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Impact of vehicle usage on consumer choice of hybrid electric vehicles

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ABSTRACT

We analyze the vehicle usage and consumer profile attributes extracted from both National Household Travel Survey and Vehicle Quality Survey data to understand the impact of vehicle usage upon consumers' choices of hybrid electric vehicles in the US. In addition, the key characteristics of hybrid vehicle drivers are identified to determine the market segmentations of hybrid electric vehicles and the critical attributes to include in the choice model. After a compatibility test of two datasets, a pooled choice model combining both data sources illustrates the significant influences of vehicle usage upon consumers' choices of hybrid electric vehicles. Even though the data-bases have in the past been used independently to study travel behavior and vehicle quality ratings, here we use them together.

1. Introduction

Alternative fuel vehicles have drawn increasing attention, because of their potential to reduce greenhouse-gas emissions and utilize renewable energy sources. The use of alternative fuel vehicles, such as plug-in hybrid electric vehicles (PHEVs) is expected to grow significantly in the near future; in particular, US President Obama has called for half of all the cars purchased by the federal government to be PHEVs by 2012 and to have a million PHEVs on the road by 2015. Ample literature can be found in the transportation research domain that deals with potential environmental impacts of PHEVs.

While PHEVs are just now becoming available, hybrid electric vehicles have been sold to consumers since the late 1990s. In terms of future developments, however, understanding consumers' choices of HEV is challenging because their preference construction process involves many aspects beyond comparing vehicle specifications. For instance, mileage per gallon, heavily depends on total vehicle use and its form; e.g., local versus highway driving. As a result, consumers who drive primarily on local roads are expected to prefer HEV more than those who mainly drive on highways. In addition to its impact on product performance, vehicle use may also influence the preference structure. Understanding the impact of vehicle usage can be as important as understanding the other heterogeneous aspects, such as the demographic and socio-economic attributes of consumers.

2. Methodology: hierarchical choice modeling

To capture the impact of vehicle usage attributes upon consumers' choices of hybrid electric vehicles, a hierarchical choice modeling framework is employed. As seen in Fig. 1, the vehicle choice modeling framework utilizes a hierarchical modeling structure (Hoyle and Chen, 2009) that considers the impact of vehicle usage attributes **E** by including them as the input of the choice model at the top level together with their bottom-up influence on the vehicle performance attributes which also serve as input of the choice model. With discrete choice analysis (Train, 2003), the choice utility is derived by

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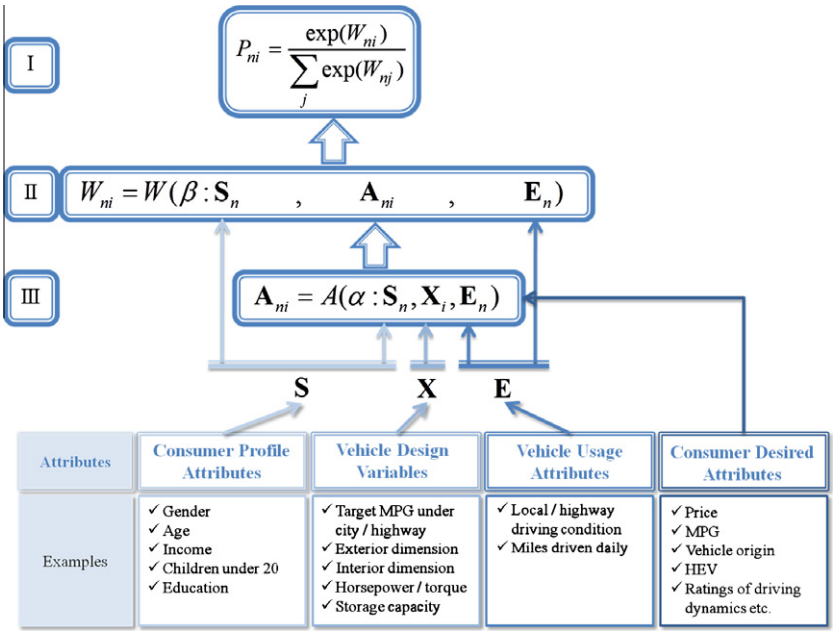

Fig. 1. Hierarchical choice modeling for hybrid electric vehicle.

assuming that the individual's (n) true choice utility, u, for a design alternative, i, consists of an observed part W, and an unobserved random disturbance ε (unobserved utility).

$$u_{ni} = W_{ni} + \varepsilon_{ni} = W(\beta : \mathbf{S}_n, \mathbf{A}_{ni}, \mathbf{E}_n) + \varepsilon_{ni} \tag{1}$$

The observed part of utility for respondent n and for alternative i, W_{ni}, is expressed as a function of consumer profile attributes $\mathbf{S}_n$, consumer desired vehicle attributes $\mathbf{A}_{ni}$, vehicle usage attributes $\mathbf{E}_n$, and the β coefficients, which are estimated by observing choices respondents make. Typical consumer profile attributes **S** include *gender*, *age*, *household income*, etc., while *local/highway driving condition* and *miles driven daily* are two of the commonly used vehicle usage attributes **E**. Consumer desired vehicle attributes **A** refer to key vehicle features that influence consumers' choice in selecting a vehicle. The inclusion of consumer profile attributes **S** and vehicle usage attributes **E,** in addition to consumer-desired vehicle attributes **A,** in the estimation of demand to capture the heterogeneity of consumer preference and their vehicle usage, is the key component in the hierarchical choice modeling framework.

Level I in Fig. 1 is the choice probability prediction function in multinomial logit model with Type I extreme value error distribution (Train, 2003), and level II represents the deterministic portion of the choice utility as a function of **S**, **A**, and **E**. At Level III, the bottom of hierarchy, a separate prediction model is established to link **A** with **X**, **S**, and **E**.

$$\mathbf{A}_{ni} = A(\alpha : \mathbf{S}_n, \mathbf{X}_i, \mathbf{E}_n) \tag{2}$$

While product attributes are often fixed as constants for different consumers in conventional choice modeling, their dependence on consumers and usage context is considered here. For example, mileage per gallon (mpg) is one of the key vehicle attributes. Even though vehicle manufacturers provide target mpg measures under city and highway driving condition for each of their car models, the actual mpg value varies significantly from consumer to consumer because of the heterogeneous usage scenarios and consumer driving habits. Similarly, consumer ratings of vehicle performances are also influenced by individual profile attributes such as *gender* and *age*.

In Eq. (2), the coefficients α can either be established by physical relations or determined through modeling. For quantitative attributes, the above model can be expressed by physical equations. When ratings are used to measure qualitative attributes, an ordered logit model can be used due to its capability of handling discrete data (He et al., 2011). By establishing a relation with vehicle design variables **X** through the hierarchical modeling framework**,** the obtained choice model can be used to support engineering design decisions (Wassenaar et al., 2005).

3. Data

While vehicle usage **E** plays an important role in consumers' choices because both product performance and consumer preference change under various usage conditions, questions about the relationship between vehicle usage and consumer profile attributes remain. To address some of these, National Household Travel Survey (NHTS) data is used; this includes