Do Public Subsidies Sell Green Cars? Evidence from the U.S. "Cash for Clunkers" Program

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Abstract

One question surrounding the 2009 U.S. "Cash for Clunkers" program is whether it induced consumers to purchase greener vehicles than they would otherwise have purchased. This paper views the program as a natural experiment, which offered higher rebates to consumers buying more fuel-efficient vehicles, and shows that awarding an extra $1,000 on a vehicle made 7.2% of consumers switch to it. Hence the program, giving away nearly $3 billion, should have drawn many consumers to the subsidized greener vehicles, producing substantial environmental gains. This finding should interest policymakers evaluating similar programs to stimulate the economy while aiding the environment.

Announced in a difficult time for consumers and automakers, the 2009 U.S. "Cash for Clunkers" program was much more popular than expected. It offered up to a $4,500 rebate on a fuel-efficient vehicle replacing a gas-guzzler, and consumers rushed to showrooms across the country. Only days into the program, the projected payout exceeded the initial budget of $1 billion; and, despite another $2 billion pledged by U.S. Congress, the program used up all the fund and had to conclude two months ahead of schedule. In the end, the program helped nearly 700,000 consumers exchange vehicles in only 55 days.

The efficacy of the program has been at the center of public interest. In particular, there is concern that consumers may have taken advantage of the subsidies and purchased vehicles they would have purchased anyway. In this case, the program could not claim much environmental credit, as even without the program, the fleet's fuel economy would still have improved. And, if vehicle demand cannot be manipulated by subsidies, policymakers should focus instead on setting more stringent fuel economy standards to make the fleet greener, even though such regulations rarely appeal to automakers and their customers.

Thus, a central question in evaluating the program is whether it lured consumers to purchase greener vehicles than they would otherwise have purchased. There are two possible methods for answering this question: conduct a survey, or analyze actual purchases. As mentioned in the DOT Report to Congress (2009), the agency surveyed consumers when they applied for the rebates, asking what they would have purchased in the absence of the program. Roughly 23% of respondents stated that they would have chosen larger, presumably less efficient, cars or trucks. While this was a response to a hypothetical survey, it seems to indicate that the program succeeded in selling fuel-efficient vehicles to people who had not planned to buy them.

This paper uses the second method, analyzing the actual transactions based on a special feature of the program: consumers had the opportunity to receive either $3,500 or $4,500, depending on how much they "improved" the fuel economy between their trade-in and a new vehicle. The higher rebate was granted only if the improvement reached a certain threshold (e.g., for a new car, running at least 10 more miles per gallon than the trade-in vehicle). As a result, consumers trading in very inefficient vehicles could pick among most new vehicles to collect the rebate of $4,500, while others had to choose from a smaller pool of vehicles or forgo the extra $1,000. Because of this variation in rebates among consumers, the program may be seen as a "natural" experiment (i.e., unintended by Congress), revealing the relationship between subsidies and vehicle selections of consumers.

Analysis results suggest that awarding $1,000 more on a given vehicle made 7.2% of consumers switch to that vehicle. By extrapolating from this relationship, the program—granting roughly an average of $4,200 per vehicle—may have made 25-30% of consumers change their vehicle choice, a range not far from the stated 23% in the DOT survey. Quite consistently, then, both methods suggest that the program prompted a large number of consumers to buy the subsidized, more fuel-efficient vehicles. So, not only did the program stimulate economic activity, but it may have also benefited the environment by reducing emissions and fuel consumption. This finding should encourage policymakers to consider similar proposals, such as a fee-bate program that subsidizes fuel-efficient vehicles with taxes on gas-guzzlers, distorting vehicle prices but without incurring additional budget deficits (see Greene et al. 2005 for more discussion).

Other researchers have found that subsidies can help expand a vehicle's market share, such as Gallagher and Muehlegger (2008) and Beresteanu and Li (2009) regarding hybrid cars. These studies, however, often rely on subsidy variations between cities or states over a few years. During this period vehicle demand could have influenced, and been influenced by, gasoline prices, vehicle supply, and decisions to grant subsidies. As a result, the causality between subsidies and vehicle selections indicated by those studies may not be as established as in this paper, the analysis of which is based on the same "Cash for Clunkers" program in effect for less than two months.

