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Gasoline savings from clean vehicle adoption

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ABSTRACT

Conventional counterfactuals used in literature may underestimate fuel savings from clean vehicle adoption, thus overestimating the costs of securing associated environmental benefits. Using a large-scale nationally representative sample of U.S. new car buyers, we propose a choice model-based counterfactual approach to predict what consumers would purchase if clean vehicles were unavailable. We find that gasoline consumption under a no clean vehicle scenario increases by 1.7%, compared with 1.1% based on a conventional counterfactual. The conventional counterfactual overestimates the cost of gasoline savings from clean vehicle adoption incentives by $1.16 (27%) per gallon compared with the choice model-based counterfactual.

1. Introduction

The goal of many transportation policies is to increase clean vehicle market share. However, evidence suggests that consumers most likely to purchase advanced clean vehicle, such as plug-in electric vehicles (PEVs), are early adopters and environmentally conscious (e.g., Sheldon et al., 2017; Dua et al., 2017). These consumers may therefore be more likely to 'trade up' from a hybrid to a PEV, resulting in considerably lower gains than replacing a standard, internal combustion engine (ICE) vehicle with a PEV. On the other hand, luxury PEV consumers may otherwise purchase high emitting, high performance vehicles. Achieving greenhouse gas (GHG) and pollution reduction goals depends not only on clean vehicle market share but also on which vehicles are taken off the road as a result of clean vehicle sales. Failure to account for such counterfactuals may result in significant over- or underestimates of environmental benefits of clean vehicles. Here we estimate a detailed vehicle choice model to provide a better counterfactual than the existing literature.

Complicating the analysis of a counterfactual fleet is the impact of Corporate Average Fuel Economy (CAFE) and Environmental Protection Agency's recent GHG standards, which regulate carbon dioxide emissions from automobiles under the Clean Air Act. The CAFE and GHG standards set specific sales-weighted fuel economy and GHG emissions targets for automakers with the goal of improving energy use and reducing emissions. PEV sales help auto manufacturers meet CAFE standards. In a counterfactual world without PEVs, auto manufacturers would still have to meet CAFE and GHG targets, meaning that in theory, fleet fuel economy could not decrease below the targets, at least in the medium and long run. Nevertheless, since CAFE standards vary by vehicle size, a change in the vehicle class mix could still impact fleet fuel economy. Additionally, gasoline savings from PEV adoption depends not only on which ICE vehicles are taken off the road, but also on how much those vehicles are driven.

In this paper, we fill the gap in the literature on environmental benefits of clean vehicles by predicting a counterfactual fleet and estimating fuel savings from clean vehicle adoption. Our nationally representative sample of nearly 275,000 new vehicle purchases in the U.S. in 2015 includes household level demographic and attitudinal variables. Linking these data to a database of vehicle characteristics, we estimate an innovative vehicle choice model that incorporates consumer heterogeneity, resulting in more precise market share estimates. Using this model, we predict national vehicle sales at the make-model level assuming unavailability of 1) PEVs and 2) PEVs and hybrid vehicles (HEVs). We use these predictions to construct counterfactual fleet fuel economy and gasoline consumption for both scenarios.

Results suggest that if PEVs, which account for 0.81% of the 2015 market share, were not available, fuel economy of cars would decrease nearly 1% and that of light trucks would drop by 0.23% for a total decline in fleet fuel economy of 0.60%. If PEVs and HEVs, which jointly account for 3.38% of the 2015 market share, were not available, fuel economy of cars would decrease by 2.49% and that of light trucks would drop by 0.37% for a total decline in fleet fuel economy of 1.68%. Since many would-be PEV and HEV buyers would otherwise purchase a larger vehicle, an absence of PEVs and HEVs would lead to a shift in the vehicle class mix towards light trucks, which are subject to less stringent fuel economy standards. Lastly, since PEV and HEV consumers also

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tend to drive more miles, in the absence of clean vehicles gasoline consumption rises by 1.71%, greater than the decrease in fleet fuel economy.

Together, these results imply that clean vehicle technology has still led to a significant reduction in gasoline consumption. Finally, we estimate greater increases in fuel economy and decreases in gasoline consumption relative to counterfactuals relied upon in existing literature ('conventional counterfactuals'). A simple calculation estimates that the cost of the gasoline savings resulting from PEV adoption incentives to be $4.31 per gallon, assuming a vehicle life of approximately 16 years (Davis et al., 2013). While relatively expensive, it is significantly less than the $5.47 per gallon we estimate using conventional counterfactuals.

2. Background

Federal, state, and local governments in the U.S. offer a variety of incentives to promote clean vehicle adoption. There is a federal tax credit for PEVs and a dozen states offer additional financial incentives to PEV buyers in the form of rebates, tax credits, and sales tax exemptions. Local incentives include subsidized battery recharging stations, preferred parking, and access to high occupancy vehicle lanes. These policies are generally intended to decrease carbon dioxide emissions as well as to reduce local air pollution such as sulfur dioxide and nitrogen oxides.

