Policy Monitor

Improving Incentives for Clean Vehicle Purchases in the United States: Challenges and Opportunities

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Introduction

In recent decades, federal and state policymakers in the United States have adopted various policy incentives to induce drivers to purchase advanced clean vehicles, aimed at reducing air pollution and greenhouse gas (GHG) emissions. Although these policies initially focused on hybrid and natural gas vehicles, they now also support purchases of plug-in electric vehicles (PEVs), a new generation of which became available in 2010. The development of fuel-cell and other emerging vehicle technologies, currently in the early stages of commercialization, may encourage policymakers to implement the next generation of clean vehicle purchase incentives within a few years.

Federal and state vehicle incentive policies differ along many dimensions. They take many forms, including rebates, income tax credits, sales tax exemptions, and fee exemptions. Some policies target specific vehicle technologies, such as offering differential incentives for pure battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) or by varying the incentive on the basis of battery capacity. Other policies target specific types of drivers (e.g., based on their residence in a high air pollution area). Finally, some policies offer financial incentives only for drivers' vehicle replacement decisions, whereas others are evolving toward combining retirement and replacement decisions (e.g., "cash for clunkers" programs and incentives for the purchase of an advanced clean vehicle).

The goal of this article is to evaluate the effectiveness of current vehicle incentive policies in the United States and to suggest improvements for this broad class of policy instruments. To evaluate the effectiveness of policies, I examine three broad questions. First, what factors influence the ability of the policies to deliver actual cost savings to drivers? Second, how effectively do the policies target the externality that they are intended to address? Third, how can we improve the cost effectiveness of these policies in practice?

The remainder of the article is organized as follows. In the next section, I provide background on the growth in the early PEV market and present evidence on the types and value of vehicle purchase incentives adopted by the U.S. federal government and state governments. Then I examine several potential obstacles that may prevent these incentives from ultimately offsetting

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consumers' cost of purchasing PEVs. Although these obstacles vary across types of incentives, they may include low policy salience, complex or limited eligibility, higher-than-expected redemption costs, and market incidence conditions that may enable manufacturers or dealers to capture part of their value. This is followed by a discussion of the challenges that arise as policymakers seek to use a single policy to target multiple externalities. Next I discuss the limitations of these "second-best" policies to efficiently maximize welfare and suggest several modest and practical steps aimed at making these policies incrementally more efficient. To illustrate how such policies might work in practice, I focus on California's experience. Finally, I explore options for improving the cost effectiveness of vehicle purchase incentives. I conclude by suggesting specific policy design improvements that would enhance economic efficiency and cost effectiveness and then briefly discuss future research needs.

Plug-In Electric Vehicles: Market Trends and Policy Incentives

A brief overview of the development of the PEV market and the types of purchase incentives offered by federal and state governments will set the stage for the more detailed analysis I present later. PEVs include BEVs, which rely solely on off-board electricity, and PHEVs, which can use both gasoline and off-board electricity.

Sales and Models of Plug-In Electric Vehicles

Sales of PEVs have grown faster than sales of hybrids during the first four years of each market. Unlike the early hybrid market, which was dominated by two models (the Toyota Prius and Honda Insight), the PEV market has been characterized by more models across multiple body types and vehicle classes. To illustrate, table 1 presents data on PEV sales in California by release year and model between 2010 and 2014. I focus on California because, with more than 40 percent of the U.S. market, California's results are likely to reflect the aggregate results for other states. As shown in table 1, almost 120,000 PEVs across more than twenty-eight models were sold in California during this time period, and over the last three years the number of new models released each year has remained fairly constant. Based on automakers' announcements, this rate is expected to continue through 2016. Although over half of these new models are hatchbacks or smaller coupes, larger sedans, coupes, and SUVs have also been introduced and are beginning to infiltrate these product niches (e.g., KIA's Soul and Tesla's Model X). In addition, several traditional luxury brands (e.g., Porsche, BMW, and Mercedes) entered the PEV market in 2014.

Despite the large number of models indicated in table 1, most of the volume in this market is concentrated in just a few models. The final column of the table presents a top-ten ranking by sales. Early entrants in 2010, including the Chevrolet Volt (ranked first), Nissan LEAF (ranked second), and the Tesla Model S (ranked fourth), lead the market in total sales, with PEV versions of long-standing models (e.g., the Toyota Prius) accounting for the remaining models ranked in the top ten. The models with very low sales include "compliance cars"—that is, vehicles introduced solely to satisfy California's Zero Emission Mandate (e.g., Honda Fit, Mitsubishi I Miev) or models that automakers hoped to scale but that have not yet found a receptive consumer base (e.g., Ford Focus, Volkswagen Golf).

