Accelerator or Brake? Microeconomic estimates of the 'Cash for Clunkers' and Aggregate Demand*

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December 2014

Abstract This paper uses vehicle-level data and differences-in-differences methods to measure the impact of the Federal Government's Car Allowance Rebate System (CARS) on partial-equilibrium aggregate demand for automobiles. We use confidential data at the BLS on the make, model and model year of cars owned by households in the Consumer Expenditure Survey. We identify the effect of CARS by comparing the transactions of households with automobiles that are eligible for CARS based on model year and miles-per-gallon, to the transactions of households with automobiles that are just ineligible for CARS based on these criteria. A partial-equilibrium calculation implies that this program raised aggregate purchases over a couple of months by 540,000 automobiles, generating roughly $12 billion in additional demand for $2.9 billion in Federal outlays and coinciding with the end of the Great Recession. However, consistent with theory and previous research, this large effect was due to short-term intertemporal substitution in response to the temporary price subsidy: point estimates suggest that cumulative, partial-equilibrium auto sales were unaffected by the program 7 months after its initiation.

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The Federal Government program the Car Allowance Rebate System (CARS), colloquially known as 'Cash for Clunkers,' provided $3,500 to $4,500 payments to consumers who traded in old, fuel-inefficient cars to purchase new, more-efficient cars during July and August of 2009. The program had larger than expected participation, with nearly 680,000 trade-ins and $2.85 billion in payments by the government. While CARS was in part motivated by its effects on safety, fuel-efficiency, and inequality, the primary goal of the program was to stimulate aggregate demand in the United States to fight the recession that had started in December of 2007 and accelerated precipitously in September of 2008.[1] Nominal interest rates on safe short-term loans were at zero so that traditional monetary policy had seemingly reached its limits. And economic theory suggests that fiscal policy that generates increased demand can have large benefits under these circumstances (e.g. Eggertson and Woodford 2003, Christiano, Lawrence, Eichenbaum and Rebelo, 2011; Werning 2011).

This paper estimates the impact of the CARS program on vehicle purchases by using vehicle-level data from the Consumer Expenditure (CE) Interview Survey and exploiting sharp differences in program eligibility among otherwise similar vehicles. We address three questions concerning the effects of the CARS program. First, by how much did vehicle purchases respond to the program, both initially and over time? Second, how responsive were purchases to the size of the program subsidy? Third, by how much did CARS stimulate aggregate (partial-equilibrium) demand for vehicles, both initially and over time?

Methodologically, we use a differences-in-differences approach that exploits variation in program eligibility depending on the fuel economy of the trade-in vehicle. Eligibility for CARS varied discretely around a cut-off of 18 miles per gallon (MPG) – vehicles rated at 18 MPG or lower qualified, while vehicles with efficiency of 19 MPG or higher were excluded. Within the CE data, we observe each household's inventory of vehicles and estimate program eligibility based on the make, model and model year of the vehicle. Although vehicle model is not released in the public micro-data files, we followed BLS protocols and obtained access to the internal confidential data. For each make, model, and model year of vehicle in the CE data, we estimate the appropriate measure of the fuel efficiency using a dataset from the U.S. Department of Energy. We estimate the true economic subsidy of the CARS program – the payment less the

[1] See Blinder (2008).

market value of the vehicle, using data on trade-in values from Edmunds. We form two subgroups of all vehicles held by households in the CE survey: a treatment group of vehicles eligible for the CARS program, and a comparison group of vehicles that are ineligible but close to eligible. We then track over time the new purchases associated with the trade-in or sale of these vehicles using the CE's month-by-month information on disposals and purchases.

We estimate the program's impact on new vehicle purchases by comparing the rate of purchases associated with less efficient, CARS-eligible vehicles to the rate of purchases associated with somewhat more efficient, CARS-ineligible vehicles. The key identifying assumption in our analysis is that trade-in activity of vehicles above and below the eligibility cut-off would have been similar in the absence of the program. In order to focus on vehicles that are similar except in their eligibility for CARS, we incorporate two sample restrictions: we exclude vehicles with estimated trade-in value above $5,000, for which the CARS rebate provided no benefit, and we exclude vehicles with fuel-efficiency rating below 12 MPG or above 25 MPG.[2] We refine our approach further by controlling for vehicle age and value in our analysis, so that we can separate time-varying differences in the propensity to trade-in vehicles that are related to vehicle age and value from the effect of the CARS program.

We find that, during the CARS program, vehicles eligible for the program were roughly one percent more likely to be traded-in for new vehicles relative to 'similar' vehicles that were ineligible. This change represents a substantial increase in purchases – roughly a tripling in the rate of purchases in the CARS-eligible group compared to the CARS-ineligible comparison group. This result is statistically significant, but limited in precision due to the relatively small sample of vehicle purchases in the CE. This result is also reasonably robust to control variables included in our specification, and to whether the analysis is conducted at the vehicle or household level.

We find further that the program's impact on vehicle purchases reversed quite rapidly. By February 2010, 7 months after the initiation of the program, the cumulative difference in purchases between our treatment group of CARS-eligible vehicles and our comparison group of CARS-ineligible vehicles is zero. Thus, consistent with basic economic theory, previous studies

[2] This approach contrasts with the methodology of Mian and Sufi (2012) which compares responses across U.S. state-level aggregates. Our methodology is more similar to that of Hoekstra, Puller, and West (2014) using registry data in the single state of Texas, although they focus only on barely CARS-eligible vehicles for which new purchases are constrained, as we discuss in Section I.

of the CARS program, and similar corporate investment tax credits, the timing of durables purchases is highly sensitive to temporary price subsidy.[3]

How responsive were households to the size of the subsidy provided by CARS? Because the CARS program required scrapping the old vehicle, the true economic value of the subsidy was not the face value of the credit, but that amount less the trade-in value of the old vehicle in the absence of the program. While the effect of vehicle trade-in value does not have a conventionally statistically significant effect on the probability of purchasing a new vehicle, the point estimates are consistently negative. During the period of the program, a hypothetical CARS-eligible vehicle with zero trade-in value was twice as likely to be used to purchase a new vehicle as the average vehicle. A vehicle of a make, model and model year that had an average trade-in value of $4,500 (the CARS payment amount) was half as likely to be used to purchase a new vehicle as the average vehicle.[4] Over time, the estimated effect for a hypothetical car with no trade-in value declines by half by February 2009, and for a vehicle an average trade-in value of $4,500 the cumulative effect of CARS rapidly becomes zero (and then statistically weak and unstable).

