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How may incentives for electric cars affect purchase decisions?☆

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ABSTRACT

In this paper, the impact of five different incentives for buyers of zero emission vehicles (ZEV) is investigated with a stated choice experiment. The tested incentives are direct subsidies, free parking, a separate CO2 tax, an increase of fuel costs by tax elevation, and an increase of available charging infrastructure. By implementing the mobility patterns of the respondents, it was possible to simulate estimations of ecological impact and modal shift with a random utility model (mixed logit). Based on 875 complete questionnaires, the simulation results show that giving incentives to these buyers ecological rebound effects are expected: Mostly people with a low CO2-emission rate regarding their daily transportation routines (cyclists and public transport users) will exploit these incentives. They show a significantly higher likelihood of choosing alternatively propelled cars than conventional car users. Consumers that usually use a passenger car for their daily mobility routines are mostly unwilling to change to ZEV even when incentives are given.

1. Introduction

In the fight against global warming and forthcoming oil shortage zero emission vehicles (ZEV) such as battery electric vehicles (BEV – running only on electricity from the grid), plug-in hybrid electric vehicles (PHEV – running on electricity from the grid and on fossil fuel) or fuel cell electric vehicles (FCEV – running on hydrogen) have come into the focus of transport policies in order to decrease greenhouse gas emissions from the transportation sector. The German government for example established the German Federal Development Scheme for Electric Mobility (Federal Republic of Germany, 2009) in 2009. With this scheme the government set the ambitious target of 'one million electric cars on German roads by 2020'. With a traditionally strong automobile industry, Germany wants to position itself as the market leader of electric cars (Federal Republic of Germany, 2009). But, even years after introduction of this scheme, purchases of ZEV show small numbers: only about 19,000 BEV and 33,000 HEV are on Germany's streets in the end of 2014 (Federal Motor Transport Authority, 2015). Due to the slow market penetration of ZEV, a debate on implementing incentive schemes to stimulate the demand for electric cars arose. Different stimulation schemes have been introduced in other European and non-European countries. The variety of incentives as push and pull measures is broad: tax exceptions, privileges (free parking, using bus and taxi lanes, carpooling lanes,[1] etc.), direct purchase subsidy, introduction of CO2-free zones are the most frequently discussed. International approaches differ strongly: While countries such as Denmark and Norway subsidize ZEV purchases and liberate from tax, countries such as Germany used to support only research and development projects. In some countries a strong increase of purchase numbers of ZEV can be observed where subsidies (buying grants and tax reductions) are given, e.g. Norway (Breivik and Volder, 2014). A recent global review about incentives for plug-in electric vehicles is given in (Zhou et al., 2015). But, purchase decisions have not been investigated in dependence of the buyer's mobility behavior. Studies so far investigate elasticies of incentives, e.g. (Jenn, 2014) or technological attributes in order to predict general sales numbers of ZEV. They do not account for the energy ratio for mobility of the buyers.

This paper gives first insights about possible ecological effects of different hypothetical incentives fostering ZEV in combination with the mobility behavior of the respondents. Subsidies on the one hand may increase sales of ZEV. But on the other hand, from the ecologic perspective vehicles with a combustion engine should be exchanged by ZEV and drivers should preferably have a high

☆A discrete choice study investigating the ecological impact and modal shifts due to governmental incentives fostering the market penetration of zero emission vehicles in Germany.

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[1] USA and Canada specific.

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annual mileage in order to reduce the energy ratio for mobility. This is very important since electricity from the grid in Germany still is not 100% renewable. That means also ZEV emit greenhouse gases in a well-to-wheel consideration. The energy ratio would even worsen if incentives would bring cyclists and users of public transport (PT) to use ZEV since they become affordable. Additionally, these cars are considered as environmental friendly. Especially these groups showing a very low energy ratio for mobility should not be motivated to buy an individual passenger car. Sales of ZEV should not be additive but replace existing conventional vehicles. Against the background of the current discussion in Germany about the effects of incentives for ZEV and which incentives should be implemented, an online stated preference experiment which is representative for Germany was conducted.

