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The Marginal Social Value of Electric Vehicle Subsidies - Preliminary Evidence

Ian Irvine
Concordia University, Montreal

Abstract

This paper estimates the distributional impact of electric vehicle subsidies. While micro-data that would establish their exact impact, are not yet available, other data sources provide strong priors that can be used to evaluate their distributional consequences. Using a social evaluation function, and modelling the income distribution using the Pareto function, these subsidies are found to be enormously regressive. This regressivity has become particularly marked due to the changing sales pattern, between 2013 and 2015, in favor of luxury brands. The paper also demonstrates that an analysis of the distributional impact of the subsidies can be validly separated from potential efficiency gains associated with reduced greenhouse gases. This separation is possible because of the way in which current vehicle-attribute standards influence producer decisions, and hence greenhouse gas emissions.

The author a professor of Economics at Concordia University, 1455 de Maisonneuve Boul. West, Montreal, Province of Quebec, Canada, H3G 1M8. He is grateful to Charles de Bartolome and Jim Alm for providing comments on an earlier draft of the paper. Any errors are the author's responsibility. Comments to ian.irvine@concordia.ca. This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors. The author has no conflict of interest.
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Contact: Ian Irvine - ian.irvine@concordia.ca.
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1 Introduction

This paper explores the distributional impact of electric vehicle (EV) subsidies for the period 2013-2015. Subsidies that incentivize the purchase of electric vehicles (EVs) are available in numerous jurisdictions. The US federal government provides grants up to $7,500, and most states give further subsidies. Canada's three most populous provinces grant approximately the same amounts in Canadian dollars. In the UK grants of up to £5,000 are available. Typically such subsidies come in the form of income tax credits, and pure, battery-powered, electric vehicles command a larger subsidy than hybrid electric vehicles.

From an efficiency standpoint, it is difficult to find support for subsidies: Subsidies are plagued by free-ridership and shifting problems (Chandra, Gulati and Kandlikar, 2011); a deadweight loss (DWL) is associated with raising the associated taxes; continually tighter year-to-year emissions standards govern the North American automobile market at the present time (ICCT, 2016), and the incremental value of subsidies in that context can be perverse (see section 4 below); subsidies may not be as efficient as sales tax remissions (Gallagher and Muehlegger, 2011, or Chetty, Looney and Kroft, 2009); investment in charging stations to reduce 'range anxiety' may be more productive (Li, Tong, Xing and Zhou, 2015); and EVs that run on coal-based electricity emit twice as much carbon dioxide, CO_2, as an average gasoline-powered vehicle (Holland, Mansur, Muller and Yates , 2015). Sallee and Slemrod (2012), in a widely-cited paper paper, explore the inefficiency of subsidies and taxes when they are of a 'staircase' type, meaning there are 'notches' in the tax/subsidy schedule, and in addition involve rounding mileage performance to integer values. They find bunching of vehicle sales with m.p.g. (miles per gallon) ratings ending in decimal five rather than decimal four. Hence lump-sum taxes or subsidies that vary with m.p.g. performance may induce almost infinitesimally small improvements at a high cost.

An efficiency metric of the economic cost of raising the tax revenue for a subsidy is the associated DWL. This cost can then be balanced against the valuation of reduced CO_2 emissions. However, the social evaluation of a tax-and-subsidize program depends upon how the revenue is distributed. EV subsidies have become progressively more concentrated in the top quantiles of the income distribution over the period 2013-2015. If more EVs are purchased by subsidizing the very wealthy the project differs from one where the same outcomes are achieved by granting subsidies to individuals around the median of the income distribution, because the social evaluation of transfers declines with income. Given that public-use micro-data files for 2015 will be unavailable for some time yet, I draw upon alternative data sources to explore regressivity. I model the income distribution by a Pareto function, specify a social evaluation function, compute the social value of subsidies to EV buyers, and compare it with a counterfactual. I conclude that the social value of subsidies is extremely low at the present time.

Section two presents data that are available up to 2015 that indicate where the subsidies 'land'. Section three develops a methodology and computes the social value statistics. The fourth section illustrates why it is valid to examine the distributional aspects of EVs independently of efficiency effects. The final section concludes.

2 Distributional facts and priors

Table 1 below contains data on sales of electric vehicles by manufacturer for the years 2013, 2014 and 2015. Two features are notable: First, sales of EVs declined by several percentage points between 2014 and 2015, primarily as a result of dramatic reductions in energy prices, favoring conventional vehicles. Second is the remarkable growth in the luxury component of the market. The luxury share has more than doubled in two years and now accounts for almost 40% of the total. I consider the luxury segment to be composed of vehicles sold by the first five manufacturers listed.

