Transport Policy 38 (2015) 19–26

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Cost-Benefit Analysis of policies for the development of electric vehicles in Germany: Methods and results ☆

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ARTICLE INFO

Article history:
Received 7 February 2013
Received in revised form
29 September 2014
Accepted 4 October 2014
Available online 11 December 2014

JEL Classification:
C53 Forecasting Models
Simulation Method
O33 Technological Change: Choices and Consequences
Diffusion Processes
D61-Allocative Efficiency
Cost-Benefit Analysis

Keywords:
Electric vehicles
evaluation
Cost Benefit Analysis

ABSTRACT

Policies toward the diffusion of electric vehicles received a lot of attention in the latest years in many developed countries. Yet the real costs and benefits for society as a whole of this technology have received limited attention from economists. In this context, the present paper proposes a thorough cost benefit analysis of policies for the development of electric vehicles in Germany. It also reviews the main existing models of EV diffusion to shed light on the modeling issues underlying the evaluation of EV policies. Elaborating on a comprehensive simulation model, it shows that the potential for EV is fairly limited while there is more room for intermediate technologies like Plug-in Hybrid Vehicles and Range Extenders. The paper concludes that most of the investigated policies have a negative benefit-cost balance. These results are strongly driven by the regulatory framework in which EV diffusion could take place and especially the Car Average Fleet Emission regulation EU 443.

1. Introduction

Electric cars as an alternative to conventional internal combustion engines are becoming increasingly popular among policy makers and the general public since they appear as a way to address environmental concerns as well as rising prices of fossil fuels. In this context, a number of countries are considering ambitious policies in order to foster the diffusion of such technologies. It is however unclear how such policies can represent a welfare improvement i.e. if their social benefits are larger than their costs. This is already apparent considering the high costs of some measures decided in given countries (consider a 5000 € premium proposed in numerous European countries) and the high targets of some policies (consider the target of 1 million vehicles in the German fleet in 2020 set by the German government). Such high targets and heavy costs should not, in themselves, be a sufficient rationale for rejecting these policies but they strongly suggest that they should be submitted to rigorous assessment.

In order to assess the validity of these policy packages, one needs to establish a consistent evaluation framework based on a realistic representation of the mechanisms leading to the diffusion of electric vehicles and a comprehensive representation of the costs and benefits that accrue to the different actors. Such an ambition was at the origin of the EMOB project, a research project funded by the German Ministry of the environment.

In this paper, we provide a description of the simulation tool developed within this project and show the main results obtained.

In Section 2, we review the main existing models for diffusion simulation and for evaluation of electric cars and the main findings of Cost Benefit Analysis and propose a number of guidelines for future developments. In Section 3, we provide a brief description of the model. In Section 4, we show results of selected policy scenarios. In Section 5, we discuss the results and conclude.

2. Existing models and results

The literature regarding the diffusion of electric vehicles consists of several types of approaches: diffusion forecast (which typically provide the foreseen development of electric vehicles in a given context), simulation models (that allow for large scale

☆Most of the findings of this article were obtained during the project MMEM made by the European School of Management and Technology, on behalf of the Federal Ministry of Environment and Nuclear Safety. The views expressed are however only those of the author.

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http://dx.doi.org/10.1016/j.tranpol.2014.10.005
0967-070X/

simulation of various policy scenarios), and evaluations (which provide results about the costs and benefits of policies). While these different materials should ideally be interlaced, it is often observed that they are actually separated which makes it possible to proceed our examination using this categorization.

2.1. Diffusion forecast can be based on Bass diffusion models or SP surveys

As far diffusion forecast is concerned, the available material mainly consists of simplified market penetration forecasts that are mainly based on the Bass diffusion theory (a methodology defined in Bass (1969, 2004) and used in studies like Becker et al. (2009) or ad hoc Stated Preferences surveys (Zito and Salerno, 2004, Mabit and Fosgerau, 2011). Some other studies (mainly carried out in a professional rather than a scientific context) rely on the concept of Total Cost of Ownership (TCO), an approach that, unless some extra complications are introduced, substantially assigns the demand to the cheapest technology (for a critic of cost driven decision process see Turrentine and Kurani, 2006).

