Benefits of the Cash for Clunkers (C4C) Program

Final Report
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1.   Executive Summary

In the summer of 2009, the U.S. government operated a $3 billion incentives program called Cash for Clunkers (C4C) to encourage the public to trade in old vehicles for more fuel-efficient models. This report estimates the net fuel savings, cost reductions and social benefits anticipated as a result of the program.

Net fuel savings due to C4C are projected to reach **30 to 43 million gallons** of gasoline in the first year and **230 to 513 million gallons over 12 years**. Compared to business as usual, C4C is expected to save an extra 16 to 23 million gallons of fuel in the first year.

These savings represent a **reduction of 0.03% to 0.06%** in total annual fuel consumption by passenger cars in the United States. The impact on total fuel consumption is roughly proportional to the ratio of C4C vehicles (690,000) to total passenger vehicles (136 million[1]). In order to reduce total fuel consumption of passenger vehicles by 10% - 50%, drastic changes in the C4C program would be needed. Mathematically speaking, the reduction could be achieved by **expanding the scope of C4C to cover 14 – 68 million vehicles at a cost of $49 - $306 billion dollars**.

The relative benefit or cost of participation in the C4C program to individual consumers depends largely on their driving habits. **In all cases, if a consumer were to only drive 6,000 miles per year, they would be better served by keeping their current vehicle**. Many favorable options are available (but not guaranteed) if a consumer is planning to drive 20,000 miles per year.

In the best case scenario, **the C4C program incurred a net present loss to society of $336 per vehicle or $0.54 per gallon of gas saved**. In the worst case scenario, C4C had a net present cost to society of $7122 per vehicle or $25 per gallon saved. **Based on these findings, the authors do not recommend expansion of the C4C program as a means to significantly reduce total fuel consumption of passenger vehicles.**

2.   Fuel Savings

    2.1   New Vehicles vs. Trade-ins

To estimate the fuel savings attributable to C4C, we first compared the projected fuel consumption of purchased cars and trade-ins over the expected lifetime of the new vehicles. The Top 10 new and trade-in models were taken to be representative of all 690,000 cars exchanged under the program, including Category 1 – 3 trucks. Each model was weighted in the analysis according to its share of Top 10 transactions. For example, the number of Toyota Corollas was scaled up from about 30,000

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[1] Bureau of Transportation Statistics. 2009. National Transportation Statistics: Internet Edition. Table 1-11, updated June 2009.<http://www.bts.gov/publications/national_transportation_statistics/html/table_01_12.html>.

to 110,000, representing 16% of all cars and trucks in the final estimates. The analysis considered a 12-year forecast horizon based on the expected lifespan of a new car.

Fuel consumption was calculated as the product of each vehicle's age-adjusted annual mileage and its fuel efficiency in miles per gallon (mpg). As a car gets older, the annual miles driven tend to decrease[2]. In a vehicle's first year the weighted average of miles driven, over all types of travel profiles, ranges from 12,000 to 16,000; by the tenth year annual travel maxes out just over 10,000 miles[3]. The annual mileage estimates used for each vehicle are based on weighted averages of U.S. Department of Energy (DOE) transportation statistics across a distribution of driving profiles as shown in Figure A1 in the Appendix. For trade-in vehicles, assumed to be 10 years old, mileage in the first year of the forecast was based on the statistics for 10-year-old cars. By the end of the forecast period, trade-in vehicles were assumed to be driving the typical mileage of 21-year-old cars.

Dividing the total mileage of each model by its respective fuel efficiency yielded projected fuel consumption. Fuel efficiency ratings were obtained from the cars.gov website. Where more than one version of a model was listed (e.g. Toyota Corolla 2.0 and 2.4), a simple average of all versions' fuel rating was calculated. The fuel efficiencies of the cars are shown in Tables A1 and A2 in the Appendix. Finally, fuel totals were summed across models to produce the one-year and 12-year estimate bands.

Net fuel savings from C4C are projected at 30 to 43 million gallons of gasoline in the first year and 230 to 513 million gallons over 12 years (Table 1). These savings represent a reduction of 0.03% to 0.06% in total annual gasoline consumption by passenger cars in the United States[4].

Table 1: Results of Fuel Savings Analysis: New Vehicles vs. Trade-ins

	Projected Fuel Consumption (millions of gallons)			Net Fuel Savings (% of fuel consumption by passenger cars)
	Trade-in Vehicles	New Vehicles	Difference	
First Year	335 - 458	306 - 415	30 - 43	0.04 – 0.06 %
12-Year Total	2,983 – 4,251	2,753 – 3,739	230 - 513	0.03 – 0.06 %

Source: Galvan et al.

