Transportation Research Part A 100 (2017) 294–310

Contents lists available at ScienceDirect

Transportation Research Part A

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

A time-dependent stated preference approach to measuring vehicle type preferences and market elasticity of conventional and green vehicles

Cinzia Cirillo *, Yan Liu, Michael Maness

University of Maryland, Department of Civil and Environmental Engineering, United States

ARTICLE INFO

Article history:
Received 1 March 2016
Received in revised form 29 November 2016
Accepted 24 April 2017
Available online 5 May 2017

ABSTRACT

The diversity of new vehicle technology and fuel markets, the governments' sustainable call to reduce energy consumption and air pollution lead to a change in the personal vehicle market. Considering the impact of these factors, a stated preference survey approach is adopted to analyze household future preferences for gasoline, hybrid electric, and battery electric vehicles in a dynamic marketplace. The stated choice experiment places respondents in a nine-year hypothetical time window with dynamically changing attributes including vehicle purchasing price, fuel economy, recharging range, and fuel price. A web-based survey was performed during 2014 in the state of Maryland. The collected data include household social-demographics, primary vehicle characteristics, and vehicle purchasing preferences of 456 respondents during the year of 2014–2022. Mixed Multinomial logit (MMNL) models are employed to predict vehicle preferences based on households' socio-demographics and vehicle characteristics. The estimation results show that young people are more likely to buy vehicles with new technology, especially battery electric vehicles (BEV). Women with a high education level (bachelor degree or higher) prefer to choose hybrid electric vehicle (HEV) while men with a high education level are more likely to buy BEV. The estimated vehicle market elasticities with respect to vehicle price are from −1.1 to −1.8 for HEV and BEV, higher than those for gasoline vehicles from −0.6 to −1.0. The vehicle market cross-elasticities estimated by MMNL models range from 0.2 to 0.6. In addition, willingness to pay (WTP) of vehicle characteristics estimated by MMNL models provide a good understanding of household future vehicle preferences.

1. Introduction

The development and the deployment of advanced vehicle technology has become a high priority for many governments and vehicle manufacturers around the world. These technologies include alternative fuels, plug-in electric vehicles, batteries, electric drive technologies, advanced combustion engines, and lightweight materials. Highly efficient combustion engines, innovative power systems and greener fuels can lead to fuel economy improvements, setting the foundation for clean, efficient, sustainable, and cost-competitive vehicles. The production of such vehicles and their adoption on a large scale is expected to improve mobility and energy security, while lowering costs and reducing environmental impacts (DOE, 2015).

Low carbon vehicles will help modern societies to build a more sustainable transportation system and achieve balance between social, economic, and environmental objectives. Purchasing a vehicle with better fuel economy can save consumers

* Corresponding author.
E-mail address: ccirillo@umd.edu (C. Cirillo).

http://dx.doi.org/10.1016/j.tra.2017.04.028
0965-8564/

a substantial amount over the lifetime of the vehicle; which also means that families will have more money to reinvest in other economic activities. Americans spend more than half a billion dollars a day to import oil, with transportation accounting for more than two-thirds of this use. While demand for oil products in Organization for Economic Co-operation and Development (OECD) Europe has reached a plateau as the population remains flat in most countries. China is expected to experience the largest absolute growth in liquid fuels consumption, growing by about 46% in 2020 and doubling in 2040 compared to the 2010 level, as it moves from an industrial manufacturing economy to a more service-oriented economy with greater automobile saturation. India will have the fastest growth rate in liquid fuels consumption from 2010 to 2020 (3.0% per year) and experience the second-largest absolute growth (behind China), primarily driven by diesel fuels used in transportation (U.S. Energy Information Administration, 2014).

