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**Abstract**

Stabilization policies frequently aim to boost spending as a means to increase GDP. Spending does not necessarily translate into production, however, especially when inventories are involved. We look at the "cash-for-clunkers" program that helped finance the purchase of nearly 700,000 vehicles in 2009. An analysis of auto sales and production movements reveals that the program did prompt a large spike in sales. But the program had only a modest and fleeting impact on production, as inventories buffered the movements in sales. These findings suggest caution in judging the efficacy of such policies by their impact on spending alone.

Key words: cash-for-clunkers, automobiles, stimulus

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During July and August of 2009, Americans purchased nearly 700,000 new automobiles or light trucks under the government's "cash-for-clunkers" program—officially the Car Allowance Rebate System, or CARS. Under the terms of the purchase, qualified buyers traded in their old vehicles to receive a rebate on the price of a new vehicle; the amount of the rebate—either $3,500 or $4,500—depended on both the model that was traded in and the model that was acquired. The direct cost to taxpayers of subsidizing these purchases was roughly $2.8 billion.

The program had two primary goals: to reduce energy consumption and pollution by inducing consumers to replace their old gas-guzzlers with newer, fuel-efficient models, and to serve as a stimulus for the troubled automobile industry and the U.S. economy as a whole. In this article, we take a close look at the second objective, exploring how the CARS program affected sales and, more important, production in the automobile industry.[1] Drawing on our findings, we then propose an answer to the more difficult question of the program's impact on U.S. GDP.[2]

In line with other recent studies, our analysis shows that the CARS program had only a transitory cumulative effect on sales. We estimate an initial impact of about 450,000 additional automobile sales, but these were essentially shifted from the periods before and (especially) after the program. We calculate that by January 2010, the cumulative effect of the CARS program on auto sales was essentially zero.[3]

More important for our purposes, however, is the program's effect on automobile production. While most studies of CARS have focused on sales, we argue that the program's success as a stimulus to the economy hinges on its impact on production. Production increases are more likely to translate into higher GDP and employment, GDP being fundamentally a measure of production. Sales clearly rose at the outset, but given that the industry can simply let

[1] An assessment of the returns on the $2.8 billion government expenditure would have to include a valuation of the energy efficiency gains achieved through the program. However, this is an issue we do not address in the article.

[2] Li et al. (2010) and Mian and Sufi (2010) examine only the sales impact of the CARS program. Abrams and Parsons (2009) study the welfare effects of the program, weighing the benefits to consumers who received subsidies from the CARS program against the costs to taxpayers and taking into account the environmental gains of cleaner air. Their back-of-the-envelope calculations show that the costs exceeded the benefits by approximately $2,000 per vehicle.

[3] In dollar terms, our estimates suggest that almost $4 billion in nominal sales were moved up from the fourth quarter to the third quarter of 2009.

inventory stocks absorb the increase in sales, higher sales alone do not imply higher GDP or employment.[4]

Overall, we find that the program had a very modest and short-lived effect on production. Production was about 200,000 units higher during the program (in comparison to the 450,000 increase in sales). Sales from September 2009 to January 2010 were correspondingly lower than they would have been in the absence of CARS, which allowed producers to have lower production while still replenishing their inventory stocks. Thus on a quarterly basis we estimate that the CARS program shifted production by around 100,000 units from 2009Q4 and 2010Q1 to 2009Q3.

These calculations suggest that the program had a negligible direct effect on GDP, shifting less than roughly $2 billion (or less than one-tenth of one percent of GDP) into 2009Q3 from the subsequent two quarters. This contrasts starkly with a study released by the Department of Transportation (DOT) in the immediate aftermath of the program, which concluded that CARS had given a substantial boost to both GDP and employment. In the final section of the article, we discuss why our conclusions differ from those of the DOT study.

Our findings raise broader questions, beyond just this particular program, about the efficacy of efforts to stimulate short-term spending. It is clearly a mistake to gauge their impact by just looking at the spending they induce, without looking at the supply side. It is reasonable to expect that producers will use other margins than production and employment to respond to temporary movements in sales, so the only question is quantitative: How large is the gap between the sales and production impact? We find it to be large in the case of "Cash-for-Clunkers."

In what follows, we will lay out the economics behind our analysis by examining how rebates and other transitory price changes affect consumer purchases and manufacturers' inventory decisions. We then provide some background on the Cash for Clunkers program in Section II. Sections III and IV provide our analysis of the impact of the program, and Section V concludes.

## I. Durable Goods and Inventories

### *A. Consumers*

[4] Even production increases might not result in higher GDP if resources are diverted from other industries. This is perhaps less likely to be an issue during a recession.

The consumer response to temporary price changes—including rebates and other subsidies—differs dramatically for durable and nondurable goods. Automobiles are a type of durable good, that is, a good that can be used or "consumed" over a number of years. Because a durable good can be stored, a temporary decline in its price will prompt consumers to "stock up." By contrast, a temporary drop in the price of a nondurable good—a good, such as milk or lawn-mowing services, that is quickly consumed through use and cannot be stored—will not cause people to stock up.

Moreover, in the case of durable goods, consumers have considerable latitude in timing a purchase. Someone planning to replace a "clunker" can easily shift the timing by a few months. So it is natural not only to expect a large sales response to a temporary subsidy for any durable good, but also to expect that much of that response will be offset by lower sales before or after the subsidy period, as consumers defer or move up their purchases to take advantage of the subsidy.[5] Thus the cumulative impact on sales (and hence, production) is likely to be modest, if not zero, over a longer time frame. The only issue is how long it takes for the impact to dissipate: Do consumers shift their purchases by a few weeks, a few months, or longer?

*B. Producers*

For automobile producers, the key decisions are when and how much to produce in response to a temporary subsidy. Most automobiles are sold from inventories, not specially ordered. Dealers on average maintain inventories equivalent to approximately two and a half months' worth of sales.[6] Deviations from the average may occur for a variety of reasons—seasonal factors, an unexpected blip in sales, or changes in production or inventory holding costs—but they rarely persist. A large positive surprise in sales will cause inventories to decline for a time until they can be replenished by additional production. An anticipated jump in sales, if believed to be temporary, will also result in a decline in inventories, largely because producers

[5] Erdem, Imai, and Keane (2003), Hendel and Nevo (2006), and Gowrisankaran and Rysman (2010) demonstrate the importance of accounting for the timing of consumer purchases when comparing the effects of temporary and permanent price changes in durable goods.

[6] One explanation for the large inventory holdings is that dealers wish to avoid "stocking out," that is, not having the models on hand that buyers want. See, for example, Kahn (1987, 1992) and Bils and Kahn (2000).

generally find it costly to change production by a large amount in either direction.[7] And if that jump is viewed as, in effect, borrowed from future sales, no additional production is necessary to replenish inventories; the subsequent drop in sales will restore stock levels if production remains constant. Given this reluctance to boost or cut production significantly, an increase in sales that is accompanied by an increase in inventories is a sign that producers view the sales upturn as likely to persist. But if the jump in sales is viewed as just coming at the expense of future sales, it makes sense for firms to let inventory movements accommodate much of the sales movement rather than change production by a substantial amount.

Automobile producers and dealers thus have a number of options in responding to programs like CARS. If they have advance notice of the program, manufacturers can shift production forward to build up inventories, and then let the spike in sales following the launch of the program reduce inventories to normal levels. At the other extreme, they can leave their production plans unchanged, let inventories absorb the spike in sales, and then wait for inventories to recover when sales drop after the program expires. The first approach emphasizes the desire to avoid any stockouts, so as to maximize the sales from the program; the second emphasizes the firm's goal of minimizing its costs by smoothing production and letting inventories serve as a buffer. [8]

In actual practice, producers most likely adopt some combination of the two responses, because they care about avoiding stockouts *and* smoothing production. The relative importance that they assign to these motives will depend in part on the costs of shifting production forward to meet increased demand—for example, paying workers overtime, running second shifts, and coping with bottlenecks in supplies. It will also depend on the amount of profit that would be lost in the event of a stockout, which in turn depends on the size of the price-cost markup on the automobiles. Since the CARS program likely boosted these markups, we would expect at least some increase in production to avoid stockouts.

*C. Seasonality*

[7] Bresnahan and Ramey (1994) analyze the different ways that automobile manufacturers adjust production and the respective costs.

[8] Copeland and Hall (2011) offer a detailed empirical analysis of automakers' response to temporary demand shocks. They find that shocks are almost entirely absorbed through adjustments in sales and production rather than adjustments in prices.

An additional complication affecting the production of automobiles is seasonality. U.S. automobile manufacturers typically shut down production for a period of weeks in the summer to retool plants for the next model year. During this time, they draw down inventories of the previous year's model and then begin to accumulate inventories of the new model after production starts up again. Manufacturers also shut down production during the Christmas–New Year's period for a week to ten days. These large and variable seasonal movements must be taken into account in analyzing industry data, especially the numbers in July and August—all the more so because in 2009 the CARS program was in effect during precisely those two months.