[2] U.S. Department of Energy (DOE). 2009. Transportation Energy Data Book: Edition 28. <http://www-cta.ornl.gov/data>. Accessed 9/24/2009. Ch.8, Table 8.11.
[3] Ibid.
[4] According to the U.S. Bureau of Transportation Statistics, total annual gasoline consumption by U.S. passenger cars is 75 billion gallons. Source:
<http://www.bts.gov/publications/national_transportation_statistics/html/table_automobile_profile.html>. Accessed 9/24/2009.

2.2 C4C vs. Business As Usual

In order to improve the realism of the model, the present section compares the fuel savings of C4C to fuel savings under a Business As Usual (BAU) scenario. As in Section 2.1, the methodology for calculating fuel savings is based on displaced fuel consumption of traded-in vehicles.

We define "business as usual" as the number of new cars sold without C4C incentives. Data from the Bureau of Transportation Statistics indicates that 7.6 million new cars are sold annually in the U.S. (630,000 per month)[5]. Assuming that 80% of new car sales are accompanied by a trade-in, about 6.2 million used cars would be traded in per year (515,000 per month) under BAU. By comparison, about 690,000 cars changed hands within a month during the C4C program (July – August 2009). As such, the C4C removed an additional 175,000 cars from the road compared to BAU. This differential is the source of the excess fuel savings.

Using the upper and lower-bound annual mileage estimates cited in Section 2.1, the first-year fuel saved under BAU due to cars purchased from July-August 2009 is estimated at 14 to 20 million gallons. Over the 12-year lifespan of the cars, total fuel saved under BAU is estimated at 111 to 227 million gallons.

This would mean that the C4C has brought about a higher fuel savings compared to BAU of 16 - 23 million gallons in the first year and 119 – 286 million gallons over 12 years. In other words, C4C is on average 48 – 54% better (in terms of fuel saved) than BAU (Figure 2-1).

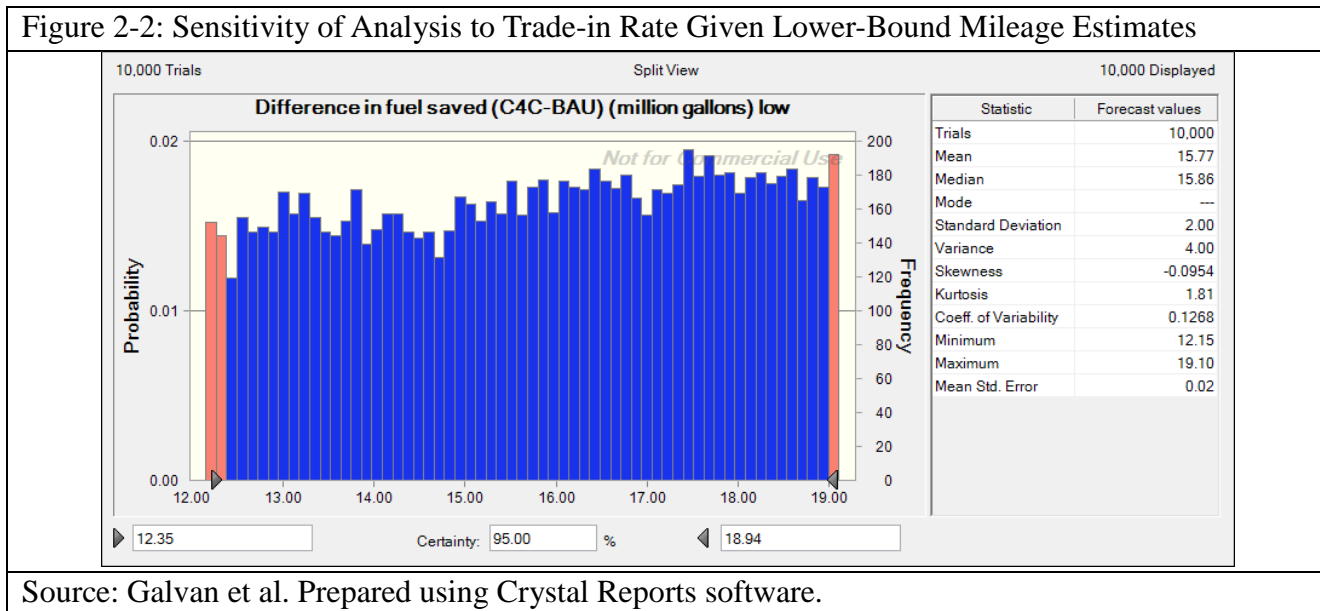Figure 2-1: Fuel Savings of Cash for Clunkers vs. Business As Usual*
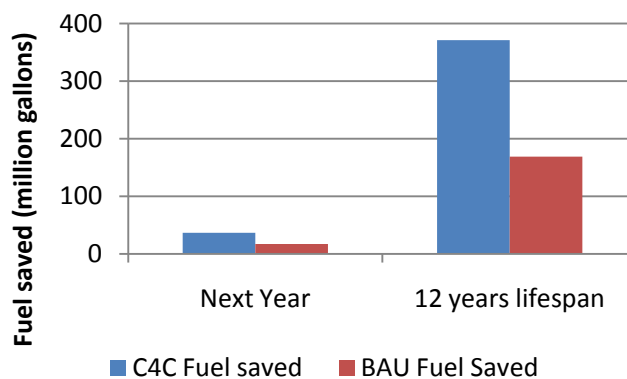
*Fuel savings are measured in reference to displaced fuel consumption of trade-in vehicles.