This paper also relates to studies investigating what factors affect vehicles selection at the consumer level (e.g., Berry et al. 2004; Train and Winston 2007). In these studies, vehicle price is often a strong decision driver, and it is no surprise that the program's rebates, directly altering vehicle price, have also swayed consumers' decisions. Nevertheless, this paper differs in its approach to arrive at the conclusion. Thanks to the experimental design of the program (see Meyer 1995; Angrist and Pischke 2009 for literature review on natural experiments), this paper uses graphical comparisons and simple statistical tests, rather than assuming and estimating the consumers' utility function with an exhaustive list of variables—a challenging task in choice modeling as pioneered by McFadden (1972).

This paper is organized as follows. Section 1 puts the program in the context of a natural experiment. Section 2 introduces the data and their descriptive analysis. Section 3 discusses the results from formal statistical tests. Section 4 concludes.

1 "Cash for Clunkers" as a Natural Experiment

Established by the Consumer Assistance to Recycle and Save Act of 2009, the U.S. "Cash for Clunkers" program awarded two distinct cash rebates—$3,500 or $4,500—to a consumer replacing a gas-guzzler with a new, more fuel-efficient vehicle. The actual rebate amount depended strictly on the improvement of fuel economy. For example, a consumer would receive $3,500 for a new car rated 4-9 MPG (miles per gallon) higher than the vehicle traded in, and the rebate would move up to $4,500 for an improvement of 10 MPG or more. As for consumers looking to buy new trucks (most sport utility vehicles included), the program lowered the requirement, awarding $3,500 for an improvement of 2-4 MPG and $4,500 for 5 MPG or more.

Table 1: Cash Rebates for Buying New Passenger Cars (US$)

	New MPG								
	≤21	22	23	24	25	26	27	28	≥29
Trade-in MPG									
≤12	0	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**
13	0	3,500	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**
14	0	3,500	3,500	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**
15	0	3,500	3,500	3,500	**4,500**	**4,500**	**4,500**	**4,500**	**4,500**
16	0	3,500	3,500	3,500	3,500	**4,500**	**4,500**	**4,500**	**4,500**
17	0	3,500	3,500	3,500	3,500	3,500	**4,500**	**4,500**	**4,500**
18	0	3,500	3,500	3,500	3,500	3,500	3,500	**4,500**	**4,500**
≥19	0	0	0	0	0	0	0	0	0

-All MPG ratings are "combined highway/city" ratings published by the U.S. Environmental Protection Agency (EPA).
-Maximum MPG of trade-in vehicles (cars or trucks): 18
-Minimum MPG of new passenger cars: 22

Table 1 shows the rebates for consumers buying new cars. Obviously, customers faced different rebate schedules while choosing from the same stock of cars. From this aspect, the program worked like an experiment. The treatment is the extra \$1,000, applicable to some vehicles for some consumer groups, assembled according to the MPG ratings of their trade-ins. The observable outcome is each consumer group's selections, defined as the percentages of the consumers buying certain vehicles (e.g., 10% of the group purchased 22-MPG cars, 15% purchased 23-MPG cars, etc.). The null hypothesis is that the treatment had no effect on these percentages; that is, as some worry, consumers bought the vehicles they always had in mind, regardless of the rebates.

In this regard, the program had two additional restrictions that strengthened and simplified this natural experiment. First, consumers could not change their rebate schedules by buying used vehicles at the last minute, since trade-in vehicles were accepted only if they had been insured and registered to the same consumers for the year before. Second, the program did not issue credits for future orders, so the consumers had to choose from a limited set of existing vehicles, sign the contracts, and turn in their gas-guzzlers all at the same time.

As in any other experiment, artificial or natural, having a good control group is essential in order to test this hypothesis, as it can shed light on what would happen to the treatment group in the absence the treatment, thereby revealing the treatment effect. Here, one consumer group may be considered a suitable control for another if they both have similar tastes in vehicles. To be more specific, when two consumer groups choose from several vehicle models under the same conditions (e.g., prices, warranties, etc.), each model should attract similar percentages of the consumers in either group.

Following this train of thought, it is convenient to focus on adjacent consumer groups, such as the groups trading in vehicles rated 14 or 15 MPG. They both faced the same rebates, except that the 14-MPG consumer group would collect \$1,000 more for buying 24-MPG cars. So, both groups can be compared in two steps. The first is to study their selections on vehicles with identical rebates; if similar percentages of both groups bought these cars, then one group can control for the other in this experiment. The next step is to analyze the purchases of 24-MPG cars; the difference in their attractiveness to either group may be attributed to the extra \$1,000 only for the 14-MPG consumer group.