Finally, turning to aggregate effects, we estimate that CARS caused roughly 540,000 new purchases, relative to 680,000 vehicles traded in under the program. Accounting for an average purchase price of just over $22,000 per vehicle, we estimate that the program induced $12 billion of durables purchases in the third quarter of 2009 at a fiscal cost of $2.85 billion. Half of the spending was on domestically produced vehicles, so that the CARS program caused a large increase in consumption demand with minimal government outlays and coinciding with the end of the Great Recession. However, these additional purchases were drawn from purchases that would have occurred anyway over the subsequent seven months. The concluding section of the paper discusses the implications of these findings for the stabilization policy.

Our estimates indicate a larger initial impact than most previous research on CARS but confirm the near complete reversal in demand over the following months. Obviously, some of the 680,000 recorded CARS-related purchases of CARS trade-ins would have occurred around the same time in the absence of the program. The Council of Economic Advisers (2009)

[3] See House and Shapiro (2008).
[4] Presumably the actual vehicles with this make, model, and model year that were traded-in under CARS were those with the highest mileage and in the worst shape with actual values below $4500.

estimates that CARS caused 440,000 additional purchases.[5] Based on a survey of households that participated in CARS, National Highway Traffic Safety Administration (2009b) estimates that CARS caused an additional 600,000 purchases. Li, Linn and Spiller (2012) consider the experience of Canada as a counterfactual to the United States and estimate a (different, general equilibrium) effect of the program as causing 370,000 new purchases and little evidence for any cumulative difference past the end of 2009.

Mian and Sufi (2012) study differences in vehicle purchases across metropolitan areas with different ex ante ratios of CARS-eligible vehicles to 2004 automobile purchases, and estimate that CARS caused only 370,000 new car sales during July and August. The paper also documents the near-complete reversal in purchases over the 10 months following the program. While Mian and Sufi (2012) rules out many biases, it is possible that areas with different levels of CARS-eligible vehicles evolve differently in 2009 in ways related to exposure to CARS but not caused by the CARS program.[6] The advantages of our study are two-fold: our use of micro data allows us to identify the effect using a narrowly defined, similar comparison group, and the detail in the CE allows more accurate assignment of vehicle eligibility.[7] The main disadvantage is that we observe a relatively small sample of households with few purchases rather than aggregated data on all households.

Finally, Hoekstra, Puller and West (2014) apply a regression-discontinuity methodology that is similar, but not identical, to our approach. They use a large sample of department of motor vehicle registrations in Texas, a state which had both fewer share of clunkers and clunker purchases than the typical state (Mian and Sufi 2012). They identify the effect of CARS by comparing purchases by households with just-eligible vehicles (18 MPG) to purchases by households with just-ineligible vehicles (19 MPG). They also find a large initial program impact and a complete reversal in purchases over the 6-9 months following the program, and they argue further that CARS reduced cumulative vehicle spending (over 6 – 9 months) by about $3 billion

[5] This method attributes to CARS any deviation of actual sales from a counterfactual based on the prevalence of CARS-eligible vehicles and an assumed replacement rate. At the time of the program, however, the economy was just emerging from the Great Recession, so coincident changes to incomes, wealth and uncertainty could also be responsible for deviations from the estimated path of sales.

[6] Mian and Sufi (2012) shows that the paper's estimates are robust to several linear controls for characteristics of cities, and that placebo tests run in different periods as if CARS were in effect in that period do not lead to as large estimated effects between 2004 and 2008.

[7] We also construct counterfactual aggregate demand based on the assumption that close-to-clunker ineligible vehicles were not affected by the program instead of that the state with the fewest (normalized) clunkers was unaffected.

by pushing consumers to purchase more fuel-efficient, but smaller and less expensive vehicles.[8] Though our study relies on the same primary source of variation at the program-eligibility cut off of 18 MPG, we choose not to narrow the treatment group as tightly as in a regression discontinuity approach. The reason for this choice is that owners of barely-eligible vehicles faced the most restrictive choice set upon participating in CARS. While they could purchase a new vehicle with fuel economy of at least 22 MPG and receive a $3,500 payment, they had to purchase vehicles with fuel economy of 28 MPG or higher to qualify for the full rebate of $4,500. Accordingly, the behavior of people with vehicles at the 18 MPG cutoff may not be representative of potential participants that own less-efficient vehicles, for whom the new vehicle choice set was much broader and included substantially larger, higher priced vehicles.

Our paper is organized as follows. The next section described the CARS program. Section II presents our three data sources and describes how we combine the information. Section III discussed our methodology and Section IV presents our main results at the household level. Section V discusses the partial-equilibrium implications for aggregate sales and Section VI concludes.

I. The CARS program

After being introduced into Congress in January 2009, the Consumer Assistance to Recycle and Save Program was signed into law on June 24, 2009 as part of the Supplemental Appropriations Act of 2009.[9] The program was titled the Car Allowance Rebate System (CARS) and provided a $3,500 or $4,500 credit for trading in an old, fuel-inefficient vehicle and purchasing or leasing a new, more fuel-efficient vehicle. After some initial delays in implementation, the final rule implementing the program was released in late July and dealers began submitting transactions for approval on July 27, 2009. The program's initial funding allotment of one billion dollars was quickly exhausted due to consumers' much larger than expected response.[10] Congress appropriated an additional two billion dollars in early August, but

[8] Busse, Knittel, Silva-Risso, and Zettelmeyer (2012) estimate that the subsidies went entirely to consumers rather than dealers or producers, so that the difference in consumer purchase prices completely reflects real (not price) differences in vehicles.

[9] This section draws from Council of Economic Advisers (2009), Department of Transportation (2009), and Gayer and Parker (2013).

