) published a paper to maintain consistency of assumptions used in the calculation of emissions from vehicles. To determine the number of miles driven, the EPA assesses a number of sources including the Federal Highway Administration's (FHWA) National Highway Statistics,[9] EPA's MOBILE6 model[10] and EPA's commuter

---

[8] UNOCAL divided the expected remaining life of pre-1971 vehicles (6 years) by two to get their estimate of 3 years.

[9] FHWA estimates passenger cars and light trucks at 11,766 and 11,140, respectively. These values include all vehicles in the fleet, including those more than 25 years old.

[10] EPA's MOBILE6 shows an average of about 10,500 and 12,400 VMT for passenger cars and light trucks, respectively, also including all vehicles in the fleet. The EPA adjusted this number to provide a better representation of the vehicle fleet by eliminating vehicles more than 10 years old from this estimate, resulting in annual average mileage of 12,000 and 15,000 for passenger cars and light trucks, respectively.

model.[11] The EPA paper estimates that 12,000 miles are driven per year for the typical passenger vehicle. Following the EPA (2005), the base VMT estimate assumes that all vehicles are driven 12,000 miles annually, such that new and scrapped vehicles are driven identically.

(2) Rebound Effect VMT Assumption

The second VMT estimate assumes that individuals adjust VMT due to the rebound effect. Small and Dender (2006) estimate the rebound effect to be 10.66%, given income levels and fuel prices of 1997-2001. Equation (1) presents Small and Dender's estimate of the rebound effect.

$$\frac{\%\Delta\, VMT}{\%\Delta\, gasoline\ cost/mile} = -.1066 \qquad (1)$$

An increase in fuel efficiency from 15.8 miles per gallon to 24.9 miles per gallon results in a 36.55% decrease in the cost of driving.[12] Using Equation (1), I estimate the rebound effect to result in a 3.90% increase in VMT. To better compare the rebound effect VMT assumption results to those of the base VMT assumption, I use 12,000 miles per year as the VMT of scrapped vehicles and calculate 12,467 miles per year as the VMT of new vehicles.

(3) Vehicle Age VMT Assumption

The third VMT assumption estimates VMT as a function of vehicle age. In a report published by the NHTSA's National Center for Statistics and Analysis, Lu (2006) models annual VMT as a function of vehicle age using data collected from vehicle odometers between 2001 and 2002 by the National Household Travel Survey (NHTS).

[11] EPA's commuter model uses 1997 data from Oak Ridge Laboratories and estimates VMT just over 12,000 for the average passenger car in the US.

[12] Calculation of the decrease in the cost of driving is shown in Appendix 1.

The author estimates VMT as a cubic function of vehicle age for cars up to 25-years-old and light trucks up to 36-years-old. Following Lu, I assume model year 2008 vehicles are two years old and vehicles purchased through CARS are new (age of zero) because they were required to be new.[13]