Source: Galvan et al.

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[5] BTS (2009): Table 1-12, updated March 2009.

The ratio of trade-in cars to new cars purchased is one of the key assumptions in this analysis. We were unable to find an authoritative source of data for this statistic. Therefore, we conducted a sensitivity analysis on the trade-in ratio using a Monte Carlo simulation. The simulation calculated the difference in fuel savings between C4C and BAU, assuming that the trade-in ratio had a uniform probability distribution between 70% and 90%.

The results of 10,000 trials showed that C4C saved 16 million gallons more than BAU on average, assuming lower-bound annual mileage estimates as shown in Figure 2-2. The 95% confidence interval had a range of 6.6 million gallons. The Monte Carlo simulation was repeated using upper-bound annual mileage estimates as inputs. The mean improvement of C4C vs. BAU was 23 million gallons under the high mileage scenario, while the 95% confidence interval had a range of 9.4 million gallons.

Figure 2-2: Sensitivity of Analysis to Trade-in Rate Given Lower-Bound Mileage Estimates

Statistic	Forecast values
Trials	10,000
Mean	15.77
Median	15.86
Mode	---
Standard Deviation	2.00
Variance	4.00
Skewness	-0.0954
Kurtosis	1.81
Coeff. of Variability	0.1268
Minimum	12.15
Maximum	19.10
Mean Std. Error	0.02

Source: Galvan et al. Prepared using Crystal Reports software.

This sensitivity analysis indicates that our estimates of the magnitude of fuel savings associated with C4C vs. BAU are subject to a margin of +/- 20% due to uncertainty regarding the ratio of trade-ins to new cars sold. The sensitivity analysis supports the main finding that the C4C program is likely to reduce fuel consumption in absolute terms more than business as usual would have.

2.3   How to Reduce Gasoline Consumption by 10% - 50%

In Section 2.1 we estimated that C4C reduced national gasoline consumption by passenger vehicles by less than one-tenth of one percent. This result is not surprising, given that the ratio of C4C vehicles (690,000) to total passenger vehicles (136 million in 2007[6]) is of a similar order of

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[6] BTS (2009): Table 1-11, updated June 2009.

magnitude. In order to reduce national consumption by 10% - 50%, drastic changes in the program would be needed. Mathematically speaking, the reduction could probably be achieved by expanding the scope of C4C to cover 14 – 68 million vehicle trade-ins at a cost of $49 - $306 billion dollars. From a political perspective, American voters would be unlikely to tolerate this level of spending.

3.   Cost Savings

3.1   Consumers

The analysis that follows identifies the relative net costs or savings to consumers as a result of participating in the C4C program. Fuel, insurance, purchase price and payment methods were modeled to determine the net present value (NPV) of a C4C trade to individual consumers. In the scenarios that follow, illustrated by the cash flow diagrams in Figure 3-1, consumers have the option of retaining their current vehicle, purchasing a new vehicle with cash under C4C, or purchasing a new vehicle with a loan under C4C. Descriptions of model inputs and key assumptions are summarized in Box 3-1 at the end of Section 3.1.

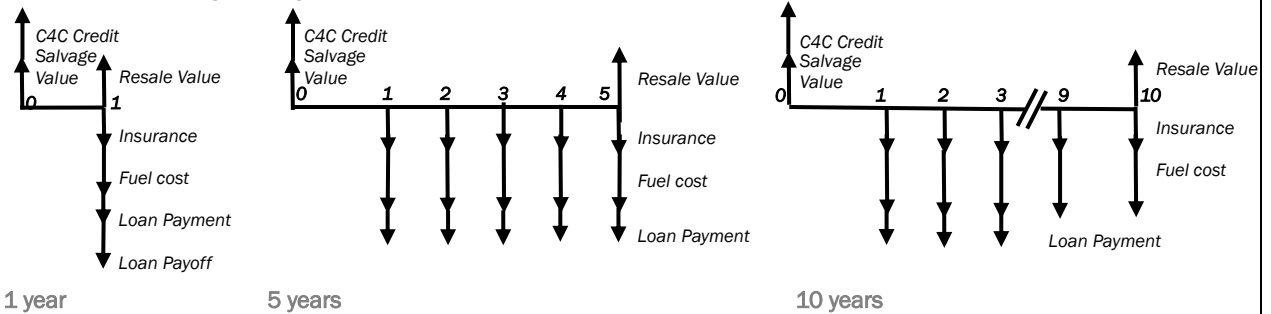Figure 3-1: Cash Flow Diagrams for Consumer Net Benefit Model

Source: Galvan et al.

