Policy Measures to Promote Electric Vehicles: Are They Effective and Efficient?

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1. Introduction

Passenger and freight mobility are essential for economic and cultural development. Yet, they are responsible for a large share of energy consumption, CO_2 emissions, local pollutants and noise emissions. In an effort to mitigate climate change and to improve urban quality, countries and cities are adopting controversial sustainable mobility policies. German cities are implementing access bans for old diesel cars, causing public protest due to both accessibility restrictions and economic loss of the cars' resale value. In France, the «gilets jaunes» movement took to the streets also because of the government's proposal to increase fuel taxes to meet its climate change goals. In Italy, the government introduced a controversial «Ecobonus Transporti» policy (revised because of the opposition of the automotive industry) and various cities enacted stringent traffic regulations. Similar controversies have taken place in the USA, with the Trump government and the EPA favouring a relaxation of the policies enacted by the previous administration.

Electric vehicles[1] (henceforth EVs) are an interesting technological innovation because they are credited with reduced CO_2 emission and noise, and zero in-use local pollutant emissions. Since electricity can be produced

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[1] «Electric vehicle» is a generic term for vehicles of various kinds (cars, vans, mopeds, buses, trucks). In this paper we will mainly refer to car and vans. Electric cars comprise three main technologies: BEVs (battery-only electric vehicles), REEVs (range-extender electric vehicles) and PHEVs (plug-in hybrid electric vehicles). The term «electrification» also denotes HEVs (hybrid electric vehicles) which cannot be charged with a plug, FCEVs (fuel cell electric vehicles), and CNG (compressed natural gas vehicles). Petrol, diesel and LPG vehicles are called ICEVs (internal combustion engine vehicles).

from many sources including renewable ones, EVs have also the potential to alleviate oil dependence. Consequently, it is not surprising that governments at different levels (European, national, regional or urban) have promoted policies supporting EVs. From an economic viewpoint, one can distinguish between command-and-control (regulatory, or «sticks») and fiscal policies (market-based, or «carrots»). The two approaches have quite different efficiency and effectiveness properties. Examples of the former are the European Directives on alternative fuels and vehicle standards; the California Air Resources Board (CARB) policy in some US states; the traffic restriction on vehicles with old petrol or diesel engines; or the preferential treatment given to EVs in terms of access to bus lanes (Norway) or High Occupancy Vehicles (HOV) carpool lanes (California). Examples of the latter are the CO_2-based taxation measures applied in 20 EU Member States or the incentives for EVs adopted in 24 EU countries (ACEA, 2019). These take many forms, including reduced registration, purchase or annual circulation taxes, direct purchase subsidies, waivers on road toll fees, reduced parking fees or subsidies for public or private charging equipment.

Depending on the political attitude and specific circumstances, policy makers propose the application of a specific policy or a combination of policies. However, are these policies effective (do they achieve the intended goal) and efficient from a social point of view? The challenge for scientists is to provide policy makers with scientifically sound answers to these questions.[2] We will discuss both issues with the help of the most recent literature. In our view, the effectiveness question has been answered positively and satisfactorily, whereas the efficiency question is still controversial and warrants close attention.

2. Policy effectiveness and efficiency

2.1. The effectiveness of the policies promoting EV uptake

A first way to judge the effectiveness of EV promoting policies is to consider the evolution of EV market uptake. In absolute terms[3], EVs started entering the market in significant numbers only in 2011. Sales reached an annual amount of half a million in 2015, of one million in 2017, and of two million in 2018. By country, more than 50% of EVs are sold in China, 18% in North America, and about 20% in Europe. In terms of market share, Norway stands out as an absolute outlier with a combined BEV and PHEV

[2] A similar question is discussed in this issue by Legras and Védrine (2019) regarding the impact of urban traffic restriction policies on urban air pollution.

[3] IEA (2018) for the years 2010-17 and Wikipedia (*Electric Car Use by Country*, accessed on February 1st, 2019).

new sales market share in 2018 of 49.1%. However, the smaller northern European countries follow suit with Sweden at 8.2%, the Netherlands at 6.5% and Finland at 4.7%. China is making major strides forward, each year doubling its EV market share and reaching the 4.2% level in 2018. The largest European countries, hosting the most important car manufacturers and the USA are also advancing, reaching a 2% market share in 2018. California is leading the way among the American states with a 7.1% market share, mostly thanks to the Tesla Model 3. Since the countries with the largest market shares are those that have adopted the strongest and most comprehensive EVs incentivising measures, one is tempted to answer the effectiveness question positively.