Despite these complications, the CARS program represents a unique opportunity to study the behavior of both consumers and producers. Particularly advantageous for our analysis is the fact that only some vehicle models were eligible for the rebate.[9] While the existence of a subsidy may have induced some consumers to buy an eligible model when they otherwise would have chosen to buy an ineligible model, we nonetheless are able to use the data on the production and sales of ineligible models as a "control group" to help gauge the impact of the program.

## II. A Timeline of the CARS Act

Early notice of the cash-for-clunkers program appeared in a December 2008 article in the *San Diego Union-Tribune* reporting that the National Automobile Dealers Association was lobbying the incoming Obama administration to include the program in the economic stimulus bill.[10] Cash for clunkers quickly became a part of the economic stimulus package. In late March 2009, the Obama administration endorsed the idea of a trade-in program for automobiles and, on June 9, the House of Representatives passed a cash-for-clunkers program.[11] The Senate quickly followed and, on June 24, the CARS Act of 2009 was signed into law.[12] Congress allocated $1 billion to fund the program, and new car purchases and leases on and after July 1 were made

[9] The availability and size of the rebate depended on the extent to which the purchaser traded up in fuel efficiency. Some models were not eligible at all, while higher-fuel-efficiency models increased the number of buyers who could meet the eligibility requirements.

[10] James Oliphant and Richard Simon, "Line Forming for Slice of Stimulus Pie," *San Diego Union-Tribune*, December 15, 2008.

[11] Bryan Walsh, "Cash for Clunkers: A Green Deal to Help Detroit?" Time.com, April 15, 2009; Jennifer Liberto, "House OKs $4 Billion 'Clunker' Bill," CNNMoney.com, June 10, 2009.

[12] The CARS acronym was applied to both the legislation establishing the program and the program itself, but the acronym was interpreted differently in the two cases. While the title of the program was "Car Allowance Rebate System," the "CARS Act of 2009"was short for "Consumer Assistance to Recycle and Save Act of 2009."

eligible for rebates.[13] Because of the popularity of the CARS program, an additional $2 billion was allotted to the program on August 7.[14] Even with this extra allotment, the cash-for-clunkers program ran out of funds and ended on August 24. Overall, more than 677,000 vehicles received cash-for-clunkers financing, and roughly $2.8 billion was disbursed through the program.[15]

The size of the cash-for-clunkers rebate was linked to the difference in miles per gallon between the vehicle traded in and the new vehicle purchased (Table 1).[16] The set of new vehicles eligible for financing through CARS was quite broad, and included larger vehicles such as sport utility vehicles (SUVs), vans, and pickups. However, a quick scan of the vehicle types purchased under the program (Table 2) reveals that the program mostly helped to finance the purchase of small cars and crossover utility vehicles (CUVs). Cash-for-clunkers rebates were received for 45 percent of all small car sales and 35 percent of all CUV sales in July and August. In contrast, large cars and luxury cars received little direct benefit from the CARS program.

With 70 percent of all cash-for-clunkers rebates going to sales in August, the program clearly had a much larger impact in August than in July. The injection of $2 billion in additional funding on August 7 no doubt helps account for this difference, as does the fact that the CARS program eligibility criteria for a new vehicle purchase were not finalized until July 24. Hence, consumers may have delayed their purchase decisions in order to be sure that they qualified for the cash-for-clunkers rebate.

The CARS program was used to finance sales of "old" 2009 model vehicles more often than "new" 2010 model ones. More than 75 percent of all sales receiving a cash-for-clunkers rebate were 2009 model vehicles. Because most automobile manufacturers switched from producing 2009 models to 2010 models over the summer of 2009, the vast majority of 2009 model sales in July and August came from inventories. In contrast, because inventories of 2010 vehicles were quite low in the late summer months, most of the new models financed through the cash-for-clunkers program came from current production.

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[13] Catherine Clifford, "'Cash for Clunkers' Coming Soon," CNNMoney.com, June 24, 2009.

[14] Sharon Silke, "Obama Signs $2B Cash for Clunkers Extension," ABCnews.com, August 6, 2009.

[15] "Secretary LaHood Touts Success of Cash for Clunkers; Responds to Reports by DOT Inspector General, GAO," Department of Transportation press release, April 29, 2010.

[16] Visit http://www.cars.gov for a full description of the CARS program and its eligibility requirements. For a list of the names of vehicles that were eligible for CARS financing, see http://www.edmunds.com.

## III. Impact of the CARS Program: Production, Inventory, and Sales Data

As a first step in analyzing the effects of the CARS program, we look at aggregate data on sales, production, and inventories for the U.S. automobile market in the period from January 2007 through February 2010. We then break out the data into vehicles that were eligible for financing under the CARS program and vehicles that were not. Eligible models accounted for roughly 75 percent of sales before the start of the program.[17] More details about the data construction are available in the appendix.

The U.S. recession that began in December 2007 hit automobile sales particularly hard. Sales declined sharply from the beginning of 2008 and bottomed out in the first half of 2009 (Figure 1).[18] During the lows reached in early 2009, both Chrysler and General Motors declared bankruptcy.[19] The launch of the CARS program reversed this downturn for a time, producing a temporary burst in sales in July and August of 2009 (Figure 1, shaded area).

The decline in automobile sales during the recession led to a large buildup in inventories from mid-2008 through early 2009. Economists often measure inventory holdings by looking at the ratio of inventory to sales, or "months' supply." This statistic captures how many months of sales—*at the current rate of sales*—could be sold out of the current stock of inventories. Figure 2 shows that at their height in the last quarter of 2008, automobile inventories were equivalent to 3.8 months of sales. However, months' supply declined substantially thereafter, essentially returning to its normal level of about 2.5 months by June 2009. Given the low level of sales, the drop in months' supply had to reflect a particularly large decline in inventories. Indeed, inventories fell from a pre-recession peak of about 3.3 million vehicles to less than 2 million. With the implementation of the CARS program, inventories plunged further, and months' supply fell below one and a half months, its lowest level in our data for the 1994-2010 period.

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[17] We caution that eligibility had a quantitative as well as a qualitative component: Because the program required a discrete improvement in fuel efficiency, some models would be eligible for only a small fraction of buyers.

[18] Unless indicated otherwise, all data have been seasonally adjusted using month dummy variables in a log-linear regression. The Bureau of Economic Analysis only provides seasonally adjusted data for aggregates, but our analysis requires data on eligible and ineligible models.

[19] We do not explicitly take into account any impact from the bankruptcies of Chrysler and General Motors, because these took place before the launch of the CARS program.

The large decline in inventories during the CARS program indicates that production, together with net imports,[20] remained far below sales. Production did increase at the beginning of the program, however (Figure 3). The seasonally adjusted data show a production upswing in July 2009; moreover, actual, or unadjusted, output did not experience the usual 40 percent July decline (evident in 2007 and 2008) associated with the model changeover period but instead rose 1 percent. Production then remained close to July's level through February 2010, suggesting that automakers expected the demand for automobiles to remain firmer than in the first half of 2009.

A breakout of the inventory data into vehicles that were eligible for CARS financing and vehicles that were not reveals that the August drop in the months' supply of vehicles took place entirely in the "eligible" category (Figure 4). This measure fell because sales of eligible vehicles increased while inventories of these same vehicles decreased. Recall that 2009 model vehicles made up fully three-fourths of CARS-financed sales. Since production of these "old" model vehicles ended in the summer of 2009, the data suggest that inventory reductions rather than additional production accounted for a substantial portion of the increased sales in July and August of 2009.

More direct evidence of the production and sales patterns for eligible and ineligible vehicles can be found in Figure 5. Sales of both types of vehicles dip in June 2009—in part, most likely, because of consumers' awareness of the impending program (Figure 5, top panel). Subsequently, sales of eligible vehicles spike in July and August 2009, when the CARS program was in effect. A trough in sales of eligible models follows this sharp rise, suggesting that a large number of sales were shifted from September to August, as would be expected. Production, however, shows little evidence of a spike during the period of the program, especially if one looks at the production of eligible relative to ineligible vehicles. Still, production of both types of vehicles did increase modestly at the onset of CARS, and remained at a higher level thereafter. But the similarity in the pattern of production for both eligible and ineligible vehicles, together with the permanence of the response, suggests that the increases were not primarily due to the CARS program, but instead owed much to the general firming of automobile sales that was taking place as the recession was ending.

[20] See the appendix for a discussion of the importance of controlling for net imports when analyzing the CARS program's effects on production.