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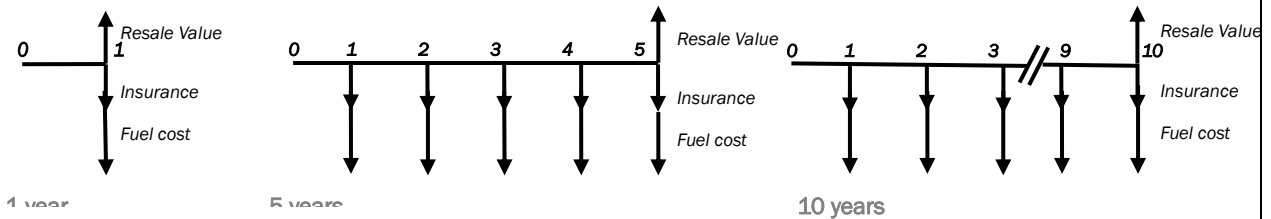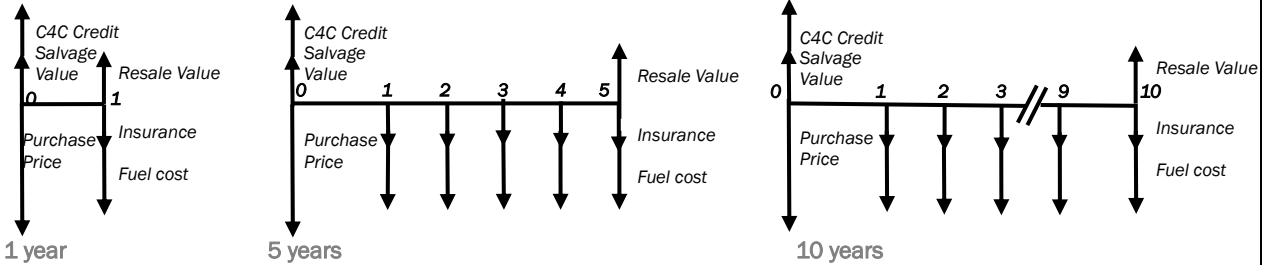
<u>Sensitivity analysis reveals that the number of miles driven each year has the greatest impact on the net benefits to the consumer (Figure 3-2).</u> In all cases, if a consumer were to only drive 6,000 miles per year, they would be better served by keeping their current vehicle, while many favorable options are available (but not guaranteed) if a consumer is planning to drive 20,000 miles per year. Fuel price is the second most important variable in the analysis. Under the vehicle combinations employed, the weighted net benefit to consumers becomes positive only near 20,000 miles or near $4.00 per gallon of fuel.

All other effects of input variation remain negative under the present assumptions. Given that the loan interest rate is 5% and the future discount rate for this analysis is 5%, there are no differences in the cost of the purchase once the loan has been paid in full. At the end of the first year, however, there is a difference in favor of the cash purchase, given that the outstanding loan balance is greater than the current value of the vehicle.

