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Modeling the uptake of plug-in vehicles in a heterogeneous car market using a consumer segmentation approach

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ABSTRACT

There is broad agreement on the need for substantial use of low carbon vectors in the long term in the transport sector. Electrification, via mass market adoption of plug-in vehicles (i.e. battery electric and plug-in hybrid electric vehicles), has emerged as a front runner for road transport across the globe, but there are concerns that the pace and extent implied by many modeling studies is problematic and that assessment of (a) the heterogeneity in the market, (b) other low carbon vectors (e.g. conventional hybrids, hydrogen fuel cell) and (c) life cycle energy and environmental impacts have been relatively neglected. This paper aims to fill these gaps by examining the timing, scale and impacts of the uptake of plug-in vehicles in the heterogeneous UK car market from a consumer perspective. To achieve this aim it (a) brings together a bespoke disaggregated model of the transport-energy-environment system (the UK Transport Carbon Model) with previous work by the authors on heterogeneity in the demand for and supply of plug-in vehicles and (b) applies the improved model to develop future low carbon scenarios that assess the potential impact of different investment pathways and policy approaches to the electrification of cars with the view to meeting the UK's legally binding carbon budgets to 2050. The results show the importance of accounting for the heterogeneity in and dynamic nature of the car market in terms of new technology adoption by private consumers, so called 'user choosers' and fleet managers, as well as accounting for potential effects on wider life cycle emissions resulting from different uptake pathways. It allows an assessment of the effectiveness of different policy instruments, market conditions (vehicle supply, private vs fleet market, vehicle segments) and social factors (consumer awareness, range "anxiety", perceived charging requirements) on different consumer segments, thus providing more policy-focused conclusions on the likely pathways to high penetration of plug-in vehicles that may be required to meet future carbon and air quality targets.

1. Introduction

1.1. The need to better understand (and model) the electrification of light duty vehicles

There is broad agreement on the need for substantial use of low carbon vectors in the long term in the transport sector. Electrification, via mass market adoption of plug-in vehicles (PIV, i.e. battery electric vehicles, BEV, and plug-in hybrid

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electric vehicles, PHEV), has emerged as a front runner over the past decade (AEA Technology, 2009; CCC, 2015; IEA, 2011, 2015a; OLEV, 2013; Sims et al., 2014), but there are concerns that the pace and extent implied by the underlying modeling studies is problematic and that assessment of consumer and market factors, effects of climate change mitigation policies on air quality emissions and overall life cycle emissions have been relatively neglected (Anable et al., 2012; Graham-Rowe et al., 2012; Leinert et al., 2013). In the UK, for instance, uptake of the recently released new generation of PIV has been slower than originally anticipated, although there are positive signs that this is improving. Whilst only 0.6% of new cars were PIV in 2014, the share of sales has nearly doubled to 1.1% in 2015 (Fig. 1); PHEV account for around two-thirds of PIVs being sold in the UK, and BEV a third (ibid). These figures represented a similar proportion of new car sales in the UK in 2014 as they did in the US, France and Germany, while California (3.2%) and Norway (17.8%) had two of the largest PIV market shares globally (Brook Lyndhurst, 2015). HEV still dominate the electric vehicle market, but they are not dissimilar to conventional gasoline/diesel ICVs and may not meet ultra-low emissions vehicle (ULEV) standards (currently < 75 gCO_2/km) in the future.

UK policy measures to support higher uptake are in place to 2020, although the recent announcement by the UK Government (HM Treasury, 2015) to abandon CO_2 grading of the road tax (or Vehicle Excise Duty) regime and weakening of the company car tax regime[1] has undermined its carbon mitigation commitment. So while the sales figures are encouraging, analysis by the UK Committee on Climate Change suggests that 9% of new car sales should be EVs by 2020 and 60% by 2030 (CCC, 2015) to meet carbon budgets cost-effectively. This implies mass market adoption of PIV at a rate of nearly doubling each year.