While the analysis thus far cannot put precise numbers on the production impact of the CARS program, it is clear that inventory reductions contributed substantially to accommodating the spike in sales. The next section quantifies these contributions in order to gauge the net impact of the program on U.S. motor vehicle production and, ultimately, on GDP.

## IV. An Empirical Model of Production and Inventory Behavior

In this section, we undertake the more challenging task of quantifying the impact of CARS by estimating what would have happened if the program had not been in place. We start with a forecasting model based on automobile sales and production data from January 1994 through June 2009 as well as on contemporaneous indicators of economic conditions during and after the CARS program. From this, we obtain an estimate of what sales would have been from July 2009 to February 2010 in the absence of the program.

We then examine alternative assumptions about inventory behavior to obtain estimates of what production would have been. The difference between actual automobile sales and production and these counterfactuals provides estimates of the net impact of the program. Overall, the stronger the sales and production measures in our counterfactuals, the smaller the impact of the program will appear to be.

The first counterfactual scenario (Scenario 1) relies solely on the results of a *vector error correction* (VEC) model. We use a VEC model to reflect the long-term relationship between inventory levels and production. Our model has two endogenous variables (all variables are in logarithms): U.S. sales of vehicles eligible for CARS at date *t* ($s_t^e$); and U.S. inventories of eligible vehicles ($i_t^e$). We also include non-motor-vehicle industrial production ($z_t$) and sales of ineligible vehicles ($s_t^{ne}$) as exogenous variables, current and lagged. Both of these represent variables that are intended to help with the difficult question of what would have happened to the endogenous variables in the absence of the CARS program. The industrial production variable is designed to reflect broader economic developments that could affect the automobile industry, such as an economic recovery or downturn. The data on sales of ineligible vehicles represent a type of control group that can serve as a proxy for what sales would have been in the absence of the program.

Specifically, we estimate the following model of eligible sales and inventories:

$$\Delta s_t^e = \sum_{j=1}^{6}\left(\alpha_{ssj}\Delta s_{t-j}^e + \alpha_{sij}\Delta i_{t-j}^e + \alpha_{sxj}\Delta z_{t-j+1} + \alpha_{snj}\Delta s_{t-j+1}^{ne}\right) + \gamma_s\left(i_{t-1}^e - \beta s_{t-1}^e\right) + \varepsilon_{st}$$

$$\Delta i_t^e = \sum_{j=1}^{6}\left(\alpha_{isj}\Delta s_{t-j}^e + \alpha_{iij}\Delta i_{t-j}^e + \alpha_{ixj}\Delta z_{t-j+1} + \alpha_{inj}\Delta s_{t-j+1}^{ne}\right) + \gamma_i\left(i_{t-1}^e - \beta s_{t-1}^e\right) + \varepsilon_{it}$$

The error correction term (ECT), $i_{t-1}^e - \beta s_{t-1}^e$, reflects the "target" months' supply, and we would expect $\beta$ to be very close to one. The coefficients $\gamma_s$ and $\gamma_i$ indicate the response of the dependent variable to movements in the ECT. We would expect $\gamma_s$ to be positive for two non-exclusive reasons: higher overall inventories mean fewer stockouts of individual models; and excess inventories above target could lead dealers to cut prices or find other ways to reduce excess inventory. The coefficient $\gamma_i$ on the ECT of the equation for inventories should of course be negative.

A crucial assumption is that both industrial production ex-autos and sales of ineligible vehicles were not materially affected by the CARS program. There are certainly hypothetical reasons to doubt this assumption. Regarding sales of non-eligible vehicles, on the one hand, the availability of a rebate might have led many consumers to buy an eligible vehicle when they otherwise would have chosen an ineligible vehicle—a "substitution effect" that could have lowered sales of ineligible vehicles. On the other hand, working in the other direction is the possibility of individuals who did not qualify for the subsidies (because, for example, they lacked an eligible trade-in vehicle) opting to buy ineligible vehicles instead. In principle, either effect could dominate. We assume that the net effect is small relative to other influences on demand for these vehicles.

As for the industrial production series, although the series excludes production from the motor vehicle industry, there may have been spillover effects on related industries. Even the most sanguine accounts of the impact of the CARS program, such as the report of the Department of Transportation, suggests these effects were tiny and short-lived relative to the scale of the U.S. economy, and thus would not have accounted for virtually any of the nearly seven percent increase (at an annual rate) in this index in the second half of 2009.

These predictions are borne out; Table 3 provides estimates of these coefficients. The coefficient $\beta$ is not significantly different from one, while the others have the expected signs. While the estimates are qualitatively sensible, however, the model coefficients imply an implausibly slow adjustment of inventories. Figure 6 shows the impulse response functions

implied by the parameter estimates of the model. Note that it takes approximately one year for inventories to respond fully to a shock to sales. Also somewhat surprising is the negligible (and initially slightly negative) impact of an inventory shock on sales, despite the positive and significant sign of $\gamma_s$.

A possible reason for the slow response is that the model is estimated over the relatively tranquil January 1994–June 2009 period, which included only one significant downturn at the end of the sample. The experience of the second half of 2009, as well as other episodes involving large change in sales, suggests that inventories can and do adjust more rapidly to some shocks. We will return to this idea later in the discussion of the counterfactuals.

The results of this first counterfactual exercise are plotted in Figure 7 as "Scenario 1." The difference between this scenario and the actual path of sales (top panel) suggests that the CARS program essentially shifted sales that would have taken place from September through December 2009 to the months of July and August. Thus, by January 2010 cumulative sales since June were no higher, according to this counterfactual exercise, than they would have been without the CARS program.[21]

As foreshadowed by the impulse response function results, the production response in this first counterfactual is quite sluggish (Figure 7, middle panel), implying that inventories would have fallen and remained below two months' supply for at least six months in the absence of the CARS program (Figure 7, bottom panel). This representation of the behavior of inventories is, however, implausible: In the data going back to 1994, months' supply has never been below two for more than two consecutive months. The weak production response also implies an implausibly large and prolonged impact of the CARS program on production, as discussed below. Since actual production rebounded to its December level,[22] the cumulative impact of CARS on production implied by this counterfactual was still strongly positive long after the impact on sales had dissipated.

[21] This conclusion is somewhat affected by seasonal adjustment. The Bureau of Economic Analysis' adjustments of the data smooth the series more than our method does. We estimate that if the adjusted data had been available for eligible and ineligible vehicles, we would have found that the cumulative impact extended into February 2010 rather than December 2009. The fourth-quarter impact would still have been negative, however.

[22] Of course, as we suggested earlier, the rebound in production may owe more to the general strengthening of the economy than to the CARS program.

The fact that months' supply actually remained close to normal from October 2009 onward suggests that the industry viewed the higher level of sales in the second half of the year as likely to persist, and accordingly ramped up production and built up inventory levels.[23] This rapid return of months' supply to normal levels occurred in other recent episodes involving temporary incentive programs, and it calls into question the model's prediction that, in the absence of the program, production would have adjusted only slowly to an increase in sales.

But why would the VEC estimates fail to accurately depict the production response? Our argument is that while the VEC model may be reasonable for some purposes, such as generating conditional sales forecasts, it may be too simple to capture inventory behavior, especially in the unusual circumstances of the unprecedented downturn of 2008-2009. In addition, going back to Feldstein and Auerbach (1976) there has long been a suspicion that simple dynamic adjustment models are misspecified in a way that results in implausibly slow inventory adjustment.

In the case of the VEC, the linearity and symmetry of the error correction term may be at issue. Many inventory models have different properties when inventories are far away from their long-run steady state, and may respond differently when that gap is positive versus negative. For example, if inventory-sales ratios are extremely high, the non-negativity constraint on production can bind. The marginal cost of being away from the target ratio may be nonlinear. As evidence, we added threshold indicator variables to the VEC specification, one for when the inventory-sales ratio exceeds 3.0, and one for when it falls below 2.0. When we estimate the VEC model over the full sample with these variables added as exogenous explanatory variables, we find that the "above 3'' dummy variable is not significant, but the ``below 2'' one is highly significant with coefficients of 0.066 in the inventory equation and –0.078 in the sales equation. This means that when the ratio falls below two, it gets a "kick'' to the tune of an extra 15 percent relative to the simple VEC estimate.

In light of this apparent weakness in our first counterfactual based entirely on the VEC estimates, we propose two alternative scenarios, premised on the view that manufacturers' would not have allowed inventory-sales ratios to remain persistently below two as depicted in Figure 7, Scenario 1. The idea is that manufacturers' recognized the increase in sales in late 2009 (after the CARS program ended) as a genuine, albeit incomplete, recovery and produced so as to

[23] In the five months from October 2009 through February 2010, sales averaged more than 900,000 units, compared with approximately 800,000 in the first five months of 2009.

maintain inventory/sales ratios at relatively normal levels (as they actually did even with the CARS program except for August 2009). The fact that the industry was able to keep months' supply close to normal in the wake of the large jump in sales due to the CARS program, it likely would have done so with the more gradual sales increase depicted in Figure 7.