Figure 3-2: Sensitivity of Weighted Net Consumer Benefit to Variations in Miles Driven, Fuel Price, Fuel Inflation, and Years Driven
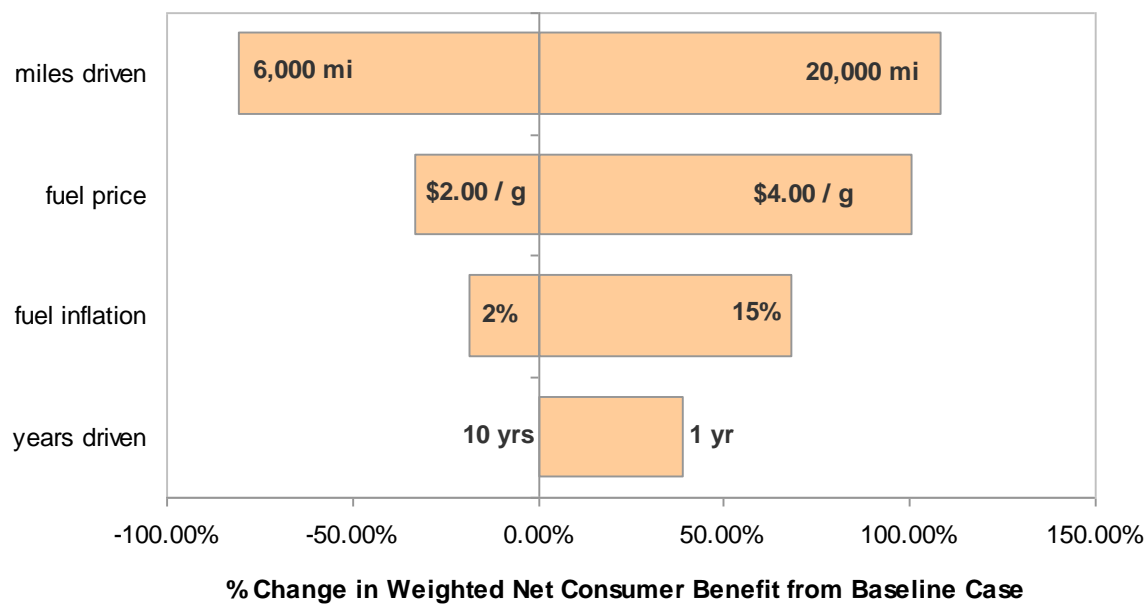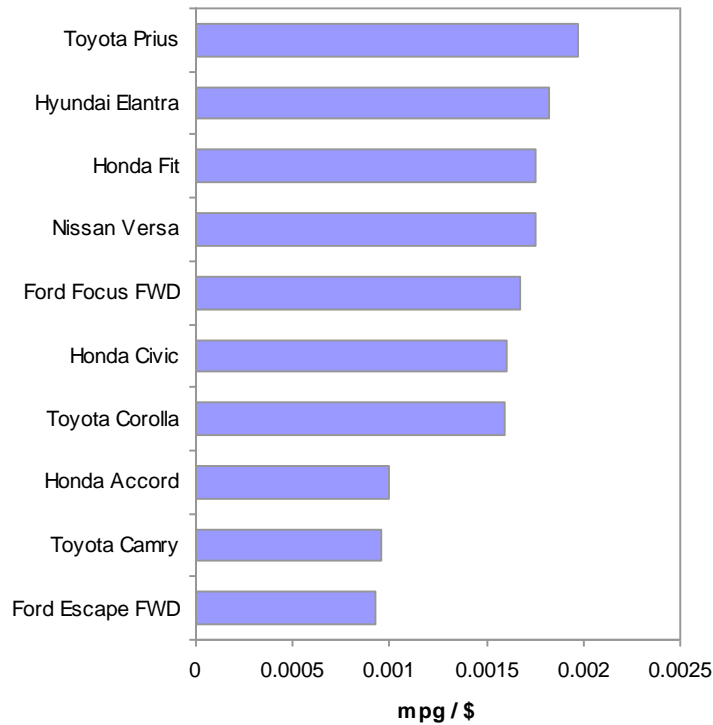

Source: Galvan et al.

The choice of new vehicle has a considerable effect on the relative benefit or cost of participation in the C4C program to an individual. In general, the more fuel efficient and the lower the purchase price, the better for the consumer over the long term of trading in their current vehicle. As shown in Figure 3-3 below, three of the vehicle choices in particular lie in a second tier in the fuel efficiency value metric of miles per gallon per dollar purchase price: the Toyota Camry, Honda Accord, and Ford Escape. <u>Regardless of a consumer's current vehicle, the purchase of one of these three models generally results in a net cost to the consumer over any time period or range of miles driven.</u> Likewise, among currently owned vehicles, trade-in of the minivans (Dodge Caravan and Ford Windstar) is not favored under most circumstances due to the relatively high fuel economy of these models.

Figure 3-3: Relative Fuel Efficiency per unit Purchase Price of New Car Purchase Options

Source: Galvan et al.

The results of the analysis show a wide variability on the basis of the particular vehicle combination. Table 2-2 below displays the net present benefit of the trade-in for all vehicle combinations at the time period of 1 year, 12,000 miles driven, and a cash purchase option. As these values are all negative, the conclusion is that <u>the consumer would be better served financially by keeping their present vehicle rather than seeking to trade it in under the C4C program.</u> Additionally, as many of the net present costs are between $1,000 and $2,000 it means that a change in the C4C credit of that amount would make several of these options viable.

Table 2-2: Trade Matrix for Consumers at 1 year, 12,000 miles driven, Cash Purchase