Table 1 Sales of PEV models in California, 2010–2014

Release year	Model	Body	Number of vehicles sold	Top 10 ranking
2010	Tesla Roadster	Luxury coupe	156	
	Nissan Leaf	Hatchback	25,206	2
	International eStar	Van	37	
	Chevrolet Volt	Hatchback	26,197	1
2011	Smart Fortwo	Coupe	2,122	9
	Azure Transit Connect	Van	59	
	Mitsubishi I-MIEV	Hatchback	255	
2012	BMW Active E	Luxury coupe	457	
	Ford Focus	Hatchback	1,209	
	Tesla Model S	Luxury hatchback	15,521	4
	Honda Fit	Hatchback	92	
	Toyota RAV4 EV	SUV	2,221	8
	Fisker Karma	Luxury sedan	270	
	Toyota Prius Plug-In	Hatchback	18,163	3
2013	Chevrolet Spark	Hatchback	1,338	10
	FIAT 500	Hatchback	7,736	6
	Ford C-MAX	Hatchback	6,002	7
	Honda Accord	Sedan	589	
	Ford Fusion	Sedan	7,945	5
2014	BMW 13 BEV PLU	Hatchback	896	
	Mercedes-Benz B-Cclass BCL	Hatchback	565	
	KIA Soul EV	SUV	286	
	Cadillac ELR	Luxury coupe	302	
	Porsche Panamera S HYB	Luxury sedan	202	
	McLaren P1 PLU	Luxury coupe	15	
	BMW 13 REX HYB	Hatchback	1,040	
	Porsche 918 SPY PLU	Luxury coupe	14	
	Volkswagen Golf SPR PLU	Hatchback	219	

Source: Author's calculations

Types and Size of Policy Incentives

Both the federal government and many states currently offer vehicle purchase incentives.[1] The federal government offers a tax credit based solely on the vehicle's battery capacity. To qualify, a vehicle must have a capacity of at least 4 kilowatt hours (kWh) and be capable of being recharged from external sources. The federal tax credit is $2,500, plus $417 for a vehicle that has a battery with at least 5 kWh of capacity, with an additional $417 for each additional kWh, up to $7,500.

State incentives to purchase PEVs have taken several forms (see summary in table 2). Six states currently offer rebates to drivers, who must apply after they purchase a PEV. Seven states

[1]Although vehicle purchase incentives are the most visible policy associated with PEV adoption, other incentives have also been offered, including access to high-occupancy vehicle lanes, subsidies for the purchase of charging stations, and free parking.

Table 2 Type and frequency of policy instruments by state

Policy instrument	States
Rebates	CA, IL, MA, NY, PA, TX
Tax credit	CO, GA, LA, MD, SC, UT, WV
Sales tax exemption or reduction	CO, NJ, WA
Fee exemptions or reduced fee	AZ, IL

Source: Author's calculations

offer income tax credits. Three states offer vehicle sales tax exemption or reductions. Two states offer other forms of registration fee exemptions or reductions.

The basis for calculating the size of the incentive offered to a PEV buyer varies across states. One way to compare state incentive policies is to examine the maximum incentive level available for an eligible PEV purchase. Figure 1 indicates the maximum rebate, income tax, or sales tax incentive available in 2014, which ranges from a high of $7,000 in West Virginia to a low of $500 in Utah, with about $2,500 being the median incentive size.

Factors Affecting the Actual Cost Savings from Vehicle Purchase Incentives

The stated goal of these federal and state policies is to reduce the effective purchase price of a PEV. However, ensuring that such cost savings actually accrue to drivers is not as straightforward as it may first appear. In particular, policymakers must consider the following factors: (1) the salience (or role) of purchase incentives in consumers' decision making, (2) the eligibility requirements for the incentive, and (3) the incidence (or economic consequence) of the subsidy for drivers and dealers, respectively.[2]

Salience of Alternative Incentives in Vehicle Purchase Decision

The recent literature on salience focuses on the extent to which purchase incentives are visible, relevant, and ultimately influence consumers' decision processes and outcomes (Chetty, Looney, and Kroft 2009; Gabaix and Laibson 2006). In the PEV context, this literature suggests moving the incentive forward in the decision process so the incentive is available at the time of the purchase decision. This suggests a policy preference for rebates and sales tax reductions, which could be made available at the point of sale, over tax credits and registration fee exemptions, which would become available after the sale has occurred. Shifting rebates and sales tax reductions to the point of sale could also reduce the loan amount that consumers would have to finance. However, research has shown that consumers respond less to sales tax reductions than to reductions in the offered price (Chetty, Looney, and Kroft 2009).

In addition to salience, consumers' decisions are influenced by transaction or redemption costs. These costs vary in terms of their timing, complexity, and the labor costs of applying for different incentives. For example, sales tax and registration exemptions do not involve any action by consumers and thus have no transaction or redemption costs. In contrast, consumers must apply for rebates or income tax credits, which may diminish the expected value of these

[2]The effects of these factors may also differ for vehicle leasing versus vehicle ownership.