For a more scientific conclusion, one should consider the econometric evidence. Several studies have explored the relationship between EV policies and EV penetration using cross-sectional data (Sierzchula *et al.*, 2014; Broadbent *et al.*, 2018). There is a consensus that market shares are positively correlated with monetary incentives for the purchase of the vehicle and for the deployment of the charging infrastructure. Broadbent *et al.* (2018) argue that EV uptake is also positively affected by the dissemination of accurate and up-to-date information, the adoption of government procurement policies, and the implementation of a range of other policies such as free toll road access, HOV/bus lanes access, free use of local car ferries, and free electricity at public rechargers.

The importance of monetary variables (purchase price, petrol and energy prices, subsidies, tax exemptions, etc.) can also be gauged using total cost of ownership (TCO) models (see Danielis *et al.*, 2018; and Scorrano *et al.*, 2019 for recent reviews). A common finding is that EVs – both cars and vans – have a higher TCO than their ICEVs counterparts, unless high annual distances are travelled. Consequently, subsidies are essential for the BEVs to be competitive. Only if battery prices decrease due to technological innovation and economies of scale, thus reducing the purchase price gap, could EVs be cost competitive without financial incentives. Breetz and Salon (2018) reach the same conclusion.

Another source of information on the impact of EV policies consists of discrete choice models. These models, based on disaggregated data, identify consumers' preference when buying a vehicle. They thus estimate the relative importance of each attribute in the vehicle choice. Attributes are monetary (purchase price, energy price, maintenance costs, etc.) and non-monetary (driving range, charging time, acceleration, charging network density, etc.). Discrete choice models are then used to perform policy scenario analysis. Giansoldati *et al.* (2018), for instance, find that the BEV market share would increase to 30% if there was a € 5,000 purchase subsidy, 10% of fuel stations were equipped with fast charging stalls, and the BEV range increased by 50%.

However, there is no consensus on the relative effectiveness of each EV policy. Lévay *et al.* (2017) argue that financial incentives are crucial in market formation, although EVs will gain significant market shares only when their price is competitive with ICEVs. Langbroek *et al.* (2016) find that all incentives encourage EV uptake to varying degrees, particularly for people already inclined to EVs. Cluzel *et al.* (2013) contend that consumer awareness is the crucial factor together with better charging infrastructure. Finally, there is growing evidence that joint policies, involving the entire supply chain (research, infrastructure, car manufacturers, and consumers), are needed in order to reach maximum effectiveness (Giansoldati *et al.*, 2019; Broadbent *et al.*, 2018).

In our view, an issue not adequately addressed in the literature is the interaction between EV demand and supply. EV uptake takes place only when appealing EV models are supplied with good performances and reasonable prices. The Tesla Model 3 example is illuminating. Its appearance in the US market doubled the EV market share in the second half of 2018. Similarly, the Chinese market developed when a variety of highway-capable EVs entered the market. In Europe, EVs are, according to many commentators, supply-constrained since long waiting times are still necessary before delivery to the customer. Unless the main European car manufacturers produce EVs on a larger scale, their sales will not increase to a significant extent.

2.2. The efficiency of the policies promoting EV uptake

Economic theory states that subsidies or taxes make economic sense when externalities exist, since negative externalities cause social costs that individual decision makers do not take into account in their decisions. Local and global air pollution and noise are negative externalities that EVs reduce. However, estimating the social cost savings generated by an EV vs. an ICEV is not an easy task. It requires for both vehicles:

– knowledge of the quantity and type of air pollutants or noise generated. The estimate should take into account not only the in-use phase but also the entire life cycle of the vehicle. A life-cycle analysis accounts for the emissions: *a*) in the phases of extraction, refinement, and distribution of the fuel needed to operate the ICEVs or to produce electricity; *b*) in the production and transmission of electricity; *c*) in the production of car components, including the battery, their assembly, disposal or reuse; and *d*) during the car use. Apart from the extensive data requirements, as underlined by Danielis *et al.* (2019), such estimates encounter two main difficulties: 1) the electricity generation mix changes over time and 2) the battery technology also changes (energy and material requirements, recycle/reuse possibility). Needless to say, such estimates need to be time- and country-specific;

– knowledge of where the vehicle is driven, since the health impacts will differ by location;

– an estimate of the social costs of CO_2 emissions, local air pollution and noise: a very controversial issue fraught with many uncertainties.

Various researchers have dealt with these issues by using cost-benefit analysis. The results are controversial. Prud'homme and Koning (2012) regarding France, and Massiani (2015) regarding Germany argue that most of the policies investigated have a negative benefit-cost balance. With reference to the USA, Holland *et al.* (2016) find that the second-best BEVs purchase subsidies range from $3,025 in California to -$4,773 in North Dakota, with a mean of -$742. Bradley & Associates (2017) reach positive conclusions regarding the State of Illinois. They find that net benefits would accrue to the electricity utilities, thanks to increased revenues, but also to their customers due to greater utilization of the electricity grid during off-peak hours. For Canada, Malmgren (2016) finds a small net benefit in terms of social total cost of ownership, excluding subsidies, but warns that the figures are subject to constant change due to fluctuations in gas prices, electricity generation mix, international political environment, market fluctuations and battery and vehicle technology improvements. Cavallaro *et al.* (2018) assess whether BEV subsidies are justified (and by what amount) with reference only to CO_2 emissions, distinguishing by car segments and countries. They find that in the small car segment BEVs should always be subsidised. However, the exact amount depends on the country, with large variations between the minimum and maximum values. Minimum values are obtained in Greece and maximum values in Sweden. In the medium-sized car segment, BEVs should be subsidised, but with smaller amounts. In the large car segment, BEVs should be subsidised only in regard to diesel ICEVs and petrol ICEVs, while in the majority of the countries they should be taxed in regard to HEVs and PHEVs.

