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The economic and environmental impacts of tax incentives for battery electric vehicles in Europe

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ABSTRACT

Vehicle taxes and purchase subsidies have been used frequently to provide incentives for electric vehicle adoption. To examine the role of the incentives in reducing total ownership costs of battery electric vehicles (BEVs), increasing BEV sales, and obtaining environmental benefits from switching to BEVs, we carry out cost–benefit analyses and ordinary least square regressions. We study 10 pairs of BEVs and their internal combustion engine vehicle (ICEV) counterparts across 28 European countries from 2012 to 2014. The results show that, under the incentive schemes, the costs reduced by switching to large BEVs from their ICEV counterparts are larger than the costs reduced by switching to small BEVs from their ICEV counterparts. Owing to the cost-reduction effect, a 10% increase of the total tax incentive leads to an increase in the sales share of BEVs by around 3% on average. Finally, we find that it is still costly to use the tax incentives to reduce CO_2 emissions and other environmental externalities through transport electrification, despite recent improvements in greening electricity generation and lowering battery costs.

1. Introduction

Electric vehicles, such as battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs), are regarded as key alternatives to internal combustion engine vehicles (ICEVs) for improving energy efficiency, mitigating local air pollution, and reducing carbon dioxide (CO_2) emissions in the transport sector. Many governments have established interim goals for market shares of electric vehicles in the relatively near-term time frame of 2020–2025 in order to spur the vehicle market and promote a long-term shift to an economy that is consistent with climate stabilization (Weeda et al., 2012; Mock and Yang, 2014; IEA, 2015c).

To achieve these goals, various policies have been implemented to benefit the production and sales of electric vehicles. Fuel economy standards, information labelling, and research and development (R&D) support are used to promote the development of electric vehicle technologies. On the consumer side, heavy taxation of fossil fuel (gasoline and diesel) and relatively low electricity taxes lead to lower energy costs of driving electric vehicles, compared to ICEVs. Moreover, in conjunction with complementary policies for electric vehicles (e.g. development of charging infrastructure, access to bus lanes, and free parking spots), national tax incentives have been provided directly to induce consumers to adopt innovative low-emission vehicle technologies. The tax incentives offer an important and powerful mechanism to promote the adoption of electric vehicles through tax exemptions or subsidies for electric vehicles, or higher vehicle registration taxes or annual circulation taxes for ICEVs. (Eppstein et al., 2011; Trigg et al., 2013; Sierzchula et al., 2014; IEA, 2016).

In our study, we focus on the tax incentives that are based on vehicles taxes, although fuel (gasoline and diesel) taxes, differentiated by their CO_2 content, are usually considered as the first best policy options to reduce CO_2 emissions from the perspective of welfare economics. Fuel taxes can cost–effectively decarbonize vehicle fleets by promoting purchases of low emission vehicles and optimizing decisions on driving, which vehicle taxes have limited influences on. Nevertheless, currently increasing political interest has been in CO_2 based vehicle taxes. The vehicle taxes and related incentives can reduce future political resistance to higher fuel taxes and therefore, are widely accepted as a sensible strategy to reduce CO_2 intensities in the vehicle stock via new car sales

Among all types of electric vehicles, BEVs have the most disadvantages[1] over ICEVs. Therefore, the adoption of BEVs is more likely to rely on fiscal policies, such as tax incentives. Depending on the designs of vehicle taxes and subsidies, BEVs and PHEVs might obtain different amounts of incentives. For example, contrary to the Netherlands, Norway provides higher tax exemptions/subsidies for BEVs than

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[1] The disadvantages include high purchase prices, limited travel range, long charging time, limited availability of models, limited availability of charging stations, and uncertainty regarding new technologies (Stephens, 2013).

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PHEVs. This difference leads to relatively high sales of BEVs and PHEVs in Norway and the Netherlands, respectively. Furthermore, the removal of the internal combustion engine system gives BEVs an increasingly important role in climate change mitigation, especially with greener electricity and decreasing battery costs, from about 1000 $\$/kWh$ in 2008–268 $\$/kWh$ in 2015 (IEA, 2016). Hence, we are motivated to focus our research on BEVs and explore answers to the significant research questions – to what extent the tax incentives i) reduce the total ownership costs of BEVs; ii) increase BEV sales; and thereby iii) reduce environmental externalities – CO_2 emissions, local air pollution, and noise from driving.

Research on detailed calculations for total ownership costs of electric vehicles was conducted in the 1990 s and early 2000 s (Chapman et al., 1994; Lave et al., 1995; Kazimi, 1997; Vyas et al., 1998; Funk and Rabl, 1999; Delucchi and Lipman, 2001). However, with developments in battery and vehicle technologies, integration of renewable energy in power generation and particularly recent reforms of vehicle taxes/subsidies, there is a need to re-evaluate the costs and benefits of electric vehicles, especially BEVs. Recent studies (Crist, 2012; Prud'homme and Koning, 2012; Piao et al., 2014; Nealer et al., 2015; Bubeck et al., 2016) have undertaken cost–benefit analysis for BEVs, PHEVs, and ICEVs within a single country. Quantitative cross-country comparisons of electric vehicles are presently limited to single areas of electricity production (Doucette and McCulloch, 2011; Wu et al., 2012; Buekers et al., 2014) or taxation (Kley et al., 2012; Mock and Yang, 2014). An integrated cost–benefit analysis across countries and across car models could contribute to the evaluation of tax incentives for electric vehicles.

