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Preference and lifestyle heterogeneity among potential plug-in electric vehicle buyers

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ABSTRACT

We characterize heterogeneity in preferences and motivations regarding plug-in electric vehicles (PEVs)—including plug-in hybrids (PHEVs) and electric vehicles (EVs). Using survey data collected from 1754 new vehicle buying households in Canada in 2013, we segment respondents using two approaches that prove to be complementary. Preference-based segments were constructed using latent-class analysis of discrete choice experiment data. Potential PEV buyers were split into a "PEV-enthusiast" segment (8% of the sample) with extremely high valuation of PEVs and a broader "PHEV-oriented" segment (25%) that expressed moderately positive valuation of PHEVs. Preference-based segments also varied by respondents' valuation of specific attributes such as fuel savings. Our second approach constructed lifestyle-based segments using cluster analysis on a subset of potential early PEV buyers (33% of the total sample). The six lifestyle-based clusters varied in engagement in environment- and technology-oriented lifestyles, environmental concern and openness to change. Overall preferences were fairly similar across the clusters, though apparent motivations varied substantially by cluster as indicated by their differing engagement in lifestyles and environmental concern. Taken together, both approaches suggest that PHEVs are the most likely PEV to have broad market appeal and that car buyers have high degrees of heterogeneity in both preferences and motivations.

1. Introduction

It is intuitive that consumers vary in their tastes and preferences for new products and technologies. One consumer might be wildly enthusiastic about electric vehicles, a second consumer shows cautious interest, while a third completely rejects the concept. Consumers can be segmented according to these stated or revealed preferences for new technology, where preferences are often quantified in terms of willingness-to-pay. Similarly, consumer segmentation can be based on the actual or likely timing of their purchase of a new technology, e.g. where a given consumer is either an "innovator", "early adopter" or part of the "early" or "late" majority (Rogers, 2003). Economic approaches to consumer heterogeneity tend to focus on these differences in overall preference.

In addition to preference and timing of purchase, consumers also vary in the motivations that underlie their preferences. For example, two consumers might demonstrate the same enthusiasm (and willingness-to-pay) for an electric vehicle, but one wants to drive a pro-environmental symbol while the other is excited about owning a cutting-edge technology (Heffner et al., 2007). Arguably, effective characterization of consumer heterogeneity should address variations in consumer motivations as well as overall preferences. This study aims to explore both aspects of heterogeneity, using survey data collected from a representative sample of 1754 Canadian new vehicle buying households, which included a stated choice experiment, design space exercises and questions on personal values and lifestyle engagement.

Understanding heterogeneity can be important in the anticipation of demand for emerging technologies with potentially pro-environmental attributes, such as alternatively-fuelled vehicles, solar panels, and energy efficient appliances. Such products are complex in that they can offer a mix of private, symbolic and pro-societal benefits to the consumer (Brown, 2001; Heffner et al., 2007). Consumer preference for such technologies might be motivated by one or multiple benefits—which can vary greatly across the market. We focus on the case of plug-in electric vehicles (PEVs)—an emerging set of technologies that may play a key role in a societal transition toward deep greenhouse-house (GHG) emission reductions (Williams et al., 2012). Our definition of PEVs includes plug-in hybrid electric vehicles (PHEVs) that can be powered by

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gasoline or grid electricity, as well as "pure" electric vehicles (EVs) that can only use grid electricity.

Most previous research into consumer demand for alternative-fuel vehicles has focused on preferences, typically estimating some form of discrete-choice model using empirical consumer data to quantify consumer valuation of technology (e.g. a PEV), or its attributes (e.g. one extra km of electric battery range) (e.g., Bunch et al., 1993; Potoglou and Kanaroglou, 2007). In that vein, we apply a latent-class discrete choice model as a way to identify consumer segments that primarily differ according to overall preferences (Swait, 1994). Latent-class choice modeling is an approach that has infrequently been applied to PEV demand, other than a few recent studies (e.g., Hidrue et al., 2011).

To quantitatively explore heterogeneity in consumer motivations, we also construct consumer segments based on "lifestyle theory"—which describes consumer behavior as at least partially motivated by the need to engage in coherent patterns of lifestyle that represent aspects of self-identity (Axsen et al., 2012; Giddens, 1991). Lifestyle theory postulates that a consumer is more likely to purchase and use a new technology like a PEV if it fits into a lifestyle that they currently engage in or want to engage in, such as an environment- or technology-oriented lifestyle. We identify lifestyle-based consumer segments using a cluster analysis method, and then estimate separate discrete choice models for each segment. Our final step is to integrate insights from our preference- and lifestyle-based segments to improve understanding of consumer heterogeneity in the potential early market for PEVs, and discuss implications for PEV policy and markets.

This paper is structured as follows. Section 2 provides background on theories of consumer preferences and lifestyle. Section 3 explains our data collection method and sample. Section 4 presents the method and results for our preference-based segmentation approach, and Section 5 does the same for our lifestyle-based segmentation approach. Section 6 summarizes and discusses our findings and concludes with implications for research and policy.

