Contents lists available at ScienceDirect

Technological Forecasting & Social Change

An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe

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ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 3 August 2016
Accepted 8 August 2016
Available online xxxx

Keywords:
E-mobility
Automotive technology transition
System dynamics modelling
Charging infrastructure
EU policy

ABSTRACT

This research contributes to discussions about policy interventions to stimulate the transition of vehicle technology. Concentrating on passenger cars, an extensive system dynamics based market agent model of powertrain technology transitions within the EU up to 2050 is employed. With a focus on subsidy scenarios for both infrastructure deployment and vehicle purchase, and set within the context of the EU fleet emission regulations, we find that there are important interactions between different powertrain types and with infrastructure provision. For example, strong plug-in electric vehicle (PiEV) policy could inhibit the maturity of hydrogen fuel cell vehicles. Infrastructure provision is important for improving the utility of a PiEV, but we find that in the early market it may have a weaker correlation with uptake than other policy options, until the PiEV stock share is over around 5%. Furthermore, an attempt to install a ratio of much more than one charge point per 10 PiEV may lead to little gains and high costs. PiEV sales are relatively insensitive at target levels over 25 PiEV per charge point. The results of our study can help policymakers to find the right balance and timing of measures targeting the transition towards low carbon alternative vehicles.

1. Introduction

Electro-mobility is seen by many to be at the core of future mobility patterns. Electric Vehicles (EV – comprising Plug-in Hybrid Electric Vehicle (PHEV), Battery Electric Vehicles (BEV) and Fuel Cell Vehicles (FCV)), based on an electric motor powertrain, offer a potentially substantial contribution to overcoming environmental problems created by the widespread dependence on conventional automobiles. Conventional Internal Combustion Engine vehicles (ICEV), mainly fuelled with petrol or diesel, have dominated mobility for the past century. As the transport sector currently makes the third greatest contribution to global carbon emissions (IEA, 2016) and accounts for half of daily oil consumption (IEA, 2015), a paradigm shift in mobility is required. Within the context of climate change, this transition needs to occur within the next 30 years to avoid serious irreversible shifts in our climate (IPCC, 2013). In Europe, where transport is the second largest source of greenhouse gas (GHG) emissions, accounting for around a quarter (EC, 2016), the European Union (EU) is committed to reduce GHG emissions economy wide by 40% (versus 1990 levels) by 2030 with road transport playing an important role towards achieving these targets (EC, 2014). Furthermore, the 2011 EC White Paper on Transport set a target of reducing road transport emissions by 60% of 1990 levels by 2050, and within this to "halve the use of 'conventionally fuelled' cars in urban transport by 2030 and phase them out in cities by 2050" (EU, 2011a). Here, "conventionally fuelled" is defined as those vehicles powered by Internal Combustion Engine (ICE) only. Consequently, EVs as a zero tail-pipe emitting transportation option have arisen as a critical enabler for a low carbon economy (EU, 2014a) as well as for improved air quality.

Various studies have considered future EV market penetration, with both short and long term estimates varying greatly (Pasaoglu et al., 2012), and the IEA suggesting only a 9% global light duty vehicle stock share by 2030 and 40% by 2050 under their 2DS scenario (IEA, 2016). This seems far off EU targets, and as such regulation aimed at manufacturers to reduce fleet emissions has been introduced (EU, 2014b; EU, 2014c). Currently, only Plug-in Electric Vehicles (PiEVs – PHEV and BEV), are widely available. However, as yet, and despite rapidly growing sales (ACEA, 2016) they have failed to capture a significant passenger car market share and continue to be dependent on support measures, such as financial incentives (Mock & Yang, 2014; Thiel et al., 2015). One significant reason for this is limited consumer acceptance, due to high upfront costs and the phenomenon of range anxiety (Thiel et al.,

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Abbreviations: BEV, Battery Electric Vehicle; PHEV, Plug-in Hybrid Electric Vehicle; PiEV, Plug-in Electric Vehicle – BEV and PHEV; FCV, Fuel Cell Vehicle; EV, Electric Vehicle – PiEV and FCV; HEV, Hybrid Electric Vehicle; ICEV, Internal Combustion Engine Vehicle; pCP, public (slow) Charging Point; rCP, rapid Charging Point; PTTMAM, Powertrain Technology Transition Market Agent Model; DAFI, Directive on the Deployment of Alternative Fuel Infrastructure.