An oft-raised question is whether policy makers should be technologically neutral or should favour EVs because of their environmental or energy benefits. The issue relates to the more general question of the role of the state in a market economy. In our view, it should be stressed that the transport sector is characterized by large policy interventions – both regulatory (road allocation, traffic management) and financial (infrastructure provision and tax collection on vehicles and fuels). The market structure of transport modes ranges from natural monopolies (railways, city buses), through oligopolies (air and maritime transport), to perfect competition (road freight transport). Within this context, evaluating transport policies from an efficiency standpoint is far from easy. In the specific case of the provision and choice of private vehicles the starting point is not a «level playing field», since there is a long tradition of state intervention motivated by economic, environmental and safety reasons. Especially in countries characterized by the existence of a strong vehicle manufacturing tradition, governments tend to favour the domestic industry by promoting their products and specialization. Fuel taxation is one of the central policy interventions for both developed and developing countries (an interesting analysis of the Indian case can be found in Anand *et al.*, 2013). The fact that diesel vehicles (and to a lesser extent, natural gas vehicles) have enjoyed a large market share in Europe but not in the USA and Japan proves that «technology neutrality» is far from being the rule in the vehicles market.

Given these difficulties, a theoretically sound approach with which to evaluate the efficiency of transport policies is the applied general equilibrium modelling that can take also the presence of externalities and distortionary taxes into account (Mayeres, 2000). Within this theoretical framework, Hirte and Tscharaktschiew (2013) calibrated a model with reference to a typical German metropolitan area. They find that EVs should not be subsidized but taxed. More recently, Miyata *et al.* (2018) have used a computable general equilibrium model to evaluate the economic impacts of subsidies, the possibility of price reductions, the industrial structure change, and modal shift. They find that introducing a 5-25% subsidy to EV manufacturing, EV transport, solar power, and cogeneration would be an efficient solution to the CO_2 issue. The efficiency issue is dealt with also by Green *et al.* (2014), who argue that current US policies supporting EVs are neither efficient nor effective. They claim that EV policies should focus on early adopters and niche markets using approaches such as strategic niche management, accessible loans and financing, and appropriately targeted incentives, instead of aiming at the mainstream consumers. Liu *et al.* (2017) reach opposite conclusions. They find that efficient policies spurring consumer demand accelerate the evolutionary path of the EV industry. Mirhedayatian and Yan (2018) underline the need to explore the relationships among policy measures, car manufacturers' responses to such measures, the effect on operational costs, and the resulting changes to environmental impacts and welfare.

3. Conclusions and lessons learnt

Overall, the EV incentivising policies adopted in many countries seem to have achieved their goal of allowing EVs to enter the market and gain significant market shares. The effectiveness of the policies is confirmed both by market share indicators and econometric (aggregate or disaggregate) studies. However, most papers have based their policy effectiveness considerations on the existing evidence, but, in our view, they fail to account for three crucial aspects. First, technological progress constantly improves batteries in terms of energy density, number of cycles, and safety, making them less expensive. Second, the automotive industry constantly increases the number and types of EVs available to consumers. Third, the share of renewables in the energy sector is on the rise in all countries, leading to a greener electricity mix, and to an expansion of the social cost advantages of EVs relative to ICEVs. This trend is likely to be further strengthened by advances in battery storage technology. Consequently, there is still considerable room for economies of scale and scope that will decrease EV prices, increase their market share and reduce the need for policy support.

On the contrary, there is much more uncertainty and conflicting evidence regarding the efficiency of the EV incentivising policies, on the basis of both cost-benefit analysis and applied general equilibrium models. Some authors argue against EV subsidies, other argue in their favour. More research is needed, although we believe that no general answer is possible. The results are likely to be country-, region-, and city-specific. Depending on how electricity is generated, where the vehicle is used, and what car segment is considered, one may obtain different answers. Furthermore, the question is time-dependent, since technology improvements constantly change the parameters of the evaluation model. The difficult task for the researcher is to advise policy makers on the efficiency of the proposed policy measures taking into consideration all relevant variables and case-specific parameters, and their likely evolution in the coming years.

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