The vast majority of luxury vehicles are purchased by individuals in the top deciles of the income distribution. Torquenews (2012) reports that 80% of new Tesla buyers have individual incomes in excess of $100,000. Census of Population data indicates that, in 2013, such an income corresponds to the 93rd percentile of the distribution (Townhall, 2013).

The most comprehensive study of the distribution of subsidies to buyers of energy-efficient appliances and vehicles is that of Borenstein and Davis, 2015. Using individual tax data up to 2012, they examined the concentration of clean-energy tax credits, and concluded that such credits were highly concentrated at the upper end of the distribution.

> "The bottom three income quintiles have received about 10% of all credits, while the top quintile has received about 60%. The most extreme is the program aimed at electric vehicles, where we find that the top income quintile has received about 90% of all credits."

These numbers predate the emergence of Tesla and BMW EVs, which should skew the distribution even further. The authors also compute concentration curves, that have associated Gini index values in excess of 0.8. Such values characterize the highly unequal wealth distribution in the US, where the top decile owns about 70% of total net wealth (Wolff, 2014). This extreme concentration means that virtually all subsidies go to the top quarter of the distribution.

A third source of information on EV subsidies comes from survey results on the internet. Such surveys are not scientific, but they are frequently very current. Moreover, they corroborate the earlier and more scientific results, in finding that EVs beyond Tesla, BMW and Volvo are also purchased by households with incomes in the top deciles.[1]

Federal subsidies for EVs are uniform in that an electric vehicle with a range above a minimum threshold qualifies for a tax credit of $7,500 regardless of the income of the buyer. In contrast, at the state level, incentives vary enormously. Some states (e.g. Georgia and

[1] DeMorro (2015) is one example; he states:

> "The study cited buyers of the Ford Focus as a prime example, with the conventional Focus buyer being about 46 years old, with an annual household income of about $77,000. A Focus Electric buyer, however, was on average about 43 years old with a household income of about $199,000...Buyers of the Fiat 500 and 500e were similarly divided. A regular 500 buyer has a household income of $73,000, while a 500e family brings in on average about $145,000 and an average age two years younger than the regular 500 buyer."

Colorado) have generous additional subsidies that are not income tested, whereas California's subsides are reduced as income increases. Many states offer a remission of the sales tax, or the annual registration fee, or offer a subsidy for the installation of an electric power unit in the home. The subsidies forming the social value estimates presented below should be thought of as federal subsidies: they are a given lump-sum transfer to all EV buyers, and importantly are not income-related.

Table 1 Electric vehicle sales US

Manufacturer	**2013**	**2014**	**2015**
Tesla	17,650	17,300	25,416
BMW		6,647	14,181
Cadillac	6	1,310	1,024
Porsche	86	979	1,713
Mercedes		774	2,024
Nissan	22,610	30,200	17,269
Chevrolet	23,633	19,950	18,022
Toyota	13,184	14,448	4,191
Ford	1,4981	21,947	18,923
Fiat	2,310	5,132	6,194
Smart	923	2,594	1,387
Honda	1,095	856	64
Kia		359	1,015
VW		357	4,232
Others	1029	196	444
Total	**97,507**	**123,049**	**116,099**
Percent luxury	**18%**	**22%**	**38%**

Source: http://insideevs.com/monthly-plug-in-sales-scorecard/

3 The social value of subsidies

The social value of subsidies depends upon who receives them, and upon a social evaluation function W. In view of the information in the preceding section, it can be concluded that essentially all EV subsidies accrue to the top quarter of the whole income distribution. Accordingly, by specifying a function W, the social value of the transfers can be computed. Here I use the utilitarian form $W = \int \log(y)f(y)dy$, where y denotes income. Any power function y^γ in place of $log(y)$ is easy to work with; the marginal social value of income declines with income where $\gamma < 1$. A marginal dollar accruing to any individual with income y, using the log function, has a social value y^{-1}.