Table 2: Descriptive Statistics

Type of Exchange	[1]	[2]	[3]	[4]	[5]	[1]-[5]
From	Cars	C1 Trucks	C1 Trucks	C2 Trucks	C2 Trucks	
To	Cars	Cars	C1 Trucks	Cars	C1 Trucks	
Trade-in MPG	13-18	11-18	11-16	11-18	11-16	
New MPG	22-31	22-31	18-26	22-31	18-26	
No. of Exchanges	77,389	242,855	120,109	43,077	28,512	511,942
% of Sample	15.1	47.4	23.5	8.4	5.6	100.0
% of All Exchanges[a]	11.4	35.9	17.7	6.4	4.2	75.6
Avg. Miles Driven	152,292	160,833	155,971	170,844	165,954	159,529
Avg. Trade-in MPG[b]	17.5	15.8	14.8	14.2	13.9	15.5
Avg. New MPG[b]	27.4	27.7	20.9	27.0	20.5	25.2
Avg. New MSRP	$19,989	$19,325	$26,178	$19,537	$25,326	$21,385
Avg. Rebate	$4,010	$4,233	$4,266	$4,364	$4,345	$4,224

[a]The entire database has 677,081 exchanges.
[b]harmonic means

2 Data and Graphs

Thanks to the DOT, details are readily accessible for all vehicle exchanges under the program. In this paper, these exchanges are clustered by three criteria: type of exchange, trade-in MPG rating, and new MPG rating. For example, the most common type of exchange, more than a third of all exchanges, is migrating from Category-1 trucks, including most sport utility vehicles, to passenger cars. Most exchanges of this type (over 90%) are from eight trade-in ratings (11-18 MPG) to ten new ratings (22-31 MPG). In other words, there are eight major consumer groups, one group for each trade-in rating; each consumer group, facing the same rebates under the program, chose from ten major classes of new cars, one class for each new rating.

Aside from the exchanges from Category-1 trucks to cars, the final sample in this paper includes four other types of exchange: within cars; within Category-1 trucks; Category-2 trucks to cars; and Category-2 trucks to Category-1 trucks. The sample excludes those exchanges involving Category-3 trucks, because most of them were unrated for their fuel economy and hence subject to different rebate rules. It also leaves out some smaller consumer groups and vehicle classes. After these exclusions, the sample has 34 consumer groups choosing from 10 classes of cars and 9 classes of Category-1 trucks, representing 75.6% of all the exchanges under the program (see Table 2 for other descriptive statistics).

Under each type of exchange, one consumer group's selections are defined as the shares of its purchased vehicles. For example, moving from Category-1 trucks to cars, 5.1% of the 14-MPG consumer group bought 22-MPG cars, 3.1% bought 23-MPG cars, and so on. Once expressed this way, these selections can be plotted and compared between adjacent consumer groups.

Figure 1[a] begins with the groups trading in 14- and 15-MPG Category-1 trucks for cars. As outlined earlier, the first step is to compare both groups as they received the same rebates (i.e., \$3,500 for cars rated 22-23 MPG and \$4,500 for cars rated 25-31 MPG). These group differences, highlighted in shades, are small. This suggests that both groups, making similar selections under the same conditions, should have similar tastes in vehicles, making them good control groups for each other. Next, the focus is on the remaining 24-MPG cars. The 14-MPG consumer group received \$1,000 more for these cars, and clearly a much larger percentage of the consumers bought them.

The same comparison expands to the other three pairs of consumer groups (see Figures 1[b], 1[c], and 1[d]). Repeatedly, adjacent groups showed little differences in their preferences for the cars tagged with identical rebates. But, when one group would receive higher rebates on certain cars, it favored these cars much more than the other group did. The extra rebates seem to have sparked interest in the cars they sponsored, effectively changing the selections of the consumers.