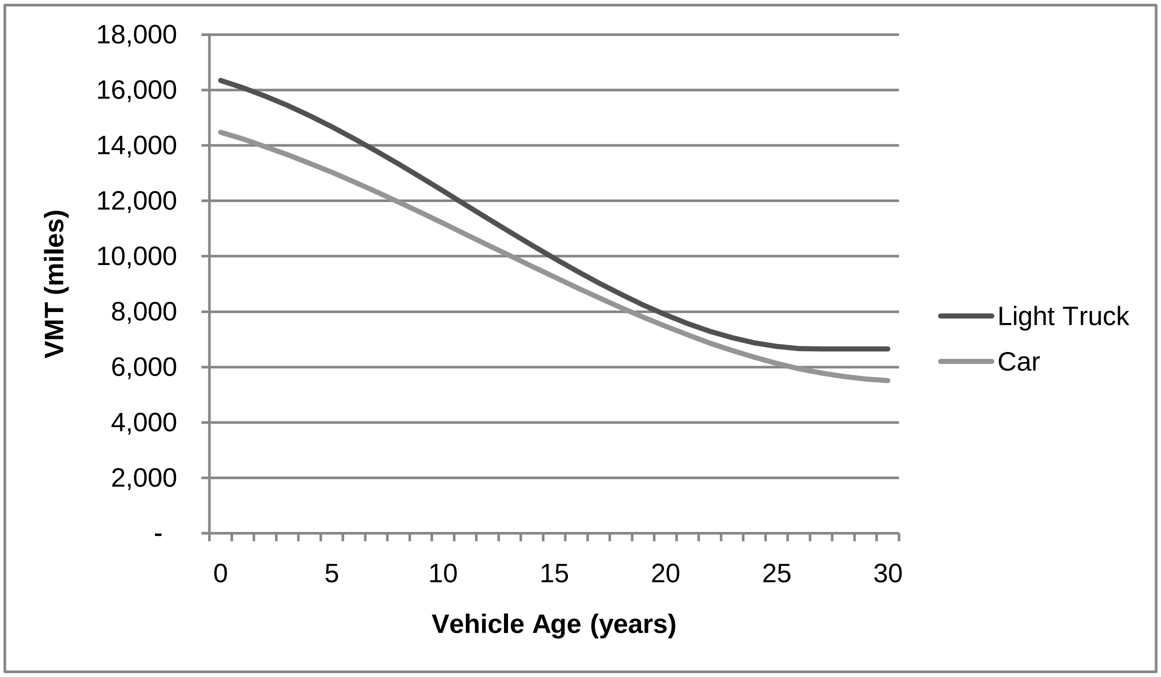
The light truck VMT model predicts a decrease in VMT until reaching a minimum age of 27 years and a VMT of 6,648 miles per year. The minimum likely occurs due to insufficient data on older light trucks; Lu uses 6,648 miles per year as the estimate for VMT of all light trucks more than 27 years old. Lu's model provides VMT estimates for cars up to 25 years old, but this thesis requires the analysis of cars up to 30 years old.[14] When extended to 30 years, Lu's VMT model for cars does not reach a minimum. Following Lu's assumptions when working with the light truck model, I do not alter the model. Table 1 presents the regression estimated by Lu and Figure 2 presents Lu's estimates of VMT based on vehicle age.

Table 1: Estimate of VMT using Vehicle Age

$VMT_i = \alpha+\beta_1(Age_i)+\beta_2(Age_i)^2+\beta_3(Age_i)^3+\varepsilon_i$				
Vehicle Type	**α**	**β_1**	**β_2**	**β_3**
Car	14,476.36	-232.85	-13.22	0.37
Light Truck (Age $\leq$ 27)	16,345.32	-238.55	-22.84	0.68
Light Truck (27 < Age $\leq$ 30)	6,648	–	–	–

[13] The vehicles purchased through CARS were model years 2007 through 2010. Approximately 75.2% and 23.4% of the vehicles purchased through CARS were model years 2009 and 2010, respectively, representing 98.6% of all vehicles purchased.
[14] The oldest scrapped cars from CARS are 25 years old plus a remaining life of 5 years results in a maximum car age of 30 years.