To implement: defining the median of the whole income distribution by m, the Pareto relative density function for the upper half of the distribution is

$$f(y) = \frac{am^a}{y^{a+1}},$$

where $\int_m^\infty f(y)dy = 1$. Hence the expected value of the marginal social value of income for the top half of the whole distribution, assuming $a > 1$, is

$$\int_m^\infty y^{-1}\frac{am^a}{y^{a+1}}dy = am^a\frac{y^{-a-1}}{-a-1}|_m^\infty = \frac{a}{a+1}\frac{1}{m}. \tag{1}$$

The same measure for the top quarter of the whole distribution, given that the mid-point of the Pareto distribution above m is defined as m scaled by the a th root of 2, is

$$\int_{m\sqrt[a]{2}}^\infty y^{-1}\frac{am^a}{y^{a+1}}dy = am^a\frac{y^{-a-1}}{-a-1}\;|_{m\sqrt[a]{2}}^\infty = \frac{a}{a+1}\frac{1}{m}\frac{1}{2.2^{\frac{1}{a}}}. \tag{2}$$

To put numerical values on expression (2) the only parameter value required is for a. The Pareto coefficient, β, is related to the single decay parameter of the Pareto distribution a by the relationship $\beta = a/(a-1)$; β defines the average income of households above the value

m. For example if $\beta = 3$ and the value m is \$70,000, then the average income of households above m must be \$210,000. Saez, Slemrod and Giertz (2012) find that $\beta = 3$ for the US. Atkinson, Piketty and Saez (2011) in their study of international inequality report that β falls almost always in the interval $\{1.5 - 3.0\}$. Values for English-speaking economies have increased dramatically since the nineteen seventies. They too report a β value just below 3 for the US. The particular value depends upon the definition of income - for example upon whether capital gains are included or excluded, and upon the tax unit - the individual or the household.

To turn expression 2 into a meaningful comparative statistic, it can be compared with the social evaluation of income transferred to the median unit, which in this case is $1/m$. Table 2 contains the results. The final two columns reflect the average of the marginal social values of a transfer to the top quartile (and the top half) of the whole income distribution, relative to the value of transfers at the median, for a series of β values. If subsidies are randomly received by the top quarter of the distribution, then the relative value of these subsidies, compared with when the subsidies are received at the median of the distribution, is exceedingly small. This result is not heavily dependent upon the skewness in the income distribution as reflected by the value of β. With a value of β for the US in the neighbourhood of 3.0, the social value of the transfers amounts to one fifth of their value, were they distributed to households at the median of the distribution. For illustrative, or comparative, purposes, the final column assumes that subsidies are distributed throughout the top half of the income distribution. Since these estimates assume an equal probability of a subsidy for an EV to a tax unit at the 75th percentile as at 95th (or any other) percentile, they likely err on the side of overestimating the social value of the transfer.

Table 2 The relative social value of EV subsidies			
β	a	Top Quarter	Top Half
1.5	3.0	0.3	0.75
2.0	2.0	0.24	0.67
2.5	1.67	0.21	0.625
2.75	1.57	0.20	0.61
3.0	1.5	0.19	0.60
4.0	1.33	0.17	0.57

4 Incidence, GHGs and tax progressivity

Concerning Incidence: Conventional public-finance incidence theory indicates that a tax or subsidy may not be borne as intended by the taxing authority. Demand and supply elasticities together determine who bears the burden. James Sallee (2011) reports on an event study in the automobile market to determine the incidence of an early hybrid-vehicle subsidy program. He concluded: "Transaction prices for the Toyota Prius were steady surrounding both large changes in the federal tax credit and changes in state tax policies. Because consumers later gain a tax benefit from the government, constant transaction prices imply that consumers bear the full burden (enjoy the full benefit) of these tax credits." He goes on to discuss a possible incidence asymmetry in that case. Busse, Silva-Risso, and Zettelmeyer (2006) also provide evidence of possible asymmetry, with the incidence depending upon which party to a trade the tax is levied or the subsidy is given; that is rebates going directly to consumers have a different impact from rebates to a manufacturer.

The social evaluation results presented in table 2 are (perhaps surprisingly) invariant to incidence assumptions. The reason is that I am evaluating the relative value of a given subsidy to individuals throughout the income distribution. Hence, whether that amount is the full federal subsidy of $7,500 or just some part of that amount - because the manufacturers have appropriated the remainder, the relative social evaluation remains unchanged.[2] In contrast to evaluating the relative social evaluation of subsidy dollars, if we evaluate the full redistributive consequence of the dollar value of the subsidy program then the dollar amount becomes important. Kakwani (1984) decomposes the redistributive impact of a tax-transfer program into (a) the magnitude of a given program measured in dollars, and (b) the progressivity or regressivity of that same program. In the current paper I am focussing upon the regressivity component, not the total. If the electric-vehicle subsidy problem is analyzed in terms of total dollars invested in the program, then shifting is important. In that case the shareholders in the corporations manufacturing the subsidized vehicles become part beneficiaries. Nonetheless, the ownership of stocks is enormously skewed in the US. Ed Wolff (2014) has analyzed balance sheets for households and concludes that, in 2013, 91% of all privately-held stocks and mutual funds were held by the top decile of the wealth distribution. This suggests that even if the subsidies are shifted back to the manufacturers, the subsidies will still land at the top of the distribution, and perhaps even exacerbate their low relative social value.

