Transportation Research Part D 25 (2013) 5–17

Contents lists available at SciVerse ScienceDirect

Transportation Research Part D

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

Consumer preferences for alternative fuel vehicles: A discrete choice analysis

André Hackbarth *, Reinhard Madlener

Institute for Future Energy Consumer Needs and Behavior, School of Business and Economics/E.ON Energy Research Center, RWTH Aachen University, Mathieustrasse 10, 52074 Aachen, Germany

ARTICLE INFO

Keywords:
Discrete choice models
Alternative fuel vehicles
Vehicle adoption policies
German transport

ABSTRACT

This paper analyzes the potential demand for privately used alternative fuel vehicles using German stated preference discrete choice data. By applying a mixed logit model, we find that the most sensitive group for the adoption of alternative fuel vehicles embraces younger, well-educated, and environmentally aware car buyers, who have the possibility to plug-in their car at home, and undertake numerous urban trips. Moreover, many households are willing to pay considerable amounts for greater fuel economy and emission reduction, improved driving range and charging infrastructure, as well as for enjoying vehicle tax exemptions and free parking or bus lane access. The scenario results suggest that conventional vehicles will maintain their dominance in the market. Finally, an increase in the battery electric vehicles' range to a level comparable with all other vehicles has the same impact as a multiple measures policy intervention package.

1. Introduction

The transportation sector is responsible for a large share of the European Union's greenhouse gas (GHG) emissions, and consequently is a focal point of the European Commission's sustainability strategies. Beyond that, most individual member countries have decided to implement programs to further accelerate the diffusion of alternative fuel vehicles[1] (AFVs) in general and electric cars in particular, including financial incentives as well as command-and-control measures. However, although there is an increased interest in less environmentally intrusive transportation technologies on the part of European governments, AFVs have not largely penetrated the market yet. Thus, drawing on German stated preferences discrete choice data and applying a mixed logit model, the purpose of this paper is to assess the relative impact of vehicle attributes, such as purchase price, fuel cost, driving range, fuel availability, CO_2 emissions, refueling time, and governmental incentives, on the choice probabilities of AFVs. In particular, we look at the willingness-to-pay (WTP) for such features and simulate how changes of these affect the potential market shares of the different propulsion technologies in a scenario-based analysis.

Our study builds on the rich body of literature on the demand for AFVs, and especially the research of Achtnicht et al. (2012), who also consider the German market, but we expand these studies by additionally taking PHEVs as choice alternative, and driving range, recharging time, and governmental incentives as vehicle attributes into account, to more realistically analyze consumer preferences regarding electric mobility.

* Corresponding author. Tel.: +49 2418049834; fax: +49 2418049829.
E-mail address: ahackbarth@eonerc.rwth-aachen.de (A. Hackbarth).

[1] AFVs are vehicles that run on liquid or gaseous fuels other than gasoline and diesel, or at least partly on electricity. These include biofuel vehicles (BVs), natural gas vehicles (NGVs), and hydrogen (fuel cell electric) vehicles (FCEVs). There are also hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and fully battery electric vehicles (BEVs).

1361-9209/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.trd.2013.07.002

Table 1
Attributes and levels of the discrete choice experiment.

Variable	Alternative (fuel type)	No. of levels	Levels
Purchase price	All	3	75%, 100%, 125% of stated reference value (€)
Fuel cost per 100 km	All	3	€5, €15, €25
CO_2 emissions	CV, NGV, HEV	3	50%, 75%, 100% of average vehicle
	PHEV, BEV, BV, FCEV	3	0%, 50%, 100% of average vehicle
Driving range	CV, NGV, HEV, PHEV, BV, FCEV	3	400 km, 700 km, 1000 km
	BEV	3	100 km, 400 km, 700 km
Fuel availability	CV, HEV	2	60%, 100% of all stations
	NGV, PHEV, BEV, BV, FCEV	3	20%, 60%, 100% of all stations
Refueling time	CV, NGV, HEV, PHEV, BV, FCEV	2	5 min, 10 min
Battery recharging time	PHEV, BEV	3	10 min, 1 h, 6 h
Policy incentives	PHEV, BEV, BV, FCEV	3	None, no vehicle tax, free parking and bus lane access

2. Survey design and data

The data were collected in a nationwide, web-based survey conducted in July and August 2011. The sample was drawn from a commercial German online panel, with the restriction that the last vehicle purchase of potential respondents did not date back more than a year, or that the potential respondents intended to purchase a new car within the next year. In total, 711 respondents completed the survey. Although the sample was supposed to represent the German population in terms of socio-economic and socio-demographic factors, a comparison with the population statistics shows certain differences.