The UK policy focus on vehicle technology and supporting fiscal incentives reflects other global transport modeling exercises that project between 40% and 90% market penetrations of PIV between 2030 and 2050 (IEA, 2011, 2015a, 2015b; Kay et al., 2013; Lieven, 2015; McKinsey & Company, 2009; WBCSD, 2004; WEC, 2007). Many of these modeling studies examine car market at the aggregate level, rely on cost-optimization (e.g. Dodds and McDowall, 2014; IEA, 2015b) or simulate market dynamics based on technological and economic barriers and enablers of uptake (e.g. Kay et al., 2013). They largely ignore the heterogeneous and segmented nature of the car market, both in terms of supply (choice of vehicles) and demand (private/fleet, consumer segments), which needs to be integrated for the models to become more useful. Psychology, behavioral economics and sociology have revealed a coherent view of the importance of non-economically rational aspects of human (choice) behavior (see e.g. Anable et al., 2012; Morton et al., 2014; Schuitema et al., 2013; Schwanen et al., 2011), which suggests that there are potentially many more determinants to include in our models. In the context of low carbon vehicle choice behavior, some researchers have recently focused on consumer heterogeneity in terms of their attitudes and demographics (Anable et al., 2014; Axsen et al., 2009; Daziano and Chiew, 2012).

1.2. The need to focus on the consumer

Consumer and market research has suggested that recharging requirements, "range anxiety", higher upfront purchase costs, lack of knowledge/awareness and limited choice of vehicles are the key barriers to adoption of PIV (Anable et al., 2014; Brook Lyndhurst, 2015; DfT, 2014a; Graham-Rowe et al., 2012; Kay et al., 2013). Recent consumer segmentation work has shown that PIV are more attractive to some segments of the population than others. Funded by the Energy Technologies Institute in the UK, the research involved in-depth two-wave surveys including attitudinal items combined with a quantitative (stated preference) choice experiment with 2729 mainstream UK consumers with recent experience of buying a new or nearly new car (Anable et al., 2011b). This showed that the top factors that distinguish consumer groups not unsurprisingly relate to many of the above barriers to/enablers of PIV uptake: lower running costs of PIV (+); high price premium over non-PIV (−); limited supply, both in terms of vehicle segments (e.g. supermini, small family) and brands (−); limited availability of charging infrastructure (at home, public) (−); shorter range and longer charging times (−); and lack of receptiveness to and acceptance of PIV or any incentives (−). As illustrated in Fig. 2, the study suggested that so-called 'Plug-in Pioneers' (about 2% of private car buyers) differ from mainstream consumers in that they are willing to pay more for fuel economy and environmental benefits, while at the other end of the spectrum, 'Image Conscious Rejecters' (18%) would "never be seen in one of those [PIV]". The factor analysis on more than 106 attitudinal statements[2] further revealed that mainstream attitudes to PHEV are very positive, but most have strong reservations about BEV (Anable et al., 2011b; ETI, 2013). Crucially, using multiple segments significantly increased the explanatory power of the statistical model, highlighting that attitudinal/demographic factors can influence PIV purchase decisions and allowing reactions to different attributes (e.g. willingness to pay for EV range) to be captured explicitly (rather than within the error term of the model) (Anable et al., 2011b).

[1] Ultra Low Emission Vehicles (ULEVs) have attracted lower tax (or 'Benefit-in-Kind') rates in the UK, with zero tax on BEVs until 2015 (Lane, 2016). Rates for ULEVs have since increased, however, and from April 2016, PHEVs are rated at 7% or 11% (depending on CO_2 ratings), and BEVs are rated at 7%. In April 2016 and 2017, BIK rates for cars in the 0–50 g/km and 51–75 g/km CO_2 bands are due to increase by 2% per year with a 3–4% rise planned for 2018.

[2] As described in more detail in Anable et al. (2016), these statements covered six main issues reflecting broad conceptual dimensions around attitudes towards owning/driving a car, innovativeness, environmental values, beliefs about plug-in cars in general, beliefs about PHEVs and beliefs about BEVs. Exploratory factor analysis (principal components and Varimax rotation) was used to uncover underlying psychologically meaningful constructs among these statements.