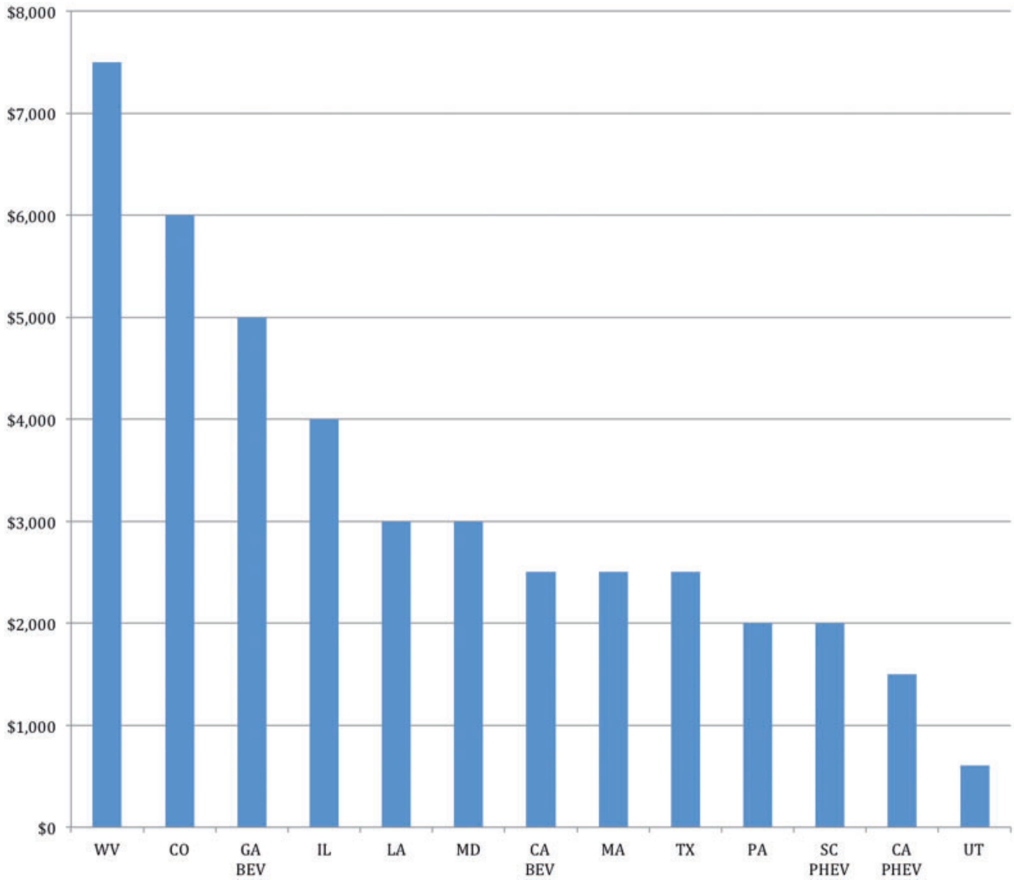

Figure 1 Maximum possible incentive per vehicle by state, 2014
Notes: Unless otherwise indicated, both BEVs and PHEVs are eligible for these incentives.
Source: Author's calculations

incentives (Demirag, Keskinocak, and Swann 2011). Evidence on the effects of these redemption costs on incentive uptake is scarce and indirect. Whether they are due to low salience or modest redemption costs, uptake rates for rebates and tax incentives appear to be surprisingly low given their face value. For example, in California, there has been an average redemption rate of 72 percent for rebates (valued at between $1,500 for PHEVs and $2,500 for BEVs) over the first four years of the market.[3] Sallee (2011) estimated that only 15 percent of hybrid drivers failed to apply for the hybrid federal tax credits.

Eligibility Requirements

Eligibility for some types of purchase incentives is limited because of interactions between the purchase incentives and other tax policies (e.g., income taxes). For example, low-income buyers may not have a tax burden that they can offset. Higher-income buyers may not be eligible if a policy disqualifies those buyers that are subject to the alternative minimum tax;[4] this was the

[3]As of 2014, more than 88,871 rebates had been issued out of an estimated 113,754 vehicles that were eligible. See Air Resources Board (2014b) and http://energycenter.org/clean-vehicle-rebate-project/rebate-statistics.
[4]The alternative minimum tax applies only to higher-income households in the United States.

case with many hybrid incentives in the 2000s. Dealerships have learned to capture the value of both the tax exemptions and the rebates by leasing vehicles to buyers. This innovation has significantly lowered leasing payments for several PEV models.

Incidence of Incentives

The incidence (or economic value) of vehicle purchase incentives captured by drivers and dealers and/or manufacturers[5] is important for assessing the effectiveness of these policies. Incidence analysis assumes that manufacturers or dealers will have an incentive to strategically adjust a vehicle's price in response to vehicle purchase incentives. Whether market conditions will allow manufacturers and/or dealers to appropriate the value of the incentive depends on the relative price elasticities of the supply and demand curves for the vehicles. In market settings where the price elasticity of demand is lower than the price elasticity of supply, dealers will be able to make price adjustments that allow them to receive a disproportionate share of the incentives. When the price elasticity of demand is higher than the price elasticity of supply, manufacturers and dealers are less able to adjust prices in a competitive market.

The empirical evidence on the incidence of vehicle purchase incentives for advanced clean vehicles comes from analyses of hybrid vehicle tax incentives. For example, Sallee (2011) examines the Toyota Prius and finds that drivers capture nearly all of the available tax incentives. In contrast, Boyle and Matheson (2009) examine five vehicle models and find that dealers or manufacturers capture more than 75 cents of each dollar of tax incentive. Busse et al. (2013) emphasize the conditions under which (and the extent to which) manufactures versus dealers (via bargaining) are able to influence final vehicle prices. More specifically, they examine the incidence of dealer- versus manufacturer-controlled incentives and find that between 31 and 81 cents of each dollar goes to the buyer depending on the type of incentive. These inconsistent findings suggest that more research is needed on the factors that influence the incidence of incentives in order for policymakers to be confident that the targets of their incentives are actually receiving them. Currently there is no empirical evidence on how the type of incentive (e.g., rebates, sales tax exemption, income tax credits) affects the incidence of an incentive.