Figure 2: Estimate of VMT using Vehicle Age



C. Results

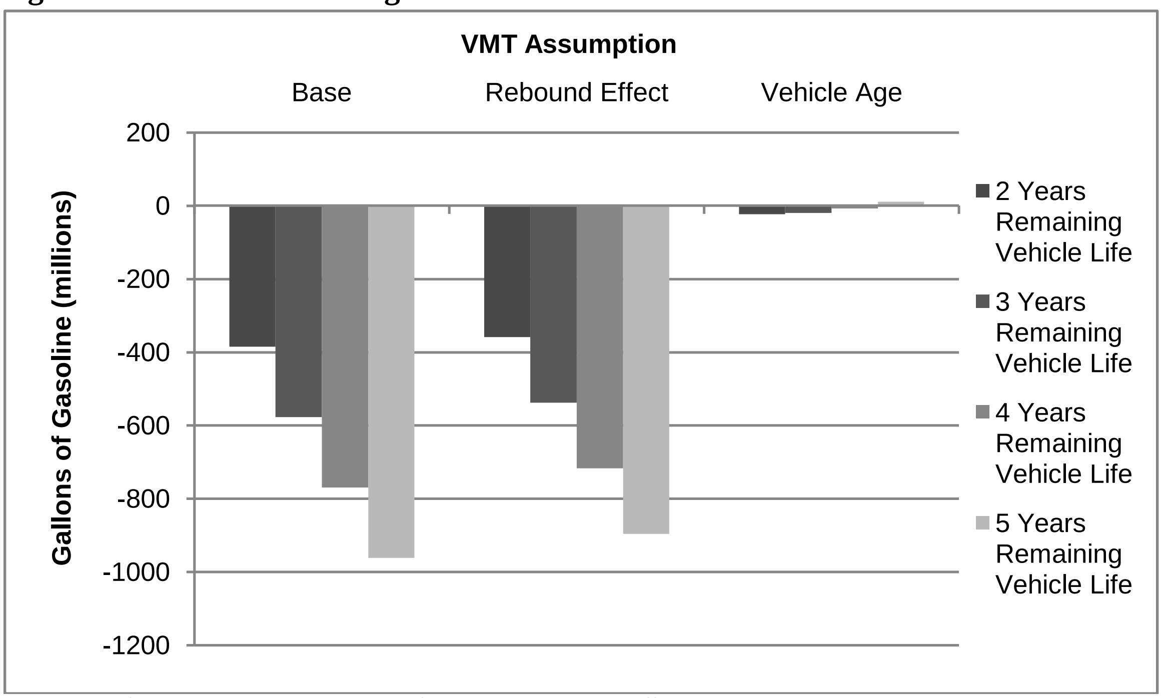
Due to a difference in the number of observations for scrapped and new vehicles, I normalize scrappage VMT by multiplying it by the ratio of new vehicles to scrapped vehicles. Estimates of VMT for each VMT assumption are presented in Table 2 as the total VMT through the end of the assumed remaining life for 692,617 vehicles. Changes in gasoline consumption (in millions of gallons), assuming remaining vehicle lives of two, three, four and five years and the three VMT assumptions, are presented in Figure 3.

Table 2: VMT Estimates

	Remaining Vehicle Life	VMT Assumption: Base	VMT Assumption: Rebound Effect	VMT Assumption: Vehicle Age
Scrapped Vehicles	*2 years*	16,623	16,305	13,663
	3 years	24,934	24,457	20,071
	4 years	33,246	32,610	26,214
	5 years	41,557	40,762	32,108
New Vehicles	*2 years*	16,623	16,940	20,961
	3 years	24,934	25,410	31,159
	4 years	33,246	33,880	41,140
	5 years	41,557	42,350	50,887

*VMT in millions; Scrapped VMT values are normalized to due to a discrepancy between the number of new and scrapped vehicle observations

Figure 3: Estimates of Change in Gallons of Gasoline Consumed

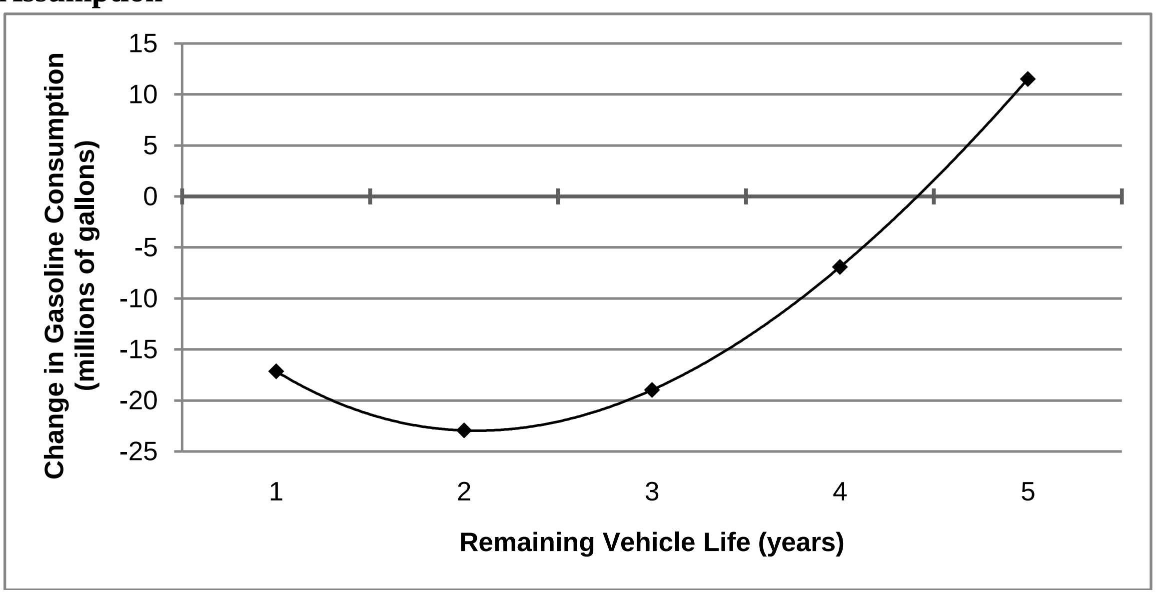


*Calculation of change in gasoline consumption for the base and rebound effect assumptions are shown in Appendix 2