In our baseline specification, Scenario 2, we assume that the inventory-sales ratio is at the VEC estimate for July and August, and then tracks the data thereafter. This allows the ratio to fall as low as 2.29 We also consider a more extreme scenario, labeled Scenario 3, in which producers let the inventory-sales track the VEC estimate through September, but then gradually adjust inventories to get the ratio back to "normal" (the level in the actual data) by November.

Scenario 3 is more optimistic because its prediction of the impact of cash-for-clunkers on production will be greater than the predictions from the baseline specification, Scenario 2. The optimistic forecast should be treated with some skepticism because it allows seasonally adjusted months' supply vehicles to fall as low as 2.0. This only happened twice in our 15-year sample prior to 2009: in October-November 2001 and in July 2005. Both of these occurred at the time of specific unusual promotions: Zero percent financing introduced in the aftermath of the September 11$^{th}$ attacks in 2001, and the "employee discount for everyone" promotions by GM and Ford in June 2005. While these were not policy interventions like the CARS program, and presumably their intent was to clear out inventory (in the 2005 case, specifically inventory of the outgoing model year), the point is that the low inventory-sales ratios were highly transitory. In both cases months' supply was back in the normal range the next month. Consequently, we consider the optimistic scenario only to highlight the robustness of the baseline scenario's predictions.

Each scenario's inventory-sales ratio assumption implies a path for production plus net imports (that is, U.S. sales plus the change in inventories). Given that net imports appear to have been unaffected by the program, we infer a path for production based on an estimated historical relationship between production and net imports.[24]

The production paths implied by Scenario 2 and 3 (see Figure 7), show a much stronger surge in assemblies in comparison to Scenario 1. As we detail below, these stronger surges are also more transitory. Indeed, both Scenarios 2 and 3 suggest that the CARS program's impact on production was mostly confined to 2009.

[24] See the appendix for details.

For all the scenarios, we assess the cumulative net impact of the program on sales and production (Figure 8). More specifically, we compute the difference between actual sales (production) and the sales (production) predicted by the counterfactual for each month. We then take the cumulative sum of these differences to gauge the sales (production) impact of the cash-for-clunkers program over time.[25] The cumulative sales impact peaks at about 450,000 cars at the end of August, and is still at 320,000 cars through September. Hence our counterfactual suggests that in the third quarter of 2009 the cash-for-clunkers programs generated 320,000 sales that would not have occurred in the absence of the program. By November, however, the cumulative impact of the program had fallen by over 50 percent to 142,000, and by January 2010 it was essentially zero, meaning that all of the additional sales in July and August of 2009 were shifted forward from the subsequent four months.

Compared to Li et al. (2010), our prediction of the impact on sales in July and August of 2009 is larger and shorter-lived. They argue that cumulative sales impact of cash-for-clunkers peaked in August at 380,000 cars, a level roughly 15 percent below our analysis. Further, their results suggest that 240,000 unit sales were pulled forward from 2010, while we estimate that almost all of the sales impact in the third quarter of 2009 was a result of sales shifting from the fourth to third quarter.[26] Our results imply that, on net, the CARS program generated little cumulative additional consumer spending on automobiles in 2009 but instead shifted roughly $6.6 billion in nominal spending from the fourth to the third quarter of 2009.[27] The unit sales forecast in Li et al. implies a shift of roughly $7.5 billion from the fourth quarter of 2009 and the first quarter to 2010, to the third quarter of 2009.

The shift in sales stemming from the CARS program directly affects GDP. National income accounting recognizes dealership services as part of production and so assigns value-

[25] Recall that both counterfactuals use the same sales forecast, but have differing production and inventory forecasts.

[26] Li et al. (2010) use Canadian sales as an indicator of what would have happened without a cash-for-clunkers program. The difficulty with this approach is that Canada's macroeconomic conditions in 2009 were very different from those in the United States. The Canadian downturn was much milder, so one would expect a milder rebound. Li et al. have some controls for these conditions, but we would argue that given the extreme and almost unprecedented nature of the U.S. downturn and the policy responses it elicited, it is preferable to use data from the U.S. market. Hence, we use U.S. sales of ineligible vehicles as our benchmark counterfactual. Mian and Sufi (2010), using a cross-sectional approach, also find that sales were merely pulled forward into the program period, so that the cumulative impact of the program had evaporated by early 2010.

[27] We calculate this nominal expenditure figure by multiplying our estimates of vehicle sales due to the CARS program in July, August, and September of 2009 by the appropriate average expenditure-per-vehicle figures reported by the Bureau of Economic Analysis.

added to the movement of vehicles from inventory to sales. We estimate this value-added from dealerships to be 4 percent of nominal expenditures (dealerships typically apply a 4 percent markup to the sale of new vehicles).[28] Consequently, the shift in sales implies a $265 million shift in GDP—equal to less than 1/100 of 1 percent of GDP—from the fourth to the third quarter of 2009.

Table 4 gives the net production impact by quarter for the three alternative scenarios. As explained above, the net impact on production implied by the first counterfactual, Scenario 1, is implausibly large and prolonged relative to the sales impact. By contrast, the production impact implied by the more credible Scenarios 2 and 3 peak earlier (in the 200,000 to 300,000 range), and most of the impact is dissipated by December (see Figure 8). Both Scenarios 2 and 3 predict that cash-for-clunkers nudged up GDP by $2 billion in the second half of 2009, by drawing roughly 100,000 units of production forward from the first quarter of 2010. This movement in output is negligible, and has little impact whatsoever on the level of growth rate of GDP.

Looking at the third and fourth quarters of 2009, our baseline specification reinforces the result that cash-for-clunkers did little to impact output. In Scenario 2, cash-for-clunkers impacts third quarter production by less than 100,000 units, an increase of less than $2 billion to GDP. As shown in Figure 8, the cumulative production impact peaks in August before rapidly falling in September. In this baseline prediction, higher sales are mostly offset by inventory reductions and the only production response to cash-for-clunkers is a rearrangement of assemblies within the third quarter (and so has no impact on quarterly GDP). Even taking into account the $265 million direct effect of sales on GDP, in this baseline specification we find at most a negligible impact of cash-for-clunkers on third quarter GDP.

To gauge how much of an impact our model could generate in the third quarter of 2009, we consider our optimistic prediction. Under Scenario 3, the cumulative production impact in the third quarter is 287,000 units, more than three times as much as our baseline prediction. This translates into a large $6.5 billion bump in third quarter GDP, enough of an increase to inch up the growth rate in the third quarter by 0.2 percentage points. This effect on GDP is short-lived,

[28] Using the same data as the Bureau of Economic Analysis, we find that the average markup for each model year from 2003 to 2007 is 4 percent. Because we do not have more recent data, we assume that the markups for the 2009 and 2010 models are similar to those in recent history.

however, with most of the increase unwound in the fourth quarter, creating a commiserate drag on the growth rate of fourth quarter GDP.

One important component of the automobile market that we have neglected so far is the secondary market for automobiles. The interaction between new and used markets could potentially affect our results. In particular, because the cash-for-clunkers program stipulated that the "clunkers" used to earn financing were to be scrapped, the reduction in the stock of used cars could have spurred demand for eligible and ineligible cars from September 2009 onward. However, such an outcome seems unlikely for two reasons. First, households own more than 250 million cars, and so the scrapping of fewer than 700,000 cars (0.3 percent of the total automobile stock) is a tiny adjustment to the stock of cars.[29] Furthermore, we expect the interaction between new car sales and "clunkers" to be minimal, given that the average age of the vehicle traded in under the cash-for-clunkers program was sixteen years.[30]

Finally, we should address the sharp differences between our findings on the effects of the CARS program and those presented by the Department of Transportation (DOT) in an official report to Congress.[31] The relevant sections of the Department's report are based partly on the results of a survey of consumers who participated in the cash-for-clunkers program, and partly on a previous analysis by the Council of Economic Advisers (CEA).[32] The report finds that the program "resulted in a $3.8 billion to $6.8 billion increase in GDP, contributing significantly to GDP growth in the third quarter, and created or saved over 60,000 jobs."

Space does not permit a thorough explanation of the differences in our findings, but a key factor is that our analysis has the advantage of hindsight.[33] Both the DOT and CEA reports were issued in the immediate aftermath of the program, and hence relied on assumptions about

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[29] R. L. Polk & Company, "R.L. Polk & Co. Reports Vehicle Age in U.S. on the Rise," press release, February 15, 2008.