2. Background: two perspectives on consumer behavior

There are a wide variety of models of consumer behavior, and each model provides different explanations for the adoption or rejection of pro-environmental technologies and behaviors (Jackson, 2005; Peattie, 2010; Wilson and Dowlatabadi, 2007). Inevitably, the selected model will influence research results and the presumed implications for policy (Shove, 2010). Given our present objective of better understanding heterogeneity in consumer preferences and motivations, the selection of a model is important. This section reviews the two models that we draw from in this paper, with implications for the representation of heterogeneity. First is the preference-based approach that has dominated quantitative research on alternative fueled vehicles to date, and second is our lifestyle-based approach that explains consumer motivations according to the need to express and trial self-identity through engagement in meaningful activities, such as vehicle purchase and usage.

2.1. The rational actor model and heterogeneous preferences

Neoclassical economics describes consumer behavior according to the rational actor model, where consumers choose to buy products that maximize their individual utility or well-being (Hanley et al., 2013). Consumers are represented as having established preferences, or likes and dislikes, for different products and their various attributes. The consumer's valuation of a product depends on their valuation of the attributes that define it. In most modeling frameworks, preferences are assumed to be pre-existing and stable, where the consumer has perfect information about the products available (Jackson, 2005). Within neoclassical economics, consumer preference is typically quantified as willingness-to-pay (WTP), which is what a consumer (or in aggregate, the market) is willing to pay for one extra unit of a positive attribute (e.g. electric driving range), or for an electric vehicle relative to a conventional vehicle (comparing two packages of attributes). Preference theory, or neoclassical economic theory more generally, is silent on the motivations of consumer behavior—preferences are assumed to exist, but generally not further explored or explained by the researcher (Jackson, 2005).

Discrete-choice modeling has emerged as the dominant method used to quantify consumer WTP for products and their attributes (Ben-Akiva and Lerman, 1985; McFadden, 1974; Train, 1980), particularly for alternative-fuel vehicles—see Hidrue et al. (2011) for a review. Discrete choice models can be estimated from empirical data, either stated (hypothetical) or revealed (actual market data). These models estimate coefficients that represent the utility that consumers associate with different products and their attributes, and WTP can be calculated directly from the estimated coefficients of the utility function.

While simple discrete choice models estimate a single WTP value for an entire sample, more recent discrete choice modeling studies attempt to incorporate degrees of heterogeneity through a variety of methods. The most common method is the inclusion of interaction terms that estimate different WTP values based on socio-demographic variables such as gender, household size, education and commute distance (Brownstone et al., 2000; Bunch et al., 1993), for example how WTP for an alternative-fuel vehicle may vary by household income (Potoglou and Kanaroglou, 2007). Other discrete choice model studies have borrowed from behavioral theories beyond economics to interact preference estimates with constructs such as attitudes. In particular, alternative-fuel vehicle studies have frequently included variables representing environmental attitudes, where WTP is higher for respondents that are actively concerned about the environment (Ewing and Sarigollu, 2000) or that have higher environmental awareness (Hackbarth and Madlener, 2013; Ziegler, 2012).

A more sophisticated technique used to quantify preference heterogeneity is latent-class modeling, which identifies unique segments or "classes" of respondents and estimates different preference coefficients for each class (Swait, 1994). This approach has been applied infrequently to alternative-fuel vehicle demand. One example is Hidrue et al.'s (2011) study that estimated consumer WTP for electric vehicles (and their attributes) and identified two different classes of respondents: conventional vehicle-oriented versus EV-oriented. Respondent membership in these classes was primarily determined by their overall preference for EV technology—EV-oriented respondents had an overall positive valuation of EVs relative to conventional vehicles. Membership in the EV-oriented class was also associated with being younger, more educated, and more likely to have transitioned toward a pro-environmental lifestyle in the past 5 years.

A third approach to quantifying preference heterogeneity is the random-parameters logit model (also sometimes called a mixed-logit), which estimates a standard deviation for an attribute coefficient in addition to estimating the mean value (Yoo and Ready, 2014). Although this approach can be statistically powerful, with r-square values that exceed those of similar latent-class models, results can be difficult to interpret—providing very little insight into the consumer characteristics or motivations that explain the observed differences in WTP (Yoo and Ready, 2014).

There is also a "hybrid" choice modeling approach that seeks to more directly integrate discrete choice modeling with modeling of other consumer characteristics, such as consumer context, perceptions, attitudes, and information processing (Ben-Akiva et al., 2002). This hybrid approach includes latent-class models that construct consumer classes based on both preferences and additional socio-demographic information or other characteristics. Such models have been applied to the exploration of a number of topics and theories in a variety of contexts, such as: the role of social interactions in teenager walking preferences (Kamargianni et al., 2014); linking psychometric data to general travel preferences (Hurtubia et al., 2014); relating lifestyle and life stage to housing choices (Walker and Li, 2007); the role of social influence in