New Cars → Old Cars ↓	Toyota Corolla	Honda Civic	Toyota Camry	Ford Focus FWD	Hyundai Elantra	Nissan Versa	Toyota Prius	Honda Accord	Honda Fit	Ford Escape FWD
Ford Explorer 4WD	($1,770)	($1,710)	($5,760)	($1,470)	($1,130)	($1,360)	($3,480)	($5,090)	($1,550)	($5,210)
Ford F150 Pickup 2WD	($1,700)	($1,640)	($5,690)	($1,400)	($1,060)	($1,290)	($3,400)	($5,020)	($1,480)	($5,140)
Jeep Grand Cherokee 4WD	($2,240)	($2,190)	($6,230)	($1,940)	($1,600)	($1,830)	($3,950)	($5,560)	($2,020)	($5,680)
Ford Explorer 2WD	($1,720)	($1,670)	($5,720)	($1,430)	($1,090)	($1,310)	($3,430)	($5,050)	($1,510)	($5,160)
Dodge Caravan 2WD	($2,800)	($2,750)	($5,790)	($2,500)	($2,160)	($2,390)	($3,510)	($5,120)	($1,580)	($5,240)
Jeep Cherokee 4WD	($1,810)	($1,760)	($5,800)	($1,510)	($1,170)	($1,400)	($3,520)	($5,130)	($1,590)	($5,250)
Chevrolet Blazer 4WD	($1,950)	($1,900)	($5,950)	($1,660)	($1,320)	($1,540)	($3,660)	($5,280)	($1,730)	($5,390)
Chevrolet C1500 Pickup 2WD	($2,600)	($2,550)	($6,590)	($2,300)	($1,960)	($2,190)	($4,310)	($5,920)	($2,380)	($6,040)
Ford F150 Pickup 4WD	($2,180)	($2,130)	($5,180)	($1,890)	($1,550)	($1,770)	($3,890)	($5,510)	($1,970)	($5,620)
Ford Windstar FWD Van	($2,590)	($2,530)	($5,580)	($2,290)	($1,950)	($1,180)	($3,300)	($4,910)	($1,370)	($5,030)

Increasing the time of interest to 10 years and the expected miles driven to 20,000 miles per year, the number of viable trade scenarios under the current program becomes much higher. As seen in Table 2-3 below, 58 of the 100 options prove to be a net benefit to the consumer with some of them significantly so.

Table 2-3: NPV Matrix for Consumers at 10 Years, 20,000 Miles Driven, Loan

New Cars → Old Cars ↓	Toyota Corolla	Honda Civic	Toyota Camry	Ford Focus FWD	Hyundai Elantra	Nissan Versa	Toyota Prius	Honda Accord	Honda Fit	Ford Escape FWD
Ford Explorer 4WD	$3,590	$3,600	($6,630)	$4,330	$4,770	$4,920	$5,440	($5,260)	$5,710	($5,550)
Ford F150 Pickup 2WD	$4,890	$4,900	($5,330)	$5,630	$6,080	$6,220	$6,740	($3,950)	$7,010	($4,250)
Jeep Grand Cherokee 4WD	$2,780	$2,790	($7,440)	$3,520	$3,960	$4,110	$4,620	($6,070)	$4,890	($6,360)
Ford Explorer 2WD	$1,310	$1,320	($8,910)	$2,050	$2,490	$2,640	$3,160	($7,540)	$3,430	($7,830)
Dodge Caravan 2WD	($3,890)	($3,880)	($13,120)	($3,150)	($2,710)	($2,560)	($1,050)	($11,740)	($780)	($12,030)
Jeep Cherokee 4WD	$240	$250	($9,980)	$980	$1,420	$1,570	$2,080	($8,610)	$2,350	($8,900)
Chevrolet Blazer 4WD	$3,690	$3,700	($6,530)	$4,430	$4,880	$5,020	$5,540	($5,150)	$5,810	($5,450)
Chevrolet C1500 Pickup 2WD	$4,520	$4,530	($5,710)	$5,260	$5,700	$5,850	$6,360	($4,330)	$6,630	($4,620)
Ford F150 Pickup 4WD	$5,280	$5,290	($3,950)	$6,010	$6,460	$6,610	$7,120	($3,570)	$7,390	($3,860)
Ford Windstar FWD Van	($2,510)	($2,500)	($11,740)	($1,780)	($1,330)	($180)	$330	($10,360)	$600	($10,650)

Maintenance costs were not included in the NPV analysis due to a lack of cost-free data. Older vehicles generally can be expected to have a higher average maintenance cost per year than newer vehicles. This implies that the inclusion of maintenance costs could improve the business case for trading in older vehicles, perhaps significantly. The acquisition of data on maintenance costs would be a high priority if funding were available.

Box 3-1: Definition of Model Inputs
Salvage Value: Residual value of the disabled trade-in vehicle that goes directly to the consumer under the C4C program at the time of purchase. The salvage value of each model is calculated as 50% of the fair-condition trade-in value in the Kelley Blue Book (www.kbb.com). Salvage value is credited to the consumer's cash flow in year zero of the NPV analysis.
C4C Credit: $4500 if the difference in fuel efficiency between the trade-in and the new vehicle is more than 10 mpg; $3500 if the difference is between 4 and 10 mpg. The C4C credit goes directly to the consumer's cash flow in year zero.
Resale Value: All vehicles are assumed to be sold to a private party at the end of the 1, 5 or 10-year NPV forecast period. Resale value of the 10-year old used cars is determined via the Kelley Blue Book (www.kbb.com) private party price including standard options and good condition for a vehicle sold in the Pittsburgh, PA area. Existing mileage on 10-year-old trade-in vehicles is assumed to be 94,000 miles. The resale value is adjusted up or down by 25% on the basis of low or high mileage respectively, and then 5% down per year on the basis of age. For the new vehicles, the resale value is assumed to be 10% to 20% lower than the original purchase price after one year on the basis of low to high mileage respectively, and then is reduced downward 5% per year for age.
Fuel Costs: Baseline fuel cost assumption is $2.50 per gallon (near current average of nationwide