2. Research design

An online survey with 1010 respondents was conducted in the metropolitan area of Hamburg, Germany, which resulted in 875 completely finished questionnaires. Hamburg was chosen due to its spatial diversity[2] (e.g. inner city and rural areas). In order to simulate hypothetical purchase decisions, a stated preference (SP) experiment using a choice-based conjoint analysis (CBCA) was conducted. The respondents were only selected by their socio economic and socio geographic attributes. The circumstance if a respondent was about purchasing a new car in the near future was not of interest, since it would bias the results against the background of the research interest investigating the effect of incentives across all citizens using different means of transport. An example of a choice set is given below in Fig. 1. The respondents' purchasing decisions are simulated with a random parameter utility model (mixed logit) to account for dependence across observations from the same respondent (Small et al., 2005). Logit models are applied to determine consumers' 'tastes' towards certain products, services or attributes of products (Brownstone et al., 2000; McFadden and Train, 2000; Lave and Train, 1979; Hensher et al., 2008; Train, 1998, 1986, 1980; Akiva and Lerman, 1985; Manski and Sherman, 1980). The estimation results simulated by mixed logit models should approximate reality more accurately than traditional conditional logit or multinomial logit models due to the ability to implement individual heterogeneities amongst respondents. The applied model is based on Revelt and Train (1998). To estimate the β-coefficients the mixed logit module by Hole (2007a) is applied. Hole's model uses a maximum likelihood simulation to estimate the coefficients (Hole, 2007b). For a detailed description of the methodology of the simulated maximum likelihood method please refer to (Hole, 2007a, 2007b; Train, 2003).

Besides the knowledge of the preferred propulsion technology and the importance of the different incentives, it is necessary to know the mobility patterns of the respondents to draw conclusions from their decision to their future mobility. Therefore the respondents are asked during the survey about their daily mobility routines, i.e. yearly mileage (higher or lower than 15,000 km/year), possession of annual transit pass, use frequency of bicycles (daily use, sometimes, never), use frequency of PT (daily use, sometimes, never). Four groups with different mobility patterns could endogenously be clustered: car users, PT users, Multimodal users – with car affinity, Multimodal users – with PT affinity.

By applying different incentives to the model, the impact of each incentive on the choice of propulsion technology could be estimated separately for each mobility group. Due to methodology the results are based on hypothetical assumptions given by the respondents, not the revealed factual behavior.

In order to identify the attributes (here: purchase incentives) which should be investigated, a literature review about the state of the art survey design gave valuable hints. Green and Srinivasan (1978) state that not more than five to six different attributes should be tested within a discrete choice experiment, while Thomas (1983) report that up to 20 attributes can be applied. Ito et al. (2013) uses a CBCA to identify the willingness to pay for alternatively propelled vehicles in Japan and the resulting cost to install the charging infrastructure. He examines nine attributes: vehicle type, brand, driving range, recharging time, CO2 emission, availability of charging infrastructure, price, and operating costs. For Canada, Potoglou and Kanaroglou (2006) conducted a discrete choice study with nearly the same attributes. The model results show that direct purchasing subsidies and the emission rate of CO2 have the highest influence on the purchasing decision. Ewing and Sarigöllü (2000) conducted a CBCA (N=881) with commuters to examine the importance of price, costs for maintenance, acceleration, recharging time, driving range, emissions, privilege to use car-pooling lanes, fuel costs, and parking costs. They show that these measures will have only a small impact on the purchasing decision towards ZEVs and come to the conclusion to foster research and development projects instead. Axsen et al. (2009) conducted an SP analysis in California and Canada to investigate governmental incentives for HEVs, which are not in the scope of this paper. Daziano and Achtnicht (2012), Achtnicht (2009), Achtnicht et al. (2008) and Ziegler (2012) applied different models to a survey conducted in 2008 using an SP experiment with six tasks each showing seven different concepts. They investigated price, fuel costs per 100 km, engine performance, CO2 emissions, availability of charging infrastructure and type of fuel. Raich et al. (2012) finds out in a survey conducted in Austria using an SP experiment that cost-affected attributes have a much higher influence on the purchasing decision than technological attributes (such as driving range, recharging time, emission rate). Mabit and Fosgerau (2011) also conducted an SP experiment in Denmark. The experiment had 12 tasks each with five alternatives to choose from. They examined propulsion technology, fuel costs, price, driving range, number of charging operations per week, acceleration and further operating costs. The survey conducted by Dagsvik et al. (2002) with respondents from Norway comprised 15 tasks each with three vehicle concepts. They investigated price, maximum speed, driving range and energy consumption. Knockaert (2005) used in his study price, operating costs, fuel consumption, propulsion technology, driving range, emissions, volume of trunk.

The literature review shows that all studies focus on investigating purchase decisions based on technological attributes of the vehicles. Purchase models are developed and the development of ZEV sales can be predicted depending of developments of these attributes. No study examines the purchase decision combined with the mobility behavior of the respondents. Therefore, rather very general statements can only be given about the ecological effect and the overall energy consumption depending from the mobility patterns of the respondents.

The literature review shows also that the CBCA is the most common SP experiment design. Therefore, a CBCA is also applied for this study. Studies of the literature review show that best results are achieved with not more than three alternatives to choose from and the 'none option' ('I would purchase none of the alternatives.'). Each respondent had to complete eight similar choice tasks in sequence with three alternatives and the 'none option', levels of attributes are changed each time. shows a sample of the display.

[2] In further studies also spatial effects will be investigated.