The base and rebound effect VMT assumptions suggest a linear relationship exists between the remaining life of scrapped vehicles and change in gasoline consumption. A one-year increase in the assumed remaining life of scrapped vehicles results in a decrease in gasoline consumption by 192 and 179 million gallons for the base and rebound effect assumptions, respectively. Assuming two years remaining vehicle life, Figure 3 shows a change in gasoline consumption of -384, -358 and -23 million gallons for the base, rebound effect and vehicle age assumptions, respectively. The assumption of five years remaining life results in gasoline consumption of -961, -896 and 12 million gallons.

The vehicle age VMT assumption suggests a positive correlation exists between remaining life of scrapped vehicles and gasoline consumption when remaining vehicle life is between two and five years. Further, the vehicle age assumption suggests that the largest reduction in gasoline consumption occurs when scrapped vehicles are assumed to have a remaining life of two years. For a better understanding of change in gasoline consumption due to the vehicle age VMT assumption, Figure 4 illustrates the change in gasoline consumption with remaining vehicle life for the vehicle age VMT assumption.

Figure 4: Change in Gallons of Gasoline Consumed for Vehicle Age VMT Assumption



A remaining vehicle life of one year is included in Figure 4 to show the overall shape of the curve and that the change in gasoline consumption is minimized when the average remaining life of scrapped vehicles is two years. The vehicle age VMT assumption in Figure 4 suggests that a lower average remaining life of scrapped vehicles through CARS would result in a greater reduction in gasoline consumption as the base and rebound effect assumptions suggest.

Using the results from the vehicle age case, I find the average VMT of cars and light trucks in 2008 (year before being scrapped) by dividing the total VMT by the total number of observations for scrapped cars and light trucks, respectively. I estimate the average VMT at 9,061 miles per year and 10,760 miles per year for cars and light trucks, respectively, while the average VMT of all scrapped vehicles is 10,505 miles per year. Alberini, Harrington and McConnell (AHM) (1996) find the average VMT of scrapped vehicles during the Delaware vehicle scrappage program to be between 6,000 and 8,000 miles per year. The difference between their results and the results from this thesis is attributed to the difference in the age of vehicles that were scrapped through the respective programs. AHM examine a scrappage program in which vehicles were required to be greater than 12-years-old to be scrapped, while CARS allowed the scrappage of vehicles greater than just one-year-old. CARS may have resulted in the scrappage of newer vehicles, in better condition, resulting in a higher VMT of scrapped vehicles than those from the Delaware scrappage program reviewed by AHM. Further, the authors find no evidence to support a correlation between an offer price and VMT, so the differences in offer prices between the 1992-1993 Delaware scrappage program and CARS should not affect VMT.

IV. Discussion of Results

A. Sensitivity Analysis of the Rebound Effect

The decrease in gasoline consumption is sensitive to the amount of miles driven due to the rebound effect assumption. Table 3 presents multiple average VMT scenarios for the change in gasoline consumption, using the rebound effect assumption. The data shows the change in gasoline consumption when the VMT of scrapped vehicles is increased or decreased.

Table 3: Change in Gasoline Consumption for the Rebound Effect Assumption

	Remaining Vehicle Life			
Avg VMT of Scrapped Vehicles - Avg VMT of New Vehicles	*2 years*	*3 years*	*4 years*	*5 years*
11,000 - 11,429	(329)	(493)	(657)	(822)
12,000 - 12,467	(358)	(538)	(717)	(896)
13,000 - 13,506	(388)	(583)	(777)	(971)
14,000 - 14,545	(418)	(627)	(836)	(1,046)

*Gallons of gasoline in millions; Parentheses () denote negative number

For the rebound effect, a linear relationship exists between gasoline consumption and average VMT. For each increase of 1,000 miles per year in the average VMT of scrapped vehicles, gasoline consumption decreases by 30, 45, 60 and 75 million gallons, given a remaining vehicle life of two, three, four and five years, respectively. For instance, if the average VMT of scrapped vehicles is estimated to be 15,000 miles per year and average remaining vehicle life of vehicles from CARS is estimated at four years, total decrease in gasoline consumption would be 896 million gallons.