[10] Initially estimates of program take-up were a flow of approximately 3,000 CARS-eligible trade-ins per day. The actual flow was initially in excess of 20,000 per day. See National Highway transportation Safety Administration (2009a, 2009b).

even with this additional funding CARS depleted its funds and ended on August 24th, more than two months ahead of the November 1, 2009 termination date written into the law. All told, the program provided $2.85 billion of credits on nearly 680,000 transactions.

In order to qualify for the CARS credit, a household had to trade in a qualifying vehicle – passenger automobile or a category 1, 2, or 3 truck – and purchase a new vehicle with sufficient improvement in fuel economy over the trade-in. The trade-in had to be less than 25 years old (model year 1984 or later) and have a combined (city and highway) fuel economy of 18 miles per gallon or less. The old vehicle also had to be in drivable condition and both registered and insured continuously for the year prior to the trade-in. These provisions excluded vehicles that were already scrapped and prevented re-shuffling of cars to households that simply wanted to buy a new car. We refer to cars that are eligible to be used as trade-ins in the CARS program as 'clunkers.'

Conditional on trading in an eligible vehicle, in order to qualify for the CARS credit the new vehicle also had to meet certain fuel economy thresholds. New passenger automobiles had to have a combined fuel economy of 22 MPG or higher and at least 4 MPG greater than the trade-in vehicle. New category 1 trucks were required to have fuel economy of at least 18 MPG and at least 2 MPG greater than the clunker. New category 2 trucks were required to get at least 15 MPG and 1 MPG more than the associated clunker. Finally, category 3 trucks had no minimum MPG but faced other requirements. Across all vehicle types, the new vehicle's suggested retail price had to be $45,000 or less in order to qualify.

By defining program eligibility based on the relative increase in fuel economy between the clunker and new vehicle, these rules had the effect of changing the new vehicle choice set depending on CARS participants

The value of the credit received by the household towards the purchase depended on both the clunker and the new vehicle, with different rules for passenger vehicles and trucks. For eligible traded-in passenger cars, the credit was $3,500 if the new vehicle had a combined fuel economy between 4 and 10 MPG higher than the clunker. The credit was $4,500 if the new vehicle had a combined fuel economy more than 10 MPG greater than the clunker. If the difference in fuel efficiency was less than 4 MPG, then there was no credit. Category 1 (2) light trucks required a 2 (1) MPG improvement to be eligible for the $3,500 credit and a 5 (2) MPG

improvement to be eligible for the $4,500 credit.[11]

To serve the secondary goal of fuel efficiency, the cars that were traded in were scrapped by having the engine and drive train destroyed.

For our purposes the critical features of the law are the restrictions on MPG and model year that determine the CARS eligibility of an existing used car. These cutoffs give sharp variation that we use to identify the effect of the program through differences-in-differences analysis. Specifically, we compare the behavior of households with old cars that have combined MPG below the threshold and that are therefore eligible for the credit to that of households that have MPG in a small range above the cutoff and are therefore ineligible. We also exploit variation in the true size of the CARS subsidy, which is the CARS credit less the market value of the used car if not traded in and scrapped. That is, we estimate the behavioral response to treatment intensity conditional on eligibility by measuring how the response differed with the net economic value of the CARS subsidy.

II. Data

We use three sources of data. We employ the Bureau of Labor Statistics' (BLS) Consumer Expenditure (CE) Survey for information on car purchases and trade-ins for a nationally representative sample of households. We use measures of fuel efficiency for each vehicle from the Environmental Protection Agency (EPA). Finally, we use data from Edmunds on the trade-in value of used cars.

Our main data come from the CE Interview Survey. The CE survey collects information on the make, model and model year of each vehicle that a household owns when they enter the survey. As the household is re-interviewed every three months, the stock of vehicles is updated as vehicles are leased, bought, or sold during the year that the household spends in the CE interview survey. The CE records year and month of each transaction with a three-month retrospective recall window (or more if a household skips an interview).[12] The data also contain information on whether a new vehicle is leased or financed, the trade-in allowance if one vehicle was traded in for another, the purchase price and the cash down payment.

[11] In addition, dealers were supposed to credit households for the scrap value of the car, less a $50 administrative fee, but there was widespread noncompliance. See Gayer and Parker (2013).

[12] Given this recall window, there may be some mis-reporting the exact timing of new purchases. As noted, we determine clunker status as of June 2009 when the program began in late July.

Due to issues of respondent confidentiality, the BLS suppresses vehicle model in the public-use micro data files. Following BLS protocols, we obtained access to confidential internal records that include the vehicle model as well as the make and model year, and our analysis was performed with access to this confidential data. Note that some models had spelling inconsistencies in the make-model name, which were corrected for the purpose of matching the fuel economy and average trade-in value data.

The main dependent variable in our analysis is a measure of vehicle purchases. The CE Survey tracks both additions and dispositions of vehicles. For additions, we observe whether the household purchased or leased a car, whether the vehicle was new or used and the month of the transaction. For dispositions, we observe the month of the transaction and whether the household disposed of a vehicle through trade-in, sale or scrap. While the CEX does not link vehicle disposals to new vehicle purchases – that is, we do not know for certain whether vehicle A was traded-in on the purchase of vehicle B – we do know the month for the purchase and the disposition. We assume that a disposition is associated with a purchase or lease if it occurs in the same month as the purchase or lease. We code the indicator variable $Transaction_{i,t}$ to be one if the household disposes of vehicle *i* in month *t* and purchases or leases a new car in the same month. We then cumulate these purchases from the month in which we classify vehicles as clunkers to construct a measure of cumulative purchases or leases:

$$Transactions_{i,T} = \sum_{t = June\ 2009}^{month\ T} Transaction_{it}. \qquad (1)$$