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http://dx.doi.org/10.1016/j.techfore.2016.08.007

Please cite this article as: Harrison, G., Thiel, C., An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.08.007

2012). In recognition of the cost barrier, many countries are introducing fiscal incentives (ACEA, 2014). In addition, both costs and range anxiety are related to the current capabilities of battery technology. Battery costs are reducing rapidly (Nykvist & Nilsson, 2015), but to alleviate the latter concern policy makers in countries across Europe are encouraging the development of an appropriate charging infrastructure. There are various factors which may impact on the efficacy of infrastructure on uptake, including increasingly cheaper and more rapid chargers, battery capacity and private charging capabilities. This is often termed a “chicken and egg” problem, as infrastructure providers are reluctant to invest without a substantial EV market, yet drivers are wary of entering into e-mobility without the confidence of a reliant, widespread, and interoperable charging infrastructure.

Previous research related to EV policy has focused on the most widespread policies currently applied, which are fiscal incentives for users (ICCT, 2011a; Brand et al., 2013; Diamond, 2009; Gass et al., 2014; Hidrue et al., 2011; ICCT, 2011b; Lane & Potter, 2007; Tran et al., 2013) and regulation of manufacturer emissions or vehicle efficiency (IEA, 2008; ITF, 2010; Walther et al., 2010; Thiel et al., 2014). This research has generally agreed that due to the high cost differential between EVs and their conventional counterparts, fiscal incentives are required to encourage early adopters to the technology leading to successful pre-mass market penetration. From a supply-side point of view, manufacturers must be also encouraged to invest further in R&D of low carbon technologies in order to bring increasingly affordable and efficient EV into the commercial market. For example, besides fleet emission regulatory targets (EU, 2014b; EU, 2014c; EU, 2009a; EU, 2011b) and member state co-funded R&D projects, the ‘European Green Vehicles Initiative’,[1] has been an important public-private-partnership at EU level since 2008, funding numerous activities under the EU framework programmes for research and innovation (e.g. Framework Programme 7, Horizon 2020). Altogether there are >300 ongoing R, D & D projects with a total budget of nearly 3 billion euros across the EU co-funded by both the EU and member states. On the one hand these projects support technological improvements, most notably for energy storage and control devices, on the other hand, through field tests, they address customer acceptance and vehicle to grid integration (Zubaryeva & Thiel, 2013).

In general, it is not controversial to suggest that policies to introduce sufficient public charging infrastructure are necessary to encourage the introduction of EVs (Bakker & Jacob Trip, 2013; OLEV, 2011). This is to overcome issues of range anxiety, identified to be one of the most significant barriers to EV adoptions in many choice modelling studies (Batley et al., 2004; Beggs et al., 1981; Brownstone et al., 1996; Dagsvik et al., 2002; Eggers & Eggers, 2011; Ewing & Sarigollu, 2000; Potoglou & Kanaroglou, 2007). However, there has been little literature empirically exploring the relationship between minimum charge point provision and EV uptake, instead tending to focus (for example) on socio-economic or spatial distribution (Namdeo et al., 2014; Zubaryeva et al., 2012; Maia et al., 2015) and charging profiles (Robinson et al., 2013; Donati et al., 2015). Although these may be determinants of EV uptake, current EU policy is focused on guaranteeing a minimum ratio of charge points to EVs in order to avoid market fragmentation and ensure coverage across national borders (EU, 2014a). Recharging infrastructure has been analysed through evidence-based studies, expert elicitation and multi-criteria assessment for determining the policy promoters of EVs. For instance, Zubaryeva et al. (2012) identified that an adequate recharging infrastructure was one of the most important parameters for the large scale deployment of PiEVs in Europe, and (Sierzchula et al., 2014) have found that countries could achieve high adoption rates by increasing their recharging infrastructure levels. Other studies suggest that collaborative schemes between private and public authorities combining incentives and infrastructure are required for success (Mock & Yang, 2014; Thiel et al., 2012; Rowney & Straw, 2013; Norbech, 2013; Lane & RAC, 2011). Hence, recharging infrastructure can be considered one of the critical parameters in market penetration of EVs.