[30] In support of this view, Schiraldi (2010) estimates the cross-price elasticity between a new and a ten-year-old vehicle of the same type to be in the neighborhood of 0.01. Hence, a 1 percent rise in the price of a new car causes sales of ten-year-old cars to rise by 0.01 percent, a negligible amount.

[31] This report is available at http://www.cars.gov/files/official-information/CARS-Report-to-Congress.pdf.

[32] Council of Economic Advisers, "Economic Analysis of the Car Allowance Rebate System ("Cash for Clunkers"), September 10, 2009, available at http://www.whitehouse.gov/assets/documents/CEA_Cash_for_Clunkers_Report_FINAL.pdf.

[33] Surveys also have inherent limitations, especially when participation is voluntary and the number of respondents is low. The voluntary participation rate of the DOT survey was 27 percent; consequently, the survey is not necessarily representative of all program participants, nor can it reflect changes in buying decisions by nonparticipants.

the volume of new sales and production that would be stimulated by the program. By contrast, our analysis draws on actual information about production and sales that became available only subsequently. For example, in the case of the CEA report (released in early September 2009), the analysis *assumes* a boost in fourth-quarter production to replenish depleted inventories. Our findings, based on data through February 2010, indicate that the drop in sales following the expiration of the program enabled producers to maintain inventories at customary levels without expanding production.

Similarly, the DOT study's estimates of benefits from the program relied heavily on survey responses that indicated participants' *intentions* with regard to their automobiles. The survey found that, before applying to the program, only about a third of purchasers had intended to trade in, sell, or otherwise dispose of their old vehicles within a year. This finding was interpreted to mean that the program had successfully induced a large share of the participants to buy a new vehicle when they otherwise would not have done so. Sales data released subsequently, however, support our conclusion that the program simply expedited, by a few months, vehicle sales that would have taken place anyway.

This last comparison also suggests that the DOT survey's questions were not ideally framed to gauge the impact of the CARS program. Asking program participants when—in the absence of the program—they would have traded in or otherwise disposed of their old vehicles is not the same as asking when they would have purchased a new vehicle; in fact, individuals often buy a new car without trading in an old one. Thus, the design of the survey question itself may have contributed to some underreporting of individuals' plans to purchase a new vehicle.

## V. Conclusion

We have argued that the CARS program ultimately affected the timing, rather than the volume, of sales and production in the automobile industry in 2009. Specifically, the program shifted sales from September through December of 2009 to July and August, and production from the fourth quarter of 2009 and the first quarter of 2010, to the third quarter of 2009. While the program increased sales in the third quarter of 2009 by about 320,000 cars, the impact on production proved negligible on a quarterly basis, since the higher sales were offset by inventory reductions. Thus, we find that the CARS program had only a minimal direct effect on GDP, shifting roughly $2 billion from the fourth quarter of 2009 and first quarter of 2010, to the third quarter of 2009.

With regard to sales, our findings are broadly consistent with those of other recent studies, although we argue for a shorter-lived impact. For example, as late as October 28, 2009, Edmunds.com estimated that the CARS program had boosted sales, on net, by 125,000 cars. Li et al. (2010) have argued that the net sales impact remained positive into 2010.

Neither of these studies, however, examined production and inventory behavior. The key finding in our study is that despite the program's positive impact on sales in the third quarter of 2009, automobile production showed a much smaller increase in the quarter as a whole, both because a large portion of the sales increase came out of inventories, and even the modest step-up in production in July and August was partly offset by retrenchment in and September. Further, in the fourth quarter of 2009 sales and production were below where they would have been absent the CARS program, so that by early 2010 the cumulative impact of the program was nil.[34]

While the CARS program had ecological goals, its timing and limited duration suggest that its primary purpose was to stimulate economic activity. And by this measure, the program's impact appears to have been quite ephemeral. That said, the movement of sales from the fourth to the third quarter of 2009 might have had beneficial *indirect* effects—for example, by increasing revenues for automobile dealers who were struggling in the recession. In the absence of the program, some of these dealers might not have made it to the fourth quarter.

Another implication of our analysis is that inventories may be much less sluggish than many economic models—including the model used in our first counterfactual scenario—suggest.[35] Although the months' supply measure remained very elevated for about a year during the steep downturn of 2008, it had returned to its normal level by the time the CARS program was launched. Despite the large movements in sales in the second half of 2009, this measure deviated substantially from its normal level for only one month. The industry kept production and imports far below normal in the first half of 2009 to reduce inventories in line with lower sales, and then acted quickly to move production forward—both in response to the CARS

[34] While the DOT report suggests that inventory reductions were a goal of the program, presumably that was only as a means to stimulating production and employment, on the assumption that sales were not completely borrowed from the immediate future.

[35] The classic study of Feldstein and Auerbach (1976) first documented the implausibly slow estimated speeds of inventory adjustment.

program and to the sustained recovery in sales that followed—to ensure that inventories remained near target.

These findings suggest an additional caveat regarding many stimulus programs designed to give a temporary boost to spending (the recent First Time Homebuyer Credit is another example): Spending is not the same thing as output when inventories are involved; even if the desired increase in expenditures occurs, inventory reductions may undercut the broader impact on GDP.

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## Appendix: Data Sources and Details

The raw data used in our study come from Ward's Communications, a leading source of news and statistics on the automobile industry. The data consist of monthly U.S. sales, production, and the stock of dealer inventories, by model, and are expressed in physical units—specifically, the number of automobiles.

The sale of an automobile in the United States must come out of inventories, new production, or net imports (the difference between U.S. sales of imported vehicles and foreign sales of domestically produced cars). During the CARS program, dealers may have imported large numbers of vehicles that were eligible for financing rather than drawing down inventories or starting up additional production. We can track what was happening to imports during this period by using the following accounting relationship:

$$i_t - i_{t-1} + s_t = y_t + m_t - x_t$$

where $i_t$ is the stock of inventories in the U.S. at the end of month $t$, $s_t$ is U.S. sales in month t, $y_t$ is U.S. production, $m_t$ is imports, and $x_t$ is exports. This identity holds, of course, for subcategories such as CARS-eligible vehicles.

We examine the behavior of net imports during and around the CARS program and find, somewhat surprisingly, that there were no unusual movements, whether we use North American production or U.S. production (that is, calling U.S. sales of Canadian-produced cars "imports") as the basis. Thus, to the extent production did not increase when sales jumped in July and August, it was because sales were coming out of inventories, not because sales were coming out of imports. Moreover, because the sales increase was essentially borrowed from sales in September through January 2010, manufacturers did not have to increase production in those months in order to replenish inventory stocks; the lower sales accomplished that for them.

To infer U.S. production from the change in inventories plus sales in our counterfactuals, we estimated the following relationship between $i_t - i_{t-1} + s_t$ and $y_t$ over the period January 1994 to June 2009:

$$\ln(y_t) = -0.724 + 1.039\ln(i_t - i_{t-1} + s_t) - 0.001224t$$

This had an $R^2$ of 0.936 and a Durbin-Watson statistic of 1.97.

One further data note: To supplement our analysis, we use data specific to the cash-for-clunkers program from the Department of Transportation, available at http://www.cars.gov. The Department provides a transaction-level database that reports details of the vehicles traded in under the cash-for-clunkers program as well as details of the vehicles purchased.

Table 1: Overview of the Link Between Cash-for-Clunkers Rebates and MPG

| **Trade-in Vehicle** | **New Vehicle** | | | **Rebate** |
|---|---|---|---|---|
| | type | minimum mpg | difference between new and trade-in | dollars |
| Automobile | Automobile | 22 mpg | 4-9 mpg | 3,500 |
| | | | >= 10 mpg | 4,500 |
| | Category 1 Truck | 18 mpg | 2-4 mpg | 3,500 |
| | | | >= 5mpg | 4,500 |
| Category 1 & 2 Truck | Automobile | 22 mpg | 4-9 mpg | 3,500 |
| | | | >=10 mpg | 4,500 |
| | Category 1 Truck | 18 mpg | 2-4 mpg | 3,500 |
| | | | >= 5mpg | 4,500 |
| Category 2 Truck | Category 2 Truck | 15 mpg | 1 mpg | 3,500 |
| | | | >=2 mpg | 4,500 |
| Category 3 Truck | Category 2 Truck | 15 mpg | n.a. | 3,500 |
| | Category 3 Truck | n.a. | n.a. | 3,500 |

Notes: Automobiles and Category 1 and 2 trucks being traded in must have mpg <= 18.

Category 1 Truck: SUVs with a Gross Vehicle Weight Rating (GVWR) of less than 8,500 pounds , Pickups with a GVWR† of less than 8,500 pounds and a wheelbase of 115 inches or less, and Passenger vans and cargo vans with a GVWR of less than 8,500 pounds and wheelbase of 124 inches or less.