Figure 1 provides validation that the CE data measure meaningful responses to the CARS program and that consumers are fairly accurate in timing their CARS-related purchases. Panel A of Figure 1 shows the share of new vehicle purchases that are associated with vehicle trade-ins for which the trade-in value reported in the CE is $3,500 or $4,500, the CARS credit amounts. In most months outside of the program period, very few respondents – roughly 5% – report trade-ins of such amounts. During the CARS program the share increases significantly to 22% in July 2009 and 39% in August 2009, the peak month of the program. In contrast, Panel B of Figure 1 shows that the corresponding shares for purchases of used vehicles are low and show no increase around the time of the CARS program. Notably, the share of $3,500 and $4,500 trade-ins for new purchases remains elevated at 23% in September 2009 after the end of the program. This pattern of delayed program response may reflect the timing of vehicle delivery. An estimated 50,000 CARS transactions entailed September delivery despite being conducted before the program's

August 24th end date (Krebs, 2009).[13] For many consumers, it appears the delivery date is the salient transaction date. Another possibility is that the delayed response results from recall error, as households interviewed in the fall of 2009 recall their purchase as occurring in early September as opposed to late August. Such recall error does not appear to be too severe, however, since the proportion of $3,500 and $4,500 trade-ins returns to its normal low level by October 2009.

Our measures of fuel economy are chosen to match those used by the CARS program. Specifically, we use the combined fuel economy for cars defined by make, model, model-year and model options such as transmission and drive train from the Office of Transportation and Air Quality at the EPA in the U.S. Department of Energy. While the EPA's webpage www.fueleconomy.gov has available for download the MPG ratings on all makes, models and drivetrain variations by model year, these rating are based on the original fuel efficiency ratings when the car was sold. The CARS program instead used a new rating system, created in 2008, for all cars. We obtained a flat file of new ratings for model years before 2008 from the EPA directly from the Office of Transportation and Air Quality. We parse and standardize make and model names to match the CE make and model variable definitions.

While the information on each car in the CE includes make, model and model year, it does not include features or options available for some models that impact MPG rating and thus CARS eligibility, such as whether a vehicle has two wheel or four wheel drive, its engine size, and whether the vehicle has manual or automatic transmission. For models with these options, such differences can cause significant differences in fuel economy and potentially lead to mis-assignment of CARS eligibility. To avoid mis-assignment as much as possible, we drop vehicles whose eligibility is quite uncertain as described in our construction of clunker status in the next section.

Finally, to account for variation in the implicit subsidy available to owners, we use measures of each vehicle's trade-in value. Edmunds.com provided us with a flat file of trade-in value estimates calculated from dealer-provided transaction data. The file contains monthly estimated used car values for each make, model, and model year for each month from January,

[13] Along with the additional $2 billion of funding, the August XX, 2009 adjustment to the CARS program allowed for purchases or leases of cars in transit or through special order, so that many CARS purchases involved delivery in September after the end of the program.

2006 through August, 2009. The file provides estimates of a minimum, maximum and average trade-in value, assuming average condition of the vehicle and collapsing across various engines, drivetrains and trim packages for each make, model and model year.

For the main analysis, we select CE households that include data for June 2009, so records run from June 2009 through May 2010. We construct panel data that follows existing owned cars over months, and also experiment with a structure that instead tracks households across months.

We merge the information on fuel efficiency and trade-in value for each vehicle and define clunker status based on June 2009 data.[14] For some records, the CE reports a vehicle that is not in the fuel efficiency file, which means that a particular make, model, and model-year is reported but does not exist. For example, a household might report having a 2005 Jeep Cherokee, though Jeep Cherokee was only made through 2004. For such instances, we use the MPG of the model year one year after or one year before the reported model year if it exists. If a matching make, model, model-year does not exist within one year, we exclude the reported vehicle from analysis since we cannot reliably estimate the vehicle's eligibility for CARS.

III. Methodology

To measure the impact of the CARS program on vehicle transactions, we construct a counterfactual pattern of transactions using cars that were close to being clunkers but not eligible for the CARS subsidy. Our analysis uses a differences-in-differences approach: we compare the rate of trade-in for program-eligible vehicles versus similar vehicles that were not quite program eligible. By measuring program eligibility at the vehicle level we narrow the treatment and comparison groups to similar groups of vehicles, for which the identifying assumption of parallel trend in trade-in is quite plausible. We also account for time-varying macroeconomic conditions by controlling for time fixed effects. Below we define the key variables used in our analysis and then introduce the regression model.

For our analysis, we first restrict attention to a sample of vehicles that are 'similar' and that includes both clunkers, eligible for the CARS program, and close to clunkers, that are similar but ineligible. This restriction is based on model year, trade-in value, and fuel efficiency.

[14] We are unable to observe cars with a household for the full year prior to the CARS program and then have any data following the CARS program. As a result, we will mis-categorize some cars as clunkers when in fact they were ineligible due to being recently purchased.

We then split this sample into vehicles that are clunkers and those that are close to clunkers based on fuel efficiency. This assignment leaves some vehicles unassigned due to imperfect knowledge of fuel efficiency and these vehicles are excluded from our analysis.

Model year. We restrict our attention to cars that are model year 1985 or later, and so are possibly eligible for the CARS program.

Trade-in value. Because vehicles traded in under the CARS program were scrapped, the CARS program provided a fixed rebate in place of a private trade-in value (as opposed to a fixed subsidy that could be received in addition to any private trade-in value). The true economic subsidy therefore varied with the vehicle's private trade-in value. An owner trading in a vehicle with value of $4,500, for example, received no subsidy from the CARS rebate of $4,500, whereas an owner trading in a vehicle worth $1000 received a $3,500 subsidy from the CARS rebate of $4,500.

We restrict our sample of clunkers and close-to-clunkers to vehicles with make, model and model year that have average trade in values of $5,000 or less. This restriction excludes many old inefficient vehicles that, while eligible, have market values in excess of the CARS subsidy value implying that owners taking advantage of the CARS program would actually lose money. And this restriction excludes close-to-clunkers which, while ineligible, would have higher trade-in values than our sample of clunkers and so could potentially be owned by households that are not comparable to the households in our sample that own clunkers.

As described later, we also use trade-in value to measure heterogeneity in program responses depending on the value of the implicit CARS subsidy.