fuel prices) with an annual increase of 5% per year thereafter. During sensitivity analysis, the initial fuel price varied between $2.00 and $4.00 per gallon, and the fuel inflation rate varied between 2% and 15%. These values are based on the authors' judgment of likely extremes for inflation over the next decade.
Miles Driven: Ranging from 6,000 to 20,000 miles annually.
Loan Payment: The loan principal amount is the total purchase price of the new vehicle. The interest rate is 5%, and payments and compounding are calculated on a monthly basis over a 60 month term.
Loan Payoff: The loan payoff is the remaining balance owed by the consumer at the end of the NPV forecast horizon. As the vehicle is assumed to be sold at the end of the time of interest, this remaining balance must then be paid.
Source: Galvan et al.

3.2 Corporations

Further assuming that the consumer is a corporation with income tax implications has the effect of reducing the magnitude of net annual savings (if any) by the corporate tax rate, adjusted for depreciation. The corporate tax rate is assumed to be 30%, and it is further assumed that any company would have excess revenue to offset net negative costs incurred as a result of vehicle purchases.

Table 2-4 displays the net present benefit matrix for a corporation under a 5 year time horizon with 20,000 miles driven per year and a loan. A corporation under this scenario fares better, with 60 positive trade combinations, than a private consumer, with an overall weighted average net cost of ($630) [negative] versus the consumer's net cost of ($1,220) [negative]. The corporate trade-in benefit becomes more positive with more miles driven over a longer period of time.

Table 2-4: Trade Matrix for Corporations at 5 Years, 20,000 Miles Driven, Loan

New Cars → / Old Cars ↓	Toyota Corolla	Honda Civic	Toyota Camry	Ford Focus FWD	Hyundai Elantra	Nissan Versa	Toyota Prius	Honda Accord	Honda Fit	Ford Escape FWD
Ford Explorer 4WD	$830	$850	($4,070)	$1,190	$1,430	$1,430	$810	($3,340)	$1,650	($3,410)
Ford F150 Pickup 2WD	$1,400	$1,420	($3,510)	$1,760	$1,990	$1,990	$1,380	($2,780)	$2,220	($2,840)
Jeep Grand Cherokee 4WD	$620	$640	($4,290)	$970	$1,210	$1,210	$600	($3,560)	$1,440	($3,620)
Ford Explorer 2WD	$10	$30	($4,900)	$370	$610	$610	($10)	($4,160)	$830	($4,230)
Dodge Caravan 2WD	($2,290)	($2,270)	($6,490)	($1,930)	($1,690)	($1,690)	($1,610)	($5,760)	($760)	($5,830)
Jeep Cherokee 4WD	($410)	($390)	($5,320)	($60)	$180	$180	($430)	($4,590)	$410	($4,650)
Chevrolet Blazer 4WD	$900	$920	($4,010)	$1,260	$1,500	$1,490	$880	($3,270)	$1,720	($3,340)
Chevrolet C1500 Pickup 2WD	$1,230	$1,250	($3,680)	$1,590	$1,820	$1,820	$1,210	($2,950)	$2,050	($3,010)
Ford F150 Pickup 4WD	$1,490	$1,510	($2,720)	$1,850	$2,090	$2,080	$1,470	($2,680)	$2,310	($2,750)
Ford Windstar FWD Van	($1,740)	($1,720)	($5,950)	($1,380)	($1,150)	($450)	($1,060)	($5,220)	($220)	($5,280)

Source: Galvan et al.

4.   Benefits to Society

Based on the analysis in the Section 3, the overall benefits to consumers from the C4C program have a net present value ranging from -$3.1 billion (low mileage scenario) to +$537 million (high mileage scenario). Classical economists would argue that the true net benefit to consumers is likely to be closer to the high scenario, based on the assumption that consumers are rational actors who would not have participated in the 2009 C4C program unless they were high mileage drivers. The authors of this report make no such assumption.

In addition to net consumer savings, total costs to society include government payments of C4C credits; reduced dependence on foreign oil; and reduced carbon dioxide emissions. <u>Monetizing and adding up these flows results in a net present loss to society of $336 per vehicle or $0.54 per gallon of gas saved, in the best case, compared to a $7122 loss per vehicle or $25 loss per gallon of gas, in the worst</u>[7].