B. Analysis of Replacement Vehicle Method

The rebound effect VMT assumption discussed in this thesis may underestimate the reduction in gasoline consumption because new vehicles may not be a direct replacement for scrapped vehicles, but instead serve as the replacement for another vehicle in a multi-vehicle household. The situation involves a household that owns two different vehicles, a less fuel-efficient vehicle ("A") and a more fuel-efficient vehicle ("B"), and replaces "vehicle A" with a new vehicle ("C"), that is more fuel-efficient than both "A" and "B". Further, there are two drivers in the household, "1" drives less, and "2" drives more. In all of the cases I examine, it is assumed that "A" is driven less than "B" before being scrapped, because "A" is more costly to drive. Table 4 presents the scenario described above in which a household has two vehicles and scraps the older vehicle for a new vehicle; the rebound effect assumption is used to estimate VMT of the replacement vehicle.

Table 4: Alternative Vehicle Replacement Method for the Base and Rebound Effect Assumptions

Vehicle Replacement Method Employed in Results Section						
	Driver	*Vehicle*	*VMT*	*mpg*	*Gallons of Gas Consumed (annual)*	*Change in Gasoline Consumption (annual)*
Before Scrappage	-	A	9,000	15	600	**(284)**
After Scrappage	-	C	9,480	30	316	
Alternative Vehicle Replacement Method						
	Driver	*Vehicle*	*VMT*	*mpg*	*Gallons of Gas Consumed (annual)*	*Change in Gasoline Consumption (annual)*
Before Scrappage	1	A	9,000	15	600	**(324)**
	2	B	12,000	20	600	
After Scrappage	1	B	9,240	20	462	
	2	C	12,426	30	414	

*Parentheses () denote negative number

In most cases similar to the one presented in Table 4, after the family scraps "A" and purchases "C", vehicles "B" and "C" would each be driven more than "A" and "B", respectively, therefore the estimated results for the rebound effect assumption would underestimate the reduction in gasoline consumption.[15]

Small and Dender (2006) hold vehicle year constant when estimating the rebound effect while CARS replaced old vehicles with new vehicles. The rebound effect accounts for the fuel cost of driving but fails to take into account other costs of driving. The total cost of driving decreases more than the rebound effect suggests because old vehicles require a higher amount of maintenance and do not have a warranty to cover these costs. Older vehicles are also less reliable, increasing the expected travel time of older vehicles and further decreasing the cost of driving due to the purchase of a new vehicle. These additional decreases in vehicle driving costs suggest that there may be a larger actual increase in VMT than the rebound effect estimates.

C. Analysis of VMT Externalities

Although I find CARS to result in a minimal change in gasoline consumption, Lemp and Kockelman (2008) examine the external costs associated with driving vehicles of different makes and models. Their results suggest that there are substantially higher external costs to driving larger vehicles, such as SUVs and pickup trucks, than driving small vehicles. Lemp and Kockelman find pickup trucks and cargo vans to have the highest external costs of all the vehicles they examine. According to CARS program statistics released on August 26 of 2009, light trucks made up 84% and 41% of the

[15] In a few cases the results suggest an overestimation of gasoline reductions, but such cases suggest a negligible overestimation. The majority of possible scenarios my results underestimate the results, as I would expect to occur in the aggregate.

scrapped vehicles and new vehicle purchases,[16] respectively, suggesting CARS will result in a decrease of external costs.

Fischer, Harrington and Parry (FHP) (2004) examine the increase in pollution, congestion and accident externalities due to increased driving. By examining data from 2002, the authors find that lifetime emissions of cars are unaffected by fuel economy. Their findings suggest that the emissions abatement technologies in all cars deteriorate at the same rate, regardless of fuel economy. The authors find the same results for light trucks. The authors' findings suggest that CARS would have been just as effective at reducing emissions had it targeted all old vehicles, regardless of fuel efficiency. Further, FHP find that external costs of tailpipe emissions per mile traveled for light trucks exceeds the costs for cars. Therefore, the shift from light trucks to cars, through CARS, resulted in an overall decrease in negative externalities due to emissions.