Fuel efficiency. As described, the internal CE data at the BLS contain only the manufacturer, model, model year, date of purchase and price paid for the each vehicle that each household in the survey owns. Fuel economy, and so eligibility for the CARS program, depends additionally on factors like engine types (e.g., six-cylinder or eight-cylinder) and drivetrains (e.g., automatic, manual, two-wheel drive or four-wheel drive) which are not measured by the CE Survey.

To restrict our attention to similar vehicles, we restrict our sample of clunkers and close-to clunkers to have average fuel efficiency across drive trains and engine types greater than or equal to 12 MPG and less than or equal to 25 MPG.

Ideally, to measure which of our sample of vehicles are CARS-eligible, we would define a vehicle as a clunker if the vehicle's estimated fuel economy were less than equal to 18 MPG. And we would define a vehicle as close-to-clunker if its fuel economy were greater than or equal to 19 MPG. We use an approximation to such a rule that accounts for the different possible levels of fuel efficiency associated with the same make, model, and model-year vehicle.

First we define a vehicle meeting the model year, value, and MPG restrictions as a clunker if the average MPG of all drive train/engine types associated with that make, model, and model year is less than the 18 MPG cutoff to be CARS eligible, and we define a vehicle as close-to-clunker if the average MPG of that make, model, and model year is greater than the 18 MPG cutoff. This rule will denote all vehicles in our sample as clunkers or close-to-clunkers, even those for which there is actually substantial uncertainty over clunker status. Therefore we drop from the analysis two sets of vehicles. First, we drop any vehicle with maximum possible fuel efficiency and minimum possible fuel efficiencies that differ by 1 or 2 MPG and that has average fuel efficiency across drive trains and engine types between 18 and 19 MPG. Second, we drop any vehicles with maximum possible fuel efficiency and minimum possible fuel efficiencies that differ by 3 or more MPG and that has average fuel efficiency across drive trains and engine types between 17.5 and 19.5 MPG.

In our main analysis, we estimate a series of cross-sectional regressions on the sample of clunker vehicles and close-to-clunkers vehicles. For each month July 2009 through February 2010, we estimate the model:

$$Transactions_{i,T} = \alpha_T + \beta_T Clunker_i + \boldsymbol{\sigma_T X_i} + \varepsilon_{iT} \qquad (2)$$

where *Clunker=1-Close-to-clunker* is an indicator variable for a vehicle that is clunker. As noted, transaction is a cumulative measure, indicating whether vehicle *i* was associated with the purchase or lease of a new vehicle between June 2009 and month *T*. The regression coefficient β_T measures the cumulative difference – between June 2009 and month *T* – in the likelihood of disposition for a clunker relative to a close-to-clunker. The vector $\boldsymbol{X}$ includes characteristics of vehicle *i* – fuel efficiency, estimated trade-in value, age – and characteristics of the household that owns vehicle *i* (income). With these controls, we intend to capture preference and budget characteristics of households that may be correlated with ownership of clunkers, and may also affect time-pattern of purchases/leases through 2009-2010.

To account for differential sensitivity to CARS based on the available subsidy, we also

estimate a model that includes an interaction between program eligibility and estimated trade-in value outside of the CARS program:

$$Transactions_{i,T} = \alpha_T + \beta_T Clunker_i + \gamma_T Clunker_i \times Value_i + \boldsymbol{\sigma_T X_i} + \varepsilon_{iT} \quad (3)$$

In this model each β_T coefficient measures the cumulative difference in likelihood of trade-in for a clunker of zero trade-in value. That is, the coefficient measures the program response for the subset of vehicles with the maximum subsidy, equal to the CARS rebate. To estimate the program impact for a vehicle with a higher value of, say $1,500, one can compute ($\beta_T + \gamma_T 1500$).

IV. The household-level effect of the program

We begin by estimating equation (2) on our sample of clunkers and close to clunkers for months from June 2009 to February 2009. Table 1 and Figure 2 display these results.

First, there is a statistically significant and substantial effect of the program primarily during August 2009. The probability of a purchase for a household with a clunker rises by just under one percent relative to a household with a close-to-clunker. This increase is borderline statistically significant.

Second, there is some continued increase in the probability of a purchase during September and October, which is due to one of three factors. First, additional purchases could represent delays in delivery. The CE Survey inventories vehicles that the household owns and some CARS purchases were for vehicles in transit and delivered after the close of the program. Second, the delay could be recall error. The CE Survey interviews households every three months and households are asked to recall in which month they purchased a vehicle. Finally, the increase could be measurement error. The increase is not statistically significant and the August relative purchases could be underestimated and/or the September and October relative purchases overestimated.

The second notable effect is that there is a rapid reversal in the differential cumulative purchases between households with clunkers and those with close to clunkers. By February 2010, we estimate that there is no difference in the cumulative purchase of new cars between those treated with the CARS program and those just ineligible. As noted earlier, this finding of rapid reversal aligns with the findings of Mian and Sufi (2012) and Hoekstra, Puller, and West (2014).

Next we turn to the effect of the intensity of treatment. How responsive were households to different levels of subsidy? Table 2 displays the results of estimating equation (3) which includes an interaction between the indicator variable for clunker eligibility and the economic value of the CARS subsidy which is the actual subsidy less the trade-in value of the vehicle.

Focusing first on the period of the CARS program, the interaction between a vehicle being CARS eligible (*Clunker*) and the trade in value of the vehicle (*Value*) is negative from August onwards, although in no month is it statistically significant. The point estimates imply that a hypothetical CARS-eligible vehicle with zero trade-in value had a 1.74 percent greater percent chance of being traded in during the CARS period than an equivalent CARS-ineligible vehicle. This is roughly double the baseline effect in Table 1, which implied just under a one percent probability.