Although at first glance, designing a vehicle incentive that effectively reduces the consumer's purchase price may appear to be a simple task, the discussion here has revealed that the task can actually be quite complicated because incentives may possess subtle properties. For example, consumers may not find incentives to be salient because their value is not evident at the point of sale. Incentives may involve redemption or transaction costs that reduce uptake, and incentive eligibility rules may be complex or exclusionary. Finally, even if these impediments are addressed, the incidence of the incentive may be such that producers are able to capture part of the value of the incentive by adjusting retail prices.

[5]As noted by Busse et al. (2013), the effective vehicle price is jointly determined by the manufacturer, who sets the manufacturer's suggested retail price (MSRP), and the dealer, who controls a variety of incentive promotions (e.g., rebates, cash back).

Challenges to Designing Incentives in the Presence of Multiple Externalities

There are several challenges to designing a vehicle purchase incentive that is aimed at increasing economic efficiency. One challenge arises from the fact that policymakers may be using one policy incentive to target several externalities. These externalities may include locally varying air pollutant damages, GHG damages, or suboptimal knowledge spillovers across both drivers and automakers (Air Resources Board 2009, 2014b).

For example, in policy discussions in California and at the federal level, the most commonly cited externalities are those associated with regional air pollution exposure and global climate change (Air Resources Board 2009; Congressional Budget Office 2012). Both types of externalities arise from the combustion of transportation fuels, which produces emissions. In the context of a vehicle purchase decision, emissions and the associated social damages are a function of the fuel efficiency of both the retirement vehicle and the purchased vehicle, as well as the number of vehicle miles traveled. However, there is an important difference between these two externalities that may influence policy development. More specifically, the externalities associated with regional air pollution exposure arise from emissions that are nonuniformly mixed, with impacts on local public health and ecosystems. In contrast, carbon emissions are uniformly mixed, with no local impacts.

Researchers have recently started estimating the value of the avoided emissions in terms of both air pollution health impacts and climate impacts (Alberini, Harrington, and McConnell 1996; Babaee, Nagpure, and DeCarolis 2014; Michalek et al. 2011; Muller and Mendelsohn 2007; Tessum, Hill, and Marshall 2014). The more rigorous analyses account for the geographic heterogeneity in the pollution intensity associated with electricity generation (Zivin, Kotchen, and Mansur 2014). When estimating the avoided social damages associated with PEV adoption, these analyses must account for the spatial variation in vehicle emissions avoided and aggregate health impacts (Muller and Mendelsohn 2007, 2009).

Holland et al. (2015) present the most spatially resolved and rigorous analysis of the benefits and costs of driving PEVs in various regions of the United States. They estimate that the net benefits range from a positive $3,025 in California, where air pollution damages are relatively high and electricity is relatively clean, to a negative $4,773 in North Dakota. Because they focus on evaluating the federal tax credit for PEV purchases, they calculate avoided emissions as the difference between a new PEV and a new conventional gas vehicle.[6]

The case of California illustrates the historical evolution of focusing first on regional air pollution exposure as the policy goal, followed by the more recent addition of the mitigation of global climate change. California policymakers deployed clean vehicle incentives to mitigate regional air pollution emissions long before they adopted carbon mitigation policies.[7] California first adopted clean vehicle (purchase) rebates for hybrid and natural gas vehicles (Air Resources Board 2009) in 2005, with a focus on reducing the health impacts of emissions.

[6]As I will discuss later, larger avoided emissions may be achieved if the linking and targeting of retirement and replacement incentives are able to (1) hasten the vehicle retirement decision and (2) increase the magnitude of the emissions avoided per mile driven.

[7]For a history of California's Zero Emission Vehicle program, see www.arb.ca.gov/msprog/zevprog/zevregs/zevregs.htm.

Then, citing the additional cobenefits of carbon emission reduction, the state extended these rebates to plug-in electric and hydrogen fuel cell vehicles in 2010.[8]

Researchers studying PEVs have also emphasized the externality associated with suboptimal knowledge spillovers among drivers—that is, learning by using (Struben and Sterman 2008)—and automakers—that is, learning by doing (Levitt, List, and Syverson 2013). In the context of emerging innovative product markets (Thompson 2012), early adopters may face large private (learning) costs while producing large social (learning) benefits for later adopters, which leads to knowledge spillovers and adoption rates that are socially suboptimal (Stoneman and Diederen 1994).[9]

In the specific case of PEVs, early drivers have had to install and learn to operate residential charging equipment. Early drivers of BEVs have had to learn new refueling strategies that reconcile their vehicle's electric range and their travel needs. Likewise, early vehicle manufacturers have experimented with a range of vehicle design strategies to identify how to lower production costs and increase the likelihood of consumer adoption. The cumulative knowledge generated by the early consumer adopters and producers (at considerable private costs) reduces the private costs for future adopters and producers.