Category 2 Truck: Pickups with a GVWR of 8,500 pounds or less and a wheelbase greater than 115 inches and Passenger vans and cargo vans with a GVWR of 8,500 pounds or less and a wheelbase greater than 124 inches

Cateogry 3 Truck: Very large vans, SUVs and pickup (cargo bed of 72 inches or more) trucks with GVWR 8,500-10,000 pounds.

## Table 2: Cash-for-Clunkers Financed Sales by Vehicle Type

| | CFC Sales | | | cfc sales / eligible sales | cfc sales / total sales |
|---|---|---|---|---|---|
| | July (units) | August (units) | July + August (units) | (percent) | (percent) |
| **Small Cars** | 75,508 | 171,920 | 247,428 | 45.1% | 45.1% |
| **Middle Cars** | 43,883 | 97,356 | 141,239 | 27.4% | 27.0% |
| **Large Cars** | 292 | 840 | 1,132 | 4.5% | 3.0% |
| **Luxury Cars** | 1,291 | 4,708 | 5,999 | 8.1% | 4.2% |
| **CUV** | 54,702 | 111,456 | 166,158 | 36.6% | 35.1% |
| **SUV** | 5,913 | 17,742 | 23,655 | 19.8% | 16.3% |
| **Pickup** | 22,330 | 49,133 | 71,463 | 25.1% | 25.1% |
| **Van** | 4,826 | 11,483 | 16,309 | 19.2% | 16.4% |
| **Total** | 208,745 | 464,638 | 673,383 | 32.0% | 29.9% |

Note: “cfc sales” stands for sales that received a cash-for-clunkers rebate, “eligible sales” stands for sales of cars eligible for a rebate. There were 677,081 cfc sales in the original data. After cleaning the data (e.g. dropping observations with "unlisted" model names) there were 673,383 cfc sales.

Table 3: Parameter Estimates for Cointegrating Vectors

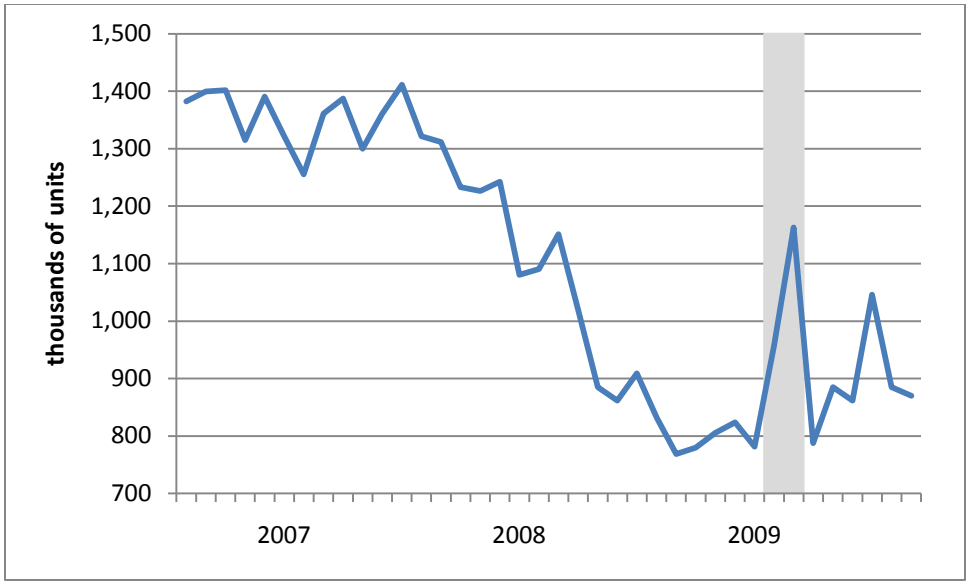
| $\beta$ | $\gamma_s$ | $\gamma_i$ |
|---|---|---|
| 1.046<br>(0.061) | 0.137<br>(0.051) | -0.124<br>(0.029) |

Table 4: Production Impact of CARS, Alternative Scenarios

| | Scenarios | | |
|---|---|---|---|
| Date | 1 | 2 | 3 |
| 2009Q3 | 287,000 | 287,000 | 84,000 |
| 2009Q4 | 45,000 | –196,000 | 5,000 |
| 2010Q1* | –22,000 | –100,000 | –100,000 |

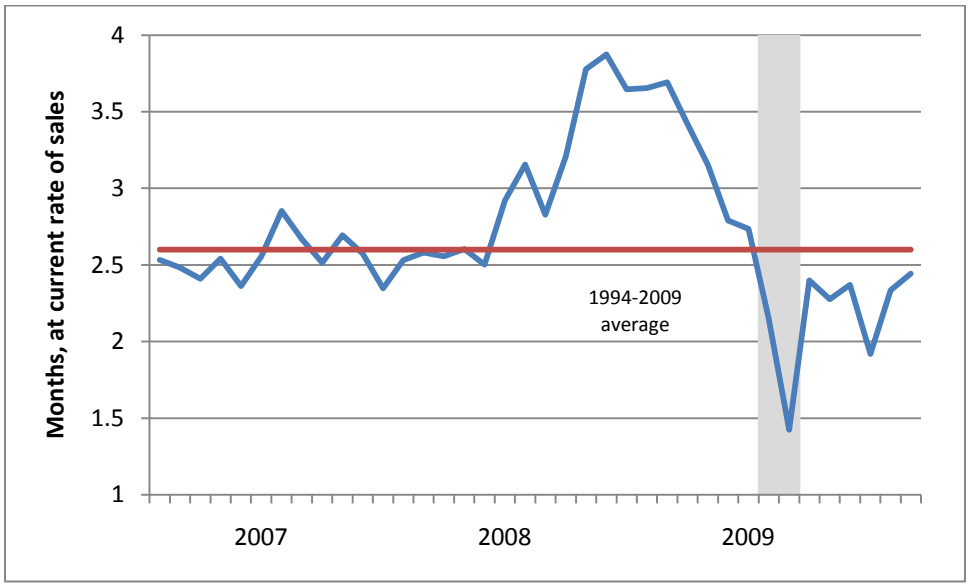
*Extrapolating based on data from January and February

**Figure 1: U.S. Automobiles (seasonally adjusted)**



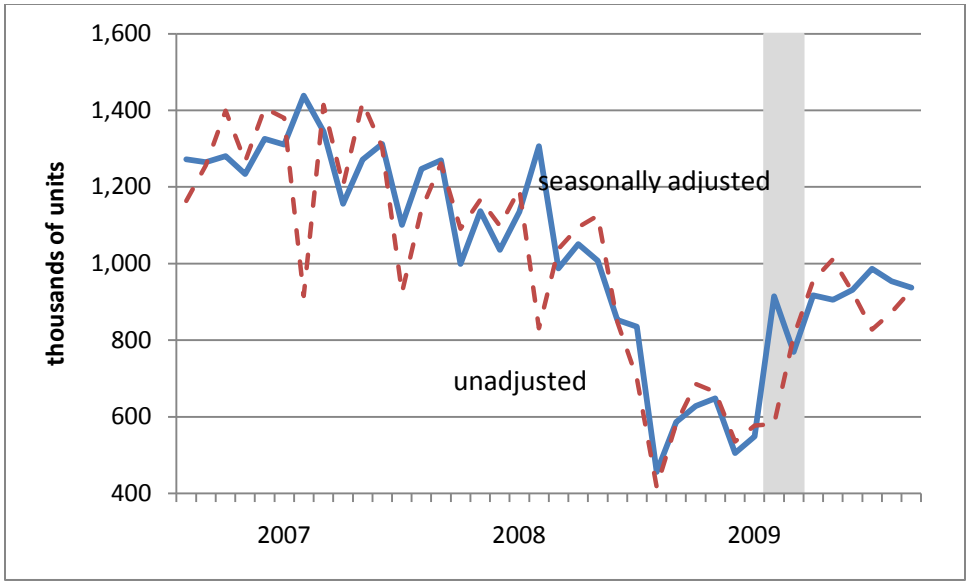

Source: Ward's Communications.
Note: The shaded area indicates the months when the CARS program was in effect.

