



How policy measures succeeded to promote electric mobility – Worldwide review and outlook

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ARTICLE INFO

Article history:

Received 6 April 2018

Received in revised form

8 August 2018

Accepted 14 September 2018

Available online 18 September 2018

Keywords:

Electric vehicles (EVs)

Policy measures

Monetary incentives

Charging infrastructure

Cross-national

ABSTRACT

Electric vehicles (EVs) have been increasingly promoted through policy measures by governments across the world. This study investigates the effectiveness of these measures in 20 countries by measuring the influence of monetary incentives, traffic regulations favoring EVs as well as the charging infrastructure on the market share of EVs in these countries. Results from a covariance-based structural equation model show that all policy measures positively influence the percentage of EVs, specifically monetary measures in interaction with the charging infrastructure. Moreover, findings indicate that governmental measures promoting electric mobility reflect consumers' preferences in the respective countries and that countries with a high purchasing power also have a higher EV penetration. An analysis of the ratio between sold battery electric vehicles (BEVs) versus sold plug-in hybrid electric vehicles (PHEVs) further shows that consumers are purchasing more BEVs (vs. PHEVs) over time. A closer examination of Norway, the Netherlands, Germany and Brazil, where EVs have been adopted more or less successfully, further highlights additional factors influencing EV adoption. It also emphasizes the need for collaboration among stakeholders from the public and private sectors in order to promote EVs. Finally, a worldwide outlook predicts a growing acceptance of EVs over time.

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1. Introduction

Governmental support for electric mobility has been growing steadily over the last few years. However, apart from a few nations such as Norway, the uptake of electric vehicles (EVs) is still rather slow in the majority of countries across the world (OECD/IEA, 2017). As there are various differences in the policy measures that have been implemented by national governments (EAFO, 2018; EV-Volumes, 2018; IEA IA-HEV, 2016; OICA, 2018), their effectiveness should be analyzed from a cross-national perspective. Although it should be recognized that electric mobility receives support at different governance levels, including supranational as well as more local and regional levels, this study focuses on national incentives. This viewpoint allows for the comparison of different countries' policy strategies worldwide. Thus, more generalizable inferences about their effectiveness can be made than if only local or supranational incentives were to be analyzed.

This study's aim is to determine the impact of governmental

incentives and a country's charging infrastructure on EV market shares in 20 countries using data from 2017. Thus, this study seeks to contribute to existing research on the influence of policy measures promoting electric mobility at an international level by investigating the effectiveness of diverse incentives on EV market shares. Furthermore, it will be investigated whether these measures also reflect consumers' preferences, how a country's purchasing power influences consumers' uptake of EVs, and how the ratio of battery electric vehicles (BEVs) to plug-in hybrid electric vehicles (PHEVs) changes over time. Moreover, a closer examination of Norway, Germany, the Netherlands and Brazil, in which EVs have been more or less successful, will highlight additional factors influencing a country's EV penetration. Finally, an assessment of the potential growth of EV market shares will provide a worldwide outlook.

2. Background and hypotheses

Previous studies on EV penetration have concentrated on regional policy measures or national incentives in one or two countries only (e.g., Bakker and Trip, 2013; Figenbaum et al., 2015; Holtmark and Skonhoft, 2014; Li, 2016; Zhang et al., 2011). For

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Abbreviations

BEV	Battery Electric Vehicle
CO ₂	Carbon Dioxide
EAFO	European Alternative Fuels Observatory
EV	Electric Vehicle
EVI	Electric Vehicles Initiative
GHG	Green House Gas
IEA IA-HEV	International Energy Agency, Hybrid & Electric Vehicle Implementing Agreement
M	Mean
MRA-E	Amsterdam Metropolitan Area Electric
n.s.	not significant
NCSL	National Conference of State Legislatures
NGO	Non-Governmental Organization
NPE	National Electric Mobility Platform

