Changes of Japanese Consumer Preference for Electric Vehicles

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Abstract
Changes of Japanese consumer preference for electric vehicles (EVs) with new EV commercialisation and subsidy implementation has been quantitatively evaluated by applying conjoint analysis to the respondents choice experiment data collected by internet questionnaire survey that have been conducted in February 2009 and 2010. Powertrains (battery electric vehicle (BEV), gasoline hybrid electric vehicle (HEV) and gasoline plug-in HEV (PHEV)), vehicle price, vehicle range, driving cost and passenger capacity have been chosen as attributes of vehicles and marginal utility and its monetary measure of each attribute have been calculated by setting the gasoline vehicle (GV) with typical specifications as baseline. The estimated results indicate that the vehicle range of BEVs under the current battery technology level lead to utility decline and that those EVs with fewer seats by mounting devices for electric driving would not be accepted by consumers. In terms of powertrain selection, consumers express strong preference for HEVs, whereas for BEVs and PHEVs they express low / negative preference or hold their judgment for choosing. From the comparison of the estimated marginal utilities for powertrain in 2009 and 2010, significant statistical differences are found for HEVs and Kei passenger type BEVs. Moreover, it is confirmed that implementation of has played an important role to enhance consciousness of HEVs and Kei passenger type BEVs as environmentally friendly vehicles. It is true that the current subsidy has played an important role to raise awareness of some kind of EVs. However, in order to improve environment by diffusing other kinds of EVs that have higher environmental performance than HEVs, not only the commercialisation of those kinds of vehicles that satisfy consumer needs at acceptable vehicle price levels but also further schemes should be required to gain consumer recognition especially for BEVs and PHEVs.

Keywords: Consumer preference, Electric vehicles, Conjoint analysis, Vehicle commercialisation, Subsidy

1 Introduction
In Japan, electric vehicles (EVs) are thought to be the promising energy saving, energy diversity and CO2 reduction technology in automotive sector and EVs are expected to diffuse further to improve environment in this sector. In 2009, we have experienced the widespread of passenger type EVs with the commercialisation of new-type
hybrid EVs (HEVs), battery electric vehicles (BEVs) and plug-in HEVs (PHEVs) for fleet users; and the implementation of sets of governmental subsidy and tax breaks for purchasing environmentally friendly vehicles as a part of economic stimulus package. Indeed, the number of HEVs sold in Japanese market had expanded to about 450000 vehicles in FY2009 (April 2009 – March 2010 period), which means that the number of HEVs held as of March 2010 is expected to be almost 1000000 vehicles. In addition, with the launch of BEVs for fleet users in July 2009, the number of BEVs sold has counted about more than 1400 vehicles. With these expansions of EVs into market, it is assumed that consumer preference for EVs might have changed.

It is true that environmental performance and driving cost of EVs prevail over conventional internal combustion engine vehicles (ICEVs). However, in terms of EV possession and use, the other aspects such as purchase price or vehicle range are different from ICEVs and therefore consumer preference for EVs would be different compared with ICEVs. It is important for vehicle makers or governments to understand consumer preference for various kinds of vehicles to decide specifications of EVs or policies to expand the use of EVs.

One of the ways to analyse consumer preference for products is to apply conjoint analysis to the collected consumer stated preference data. Conjoint analysis is a statistical method to determine what combination of limited number of attributes for products is most influential upon respondent choice or decision making. A controlled set of potential products is shown to respondents and by analyzing how they make preferences between them, the marginal utility of the individual attributes making up the product and total utility of the product can be conjointly determined using multinomial logit model from the collected stated preference data. There are already several studies that had applied conjoint analysis or its closely related method to evaluate consumer preference for alternative fuel vehicles including EVs in US [1] [2] and in Japan [3].

In our previous study [4], consumer preference for EVs in Japanese condition was evaluated using conjoint analysis based upon the collected stated preference data by internet questionnaire survey that had been conducted in February 2009. In order to investigate the effect of new EV commercialisation and governmental subsidy in FY2009 towards consumer preference for EVs, we have conducted the same questionnaire survey again in February 2010. In this paper, the changes of Japanese consumer preference for EV are evaluated by comparing the results in 2009 and 2010.