To further investigate the connection between rebates and vehicle selections, all the consumer groups in the sample are compared. While it is possible to replicate the earlier graphs many times, these comparisons can also go into one place as in Figure 2, a density plot with two cumulative distributions. The first distribution, formed by dots, represents all the differences in selections with the same rebates. For example, the earlier Figure 1[a] supplies nine such differences, calculated as follows: –0.04% for 22-MPG cars (5.12% of the 14-MPG consumer group buying these cars minus 5.16% of the 15-MPG group doing so); 0.13% for 23-MPG cars (3.13% of the former group minus 3.00% of the latter); and seven more differences for cars rated 25-31 MPG. The second distribution, formed by squares, represents the differences with one consumer group receiving \$1,000 more, and

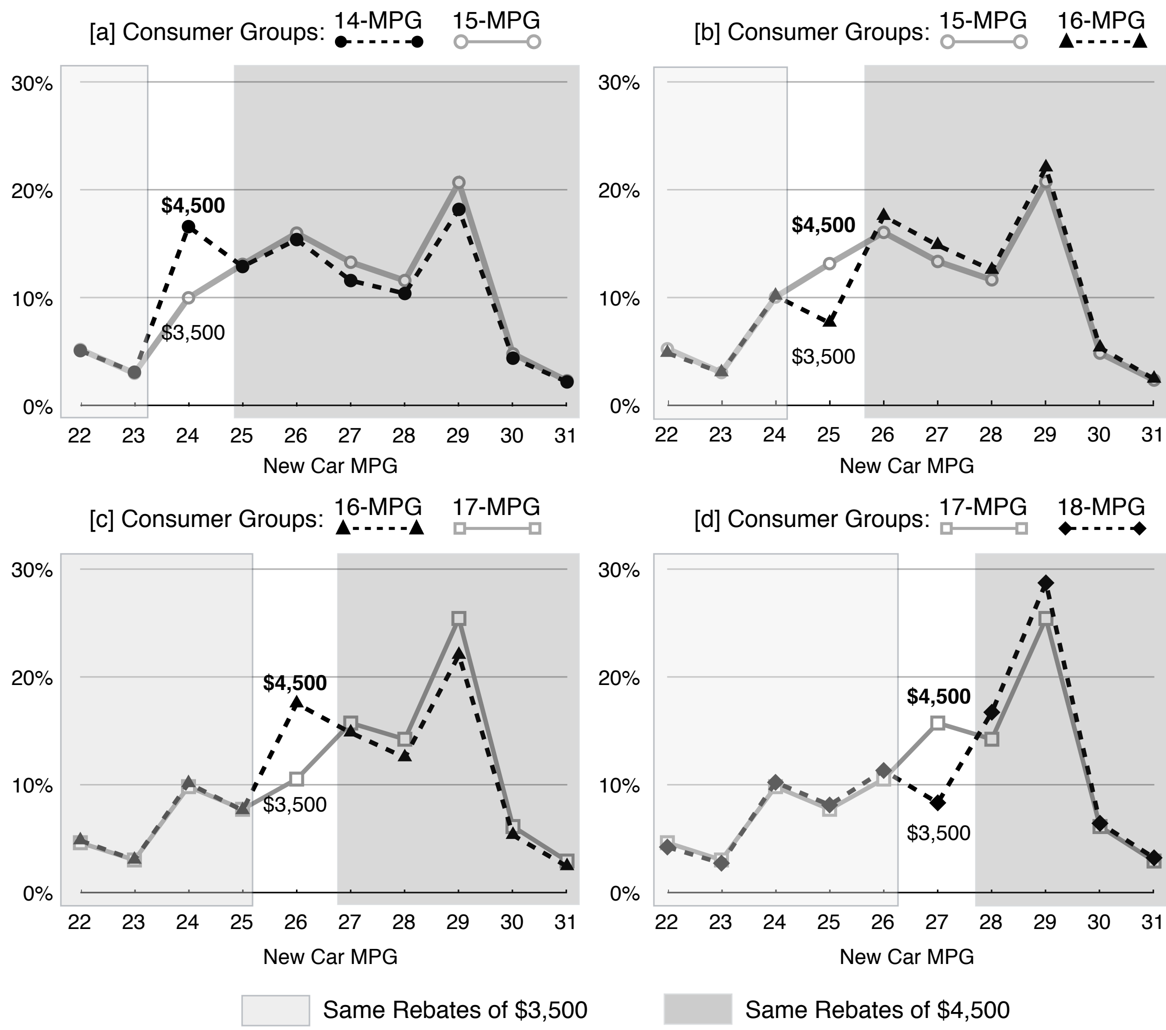

Figure 1: Vehicle Selections of Adjacent Consumer Groups

there is one such difference from Figure 1[a], which is 6.64% for 24-MPG cars (16.65% of the 14-MPG consumer group minus 10.01% of the 15-MPG group).