Existing empirical research on electric vehicles has mainly focused on sales of PHEVs or generally electric vehicles, including BEVs. Three types of methods have been frequently used: discrete choice models (Brownstone et al., 2000; Bolduc et al., 2008; Axsen et al., 2009; Axsen and Kurani, 2013; Javid and Nejat, 2017), cross-sectional and time-series models (Diamond, 2009; Chandra et al., 2010; Beresteanu and Li, 2011; Gallagher and Muehlegger, 2011; Jenn et al., 2013), and simulated models (Mau et al., 2008; de Haan et al., 2009; Eppstein et al., 2011; Lee et al., 2016). To evaluate impacts of policies on electric vehicle adoption, existing research have used cross-sectional and time-series models. Although the tax responsiveness of consumers for BEVs and PHEVs might vary, few research has studied BEVs separately. In recent years, BEVs have experienced huge sales increases in different countries, which presents a good research opportunity to study BEVs. We believe that the use of data variation across countries, years, and vehicle models leads to more precise estimation of tax incentive impacts than previously, and adds to the understanding of BEV adoption.

In our study, we compose comparable pairs of BEV–ICEV. Within each pair, BEVs and ICEVs have similar characteristics. The total tax incentive for a BEV is represented by the difference between the total taxes (vehicle registration, annual circulation tax, and subsidy) for a BEV and its ICEV counterpart. To assess the tax incentives for BEVs, we carry out cost–benefit analyses and ordinary least square (OLS) regressions. First, we calculate the vehicle total ownership costs and the net benefit of switching from an ICEV to a BEV. In light of heterogeneity in tax incentives, we compare the vehicle costs in three dimensions: cross-country, cross-(car) model, and cross-driver. Second, to estimate the influence of tax incentives on BEV adoption, we regress sales shares of BEVs by country, (car) model, and year on the total tax incentives for specific electric vehicles, controlling for country and (car) model-level differences. For robustness, we conduct regressions with alternative specifications. Lastly, from an environmental perspective, we compare the total tax incentives to the total reductions of CO_2 emissions, local air pollution and noise from driving in different countries when switching from an ICEV to a BEV.

Apart from providing a comprehensive evaluation of the tax incentives for BEVs, part of our contribution to the literature is to make use of substantial data variation not only in tax differences but also in different electricity generation mix and local environmental factors (e.g. local marginal costs of pollutants), covering 10 pairs of BEV–ICEV in 28 European countries from 2012 to 2014. The application of methods to 10 pairs of BEV–ICEV provides a creative and robust approach to evaluate tax incentives for BEVs. Last, the international comparisons of results offer a critical perspective to inform global debates on both the role of transport electrification and associated policy instruments.

In the results, the cross-country comparisons of vehicle costs show that tax incentives and energy cost savings together significantly reduce the costs of BEVs. The cross-(car) model comparisons indicate that, under the incentive schemes, the cost reduced by switching to large BEVs from their ICEV counterparts are larger than the cost reduced by switching to small BEVs from their ICEV counterparts. Lastly, as shown in the cross-driver comparisons, strong tax incentives can lower the requirements of annual distance travelled to achieve equal total ownership costs of ICEVs and BEVs.

Owing to the cost-reduction effect, a 10% increase of the total tax incentive is estimated to be associated with a 3% increase in BEV sales share on average. This estimation reflects a price elasticity of -1.3, using the percentage of tax incentive to BEV price of 15% for the sample mean. These estimated effects on BEV sales are lower than the effects of similar tax incentives for PHEV/HEV sales in the existing literature. Finally, it is observed that the environmental benefits of driving BEVs vary considerably across countries. However, it is still costly to use the tax incentives to reduce CO_2 emissions and other environmental externalities through transport electrification, despite recent improvements in greening electricity generation and lowering battery costs.

The rest of this paper proceeds as follow. Section 2 presents the features of tax incentives for electric vehicles in Europe. Section 3 shows the methods for analysing tax incentives. Section 4 describes our data. The results and discussion are in Section 5 and the conclusion in Section 6.

2. Tax incentives for battery electric vehicles in Europe

In this section, we introduce types of national incentives for passenger BEVs. In our cost calculation in Section 3, we also consider the indirect incentives resulted from energy taxes. However, we do not consider local incentives that are applied only to a few cities or provinces, such as free parking or access to bus lanes and free access to low emission zones. The amounts of those local incentives are relatively small and vary highly across drivers, depending on individual factors, such as daily routes, driving behaviour and time value.

Three main types of tax incentives have been implemented in Europe – exemptions from vehicle registration tax, exemptions from annual circulation tax, and different forms of subsidy (ACEA, 2014a, 2014b).[2] The tax incentives work through exemptions or reduction of taxes for BEVs and higher taxes on ICEVs. There are different types of vehicle tax duties imposed and numerous different bases of tax assessment and tax schedules across European countries, leading to substantial variation in tax incentives for BEVs. In recent years, CO_2 emission rates[3] have been used frequently as a base for vehicle taxes to promote fuel-efficient car purchases. These CO_2-based vehicle taxes in practice give maximum advantage to BEVs, which are considered to have zero tailpipe CO_2 emissions. Therefore, these taxes strongly incentivize the purchase of BEVs, even though, in many cases, they also differentiate support between PHEVs and between ICEVs.

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[2] Details about the vehicle taxes and exemptions are in Table A2 in the Appendix.

[3] CO_2 emission rates, sometimes also called CO_2 intensity, in grams per vehicle kilometres, is basically the same as fuel efficiency, once fuel type is given.