An emerging literature attempts to quantify environmental benefits of PEVs. Archsmith et al. (2015) estimate adoption of a PEV results in total present day environmental benefits of $425 (in western states) in terms of a reduction in GHG emissions. Holland et al. (2016) estimate environmental benefits of PEVs, including both reductions in local air pollution as well as reductions in GHG emissions. They find benefits as large as $2800 per PEV, depending on the carbon intensity of electricity generation, which varies by region. To estimate these pollution reductions, both studies must rely on a counterfactual to PEVs. For example, Archsmith et al. (2015) use average values for midsize vehicles to calculate their counterfactual gasoline mileage. Holland et al. (2016) use the ICE vehicle that is most similar to each PEV model in the analysis. The counterfactual for the Ford Focus PEV is the conventional Ford Focus and the counterfactual for the Tesla Model S is the BMW 740.

Zivin et al. (2014) estimate marginal emissions of electricity demand to assess impacts of PEVs on carbon emissions. They also find that PEVs are associated with lower carbon emissions in western states than ICEs, but higher emissions in other regions, since PEVs tend to charge during off-peak hours when marginal emissions are larger. The authors compare PEVs to two alternatives: a 'comparable' economy car and a hybrid. The comparable ICE has the average fuel economy, 31 mpg, of the Toyota Corolla, Honda Civic, Chevrolet Cruze, and Ford Fiesta. The HEV counterfactual is the Toyota Prius.

Lacking knowledge of alternative purchase decisions, these are logical counterfactuals. However, estimated environmental benefits from a PEV purchase may be overstated if the consumer would otherwise purchase an HEV or highly fuel efficient vehicle. Likewise, estimated environmental benefits from a PEV purchase may be understated if the consumer would otherwise purchase a higher-emitting larger or premium vehicle.

To encourage the development of clean vehicle technologies, the CAFE/GHG standards are less stringent for manufacturers who produce alternative fuel vehicles such as PEVs. Jenn et al. (2016) find that each alternative fuel vehicle sold in place of a conventional vehicle therefore weakens the fleet efficiency standards, resulting in an increase of up to 60 t of carbon dioxide and 7000 gallons of gasoline consumption. Existing work to estimate environmental benefits of PEVs tends to overlook the point made by Jenn et al. (2016) that if there were no PEVs, the counterfactual fleet would still have to comply with CAFE/GHG standards. For example, if PEVs were no longer available, the average fuel economy of midsize sedans might increase or else the auto manufacturers might use price induced sales shift strategies in order to be in compliance.

Table 1
Summary statistics.

	Mean	StDev
Price ($)	30,581	12,335
Fuel Economy (mpg)	25.06	8.96
Horsepower	232	85
Fuel Capacity (gal)	18.4	5.3
Curb Weight (lbs.)	3831	896
Wheel Base (in.)	113	13
Track Width (in.)	63.7	3.2
Range (mi)	426	77
HEV	2.57%	
PHEV	0.29%	
BEV	0.52%	
Convertible	0.74%	
Coupe	3.33%	
Full-Size	0.18%	
Hatchback	5.01%	
Minivan	2.98%	
Pickup	12.55%	
SUV	32.79%	
Sedan	34.06%	
Wagon	8.35%	
Monthly VMT	1116	843

3. Data

The primary dataset, which was leased from Strategic Vision Incorporated, is from a survey of households that purchased a new vehicle in model year 2015 (October 2014 – September 2015). It is a representative sample of the U.S. national new vehicle market and includes approximately 275,000 observations along with weights that correspond to the ratio of the number of buyers for each make and model in the national market to the number of respondents for the same make and model in the survey. The survey collects information on household characteristics and attitudes. It also includes information on the new vehicle purchased, including the vehicle identification number (VIN) obtained by Strategic Vision Incorporated from either the automakers or IHS Polk.[1] Household characteristics include respondent's age, education level, household income, and number of miles the respondent intends to drive his or her new vehicle each month. Although the dataset is not state-wise representative, we do know each respondent's state of residence as well as whether he or she lives in a metropolitan, suburban, rural, or farming area.

Although some households self-report new vehicle characteristics, to ensure accuracy of vehicle attributes, we match new vehicles to their characteristics on 11-digit VIN using Edmunds database of vehicle characteristics. Vehicle characteristics include manufacturer's suggested retail price (MSRP), fuel economy (EPA unadjusted/laboratory values),[2] horsepower, fuel capacity, curb weight, wheel base, track width, and body type. For PEVs, fuel economy is reported in miles per gallon (mpg) equivalent, which is the average distance traveled per unit of energy consumed normalized to the energy content of a gallon of gasoline. EPA calculations assume that in terms of energy use, 1 gallon of gasoline is equivalent to 33.7 kW-hours of electricity. For PEVs, the data also include electric range. With regard to fuel economy, for the vehicle choice model, this is calculated as the harmonic mean of city

[1] More information on the survey can be obtained by contacting Strategic Vision Incorporated at www.strategicvision.com.

[2] In practice, fuel economy tends to be lower (and fuel consumption greater) than in laboratory tests. Thus, the overall real-world savings would be lower in absolute terms (and associated costs higher) than our estimates. However, relative differences between our estimates and conventional counterfactuals would remain.