NSR	North Sea Region
OECD/IEA	International Energy Agency as an autonomous body within the Organization for Economic Cooperation and Development
OICA	International Organization of Motor Vehicle Manufacturers
<i>p</i>	Probability
PHEV	Plug-In Hybrid Electric Vehicle
PP	Purchasing Power
R ²	Coefficient of Determination
SD	Standard Deviation
SEM	Structural Equation Model
ZERO	Zero Emission Resource Organization
β	Regression parameter
χ^2	Chi-square distribution
ρ	Spearman's rank correlation coefficient

instance, Bakker and Trip (2013) examined how cities can enhance EV uptake through political incentives. Results show that investments by municipal governments, for example in the charging infrastructure, may promote EVs. Nonetheless, the authors also argue that the most influential power lies at national and regional levels. In addition, Figenbaum et al. (2015) investigate the factors which have contributed to the successful introduction of EVs in Norway and find that high levels of governmental incentives have been most influential. A further study by Li (2016), which compares EV adoption in Brazil and China, also demonstrates the significance of political incentives. According to the author, China's promotion of EVs has been much stronger than that of Brazil because of its policy measures and infrastructure investments.

The influence of policy measures on EV adoption has also been investigated from an international viewpoint (e.g., Haddadian et al., 2015; Lieven, 2015; Sierzchula et al., 2014). Sierzchula et al. (2014) analyzed the impact of policy measures on EV market shares in 30 countries with data from 2012. Although results showed that market shares positively correlated with financial incentives and charging networks, no conclusions regarding causality could be drawn. This may be due to the significantly lower EV market shares in 2012 compared to now. In fact, EVs accounted for less than 0.4% of annual car sales across the 30 countries considered. More recently, this trend has changed significantly. For instance, in 2017 Norway attained an EV market share of about 40% (EV-Volumes, 2018). It is therefore significant to explore how policy measures affect sales in light of recent market developments. Further global research was carried out in 20 countries by Lieven (2015) who investigated the impact of policy measures supporting EVs based on consumers' preferences. Findings indicate that individuals highly appreciate monetary incentives. However, they regard an extensive charging network on freeways as a necessity. Hence, results suggest that both financial incentives and political support for charging infrastructures are the most influential measures supporting consumers' EV uptake.

Based on Lieven's (2015) previous research, this study explores the influence of policy measures supporting EVs in the 20 countries that were included in the 2015 study. Specifically, various forms of political measures will be discussed. Subsequently, their impact on EV market shares will be analyzed. Lieven's (2015) findings already indicate that consumers highly appreciate political incentives and a sufficient charging network. The following hypothesis is therefore proposed:

H1. Monetary incentives, traffic regulations, as well as charging

infrastructure positively affect EVs' market share.

Moreover, most literature on electric mobility has pointed out the importance of the charging infrastructure (Lieven, 2015). In this study, it will therefore be examined whether the number of existing charging stations does not only directly influence EV percentage positively but has, in interaction with policy measures, an additional effect on EV market share. Such an interaction effect would indicate an increasing efficiency of governments' policy measures since the numbers of charging points add up over time.

H2. The interaction between charging infrastructure and the monetary measures has the strongest positive impact on EVs' market share.

Additionally, the relation between consumer needs and governmental measures will be analyzed. In countries where car drivers express their need for financial or other regulative incentives to make them switch to EVs, governments should be more likely to follow these requests.

H3. Governmental measures to promote electric mobility reflect consumers' preferences in the respective countries.

As can be seen with many technological innovations, products are relatively expensive at first. Only after some time, prices decrease. Consequently, innovations are affordable only for those with sufficient purchasing power (PP) in the early stage of market introduction. EVs can be assumed to be in this stage, thus:

H4. In countries with high PP, the percentage of EVs will be higher than in those countries with low PP.

When pure BEVs will become more affordable, there is no more need to switch to the lower-priced PHEVs. Particularly when BEVs will operate with similar range capabilities as PHEVs, the decreasing prices of BEVs will make them more attractive to consumers. Additionally, fast-charging stations will compensate BEVs' current disadvantage of time-consuming charging procedures.

H5. Over time, the ratio of worldwide sold BEVs compared to sold PHEVs increases.

3. Policy measures supporting electric mobility in 20 nations

3.1. Data collection

To compare policy measures across countries and develop a

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