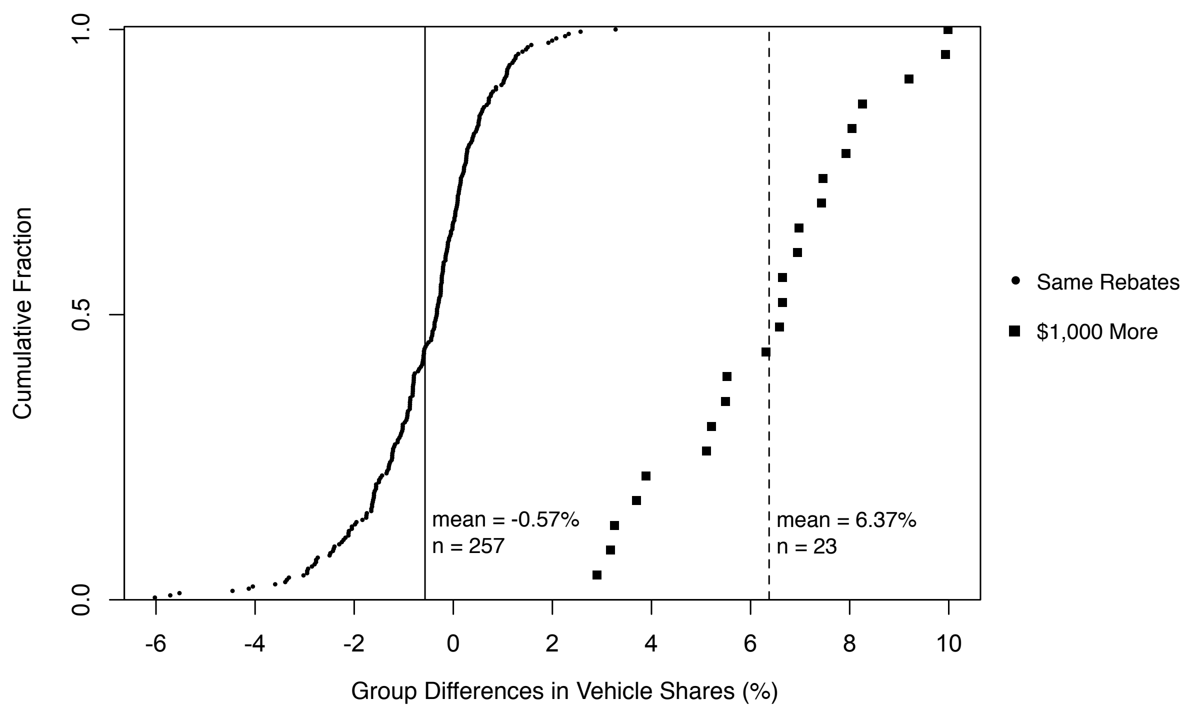

Figure 2: Empirical Cumulative Density Plot

As Figure 2 shows, the dots (group differences with identical rebates) cluster around 0%, with a mean of –0.57%, and they are trapped in a narrow band: the 10th percentile is –2.23% and the 90th is 0.91%. In the comparisons covering the entire sample, adjacent consumer groups, when offered the same rebates, still appeared to have similar tastes in vehicles. On the other hand, when the subsidies increased by $1,000 for one group, the group differences are pronounced, as almost all of the representative squares are located at the far right of the other distribution. That is, consumers seem to have strongly preferred vehicles with higher rebates.

So with the entire sample, the positive relationship between rebates and vehicle preferences is consistent, but could it be a coincidence? When Congress initiated the program, it set only two thresholds for higher rebates: fuel economy had to improve by at least 5 MPG for new trucks, or 10 MPG for new cars. As a result, the extra $1,000 fell on different vehicles for any two adjacent

Table 3: Regression Models

Model	[1]	[2]	[3]	[4]
\$1,000 Dummy (x_1)	.0694	.0735	.0740	.0721
	(.0031)	(.0024)	(.0025)	(.0024)
Specification:				
Consumer Group Dummies			Y	Y
New Vehicle Class Dummies				Y
Estimation:	OLS	WLS	WLS	WLS
R^2	.65	.77	.77	.84
F	509	943	30	27

-y: differences in vehicle shares
-Standard errors are in parentheses.
-Observations: 280 ($x_1 = 1$: 23; $x_1 = 0$: 257)
-WLS Weight: Number of vehicle exchanges for adjacent groups

groups. It seems unlikely that this simple rule would by chance match the selections of consumers so precisely, and a more plausible explanation is that the rebates *caused* some consumers to ignore their original vehicles of choice and purchase those vehicles more generously subsidized.