On the other hand, consider a vehicle with a make, model, and model year that had an average trade-in value of $4,500 – a type vehicle that on average would receive no actual economic subsidy. Our point estimates would imply an increase in the probability of trading in to purchase a new vehicle of 1.74 – 0.29 * (4.500) = 0.43 percentage points, about half the baseline rate. While this positive effect of CARS could be simply due to statistical uncertainty, it is also consistent with the fact that we are using average trade-in value for each make, model, and model year rather than the actual trade-in value of that exact vehicle. There is actually a distribution of true values associated with any make, model, and model year, and those vehicles most likely to be used in the CARS program are the least valuable of vehicles with that make, model and model year because these are the vehicles that receive the largest true economic subsidy. That is, many of the vehicles that are on average worth 4,500 are actually worth less, and so actually receive some subsidy, consistent with our finding of a positive effect of the program for these vehicles.[15]

Over time, the estimated effect for a car with no trade-in value rises to two-and a half percent greater chance of being traded in by October, and then declines to 0.8 by February 2009.

[15] It also possible that some people were not aware of the trade in value of their vehicle so that some vehicles worth more than $4,500 were traded-in in error. In this case, we would expect that dealers would not trade in the vehicle under CARS, but simply pay the customer $4,500 for the vehicle worth more. In our data, since we do not distinguish these cases, such instances would be included in our measure and be a true effect of the CARS program (although potentially an effect that might not survive repeated CARS-type policies). Such a possibility is consistent with the household responses to the employee-pricing-for-everyone sales event of the summer of 2006 which lead to enormous increases in vehicle sales at prices slightly higher than the previous months (Busse, Simester, and Zettelmeyer, 2010).

For vehicles with make, model and model year implying an average value of $4,500, the effect rises to a cumulative 0.83 percent in October and then rapidly turns negative and unstable thereafter.

In sum, while imprecisely measured, our evidence is consistent with a much higher than average effect of CARS on the vehicles for which the subsidy was largest, as well as a more persistent effect for these vehicles. Note also that on average between August and October, the more valuable a vehicle that was not CARS eligible, the less likely it was to be traded in (the negative coefficient on *Value*). This effect reverses after October, so that more valuable vehicles are more likely to be traded in. This reversal could be due to a return to normal, to the economic recovery, or possibly to an equilibrium effect of the CARS program itself.

V. The effect of CARS on the partial-equilibrium aggregate demand for vehicles

In this section we use our micro estimates to draw inferences about the aggregate impact of the CARS program on the number and dollar value of vehicle purchases. There are two steps to this calculation. First, we use estimates from our regression analysis to measure the program impact per CARS-eligible vehicle. Next, we multiply by the number of CARS-eligible vehicles to calculate the aggregate program impact on the number of vehicles purchased. Finally, we multiply this number by the average purchase price of vehicles we observe in the CE Survey purchased under the CARS program.

Our regression estimates measure differences in the rate of purchases for Clunkers and Close-to-Clunkers at various horizons. We take the difference between the Clunker coefficient in August ($\beta_{\text{Aug 2009}}$) and in June ($\beta_{\text{Jun 2009}}$) to measure the cumulative change in the rate of purchases over the program period of July 2009 and August 2009. Our estimate for the incremental impact of the program ($\beta_{\text{Aug 2009}} - \beta_{\text{Jun 2009}}$) is 0.92%. During the same period Close-to-Clunker vehicles had a purchase rate of 0.5%. The rate of purchases for Clunkers therefore nearly tripled from 0.5% to 1.42% during the program period.

Next we estimate the total number of CARS-eligible vehicles in 2009. Drawing on estimates of the proportion of CARS-eligible vehicles from the Klier (2009) and the total number of non-fleet registered vehicles, we estimate that there were 58.6 million CARS-eligible vehicles.

To calculate the number of vehicle purchases at the time of the program caused by the CARS, we multiply the increase in purchases per CARS-eligible vehicle (0.92%) by the total

number of CARS-eligible vehicles (58.6 million). This calculation implies that the CARS program caused an additional 539,000 purchases during July and August 2009.

To calculate the impact on aggregate demand, we need to estimate the average MSRP of new purchases under the CARS program. According to the National Highway Traffic Safety Administration (2009b) report, the average vehicle purchased using the CARS program was $22,450. In the CE data, new vehicle purchases between July and September 2009 with trade-in value of $3,500 or $4,500 have an average purchase price of $22,283. These numbers imply that the CARS program raised demand by $12 billion in incremental purchases (540,000 purchases x $22,283 per purchase). According to the National Highway Traffic Safety Administration (2009b), just under half of the vehicles purchased were produced domestically, and vehicles purchased that were produced domestically were slightly more expensive than those that were imported.

So, in sum, a reasonable estimate of the change in demand (meaning a partial-equilibrium, accounting estimate) is that CARS raised imports by $6 billion and durable goods purchases by $12 billion in July and August 2009, or by $24 billion and $48 billion at annual rates in the third quarter of 2009. To put these numbers in perspective, this amount is half of the increase in real GDP in the third quarter of 2009 that was the end of the recession. Real GDP had been falling by in excess of 200 billion chained dollars per quarter in the two worst quarters of the recession – the last quarter of 2008 and the first quarter of 2009 – and it fell by twenty billion in the second quarter immediately before CARS.

VI. Conclusion and discussion

This paper estimates the effect of CARS using confidential BLS CE survey data on vehicle purchases by comparing purchases associated with vehicles with fuel efficiencies eligible for CARS to purchases associated with vehicles that that are just ineligible for CARS. We have focused not just on barely-eligible vehicles – as would be done in a pure regression discontinuity approach – because barely CARS-eligible vehicles require the purchases new vehicles with unusually high fuel efficiency to qualify for a CARS subsidy. On the other hand, we compare purchasing behavior to ineligible vehicles that are close to the cutoff, thus using a comparison group of cars that are similar to those vehicles that can be used in the CARS program.

CARS had a large, but temporary partial-equilibrium effect on vehicle purchases. During the period of the program, purchases using CARS-eligible vehicles tripled relative to the comparison group, generating roughly $12 billion in additional (partial-equilibrium) demand – roughly half for imported vehicles and half for domestically produced vehicles – from a Federal outlay of only $2.9 billion. However, consistent with theory and previous research, this large effect was due to short-term intertemporal substitution in response to the temporary price subsidy: our point estimates suggest that cumulative (partial-equilibrium) auto sales were unaffected by the program 7 months after its initiation.