However, it has been a challenge for the broader innovation literature to empirically estimate the size of the social benefits of increasing early market knowledge spillovers to their optimal levels. Designing incentives to optimize knowledge spillovers requires an understanding of who is engaged in learning and the size of the private marginal costs and benefits of learning. There are few empirical examples of such marginal analyses for new technologies or products. As in many policy settings, what is difficult to measure is often ignored. For example, the U.S. Congressional Budget Office (2012) did not even mention the externality of suboptimal knowledge spillovers as a justification for the federal tax credit for PEVs.

Internalizing each of these externalities optimally requires modifying consumers' behavior in different ways or to different degrees. This means that attempts to use a single policy instrument to target multiple externalities will result in the imperfect targeting of some of the externalities. Moreover, the socially optimal incentive level is not known for even the most studied externalities, such as regional air pollutant exposure. In studies that do estimate the optimal incentive levels (Holland et al. 2015), they are likely to vary greatly across space and time, thus requiring states to offer different incentives based on exposure and vehicle travel patterns. With these challenges to welfare maximization in mind, I will later discuss the state of the art in cost-effectiveness analysis for vehicle purchase incentives.

Vehicle Purchase Incentives as a Second-Best Policy

For externalities associated with air pollution exposure and GHG emissions, vehicle purchase incentives are second-best instruments compared with first-best cap-and-trade or tax instruments. This is because, although these incentives may alter consumers' vehicle purchase

[8]See the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118, Statutes of 2007, Chapter 750).
[9]For a more detailed discussion, see Bollinger and Gillingham 2012; Fischer and Newell, 2008; and Jaffe, Newell, and Stavins 2002.

decisions, they cannot influence consumers' decisions about how much to drive a vehicle. This means that such incentives cannot precisely target those externalities that arise in proportion to the vehicle miles traveled (e.g., local air pollution, state-wide GHG emissions). Although these policies are aimed at vehicles that will be driven the most electric miles, they are able to target only a narrow set of the relevant consumer decisions and typically affect vehicle emissions only through the driver's vehicle replacement decision.

In the remainder of this section, I explore the design of existing vehicle purchase incentives, with the goal of identifying ways to modify these policies so they more comprehensively address the traditionally targeted externalities from the transportation sector, such as air pollutants and GHG emissions. As part of the discussion, I will also highlight the properties of first-best policies, such as optimal tax or cap-and-trade programs, which, through market signals, could help optimize the timing of vehicle replacements and the rate of fleet turnover. Such first-best policies would also influence the driver's choice of a replacement vehicle and the choice of electric or gasoline fuel for that vehicle. Finally, these policies would enhance the social welfare consequences of households' future choices concerning which vehicle from the household fleet to assign to specific trips.

Basing Incentive Levels on Vehicle Attributes

Although, in theory, changes in the magnitude of the incentive should be linked to the magnitude of the targeted avoided damages, in practice, policymakers can only link the incentive's levels to the attributes of either the vehicle or the buyers. Four states (Illinois, Louisiana, Texas, West Virginia) have vehicle incentives programs that do not even consider avoided damages. In contrast, federal policy and the majority of state policies have attempted to align incentives with vehicle characteristics that are believed to be correlated with electric miles driven, such as battery size and specific electric vehicle technologies.

Incentives based on battery capacity

I focus first on rebate policy designs. For example, in Pennsylvania, BEVs and PHEVs with battery capacity equal to or greater than 10 kWh are eligible for a $2,000 rebate, whereas those with battery capacity lower than 10 kWh receive $1,000.[10] With respect to tax credits, the federal government, Colorado, Maryland, and South Carolina base the credit amount on the battery capacity of the purchased vehicle. For example, Colorado uses a formula that multiplies the battery capacity in kilowatt-hours by the vehicle purchase price, deducts the federal tax credit amount, and then divides the resulting amount by 100. Colorado consumers can receive a tax credit of up to $6,000 for both PHEVs and BEVs.[11] In Maryland, the maximum tax credit amount is $3,000, with each buyer receiving a $125 tax credit for each battery kilowatt-hour.[12] In South Carolina, only PHEVs are eligible for tax credits, with the base credit set at $667 for a car with a battery capacity of at least 4 kWh, and

[10]Pennsylvania Department of Environmental Protection. Alternative Fuels Incentive Grant Program: Alternative Fuel Vehicle (AFV) Rebates.
[11]The Electric Ride Colorado. Colorado Tax Credits. http://electricridecolorado.com/get_set/my_home/ready-your-home/colorado-tax-credits.
[12]U.S. Department of Energy. Maryland Laws and Incentives. Alternative Fuels Data Center, Office of Energy Efficiency & Renewable Energy. http://www.afdc.energy.gov/laws/all?state=MD#State%20Incentives.

consumers receiving an additional $111 for each additional kilowatt-hour, up to a total of $2,000.[13]