Concerning GHG emissions: A potential concern with the results produced above is that their regressivity is not balanced by a corresponding social gain that may accrue through a decline in GHG emissions. For example, if the DWL associated with raising the tax revenue were small, and the reduced CO_2 benefits were large, then a degree of regressivity might be tolerable. Such a concern is misplaced for two reasons. First, we are estimating the social value of subsidies at different points in the income distribution, and whatever benefits may accrue from GHG reduction they will accrue regardless of the landing points of the subsidies. The second reason is less straightforward, and little appreciated in this literature; it relates to the current regulatory structure of GHG emissions and fuel standards in North American. In reality, additional EVs on the road lead to zero additional reductions in GHGs, in view of current regulations that require a continuous annual improvement in

[2] Unless the incidence were to vary over the range of the income distribution.

both fuel efficiency and CO_2 emissions, up to the year 2025. For CO_2: passenger vehicles of a given footprint (measured as the area under the vehicle between the tires) must see a 5% annual reduction in emissions; light trucks and sports utility vehicles must register a 3.5% annual reduction (ICCT, 2016). These emissions rules are complemented by continuously higher fuel-efficiency standards, known also as CAFE - corporate average fuel economy. Like North America, China, Europe, Japan and India all have similar attribute-based standards. The European standards are based upon vehicle weight rather than footprint. Theoretical models of subsidies have been developed by Ito and Sallee (2014) and Allcott, Mullainathan and Taubinsky (2014). These papers explore the impact of subsidies for more efficient conventional gasoline-powered vehicles; they do not examine how multiple-credit offsets resulting from EV sales operate.

Under current rules in North America, for each (zero emission) EV sold, the manufacturer obtains a multiple credit against conventional vehicle emissions. The multiplier stands at 2.5 in the year 2016, and will decrease to 1.5 by 2025.[3] This means that if an EV of a given footprint is notionally permitted to emit x grams of CO_2 per mile, the manufacturer may currently modify the required emission reductions on conventional vehicle sales by $2.5 \times x$. Thus, conditional upon the existing regulations, subsidy-induced sales of EVs actually increase CO_2 emissions.[4] The efficiency role of subsidies in the current regulatory structure is thus unclear.

Concerning tax progressivity: The estimates presented here have not been balanced with a computation of the degree to which taxes underlying the subsidies are progressive or regressive. However, our objective is to compare the actual redistributional impact of

[3] There exists a market in these carbon credits among manufacturers. Credits may also be carried forward in time. As a corollary, the market value of a corporation such as Tesla includes a component that reflects the anticipated value of future credit sales.

[4] This market characteristic should be distinguished from free-ridership, a phenomenon that characterizes all markets where subsidies are designed to influence choices. In that approach subsidies are valueless in influencing a subset of choices, but a separating mechanism cannot be implemented, perhaps because buyer types cannot be segregated. But the extent of free-ridership in the EV market has no impact on GHG emissions due to the emission credits that accrue to EV sales.

subsidies with the impact of the subsidies if they were distributed to individuals at the median of the distribution, conditional upon the revenue being raised in the first instance. Moreover, were revenues raised in a progressive manner, such that subsidy recipients are approximately those who pay the taxes, there remains the deadweight loss associated with raising the revenue. Hence even such a distributionally 'neutral' tax and transfer would involve a DWL cost of perhaps one quarter of the revenue (Dahlby and Ferede, 2011).

5 Conclusion

The ascent of luxury brands in the US electric-vehicle market in the period 2013-2015, means that subsidies to EV buyers in that market have become enormously regressive. From a distributional standpoint, if these subsidies are weighted in accordance with the commonly-used logarithmic utilitarian social welfare function, their social value is just one fifth of the value that would accrue if the subsidies went to individuals at the median of the income distribution. While we lack public-use tax-based micro data on the precise distribution of subsidies for recent years, that absence should not deter policy makers from concluding that subsidies are heavily regressive and have a low social value.

We have also shown why electric vehicle subsidies (even subsidies that do induce buyers to switch to an EV over a gasoline vehicle), have no positive near-term impact on GHG emissions. Under current standards, EV manufacturers are permitted, for the sale of each EV, to sell conventional vehicles that emit more GHGs than are saved by the sale of each EV. Consequently, given their extreme regressivity, and impotence in reducing GHGs in the current CAFE environment, it is difficult to understand why subsidies have such currency with governments.

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