2 Conjoint Analysis

In conjoint analysis, consumer preference for EVs will be evaluated using a choice experiment (CE). This method is a type of stated preference technique that elicits consumer preferences directly through questionnaires. In the questionnaire, 4 sets of alternatives (vehicles) consisted of 5 attributes related to vehicles are shown, and the respondents are asked to select the one they most prefer. The details of the questionnaire survey design are described in section 3.

The collected data are then analysed econometrically using the conditional logit model, which is one of the variations for multinomial logit model. In the model, each respondent is assumed to have a random utility function, which is shown in Eq. (1).

$$U_{ij} = V_{ij}(X_{ij}) + \varepsilon_{ij}$$  \hspace{1cm} (1)

where $U$ is the total utility, $V$ is the observable component of the total utility, $\varepsilon$ is the unobservable component, $X$ is the vector of the attributes, $i$ is the number of the alternatives (generally called profiles) and $q$ is the respondents, respectively. Parameters of the observable utility function $V$ are estimated using the following conditional logit model.

If $U_{iq} > U_{jq} (j \neq i)$, individuals will select alternative $i$. Hence, the probability of choosing alternative $i$ in the set of all possible alternatives $C = \{1, 2, \ldots, J\}$ by individual $q$ is expressed in Eq. (2).

$$P_{iq} = \Pr(U_{iq} > U_{jq} \forall j \in C, j \neq i) = \Pr(V_{iq} - V_{jq} > \varepsilon_{iq} \forall j \in C, j \neq i)$$  \hspace{1cm} (2)

If the error terms $\varepsilon_{jq}$ and $\varepsilon_{iq}$ are assumed to be independently and identically distributed with a Gumbel distribution (a type 1 extreme value distribution), probability $P_{iq}$ is calculated as Eq. (3).

$$P_{iq} = \frac{e^{\lambda V_{iq}}}{\sum_{j=1}^{J} e^{\lambda V_{jq}}}$$  \hspace{1cm} (3)

where $\lambda$ is the scale parameter which is conventionally normalised to 1. The Gumbel
distribution is used for analytic convenience, which is imposed in many similar models. The log likelihood function for the maximum likelihood estimate is shown in Eq. (4).

$$\ln L = \sum_{q=1}^{Q} \sum_{j=1}^{J} \delta_{jq} \ln P_{jq}$$  \hspace{1cm} (4)

where \(Q\) is the number of respondents, \(\delta_{jq}\) is the dummy variable (\(\delta_{jq} = 1\) when individual \(q\) selects alternative \(i\) and \(\delta_{jq} = 0\) when individual \(q\) selects any other alternative except for alternative \(i\)). The utility parameters that maximize Eq. (4) are then calculated. After the parameters of the utility function are estimated, the marginal willingness to pay (MWTP) for each attribute can be obtained. Assuming additive separability for the utility function, the utility function can be expressed in Eq. (5)

$$V(X, p) = \sum_{n=1}^{n} \beta_n x_n + \beta_p p$$  \hspace{1cm} (5)

where \(X\) is the vector of \(n\) attributes (\(X = (x_1, x_2, \ldots, x_n)\)), \(p\) is the price of the alternative, \(\beta_n\) is the marginal utility of each attribute and \(\beta_p\) is the marginal utility of income, respectively. The subscripts for respondents and alternatives \(i\), \(j\) and \(q\) are omitted here for simplification. The total differential of Eq. (5) is calculated as Eq. (6).

$$dV = \sum_{n=1}^{n} \frac{\partial V}{\partial x_n} dx_n + \frac{\partial V}{\partial p} dp$$  \hspace{1cm} (6)

It is assumed that utility is held constant (\(dV = 0\)) and all attributes except for \(x_1\) (\(dx_1 = 0, i \neq 1\)) including all non-measured attributes that the respondents perceive are unchanged. Thus the MWTP, the monetary measure for a unit change of \(x_1\), is calculated by Eq. (7).

$$MWTP_{x_1} = \frac{dp}{dx_1} = \frac{\partial V}{\partial x_1} / \frac{\partial V}{\partial p} = \beta_1 / \beta_p$$  \hspace{1cm} (7)