Incentives based on vehicle technology

Massachusetts bases its rebate on both vehicle technology and battery size. All BEVs are eligible for a $2,500 rebate, whereas PHEVs like the Chevrolet Volt and Cadillac ELR (that have a longer battery range) are also eligible for the $2,500 rebate. For PHEVs with smaller battery capacity, such as the Honda Accord and Toyota Prius, buyers are eligible for a $1,500 rebate.[14] In California, PHEVs receive $1,500 and BEVs receive $2,500, with no consideration of vehicle battery capacity.[15] In Georgia, PHEVs are not eligible,[16] whereas consumers purchasing a BEV receive 20 percent of the vehicle purchase price or a $5,000 tax credit, whichever is less.[17]

There are at least two important empirical issues concerning these efforts to align incentive levels to electric miles driven. First, there is currently no empirical evidence that (*ceteris paribus*) consumers drive BEVs more electric miles than PHEVs. Second, and related to battery size, researchers know little about whether larger battery vehicles are driven more miles than midsize battery vehicles. Given that commuting patterns indicate that the vast majority of households travel less than 40 miles per weekday (e.g., California Household Travel Survey 2012), we should expect to observe sharply diminishing returns to electric vehicle miles traveled as battery capacity (e.g., size) grows beyond some threshold. Most PHEVs have ranges between 22 and 44 miles. Thus, based solely on electric miles driven, there appears to be little evidence to support providing larger purchase incentives for BEVs than for PHEVs.

Options for Improving Alignment of Incentives with Consumer Decisions

Even if policymakers could design incentives that are correlated to electric miles driven, replacement incentives would not be first best or optimal. As noted earlier, such policies do not affect (1) when to replace one's previously owned conventional gasoline vehicle with a new vehicle; (2) which vehicle within the household fleet (e.g., PEV or conventional gasoline) to use for a given trip; and (3) when driving a PHEV, how far to travel on electric versus gasoline miles. Thus far, these incentives have been exclusively for new car buyers who are purchasing vehicles that already tend to be cleaner than the fleet average (Center for Sustainable Energy 2013). Furthermore, there is evidence suggesting that these replacement incentives may be used by drivers with preexisting green preferences who would thus have a higher-than-average likelihood of purchasing a hybrid (Sheldon et al. 2015). If this is true, it would reduce replacement incentives' marginal effect on avoided emissions.

[13]U.S. Department of Energy, Alternative Fuels Data Center, Office of Energy Efficiency & Renewable Energy. Plug-in Hybrid Electric Vehicle (PHEV) Tax Credit. http://www.afdc.energy.gov/laws/10252.
[14]Massachusetts Offers Rebates for Electric Vehicles. Eligible Vehicle List. https://mor-ev.org/eligible-vehicles-list.
[15]Center for Sustainable Energy. Clean Vehicle Rebate Project. July 2014. https://energycenter.org/clean-vehicle-rebate-project.
[16]U.S. Department of Energy, Alternative Fuels Data Center, Office of Energy Efficiency and Renewable Energy. Alternative Fuel Vehicle (AFV) Tax Credit. http://www.afdc.energy.gov/laws/5424.
[17]DMV.org. Low Emission Vehicle (LEV) and Zero Emission Vehicle (ZEV) Tax Credit. Green Driver State Incentives in Georgia. http://www.dmv.org/ga-georgia/green-driver-state-incentives.php.

In addition to vehicle replacement incentives, both the federal and many state governments have adopted incentives for the retirement of vehicles, often called “cash for clunkers” policies (Dill 2004; Gayer and Parker 2013; Li, Linn, and Spiller 2013). These programs seek to hasten the exit of high-polluting vehicles, often older used vehicles, from the fleet. However, many concerns have been raised about the effectiveness of these policies in reducing air pollution emissions (Sandler 2012). In particular, there is concern that such policies do not affect a driver’s choice of replacement vehicle.

One innovative option would expand the potential effectiveness of both retirement and replacement policies by linking these incentives and targeting them strategically so that owners select retirement and replacement vehicles with properties that increase the size of avoided environmental damages. By design, these policy incentives should be higher for drivers with relatively more polluting retirement vehicles (older vehicles typically owned by poorer drivers) who would drive relatively more miles (because they live in exurban and rural areas) and who own their retirement vehicles for longer periods of time (Choo and Mokhtarian 2004). In addition, such a combined policy could target areas where transportation emissions account for a large of share all air pollutant and GHG emissions relative to emissions from electricity generation.

Despite the potential benefits of combining retirement and replacement policies, with the exception of California, there are currently no federal or state policies that explicitly combine retirement and replacement incentives. In addition, none of the vehicle replacement policies target households with higher-polluting retirement vehicles, and incentives are not targeted to geographic areas exhibiting relatively higher levels of damages from pollution.

Factors Driving California’s Policy Developments

A review of California’s policy experience may be helpful for understanding the factors that are pushing policymakers toward the types of innovative policies that I have suggested here. The state began with separate retirement and replacement polices that initially did not explicitly target either consumer segments or specific geographic areas. The state’s long struggle to reduce acute air pollution damages explains the political support for both of these revenue-intensive incentives.

Over time, policymakers began to focus on two issues. First, although tremendous progress was made in reducing air pollution exposure statewide, a set of air districts remained in chronic noncompliance with the Clean Air Act, with a majority of the local emission sources coming from the transportation sector. Second, many of these emissions were coming from the state’s very large fleet of used vehicles, which are owned, in part, by moderate- and lower-income households. As a result, the state has started to (1) experiment with coupling retirement and replacement policies, (2) focus these pilot programs on critical geographical areas, (3) expand the set of rebate-eligible vehicles to include both used hybrids and PEVs, and (4) expand means-tested programs for low- and moderate-income households (Air Resources Board 2014a, 2014b).