FHP (2004) estimate the nationwide marginal congestion cost of driving at 6 cents per mile and the mean external accident cost at 4.39 cents per mile. Their results suggest that the total congestion and accident externality cost per mile is 10.39 cents, while Kleit (2004) estimates the total externality cost is 8.27 cents per mile. Kleit estimates the externality impacts of an increase in the Corporate Average Fuel Efficiency (CAFE) standards and finds that external costs due to congestion and accidents account for more than 99% of total external costs;[17] therefore the external cost of emissions is minimal

[16] In my analysis, I find light trucks to make up 84.98% and 40.29% of scrapped vehicles and new vehicle purchases, respectively. The slight difference in my estimates may be due to the omission of data that did not specify vehicle make.

[17] The factors considered by Kleit for total external costs of driving include congestion, accidents and the emissions of VOC, NO_x, and CO. For emissions, Kleit uses findings from the federal Office of Management and Budget, which estimates an external marginal cost of $1.43 per kilogram emissions of VOC and NO_x and no cost of CO emissions.

when compared to congestion and accidents. Table 6 presents total external costs due to congestion and accidents using the average of these two estimates of 9.33 cents per mile.

Table 5: Estimates of Increases in Externality Costs

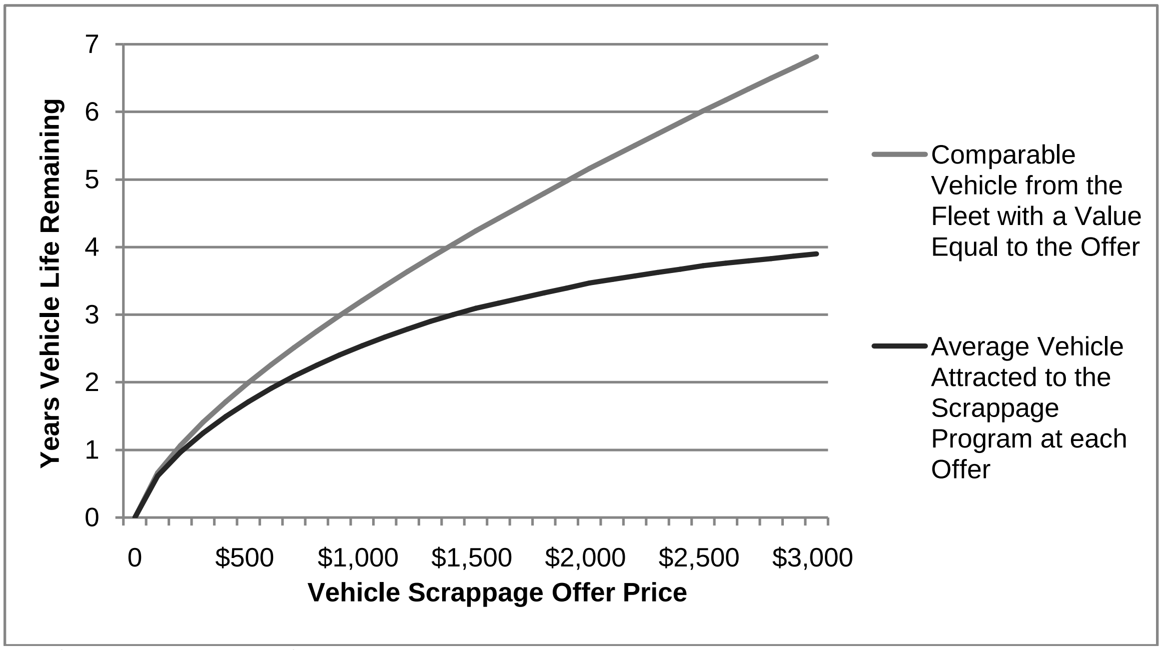
	VMT Assumption		
Remaining Vehicle Life	**Base**	**Rebound Effect**	**Vehicle Age**
2 years	-	$60	$681
3 years	-	$91	$1,034
4 years	-	$121	$1,393
5 years	-	$151	$1,752

*$ in millions

D. Remaining Vehicle Life of Scrapped Vehicles

Scrapped vehicles are not necessarily representative of the vehicle fleet. Previous research suggests they may have a lower value and remaining life than the average vehicle in the fleet, which would suggest the results of this thesis overestimate the decrease in gasoline consumption. AHM (1996) estimate the remaining vehicle life of a scrapped vehicle and a comparable vehicle from the fleet. A comparable vehicle from the fleet is a vehicle with the same market price as the offer price of the scrapped vehicle. Figure 5 presents AHM's results on remaining vehicle life of scrappage vehicles as compared to a comparable vehicle from the fleet.