Specifically, the survey under-represents individuals with low incomes, while it over-represents younger and more highly educated people, both being common features of web-based surveys. Moreover, single-person households and households without a car are under-represented. Car buyers who live in urban areas, who are not willing to spend more than €20,000 for their next vehicle, and who drive more than 20,000 km per year are over-represented. The sample, however, almost perfectly reflects the gender ratio, home ownership structure, vehicle segment, and regional distribution of the population among the 16 German federal states

The survey is sectionalized. Section 1 seeks information about the respondents' existing and planned car ownership and driving habits, such as vehicle fuel type and vehicle segment, daily and annual mileage on highways and for city trips. Section 2 focuses on familiarity with AFVs, an introduction to alternative propulsion technologies, and the stated preferences discrete choice experiment. In Section 3, respondents were asked about the importance of a wide range of vehicle attributes, including those used in the choice experiment, in their purchase decision. In Section 4, respondents indicated their level of agreement with a variety of statements regarding their environmental concerns and environmentally friendly behavior, their socio-economic and socio-demographic characteristics, such as age, income, and educational level, and specifics of their place of residence

The stated preferences discrete choice experiment was at the center of the survey, and embraced seven fuel types (NGVs, HEVs, PHEVs, BEVs, BVs, FCEVs, and conventional (gasoline, and diesel) vehicles (CVs)) to cover all propulsion technologies, that are already available on the German market, or will be in the near future. The seven vehicle types were described by: purchase price, fuel cost, CO_2 emissions, driving range, fuel availability, refueling time, battery recharging time, and policy incentives. Table 1 shows the attribute levels used.

To reduce the hypothetical bias, respondents were solicited to treat their choices as if it were a real purchase decision, and instructed to treat the vehicles as being identical other than in terms of the attributes described in the experiment. To further increase realism, purchase prices were customized for each respondent based on statements about the price range of their latest or expected next car, and allowed to vary by ±25% for all types of vehicles.[2] Fuel cost was displayed in Euros per 100 km to avoid the unit conversion of other fuel consumption measures (e.g. Euros per liter, kW h or kg), thus making it easily comparable between the different propulsion technologies.

CO_2 emissions were taken as being in proportion to the average vehicle of the respondents' favorite car segment, to establish more realistic choice situations, i.e. as if a fixed, segment-invariant measure (e.g. gram of CO_2 per kilometer) would have been used. Additionally, in contrast to CVs and NGVs, the CO_2 emissions of the non-fossil fuel vehicles were allowed to be zero.[3] The driving range was defined as the distance that can be traveled on a full tank and/or battery. Because the cruising radius of BEVs is currently limited compared to other propulsion technologies, the levels of their driving range attribute were adjusted downwards in order to increase realism. Fuel availability also varied by fuel type to reflect the current differences in refueling network density.[4] Regarding the length of the battery-charging process, the attribute levels have a great bandwidth to

[2] This range is unrealistic for some AFVs, especially BEVs. However, it was chosen to circumvent the dominance of purchase price over other vehicle attributes, making AFV choice more likely and parameter estimates more reliable.

[3] This emission value is used because AFVs, especially BEVs, are often promoted as being very environmentally friendly. Besides, FCEVs and BEVs theoretically have the potential to drive nearly emission-free, provided that electricity and hydrogen are generated with renewable energies.

[4] In 2012 there were 14,732 gasoline filling stations in Germany, with almost 7500 selling natural gas, but there were only 2073 publicly accessible battery recharging stations, 337 bioethanol, and about 35 hydrogen filling stations.