Historically, California’s cash for clunkers program attracted considerable participation compared with other state programs (Air Resources Board 2014a). However, the vehicle replacement element of the program, which was added in 2012 and targeted lower-income households, did not elicit the level of participation expected (Air Resources Board 2014a).

In an effort to increase participation in the replacement vehicle program, in 2014 the California Air Resources Board increased incentive levels and expanded the set of eligible replacement vehicles to include cleaner used vehicles, hybrids, PEVs, and other zero-emission vehicles. In addition to the state-wide incentives, the San Joaquin Valley Air Pollution Control District and the South Coast Air Quality Management District, both designated as extreme nonattainment areas for failure to meet federal air quality standards, offered their residents much higher incentives.[18] The Air Quality Control Districts also expanded rebate eligibility beyond lower-income households (i.e., households earning less than 225 percent of the federal poverty level) to include moderate income households (i.e., households earning less than 300 percent of the federal poverty level).[19] In summary, for air districts chronically in nonattainment, California has shown a willingness to strategically couple, tier, and target its retirement and replacement policies in ways that likely make them more economically efficient.

It is important to note that these policy changes in California (which I would argue should be more broadly applied) are pushing the state's policies toward the economically efficient properties of a first-best policy. More specifically, the linking of retirement and replacement policies extends the influence of the combined policies to a larger range of consumer decision making (although it still does not explicitly affect the extensive margin of miles driven). In addition, the optimal tax or cap-and-trade policies would target relatively more polluting vehicles, which are also likely to be driven longer distances and are in geographic areas where the externalities of air pollution emissions are greatest.

Improving the Cost Effectiveness of Vehicle Purchase Incentives

Given the challenges of designing socially optimal policy incentives, it is helpful to examine how such policies could be made more cost effective. More specifically, how can policymakers use their limited revenues to best achieve their policy targets for PEV sales or adoption?[20] Calls for improvements in the cost effectiveness of these policies have also grown amid concerns that these policies have disproportionately transferred public resources to wealthy new vehicle buyers who would have purchased advanced clean vehicles anyway. Economists have characterized this behavior as free-riding on the incentive policy or the failure of the policy to achieve additionality in vehicles purchased compared with the policy counterfactual of no incentive.

[18]In the San Joaquin Valley Air Pollution Control District, an additional $3,000 Drive Clean rebate is available for all-electric vehicles and an extra $2,000 Drive Clean rebate is available for plug-in hybrid vehicles. When combined with other state and federal incentives, this represents a $13,000 subsidy on BEVs such as a LEAF. Similar programs are being developed by the South Coast Air Quality District.

[19]Several new state laws requiring the Air Resources Board to increase the participation of lower-income households (California SB 459 and SB 1275) have added further impetus to these policy developments.

[20]For President Obama's goal of one million clean vehicles by 2020, see Department of Energy (2011). On March 23, 2012, California's Governor Brown issued Executive Order B-16-2012 to encourage zero-emission vehicles in California and set a long-term goal of reaching 1.5 million zero-emission vehicles on California's roadways by 2025.

Role of Consumer Willingness to Pay and Marginal Utility of Income

The economist's ability to identify ways to improve the cost effectiveness of a policy is greatly enhanced if the distribution of consumers' ex ante willingness to pay and their marginal utility of income are known. DeShazo et al. (2015) show that the probability of purchasing a PEV is proportional to the consumer's utility for the PEV and that, although the probability of purchasing the PEV increases with the size of the rebate, there is a positive probability that the consumer will purchase the PEV in the absence of the rebate. If the consumer purchases the PEV in the absence of the rebate, the purchase is nonmarginal because it was not induced by the rebate policy. They show that the higher the consumer's ex ante willingness to pay for a PEV, the higher her nonmarginal purchase probability, and that the higher the consumer's marginal utility of income, the more responsive she will be to the rebate, and thus the higher her marginal purchase probability. This leads DeShazo et al. (2015) to conclude that rebates are more cost effective when they target consumers with a higher ratio of marginal to nonmarginal purchase probability—that is, lower ex ante willingness to pay and higher marginal utilities of income. This means that, if two consumers have the same probability of purchasing a PEV in the absence of the rebate, the policymaker should target the rebate to the consumer that has the higher marginal utility of income and that, if two consumers have the same marginal utility of income, the policymaker should target the rebate to the consumer that has the lower ex ante willingness to pay. DeShazo et al. (2015) also argue that targeting consumer segments and/or products with lower market share is cost effective because it results in fewer rebates being allocated to inframarginal purchases and that targeting consumer segments and/or products with steeper demand curves is more cost effective because the rebates stimulate more marginal purchases.[21]

Evidence from California

DeShazo et al. (2015) also explore ways to improve the cost effectiveness of California's current rebate program. Using a sample of new car buyers in 2013, they estimate both the marginal utility of income for different consumer income groups and consumers' willingness to pay for BEVs and PHEVs relative to conventional gasoline vehicles. They find that consumers' ex ante willingness to pay is considerably lower for BEVs than for PHEVs. In addition, lower-income groups expressed a higher marginal utility of income (or price responsiveness) than higher-income groups, a result that has been confirmed by other researchers through the use of revealed preference data (Beresteanu and Li 2011; Bunch and Mahmassani 2009).