Given this evidence, was Federal Government's Car Allowance Rebate System (CARS) successful stabilization policy? This is a not a question that social science can currently answer, but our evidence paints a mixed picture.

On the one hand, CARS directly raised demand for domestically-produced durable goods by $24 billion at an annual rate in the third quarter of 2009, a quarter when GDP grew by only double this amount. Thus an output multiplier of two or larger would make CARS pivotal in ending the Great Recession. While an aggregate output multiplier of 2 is larger than almost all average estimates, demand multipliers can be larger than average either when the economy has more slack resources or when the economy is at the zero lower bound, both of which were the case in the summer of 2009.[16]

On the other hand, the recovery immediately following the recession was sluggish and if the multiplier remained high, the subsequent (general equilibrium) decline in GDP would have been as large as the earlier increase, rendering the policy largely ineffective evaluated over the nine months from the beginning of the program. To believe that CARS was highly effective, one has to believe that the multiplier associated with ending the recession in August 2009, or the benefit of more output at that time, was much larger than the multiplier in the subsequent fall and winter, or the benefit of more output then.

Finally, our evidence and discussion of whether CARS was a useful anti-recessionary policy are also relevant for programs that provide temporary subsidy to the purchase of investment goods for corporations. We find that the CARS program had effects on the household purchase of durable goods that are similar to those that temporary investment tax

[16] See the discussion in Parker (2011).

credits and similar anti-recessionary corporate tax policies have on the corporate purchase of investment goods.

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Figure 1a: Proprortion of Trade-ins with Value of $3,500 or $4,500 on New Vehicle Purchases

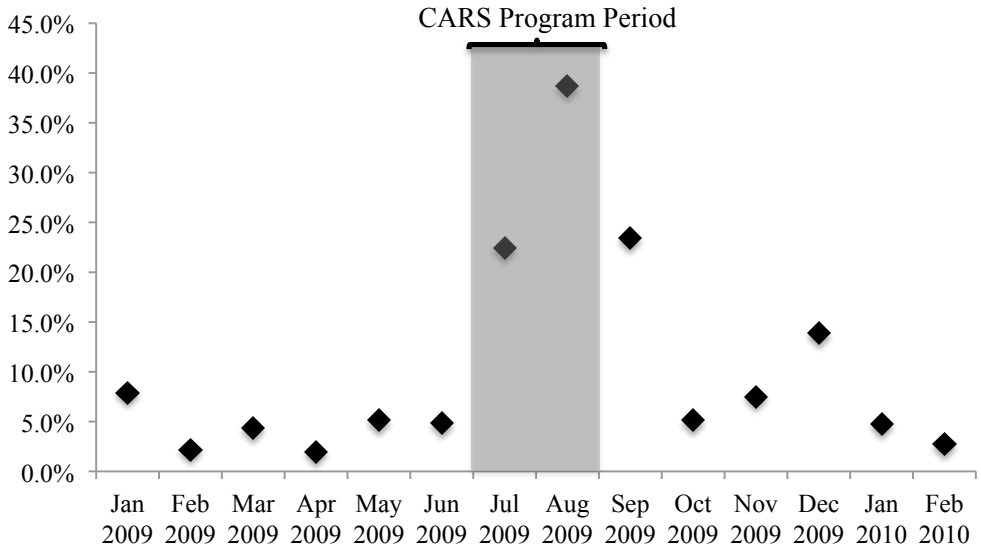
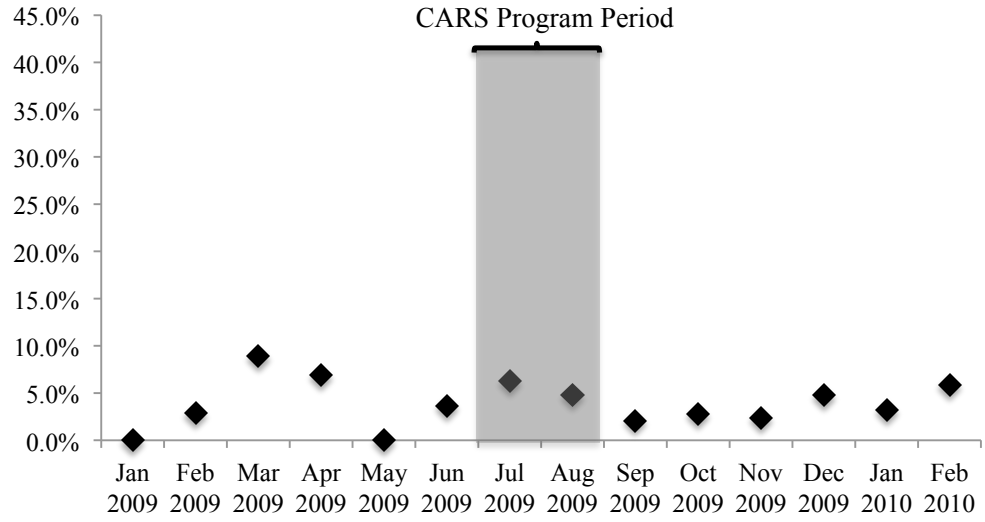
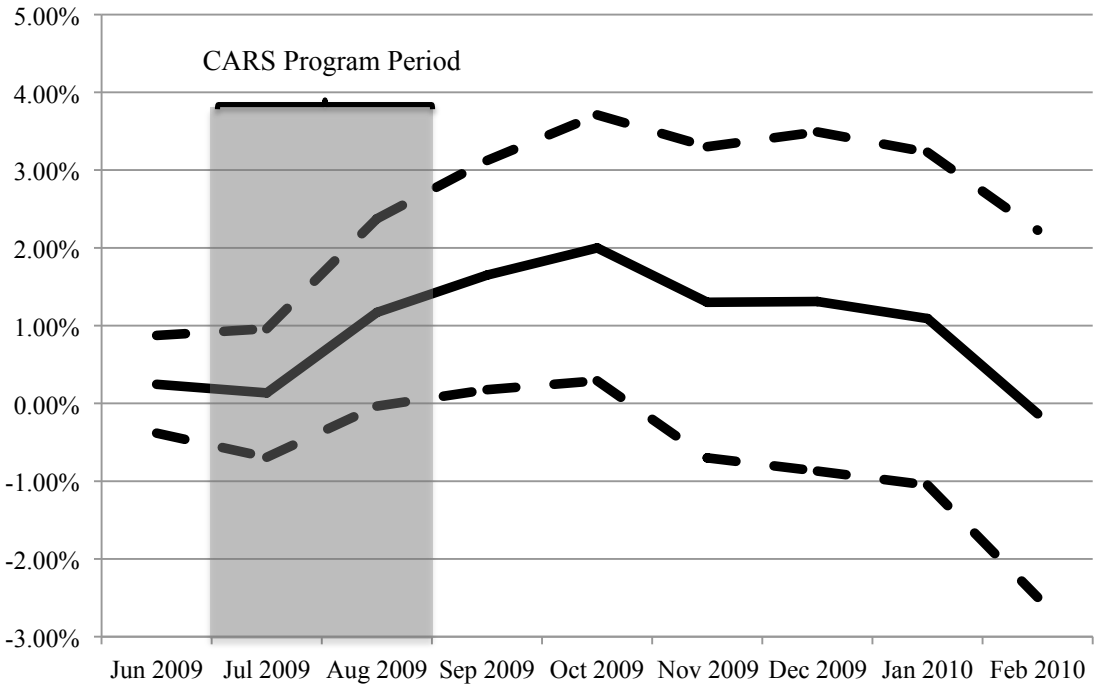