Bass diffusion models are a way to model mathematically the speed at which the potential market of a given technology is achieved based on two types of behaviors: *innovation* and *imitation*. Stated Preferences surveys, as far as they are concerned, are based on surveys that propose to consumers hypothetical products (for instance a gasoline car with a given range and fuel costs, together with an electric car with different features) and obtain information on how much consumer preferences are sensitive to the different features (for instance: range, fuel cost). This information is then used to simulate consumer purchase behavior when products with given characteristics are introduced in the market.

2.2. Simulation models

Another important body of literature relates to models. Compared with the previous category, models tend to provide a wider approach to the diffusion pattern, by interlinking it with socio-economic determinants. Table 1 indicates the most relevant models available for forecast and evaluation of electric vehicles' diffusion. This type of approach can prominently be illustrated by the U.S. project Transition toward Alternative Fuel Vehicles: TAFV (Greene 2001) and its successor: AVID (Santini and Vyas, 2005). To this type of approach can also be linked analysis based on system dynamics (Shepherd et al., 2012).

2.3. Electric car evaluation

Most of the models quoted above concentrate on market diffusion, with no connection to evaluation (TAFV, AVID and AECOM are exceptions to this). Parallel to this, the literature also proposed a number of studies labeled as "Cost Benefit Analysis" or evaluation of electric vehicles. Most of the studies falling into this category actually use this terminology improperly, at least to our view, as they consider the costs and benefits to car users only (Simpson, 2006), or alternatively, the industry, or a government agency (Kosub, 2010), or sometimes omitting the externality component of the Cost Benefit Analysis (Draper et al., 2008) negating the intrinsic holistic view of evaluation that should instead consider costs and benefits to society as a whole.

Some studies however take a broader view on the topic. Kazimi investigates the effect of electric and alternative fuel vehicles on air quality in the Los Angeles area and provides the $ value of the related benefits (Kazimi, 1997a,1997b). However, this analysis does not compare benefits against costs. Funk and Rabl analyze the private and social (= private+external) km costs of electric against gasoline and diesel vehicles in France (Funk and Rabl, 1999,

Table 1
Selection of existing models for the forecast and evaluation of electric car diffusion.[a]

Model	Country-Time frame	Type of model	Market diffusion approach	Observation
TAFV (Greene, 2001) and AVID (Santini and Vyas, 2005)	USA	Micro economic welfare maximization model	Discrete choice model. Coefficients derived from microeconomics and, partly, economic data	High level of resolution among technologies and fuel types
VISION (Singh et al., 2003) (see also VISION CA)	USA- until 2050	Spreadsheet model	Exogenous market penetration assumption for different technologies	Diffusion pattern is strongly driven by numerous exogenous assumptions
AECOM (AECOM Australia, 2009)	Australia Until 2040	Market penetration forecast	Synthetic Utility Function	
CalCars (Kavalec, 1996)	California 1994–2015	Market and policy simulation model	Nested multinomial logit for ownership and technology choice based on RP and SP data	
IPTS transport technologies model (Christidis et al., 2003)	20 developed countries: up to 2020	System dynamics	Weibull distribution based on costs,+Wood algorithm to take into account capacity constraints	Implemented in Vensim
Vector21 (Mock et al., 2009)	Germany until 2030	Extended TCO approach	TCO+wtp for "advanced vehicles"	Model includes 9 technologies and 900 customer types BEV diffusion is exogenously limited (for instance to 50% for small cars) to reflect range limitation
ASTRA (IWW et al., 2000)	EU 27: until 2050	System dynamics model integrating macro-economic transport and environment	Discrete choice model. MNL	Implemented in Vensim Discrete choice calibrated on diesel/gasoline competition 1990–2006

[a] Other existing transport models were not considered in this table (for instance Transtools. Tremove) as they have a limited focus on EV's..