This paper takes the EC Clean Power for Transport package (EC, 2013a) as a starting point and seeks to explore what impact government policy on infrastructure can have on EV uptake. In particular, we focus on the recently adopted Directive on the Deployment of Alternative Fuels Infrastructure (DAFI) 2014/94/EU (EU, 2014a), and the proposals therein regarding minimum coverage of PiEV charging infrastructure by the end of 2020. We take the approach to identify what impact policy options may have on long term EV penetration. We analyse numerous policy scenarios, recognising that single e-mobility policies should not be considered in isolation as the interaction between multiple policies is highly relevant. For example, a suite of incentives and other demand stimulating policies were employed by Norway, the most successful European country in terms of EV uptake (Mock & Yang, 2014; Norbech, 2013). Our approach seeks to understand how specifically supporting the infrastructural system may characterise uptake within the wider policy environment. For the wider policy environment we consider supply (e.g. fleet emission regulation) and demand stimulating policies (e.g. purchase incentives). To do this, our research employs an extensive system dynamics model of the EU automobile market, which reflects the relevant market agents of users, manufacturers, infrastructure providers and authorities. This research is the application of the model, which is described in detail in a Technical Report (Harrison et al., 2016), and was presented in a previous paper by the authors (Pasaoglu et al., 2016). (Pasaoglu et al., 2016) was designed as an introduction to the model that could then be built upon in future publications such as this, as it focused on only five generic scenarios reflecting three market variables (learning rate, oil price and GDP) and two policy options (vehicle purchase subsidies and fleet emission targets). The purpose of this study is to focus on the provision of infrastructure, including within the context of the previous policy options, in a timely investigation regarding the implementation of (EU, 2014a).

2. Model overview

The Powertrain Technology Transition Market Agent Model (PTTMAM) was developed at the EC Joint Research Centre (JRC) in collaboration with Ventana Systems UK using Vensim™,[2] a leading and highly flexible software for system dynamics model building and simulation. The purpose and focus of the model is to study the interaction between, and influence of, the market agents on possible technology transitions within Europe, for each of the 28 member states and across the period 1995 to 2050. The use of system dynamics to analyse possible future scenarios of technology transition in the automotive sector has been explored by many authors (Walther et al., 2010; Bosshardt et al., 2007; Gomez et al., 2013; Harrison & Shepherd, 2014; Janssen et al., 2006; Kohler et al., 2010; Meyer & Winebrake, 2009; Richardson et al., 1999; Rodrigues et al., 2012; Shepherd et al., 2012; Struben & Sterman, 2008; Shepherd, 2014; Leiby & Rubin, 1997; Stepp et al., 2009; Boksberger et al., 2012; Stasinopoulos et al., 2012; Diwaker et al., 2013). Recent overviews of such studies can be found in Harrison and Shepherd (2014) and Shepherd (2014). Many of these have a limited focus, for example on one particular powertrain or country. At the other extreme, Gomez et al. (2013) focus on a simplified high-level global view. Their purpose ranges between forecasting deployment, detailed policy analysis, manufacturer strategies and environmental or economic assessments. To our knowledge, the model presented here is the first attempt to address not only the most relevant interacting agents within the light duty vehicle market (i.e. automotive manufacturers and suppliers, infrastructure providers,

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[1] http://www.egvi.eu

[2] http://vensim.com

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