Using actual market prices and demand simulations, DeShazo et al. (2015) then examine how the targeting of different financial incentives to specific vehicle technologies and consumer segments would affect the total number of additional vehicles purchased, the total cost of the policy (e.g., required public revenues), and the cost effectiveness per additional vehicle purchased. Their results suggest that policy cost effectiveness increases when larger rebates are given to BEVs than to PHEVs because this leads to a larger total number of additional PEVs purchased. Moreover, they find that offering relatively higher rebates to relatively lower income

[21]Note that DeShazo et al. (2015) do not consider product quality differentiation within the model, which might be one cause of relatively lower demand and market share (Heutel and Muehlegger 2015).

groups also increases the cost effectiveness of a given policy.[22] This is because lower-income households are not only relatively less likely to purchase a new vehicle but also relatively more responsive to the price reduction achieved by the rebate. Finally, they find that imposing a vehicle price cap on eligibility for a rebate increases cost effectiveness.[23]

These findings about cost effectiveness prompt two conclusions. First, the case of California is a policy setting in which progressive income-segmented rebate designs improve both cost effectiveness and the equity with which rebates are distributed. Second, it seems reasonable to expect that these more progressive income-segmented rebates, which are most cost effective, will also improve economic efficiency. This is because compared with higher-income consumers, lower-income consumers are likely to retire relatively older and more polluting vehicles, which they also tend to drive relatively more (Bhat, Sen, and Eluru 2009; Choo and Mokhtarian 2004). This leads to larger avoided damages (e.g., emissions) relative to income-neutral designs.[24] Because they reduce free-riding and increase the additionality, those policy reforms that increase cost effectiveness also increase the economic efficiency of the reform policy because they lead to larger avoided damages.

Conclusions and Future Research Needs

Based on the results of this review of the literature concerning clean vehicle purchase incentives, I propose that policymakers consider the following four specific design improvements. First, policymakers should design incentives so that they are applied at the point of sale and thus offset the listed cost of the vehicle. Although this may increase the bargaining power of dealerships, it should also increase consumer actual uptake of incentives. Second, policymakers should establish incentive levels that are higher for BEVs than for PHEVs, not because they are driven more electric miles (we do not know if this is true or not), but rather because consumers have relatively low willingness to pay for them. This suggestion means that a larger incentive for BEVs will improve the cost effectiveness of the policy. Third, policymakers should strategically link vehicle purchase incentives with vehicle retirement incentives (e.g., cash for clunkers) to increase the total net avoided emissions. Purchase incentives alone do not influence the type, timing, and pollution intensity of the retirement vehicle. As a result, they fail to influence a decision that is a critical determinant of emissions. Fourth, policymakers should enact income-tiered incentive policies that offer relatively larger incentives to lower and moderate income consumers. This will improve cost effectiveness and increase net avoided emissions because lower-income consumers tend to drive more polluting vehicles, drive them further, and exhibit a lower propensity to purchase advanced clean vehicles.

[22]An example of this policy would offer rebates to consumers purchasing BEVs, with the amount of the rebate based on consumers' incomes: (1) for incomes less than $25,000, a rebate of $7,500; (2) for incomes of $25,000–50,000, a rebate of $5,000; (3) for incomes of $50,000–75,000, a rebate of $2,000; and (4) for incomes above $75,000, no rebate. Consumers in these same income categories purchasing a PHEV would receive $4,500, $3,000, and $1,000, respectively.

[23]An example of this policy would be implementation of the $60,000 vehicle price cap above which no rebate is offered, while offering consumers making less than $100,000 a rebate of $5,000 for BEVs and $3,000 for PHEVs.

[24]In addition, when cost effectiveness is measured in terms of avoided emission per mile driven, policies that target prospective drivers with relatively more polluting retirement vehicles are likely to be relatively more cost effective.

However, this review of purchase incentives for advanced clean vehicles has also revealed that many gaps remain in our understanding of the effects of vehicle incentive policies, how they interact with other policies, and how they might be improved. Further research is needed in several areas. First, researchers need to better understand how the type of policy instrument chosen (rebates, income tax credit, sales tax exemption, fee exemptions) affects the economic incidence of these policies (Diamond 1970). A related issue is the need to examine how each of these instruments influences the bargaining process between consumers and dealers at the point of sale. Second, to avoid emissions most cost effectively, researchers need to conduct demand analyses that combine retirement and replacement vehicles and that target types of households within geographic markets. California's ARB programs illustrate how such programs can be tailored to encourage changes in the composition of both used and new cars in a local fleet. Finally, little is currently known about the interaction of these policies with related policies such as carbon cap-and-trade programs and low-carbon fuel standards. Improving our understanding of the policy-related changes in gasoline prices (Beresteanu and Li 2011) and their subsequent impacts on drivers' retirement and replacement decisions is critical to isolating and evaluating the effects of vehicle incentive policies.

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