ASSESSING CONSUMER PREFERENCES FOR ALTERNATIVE FUEL VEHICLES AND AUTONOMOUS DRIVING TECHNOLOGY

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Overview

Alternative fuel vehicles (AFVs) and autonomous driving technology have been drawing considerable attention globally. The widespread adoption of AFVs may contribute to alleviating climate change and air pollution (Liao, Molin, and van Wee, 2017). According to the IEA Global Electric Vehicle Outlook 2018 (IEA, 2018), electric vehicles (EV) showed record sales in 2017 with more than half of global sales occurring in China. However, the yearly sales percentage of new battery EVs in Japan was still only 0.6%, plug-in hybrids (PHEVs) was 0.5%, and fuel cell vehicles (FCVs) was 0.01%. Conversely, the percentage of yearly sales of electric/gasoline hybrid vehicles (HEVs) was 32.6% in 2018. Currently, Japanese consumers seem to prefer HEVs over other AFVs. EVs and FCVs are still in the early stages of market expansion and both the central and local governments offer subsidies and tax exemption schemes to achieve their AFV goals to reduce CO_2 emissions by 2030. In addition to AFV promotions, the Japanese government is currently developing legislation regarding automated driving because major automobile companies are investing in research and development of autonomous technology.

The choice modelling approach is a useful tool to assess consumers' preferences for unfamiliar goods. Several studies have applied such approaches regarding AFVs (e.g., Liao, Molin, and van Wee, 2017) but few have applied best–worst scaling (BWS). This study applied a BWS multi-profile case to assess Japanese consumer preferences for AFVs and autonomous driving technology. An online questionnaire survey was conducted in March 2019 and data were collected from 1,048 drivers in Japan. The attributes of the profile in question are engine/motor type, reduction of CO_2 emissions, purchase price, fuel/electricity cost per 100 km, autonomous driving levels, and maximum driving distance. The engine/motor types used for this analysis were gasoline, HEVs, clean diesel vehicles (CDVs), PHEVs, EVs, and FCVs.

The estimation results demonstrated that respondents were likely to choose HEVs, EVs, and PHEVs compared with normal gasoline vehicles in a hypothetical environmentally friendly scenario. Specifically, HEVs showed the highest marginal willingness to pay (MWTP) and CDVs showed negative MWTP. The coefficients of purchase price and fuel/electricity cost were negatively significant. Conversely, maximum driving distance was positively significant. The coefficients of the reduction of CO_2 emissions and FCVs were not statistically significant. By identifying consumers' preference for the least attractive goods, it may be possible to improve the results of economic valuation using choice modelling approaches.

Methods

BWS is a choice modelling approach and although it is similar to conventional choice experiments, it characteristically obtains information regarding the best and worst profiles simultaneously (Louviere, Flynn, and Marley, 2015). BWS consists of three categories: object case (case 1), profile case (case 2), and multi-profile case (case 3). This study applies a BWS multi-profile case to assess consumer preferences for AFVs and autonomous driving technology. The BWS multi-profile case encourages respondents to select the best/most and worst/least profiles presented to them.

In the current Japanese vehicle market, the diffusion of AFVs, excluding HEVs, is still limited. For FCVs, the construction of hydrogen stations is key to promoting their sales but as of December 2019, there are still only 112 public hydrogen stations in Japan. Although the Japanese government provides subsidy programs, FCVs may be less attractive for ordinary consumers and the sales volume of FCVs is still low. Obtaining the worst as well as the best choice could result in robust coefficient estimations because the worst choice may reveal a preference for goods that are not usually chosen.

The orthogonal fractional factorial design of the BWS multi-profile case allowed us to prepare 32 choice sets, each comprising 4 profile types with 6 attributes and 4 levels. Respondents were each presented with eight different choice sets. Attributes of the profile are engine/motor type, autonomous driving levels (Levels 1, 2, and 3), reduction of CO_2 emissions, purchase price, operation cost (fuel/electricity) per 100 km, and maximum driving distance after filling up or at full charge. Engine/motor types were gasoline, HEVs, CDVs, PHEVs, EVs, and FCVs. The hypothetical scenario projected by the BWS analysis requires respondents to bear an additional financial burden to

purchase AFVs compared with purchasing a conventional gasoline car, which has the lowest purchase price. The purchase price of AFVs was set at up to 2 million yen.