Figure 5: Comparison of Remaining Vehicle Life for the Average Vehicle in the Fleet vs. Comparable Vehicle from the Fleet



*Data from a 1992-1993 survey of pre-1980 vehicle owners; Alberini, Harrington and McConnell (1996)

Figure 5 shows that the average remaining life of scrapped vehicles is substantially lower than a comparable vehicle from the fleet, especially as the offer price for scrapped vehicles increases. AHM conclude that vehicles attracted to scrappage programs are those from the vehicle fleet with the shortest remaining life.

V. Suggestions for Future Research

A cost/benefit analysis is not the purpose of this thesis, but it is the hope that the research laid out in this thesis may assist in the completion of one in the future. Future researchers may want to examine the variables affecting the remaining life of scrapped vehicles to create more concrete assumptions about CARS and future vehicle scrappage programs.

The results of this thesis may be used to study change in emissions due to decreased consumption of gasoline and the impact of newer, less polluting vehicles. FHP

(2004) examine vehicle emissions and find results that suggest that CARS could have achieved similar reductions in emissions if it had replaced old vehicles with new vehicles, regardless of fuel efficiency.[18] Future research on the correlation of vehicle age and vehicle emissions may be used to estimate whether the decrease in emissions due to driving new vehicles is enough to offset the increase in VMT, taking into account the specific distribution of vehicles scrapped through CARS.

The available funds for CARS depleted earlier than expected, suggesting that the offer price for scrapped vehicles was set too high for the $3 billion in funds set aside for vehicle scrappage. A lower offer price may have resulted in a greater number of scrapped vehicles without changing the total cost. Future research may examine possible scenarios to reduce the vehicle scrappage cost to society by using a pricing model, such as Kelley Blue Book, to set a different offer price for different vehicles. Such a system would reduce the number of scrapped vehicles as well as reduce the difference in the offer price and market price for each vehicle, decreasing each vehicle's replacement cost to taxpayers.

VI. Conclusion

The focus of this analysis was to determine whether the vehicle scrappage and the purchase of new vehicles through CARS would result in a net decrease in gasoline consumption. CARS raised the fuel economy of almost 700,000 registered vehicles from an average of 15.8 to 24.9 mpg at a cost of $3 billion. Previous research in the area concludes that vehicle scrappage programs are most effective on a small scale in local

[18] For more on the correlation of vehicle age and emissions, see Jiménez *et al.* (1999) or Walls and Hanson (1996).

communities. Previous research finds that small scrappage programs allow for the control of more factors and are more likely than larger programs to result in an overwhelming benefit to society due to larger decreases in emissions and larger increases in fuel economy.

The results I find do not suggest that CARS will significantly decrease gasoline consumption in the U.S. and even suggest a possible increase in gasoline consumption. For instance, the low and high estimates for the change in gasoline consumption are a decrease of 961 million gallons and an increase of 12 million gallons over five years. Using estimates from the U.S. Department of Energy (DOE), gasoline consumption over five years is approximately 690 billion gallons. CARS most likely had a negligible impact on gasoline consumption in the U.S. and change in gasoline consumption should be ignored when deciding whether to execute a similar vehicle scrappage program in the future.

VII. References

Alberini, A., W. Harrington and V. McConnell (1996). "Estimating an Emissions Supply Function from Accelerated Vehicle Retirement Programs." *The Review of Economics and Statistics*, 78(2): 251-265.

Chen, C. and D. Niemeier (2005). "A Mass Point Vehicle Scrappage Model." *Transportation Research Part B*, 39(5): 401-415.

Emission Facts (2005). "Greenhouse gas emissions from a typical passenger vehicle." *USA EPA.*

Fischer, C., W. Harrington and I. Parry (2007). "Should automobile fuel economy standards be tightened?" *The Energy Journal*, 28(4): 1–29.