5.   Conclusions and Recommendations

The present analysis shows that the C4C program may have had an overall cost to society of as little as $0.54 per gallon saved – roughly equivalent to the average U.S. gasoline tax of $0.47 per gallon[8] - or as much as $25 per gallon. Based on these findings, we would recommend that the C4C program not be replicated in its present form as a means to reduce total fuel consumption of passenger vehicles in the United States.

The C4C program could be improved by conducting an education campaign to raise awareness of the financial benefits of fuel efficient vehicles for consumers who drive more than 20,000 miles per year. Such a campaign could build on the momentum generated by the generally positive public response to C4C in order to promote purchase of new cars with higher-than-average fuel economy.

The financial model of the individual consumer's trade-in decision that was presented in this report could be improved with the addition of data on the maintenance costs of vehicles aged 10 years and older. With the completion of the data inputs, this model could be made available as an online calculator in support of the public awareness campaign suggested above.

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[7] 10-year NPV analysis is based on net consumer and government costs from the C4C program. Reduced dependence on foreign oil is quantified as a savings of $1.09 per gallon of displaced imports from OPEC, based on the average annual cost to the economy from OPEC price manipulation from 2004 to 2008 (source: US DOE, EPA. "Reduce Oil Dependence Costs". <http://www.fueleconomy.gov/feg/oildep.shtml>. Accessed 9/24/2009.) Reductions in CO2 emissions are valued at $0.048 per lbs (source: Bion Howard, "Simplified Pollution Avoidance Calculation for Builders," as referenced on the GB List, < http://www.ibiblio.org/london/renewable-energy/mailarchives/greenbuilding2/msg01253.html>.

[8] Includes state and federal gasoline taxes. Source: Wikipedia, "Fuel Tax". <<u>http://en.wikipedia.org/wiki/Fuel_tax#United_States</u>>. Page was last modified on 12 September 2009.

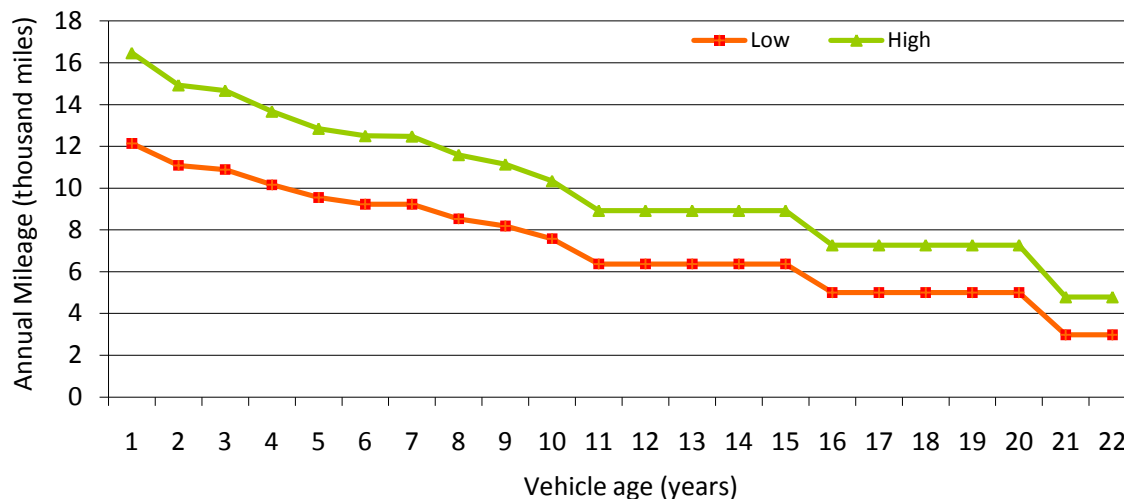Figure A1: Annual Mileage Driven as a Function of Vehicle's Age

Table A1: Average Fuel Efficiency of the Traded-in Vehicles

Old Cars	Fuel Efficiency (miles per gallon)
Ford Explorer 4WD	15.0
Ford F150 Pickup 2WD	14.8
Jeep Grand Cherokee 4WD	15.5
Ford Explorer 2WD	16.3
Dodge Caravan 2WD	18.3
Jeep Cherokee 4WD	16.7
Chevrolet Blazer 4WD	15.0
Chevrolet C1500 Pickup 2WD	14.5
Ford F150 Pickup 4WD	14.2
Ford Windstar FWD Van	17.5

Table A2: Average Fuel Efficiency of the New Vehicles

New Cars	Fuel Efficiency (miles per gallon)
Toyota Corolla	27.5
Honda Civic	27.3
Toyota Camry	24.3
Ford Focus FWD	27.5
Hyundai Elantra	27.5
Nissan Versa	28.2
Toyota Prius	46.0
Honda Accord	23.7
Honda Fit	30.0
Ford Escape FWD	22.7