Figure 1b: Proprortion of Trade-ins with Value of $3,500 or $4,500 on Used Vehicle Purchases



Notes: These figures plot the proportion of trade-ins with value of $3,500 or $4,500 on new (Figure 1a) and used vehicle (Figure 1b) purchases between January 2009 and Februrary 2010. The x-axis corresponds to the month of the purchase. The sample is constructed from CE survey responses between 2009 through 2013, and includces transactions that occurred during respondents' participation in the survey and transactions that were reported retrospectively in interviews between 2010 and the first quarter of 2013.

Figure 2: Cumulative Change in Probability of New Purchase for *Clunkers* vs. *Close-to-Clunkers*



Notes: This figure plots the *Clunker* coefficient estimates reported in Table 1. For each month between June 2009 and February 2010 (x-axis), the *Clunker* coefficient measures the cumulative difference (since June 2009) in the rate of new vehicle purchases for *Clunker* vehicles compared to *Close-to-Clunker* vehicles. The solid line plots the coefficent point estimates and the dashed lines plot the bounds of the 95% confidence interval.

Table 1: The Cumulative Impact of CARS on New Vehicle Purchases at Various Horizons

	Dependent variable: New Vehicle Purchase between June 2009 and the End of Month:								
		CARS Program Period							
	Jun 2009	Jul 2009	Aug 2009	Sep 2009	Oct 2009	Nov 2009	Dec 2009	Jan 2010	Feb 2010
Clunker	0.25	0.13	1.17	1.65	2.00	1.30	1.31	1.09	-0.13
	(0.31)	(0.41)	(0.60)	(0.74)	(0.86)	(1.00)	(1.09)	(1.07)	(1.18)
Observations	3,313	3,313	2,950	2,595	2,276	1,957	1,655	1,357	1,055
R^2	0.002	0.005	0.007	0.009	0.008	0.009	0.010	0.010	0.011

Notes: Reported above are OLS estimation results for regressions that measure the impact of the CARS program on new vehicle purchases at various horizons. The unit of observation is a vehicle-month. The sample includes all *Clunker* and *Close-to-Clunker* vehicles with estimated trade-in value of $5,000 or less that were owned as of June 2009. A *Clunker* is a vehicle with fuel economy between 12 mpg and 18 mpg that was purchased prior to July 2008 and a *Close-to-Clunker* is a vehicle with fuel economy between 19 mpg and 25 mpg that was purchased prior to July 2008. The dependent variable in each specification is an indicator for whether the vehicle was associated with a new vehicle purchase - i.e. traded-in or sold in the same month as a new vehicle purchase - between June 2009 and the end of month T. For each month T between June 2009 and February 2010, we estimate a separate cross-sectional regression. Each model includes controls for fuel economy, trade-in value and household income. Standard errors are calculated with observations clustered by household and reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 2: The Cumulative Impact of CARS on New Vehicle Purchases at Various Horizons, Allowing for Heterogeneity in the Program Subsidy

	Dependent variable: New Vehicle Purchase between June 2009 and Month:								
		CARS Program Period							
	Jun 2009	Jul 2009	Aug 2009	Sep 2009	Oct 2009	Nov 2009	Dec 2009	Jan 2010	Feb 2010
Clunker	0.38	-0.01	1.74	2.28	2.56	2.37	2.46	1.71	0.82
	(0.47)	(0.60)	(0.88)	(0.99)	(1.15)	(1.36)	(1.50)	(1.35)	(1.46)
Clunker X Value	-0.07	0.07	-0.29	-0.32	-0.28	-0.55	-0.59	-0.31	-0.48
	(0.10)	(0.15)	(0.22)	(0.27)	(0.35)	(0.46)	(0.52)	(0.55)	(0.60)
Value	-0.03	-0.21	-0.15	-0.09	-0.10	0.33	0.45	0.55	0.87
	(0.05)	(0.10)	(0.13)	(0.17)	(0.20)	(0.29)	(0.33)	(0.34)	(0.42)
Observations	3,313	3,313	2,950	2,595	2,276	1,957	1,655	1,357	1,055
R^2	0.002	0.006	0.007	0.010	0.008	0.010	0.011	0.010	0.012

Notes: Reported above are OLS estimation results for regressions that measure the impact of the CARS program on new vehicle purchases at various horizons. These models are identical to the specifications reported in Table 1, but now include an interaction between the indicator for CARS-eligibility and the vehicle trade-in value (*Value*). By including this interaction term, we allow for heterogenous responses to the program depending on the implicit subsidy value of the CARS rebate. As in the Table 1 regressions, each model includes controls for fuel economy and household income. Standard errors are calculated with observations clustered by household and reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%