Hahn, R. (1995). "An economic analysis of scrappage." *RAND Journal of Economics*, 26(2): 222-242.

Harrington, W. (1997). "Fuel Economy and Motor Vehicle Emissions." *Journal of Environmental Economics and Management*, 33(3): 240-252.

Hsu, S. and D. Sperling (1994). "Uncertain Air Quality Impacts of Automobile Retirement Programs." *The University of California Transportation Center.*

Jiménez, J., M. Koplow, D. Nelson, M. Zahniser and S. Schmidt (1999). "Characterization of On-Road Vehicle NO Emissions by a TILDAS Remote Sensor." *Journal of the Air & Waste Management Association*, 49: 463-470.

Kleit, A. (2004). "Impacts of Long-Range Increases in the Corporate Average Fuel Economy (CAFE) Standard." *Economic Inquiry*, 42: 279–294.

Lemp, J. and K. Kockelman (2008). "Quantifying the external costs of vehicle use: Evidence from America's top-selling light-duty models." *Transportation Research Part D*, 13: 491-504.

McCubbin, D. and M. Delluchi (1999). "The Health Costs of Motor-Vehicle-Related Air Pollution." *Journal Transport Economics and Policy*, 33(3): 253-286.

Small, K. and K. Dender (2007). "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect." *The Energy Journal*, 28(1): 25–51.

Walls, M. and J. Hanson (1996). "Distributional Impacts of an Environmental Tax Shift: The Case of Motor Vehicle Emissions Taxes." *Resources for the Future*.

Appendix 1: Calculating the Rebound Effect

The rebound effect is dependent on the change in the cost of driving due to a change in fuel efficiency. Equations (1) and (2) present the calculation of change in the cost of driving:

$$F_i = \frac{P}{E_i} \tag{1}$$

$$C = \frac{F_n - F_t}{F_t} \tag{2}$$

F_i represents the per mile fuel cost of driving for new (*n*) and scrapped (*t*) vehicles, *P* represents the price of fuel, *E* represents fuel efficiency and *C* represents the change in the cost of driving. Equation (3) presents the results when (1) is substituted into (2), then simplified.

$$C = \frac{E_t - E_n}{E_n} \tag{3}$$

Using equation (3), there is a 36.55% reduction in the cost of driving when the average fuel efficiency of new and scrapped vehicles is 24.9 and 15.8 mpg, respectively.

Appendix 2: Calculating the Change in Gasoline Consumption for the Base and Rebound Effect Assumptions

Equation (4) presents the method for estimating the gallons of gasoline consumed in the base and rebound effect VMT assumptions.

$$Gas_r = \left(\frac{VMT_n * Number_n}{MPG_n} - \frac{VMT_t * Number_t}{MPG_t}\right) * Life_r \tag{4}$$

Gas_r represents the change in gallons of gasoline consumed for a given remaining vehicle life, *r*. *VMT* represents the VMT of a vehicle, *Number* is the number of vehicles, *MPG* is the fuel efficiency of a vehicle, *n* and *t* represent new and scrapped vehicles for each variable, respectively, and $Life_r$ represents remaining vehicle life. VMT of scrapped vehicles is normalized to correct for the difference in the number of scrapped and new vehicle observations, so change in gasoline consumption does not also need to be normalized.

Appendix 3: http://www.cars.gov/faq

Is there a reason fuel economy is important?

YES. Buying a fuel efficient vehicle is important because it can:

- Save you money -You can reduce fuel costs each year by choosing the most efficient vehicle that meets your needs.
- Reduce greenhouse gas emissions - Carbon dioxide (CO2) from burning gasoline and diesel contributes to global climate change. You can do your part to reduce climate change by reducing your carbon footprint.
- Improve energy security and reduce oil dependence costs - Our dependence on oil makes us vulnerable to oil market manipulation and price shocks.
- Increase energy sustainability - Oil is a non-renewable resource, and we cannot sustain our current rate of use indefinitely. Using it wisely now allows us time to find alternative technologies and fuels that will be more sustainable.

For more information on the importance of better fuel economy, go to http://www.fueleconomy.gov/feg/why.shtml. For the 2009 Fuel Economy Guide, go to http://www.fueleconomy.gov/feg/FEG2009.pdf.

back to top