3 Questionnaire Survey Design

3.1 Outline of Questionnaire Survey

Internet questionnaire surveys have been conducted for 3 times to evaluate consumer preference for EVs: 2009 pretest, 2009 survey and 2010 survey. The respondents are chosen from internet monitors of the Nikkei Research Inc. Access Panel from all over Japan that have driver licenses and own passenger vehicles from the age from 20 to 60. Each survey is consisted of the following 5 parts with total of 69 questions: personal information, possession and use situation of their own passenger vehicles, CE part, free opinions for relationship between vehicles and the environment and opinions for the conducted questionnaire survey. Fig.1 summarises the timeline of three internet questionnaire surveys and Japanese market trends of EVs. 2009 pretest had been carried out from January 23rd until 27th 2009 (number of respondents collected: 1323, collection rate: 18.0%); 2009 survey from February 13th until 17th 2009 (number of respondents collected: 6935, collection rate: 32.1%); and 2010 survey from February 12th until 18th 2010 (number of respondents collected: 9657, collection rate: 31.1%), respectively. 2009 pretest had been conducted to check the adequacy of the configured levels of each attribute (see subsection 3.2 for details) before conducting 2009 survey. The estimates shown in section 4 are based upon the data of 2009 and 2010 surveys.

In Japan, passenger vehicles are categorized into Kei passenger vehicle and passenger vehicle by law. Kei passenger vehicle is restricted by regulations for its physical size; passenger capacity; engine displacement; and power and also taxes imposed upon owing vehicles are different by two categories. The way how the vehicles are used is different by Kei passenger vehicle and passenger vehicle owners. Indeed, the estimated annual average mileage from our national statistics for vehicle transport [5] and the number of the vehicles held [6] shows different trend between two categories (7186 km/yr for Kei passenger vehicles and 9026 km/yr for passenger vehicles, respectively). In this paper, consumer preference for EVs is therefore estimated separately by Kei passenger vehicles and passenger vehicles.
3.2 Choice Experiment Design

In the CE questions part, respondents were instructed to assume they would be purchasing a brand-new vehicle within the next 3 years. They were then asked to select one of two vehicle types: a Kei passenger vehicle or a passenger vehicle. Respondents were then asked to select 1 preferred vehicle out of 4 possible choices (profiles) in 8 different choice sets, each time considering the balance between each vehicle attribute. Information provided with the CE questions, as well as an example, is shown in Fig.2.

Table 1 shows the assumed attributes and levels used for each type of vehicle. By considering the CE attributes that Hasegawa et al. [3] adopted and by analysing all the differences in vehicle specifications included in our vehicle specification database ([7]; only model years after 2000), we assumed that the following 5 attributes would affect consumer choice for vehicles: powertrain, vehicle price (excluding optional equipment and taxes), vehicle range, driving cost and passenger capacity.

On the basis of the configured attributes and levels, profiles for the CE questions were generated by using an L25 orthogonal array of attributes and their levels (Table 1), which is a type of fractional factorial design that represents the most efficient (in the sense of the lowest number of combinations) set of designs available for parameter estimation. One of the 25 profiles generated was excluded because the combination level for each attribute was impractical for a passenger vehicle, and a baseline profile was added to each choice set (Vehicle D in Fig.2). Therefore, 8 choice sets with 4 profiles were generated (24 profiles divided between the 8 sets, with the baseline profile in each choice set).

3.3 EV Information Provided

To help the respondents understand EV characteristics, we provided the following general information before asking the CE questions.

3.3.1 BEV

BEVs are powered by an electric motor using electricity to charge the on-board battery.

- You have to charge BEV batteries either at your house or at a charging station, similar to how gasoline (or diesel) vehicles need to be fuelled at fuel stations.

Please assume that you are planning to buy a brand-new passenger vehicle within next 3 years. In the following questions, 4 vehicles will be shown at a time. 4 vehicles are different in combination of the following 5 items but the rest of the specs and equipment of the 4 vehicles are assumed to be the same.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powertrain</td>
<td>GV, BEV, HEV, PHEV</td>
</tr>
<tr>
<td>Vehicle price [million yen]</td>
<td>0.8, 1.3, 1.8, 2.3, 2.8 Passenger vehicle: 1.5, 2.0, 2.5, 3.0, 4.0</td>
</tr>
<tr>
<td>Vehicle range [km]</td>
<td>80, 200, 400, 600, 800 Passenger vehicle: 100, 250, 450, 700, 1000</td>
</tr>
<tr>
<td>Driving cost [yen/km]</td>
<td>1, 2, 3, 5, 8 Passenger vehicle: 1, 3, 5, 8, 12</td>
</tr>
<tr>
<td>Passenger capacity [person]</td>
<td>1, 2, 4 Passenger vehicle: 2, 4, 5, 8</td>
</tr>
</tbody>
</table>
• The battery that powers the motor is also charged by regenerated energy during braking.
• The energy efficiency of BEVs is better than that of gasoline (or diesel) vehicles. However, because the amount of electricity charged in the on-board battery is restricted owing to current battery technology, the vehicle range will be shorter than that of gasoline (or diesel) vehicles.
• The CO2 emitted by driving a BEV 1 km (the emissions from electricity generation) will be about 2% – 25% that of a gasoline vehicle.