In Europe and the United States (US), transportation accounts for more than a quarter of greenhouse gas emissions, and the total emissions from transportation are expected to grow rapidly in emerging economies. The US Department of Energy (DOE) calculates that reducing fuel consumption by 50 percent in light duty vehicles would eliminate the use of more than 4 million barrels of oil a day, and eliminate 6 billion metric tons of carbon dioxide emissions overall, almost as much as the emissions from the entire US in 2013 (DOE, 2015). These emissions contribute to global climate change and smog, which are harmful especially to the health of kids and the elderly. Reducing fuel consumption and emissions from vehicles through efficient and clean technologies can substantially contribute to lowering these emissions, improving public health and protecting global ecosystems.

Recent research in public agencies, national laboratories, private industries and academic institutions is mainly aiming at (a) enabling vehicle manufacturers to produce new, efficient technologies; (b) setting appropriate standards in terms of security and emissions; (c) estimating individuals' adoption and preferences over new vehicles; (d) studying policies and incentives that will accelerate that process. This paper contributes to the literature on new vehicle technology and to vehicle type modeling in several aspects. First, it proposes a survey that collects individuals' preferences and stated choices over time. Respondents are asked to report their intention to keep their current vehicle or to buy a new vehicle when presented with a new gasoline vehicle, a HEV, or a BEV; the characteristics of those vehicles change dynamically over the survey horizon. Second, we present estimation results from both multinomial logit (MNL) models and mixed multinomial logit (MMNL) models, which quantify tastes for vehicles with different technologies and fuel options. Finally, short and long term market elasticities with respect to vehicle price and fuel price are calculated and discussed; willingness to pay for significant vehicle attributes is also evaluated using different model specifications.

2. Literature review

The literature on advanced vehicle technology is vast and numerous. References can be found not only in transportation journals but also in applied econometrics, environmental economics, energy and sustainability related journals. Here, we mainly refer to articles that elicit individual preferences from survey data and estimate market penetration of new vehicles including electric cars and those that run on alternative fuels.

Given that their actual market shares are low and that rapid changes are expected on the supply side, it is not surprising that many studies on advanced technology vehicles are based on stated preference (SP) data (Hensher, 1994). In 1991, a three-phase SP survey was implemented in the South Coast Air Basin of California to predict the effect on personal vehicle purchases of attributes that potentially differentiate clean-fuel vehicles from conventional gasoline (or diesel) vehicles. Attributes considered included: limited availability of refueling stations, limited range between refueling or recharging, vehicle prices, fuel operating costs, emissions levels, multiple-fuel capability and performance (Golob et al., 1993). This pioneering data set has been used by several authors to estimate demand for alternative fuel vehicles. These studies often use discrete-choice or structural equations models (Bunch et al., 1993; Golob et al., 1997; Brownstone et al., 2000).

Volatility in gas price, increasing concerns about emissions and global warming, as well as progress in alternative fuel vehicle technology have caused a re-emergence of interest in alternative fuel vehicle data and in behavioral models for demand forecasting and scenario analysis. A stated choice survey was conducted in Denmark in 2007 by Mabit and Fosgerau (2011); the sample consisted of new car buyers only. The survey considered five vehicle types: conventional, hydrogen, hybrid non-plugin, bio-diesel and electric vehicles. The monetary attributes considered were purchase price and annual cost, where the annual cost is the sum of maintenance cost, fuel expenses based on intended driving, and annual taxes. The non-monetary attributes were operation range, refueling frequency, acceleration time, and a service dummy. The pollution level of alternative fuel vehicles was specified relative to the reference vehicle. Jensen et al. (2013) collected stated choices (SC) and used them to measure the extent to which the experience of using an electric vehicle (EV) may affect individual preferences and attitudes. The authors set up a "long panel" survey, where data was gathered before and after individuals experienced an EV in real life during a three-month period. They also measured attitudinal effects that might affect the choice of an EV by individuals; their results show that preferences and attitudes are indeed affected by real life experience. Rasouli and Timmermans (2013) designed a stated choice experiment to better understand the decision process of buying an electric car and to derive the relative importance of factors that affect the choice with a special focus on social influence. Attributes considered are vehicle attributes, contextual attributes and social influence attributes. In particular, the social influence attributes include reviews received from members of the social networks (family, friends, colleagues and the larger social network of peers) and their nature (positive or negative) as well as the level of new technology