3 Models and Estimates

To estimate the effect of an extra \$1,000 on vehicle selections, several regression models are used, and the basic model takes the following form:

$$y_i = \beta_0 + \beta_1 x_{1i} + \varepsilon_i. \quad (1)$$

The response variable (y) is the difference of vehicle shares between adjacent consumer groups. The predictor variable of interest (x_1) is a dummy variable, taking the value of 1 if y is subject to the extra rebate and 0 otherwise. Based on ordinary least squares (OLS), the results are summarized under Model [1] in Table 3. .

Having only one predictor variable, this model explains the variations in y quite well, with an R-squared value of 0.65, and the coefficient of x_1 is highly significant at 6.94% with a standard error of merely 0.31% (p-value<0.001%). In other words, roughly 7% of consumers switched to the vehicles subsidized with an additional $1,000.

Model [2] has the same structure as Model [1], but is estimated by weighted least squares (WLS), the weight being the number of vehicle exchanges made by adjacent consumer groups. This procedure takes into account that larger consumer groups should produce more accurate statistics on their vehicle selections. The results, however, are not very different. Although the coefficient of x_1 swells to 7.35%, the increase is not much more than the standard error. The effect of the rebates seems to be stable on consumer groups of various sizes.

To control for predictor variables other than the rebates, Model [3] adds a dummy variable for every consumer group, and Model [4] introduces yet another dummy variable for every vehicle class from which consumers chose. As before, both models yield similar results: the coefficients of the $1,000 dummy range from 7.2% to 7.4% (Models [2],[3],[4]) with the standard errors almost identical. In fact, the robustness of the estimates is expected: given that the rebates were imposed without regard to other factors that could affect vehicle selections, the effect of the rebates should not be sensitive to whether a model includes or excludes these other factors.

In all four models, the differences of vehicle shares between groups (the y's) are assumed to be independent; however, they are actually dependent, because shares of vehicles chosen by any consumer group must add up to 100%. As consumers flocked to vehicles with higher rebates, the shares of these vehicles would increase, but the shares of the other vehicles would also fall (for example, up 8% for 15-MPG cars, but down 2% for 16-MPG cars, 2% for 17-MPG cars, and so on). Compared to a control group, these changes in selections would result in a positive y with $x_1 = 1$, and several negative y's with $x_1 = 0$. In a regression, then, the coefficient of x_1 may be exaggerated, making the effect of the rebates bias upward. Fortunately, this should be a minor bias since only a small portion (8.2%) of the observations come with $x_1 = 1$, and it is unlikely that they are able to suppress the remaining observations to any meaningful degree.

In summary, all the models confirm that awarding an additional $1,000 clearly had an effect on consumers, drawing roughly 7.2% of them to those subsidized vehicles, even though $1,000 was only 4.7% of the average vehicle price of $21,385 (or 5.6% after the initial $3,500 for all the consumers in the program). This point estimate may be extrapolated to shed light on the overall effect of the program, which on average gave away \$4,224 per vehicle (19.8% of the price). For example, if consumers responded to percentage drops in price, the program could have convinced roughly 25% of them to buy more fuel-efficient vehicles ($19.8\%/5.6\% \times 7.2\%$). On the other hand, if they responded to each rebate dollar the same way, the estimate grows to 30% ($\$4,224/\$1,000 \times 7.2\%$). These two estimates are not far off what the DOT found in its survey, in which 23% of the consumers stated that because of the rebates they gave up plans to buy larger vehicles.

4 Conclusion

This paper views the 2009 U.S. “Cash for Clunkers” program as a natural experiment in evaluating the relationship between public subsidies and vehicle choice of consumers. Based on actual purchase data, this paper shows that not only did the program create a surge in vehicle sales at a difficult time for the economy, but it may have also induced a substantial number of consumers to purchase more fuel-efficient vehicles they otherwise would not have purchased, resulting in reductions in fuel consumption and emissions. This finding suggests that public subsidies may be used to advance environmental goals in addition to stimulating the economy. Public subsidies, however, are costly, and future research and policy should focus on how to fund this kind of program. One option, as many have pointed out, is to tax sales of gas-guzzlers and use the revenues to subsidize green vehicles, thereby alleviating the burden on the general budget. In fact, this option could magnify the price difference between both types of vehicles and provide an even stronger incentive for consumers to choose green vehicles.

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