The BWS multi-profile model is analyzed using a mixed logit model and the coefficients of the individual attributes are estimated. If a choice set includes a total of J items, the combination of the best and worst profiles totals J (J − 1). There are 4 × 3 = 12 combinations of the best and worst profiles in this BWS analysis. Respondents with a valid driver's license were pre-selected and 1,048 samples were collected. The gender ratio and age groups with intervals of 10 years were normalized. Of the respondents, 80.3% had at least one vehicle in their household. AFVs (HEVs, CDVs, PHEVs, and EVs) accounted for 17.4% of the vehicles owned by respondents.

Results

The data obtained from the BWS multi-profile case were analyzed using a mixed logit model. While the alternative-specific constant (ASC) for FCVs was not statistically significant, other ASCs were. The ASC was 0.593 for HEVs, -0.180 for CDVs, 0.226 for PHEVs, and 0.304 for EVs. The MWTP was 905,344 yen for HEVs, 464,763 yen for EVs, -275,023 yen for CDVs, and 350,061 yen for PHEVs. This indicated that among AFVs, HEVs, PHEVs, and EVs were likely to be chosen by respondents as opposed to a normal gasoline car in this hypothetical scenario that emphasized the attribute of environmental performance. The preference for the hybrid engine was the highest and its standard deviation parameter was statistically significant. Preference heterogeneity, that is, a difference in tastes among respondents, was confirmed only for HEVs, the most popular AFV in Japan.

The coefficients of purchase price, and fuel/electricity cost were negatively significant for both the mean and standard deviation parameters. Conversely, maximum driving distance was positively significant. The reduction of CO_2 emissions was not statistically significant. The coefficients of the mean parameters of autonomous driving were all significant. Level 1 (driver assistance) was the highest and Level 3 (conditional automation) was the lowest. Only a coefficient of the standard deviation parameter of Level 2 (partial automation) was statistically significant. The MWTPs of Levels 1, 2, and 3 were 235,237 yen, 149,130 yen, and 123,817 yen, respectively.

Interaction terms were also estimated to determine the factors affecting the attributes. The results revealed that higher household income increased the probability of choosing FCVs as well as the preference for the reduction of CO_2 emissions. Respondents who owned HEVs were likely to choose EVs. Regarding autonomous driving, elderly respondents having a greater interest in and expectation from autonomous vehicles were likely to value them.

Conclusions

This experimental study applied a BWS multi-profile case to analyze Japanese consumers' preferences regarding AFVs and autonomous driving technology. The estimation results indicated that in a hypothetical environmentally friendly scenario, all of the different types of AFVs excluding FCVs were likely to be chosen by respondents as opposed to a normal gasoline vehicle. Specifically, the hybrid engine was highly preferred by Japanese consumers, possibly because Japanese consumers are familiar with HEVs. Respondents showed a positive preference for three levels of autonomous driving technology. The coefficients of purchase price, fuel/electricity cost, reduction of CO_2 emissions, and maximum driving distance were significant. Respondents' detailed knowledge of the powertrain of AFVs affected the probability of their choosing AFVs.

The results revealed that Japanese consumers valued assistant driving technologies (Levels 1 and 2) and HEVs. The diffusion of AFVs other than HEVs is still limited in the current Japanese car market. The results suggested that general consumers are likely to change their attitudes toward AFVs if the environmental performance and price were more ideal and acceptable. Additionally, some Japanese consumers have different levels of knowledge and information regarding AFVs and autonomous driving technology. The implementation of stronger promotion activities and marketing strategies by automobile companies and governments is necessary to accelerate the shift from conventional gasoline vehicles to AFVs with autonomous driving technology in Japan.

References

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