**Figure 2: Months' Supply of U.S. Automobiles (seasonally adjusted)**



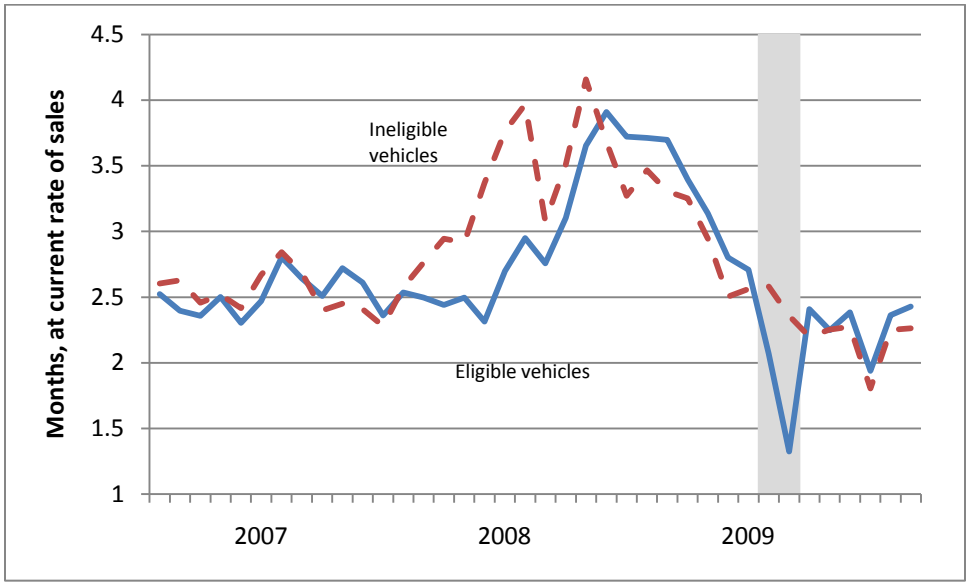

Source: Ward's Communications; authors' calculations.
Note: The shaded area indicates the months when the CARS program was in effect.

## Figure 3: U.S. Automobile Production



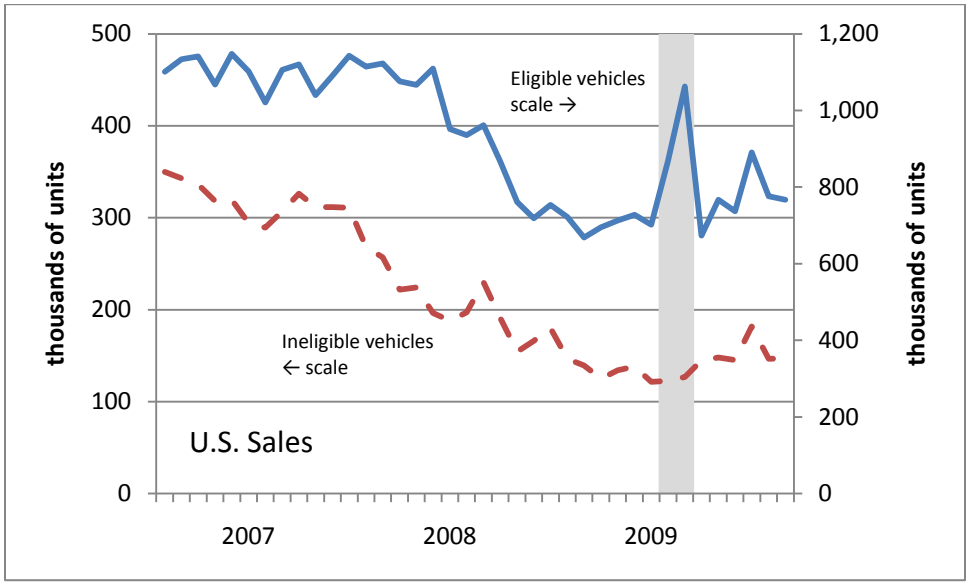

Source: Ward's Communications; authors' calculations.
Note: The shaded area indicates the months when the CARS program was in effect.

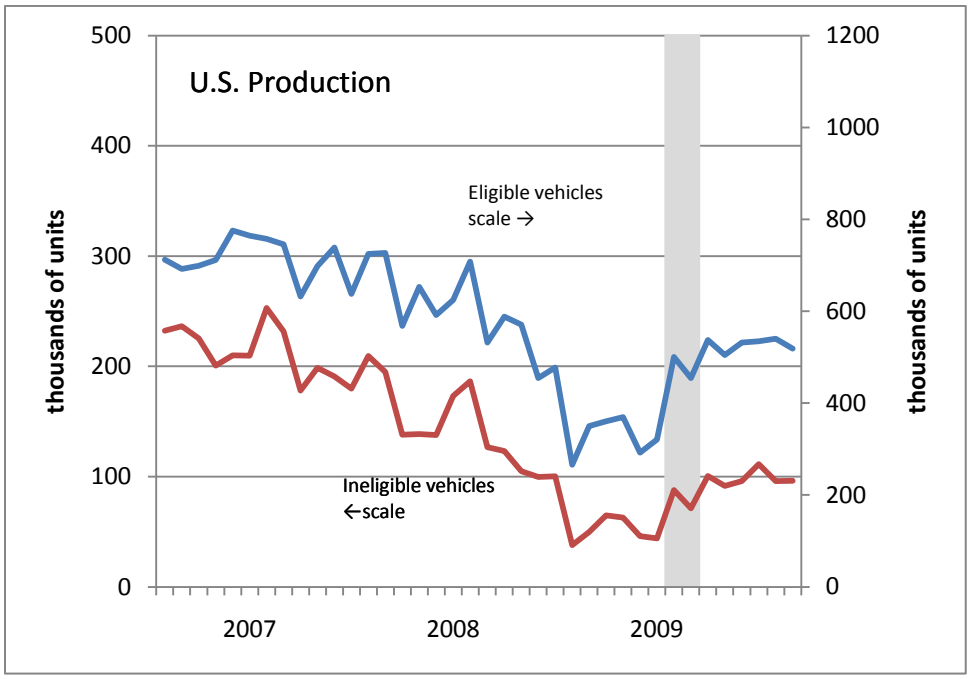
## Figure 4: Months' Supply of U.S. Automobiles, Eligible and Ineligible Vehicles




Source: Ward's Communications; https://www.edmunds.com; authors' calculations.
Note: "Eligible vehicles" are those that qualified for a rebate under the CARS program; "ineligible vehicles" did not meet the criteria for a rebate. The shaded area indicates the months when the CARS program was in effect.

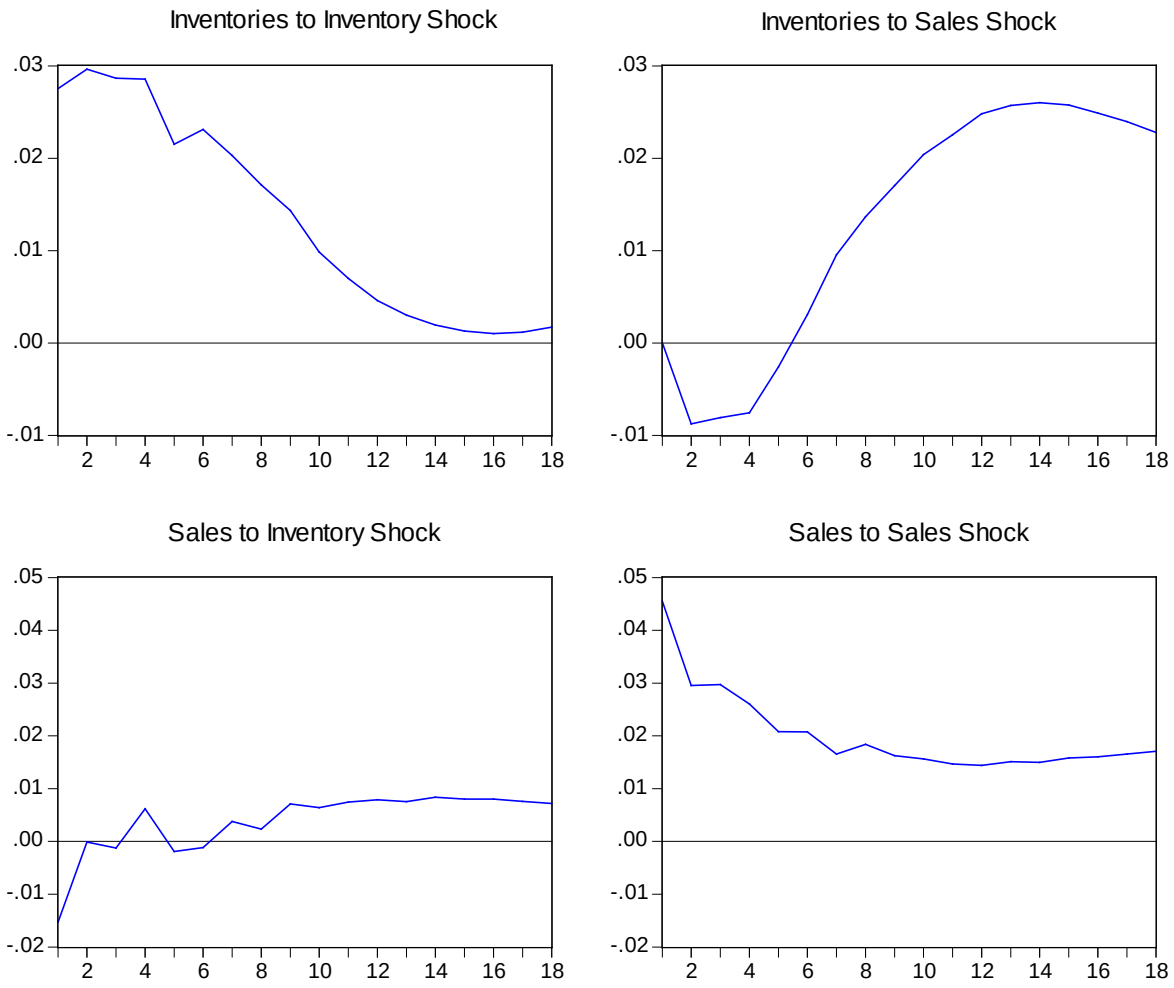
**Figure 5: U.S. Automobile Sales and Production, Eligible and Ineligible Vehicles**



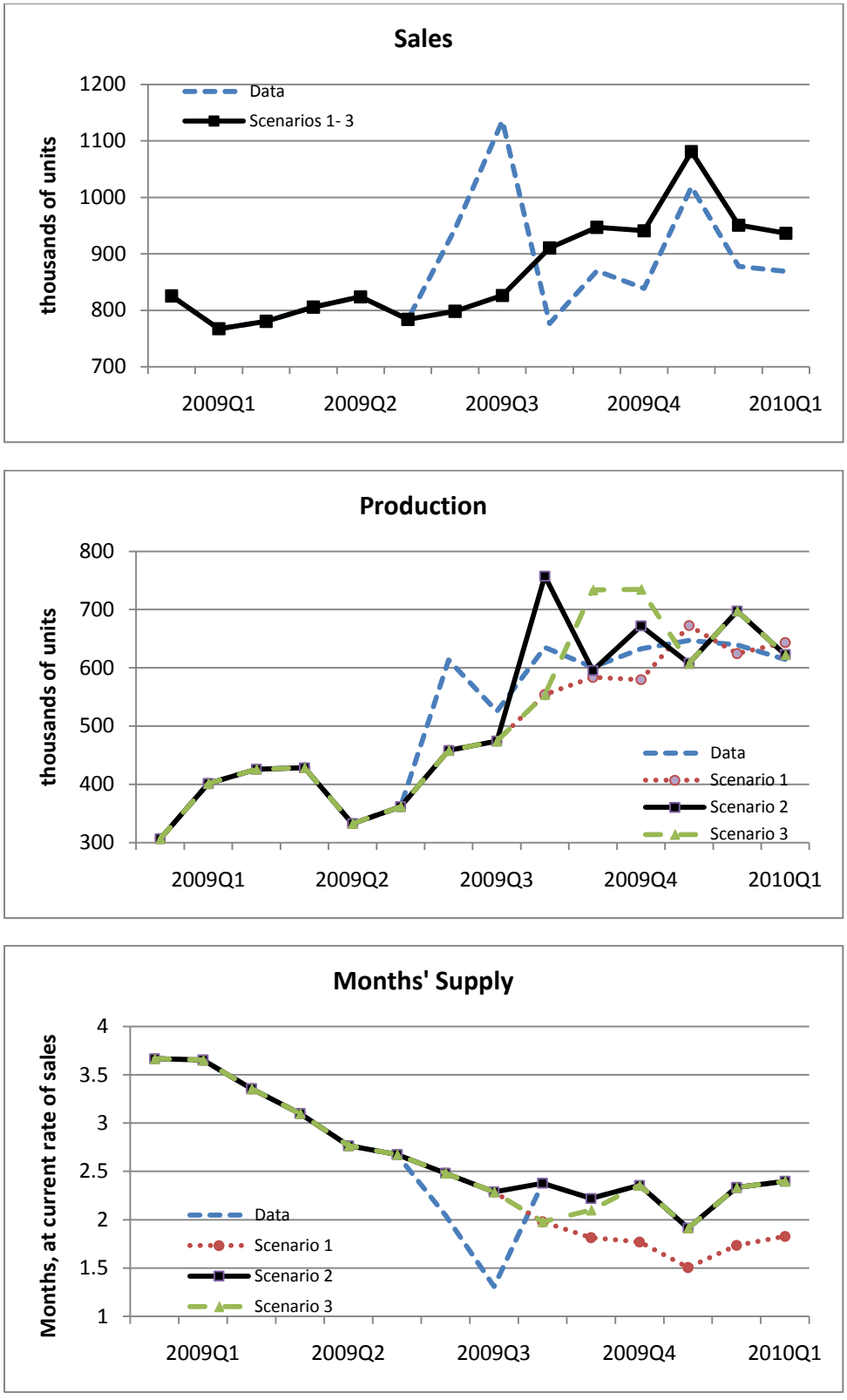

Source: Ward's Communications; https://www.edmunds.com; authors' calculations.
Note: "Eligible vehicles" are those that qualified for a rebate under the CARS program; "ineligible vehicles" did not meet the criteria for a rebate. The shaded area indicates the months when the CARS program was in effect.

Figure 6: Impulse Response Functions from Vector Error Correction Model



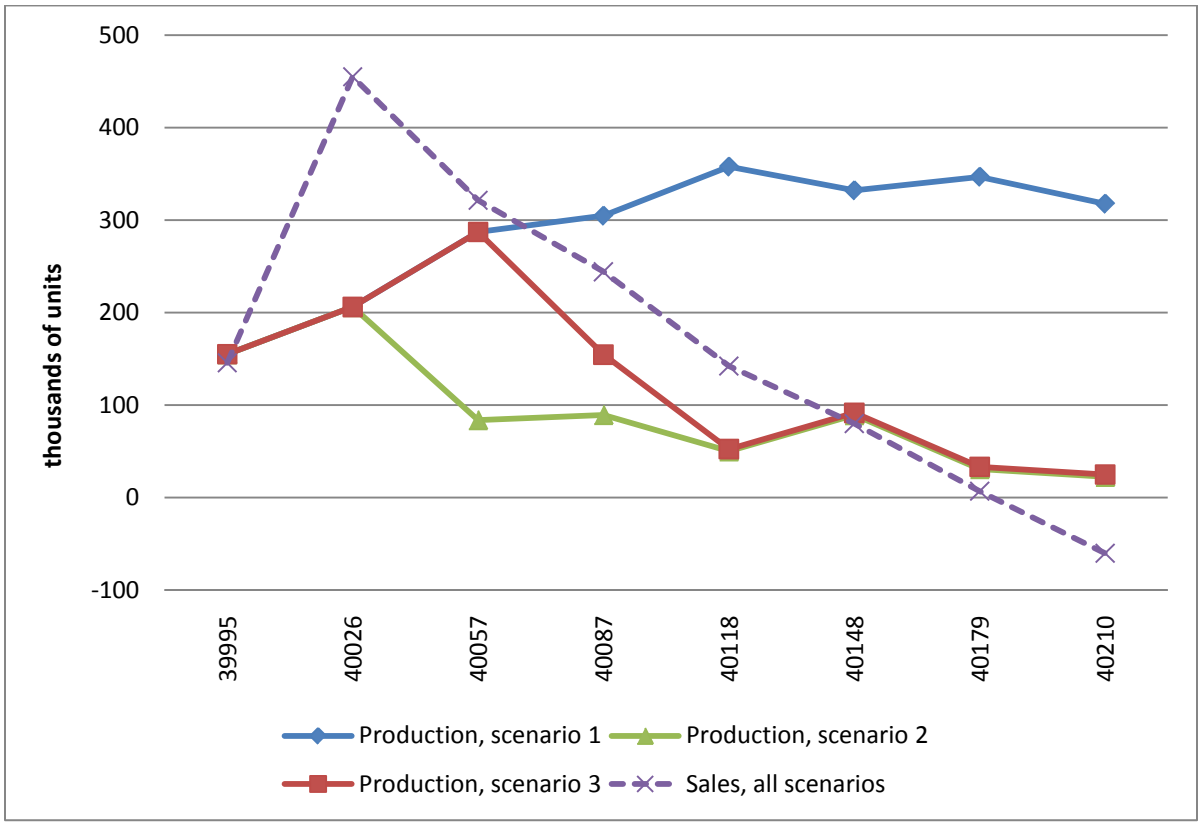

Note: Response to Cholesky One S.D. Innovations. Variables are in logarithms.

**Figure 7: Impact of CARS Program on U.S. Sales, Production, and Inventories**




Source: Ward's Communications; https://www.edmunds.com; authors' calculations.

**Figure 8: Cumulative Net Impact of CARS Program**




Source: Ward's Communications; https://www.edmunds.com; authors' calculations.
Note: A data point equals the cumulative sum of past differences between actual sales (production) and the sales (production) predicted under the scenario.