3.3.2 HEV
HEVs use both a gasoline (or diesel) engine and an electric motor to provide power.
• You have to fuel HEVs at fuel stations, as with gasoline (or diesel) vehicles.
• When you are accelerating or driving in congested traffic and the engine’s energy efficiency is low, the vehicle is powered only by the electric motor or by the gasoline engine assisted by the motor. When you are driving in smooth traffic at high speeds, it is powered mainly by the gasoline engine.
• The battery that powers the motor is charged by regenerated energy during braking.
• Since the energy efficiency (fuel economy) is high, the vehicle range will be greater than that of gasoline (or diesel) vehicles.
• The CO2 emitted by driving an HEV 1 km will be about 50% – 60% that of a gasoline vehicle, including the emissions from refining the gasoline.

3.3.3 PHEV
PHEVs use both a gasoline (or diesel) engine and an electric motor.
• PHEVs have the characteristics of both HEVs and BEVs. Not only do you have to fuel PHEVs at fuel stations, as with gasoline (or diesel) vehicles, but you can also charge the batteries either at your house or at a charging station, similar to the BEV.
• A PHEV can be powered by the electric motor and charged batteries for short distances. For longer distances, it works in the same manner as an HEV after the batteries are empty.
• If it is driven in HEV mode and you are accelerating or driving in congested traffic, it is powered only by the electric motor or by the gasoline engine assisted by the motor. When you are driving in smooth traffic at higher speeds, it is powered mainly by the gasoline engine.
• The battery that powers the motor is also charged by regenerated energy during braking.
• The energy efficiency (fuel economy) of PHEVs is higher than that of gasoline (or diesel) vehicles. However, because the amount of electricity charged in the on-board battery is restricted owing to the limitations of current battery technology, the vehicle range driven in BEV mode will be shorter than that of gasoline (or diesel) vehicles. However, the vehicle range driven in HEV mode will be longer than that of gasoline (or diesel) vehicle.
• The CO2 emitted by driving a PHEV 1 km will be about 2% – 25% that of a gasoline vehicle in BEV mode and 50% – 60% of it in HEV mode, including the emissions by power generation and gasoline refinement.

3.4 Setting the Baseline Profile
In the 2009 pretest, a null profile was shown in each of the 8 choice sets instead of Vehicle D (Fig.2). If this null profile was chosen, it meant that the other 3 profiles included in each choice set had low utility and the respondents preferred none of them. So many respondents selected this null profile for every choice set that it was not possible to obtain significant results from the conjoint analysis. This trend can be explained by the fact that passenger vehicles are expensive and consumers make conservative choices for their preferred vehicles.
Consequently, in the 2009 and 2010 surveys, instead of including a null profile, baseline profiles were configured (Table 2) and provided commonly in each choice set. The baseline vehicles are assumed to represent typical GVs, and the levels for each attribute were selected by analysing the catalogue data of those passenger vehicles [7] sold.

<table>
<thead>
<tr>
<th>Table 2: Configuration of baseline profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kei passenger vehicle</td>
</tr>
<tr>
<td>Powertrain: GV</td>
</tr>
<tr>
<td>Vehicle price: 1.2 million yen</td>
</tr>
<tr>
<td>Vehicle range: 500 km</td>
</tr>
<tr>
<td>Driving cost: 6 yen/km</td>
</tr>
<tr>
<td>Passenger capacity: 4 person</td>
</tr>
<tr>
<td>Passenger vehicle</td>
</tr>
<tr>
<td>Powertrain: GV</td>
</tr>
<tr>
<td>Vehicle price: 1.8 million yen</td>
</tr>
<tr>
<td>Vehicle range: 650 km</td>
</tr>
<tr>
<td>Driving cost: 7 yen/km</td>
</tr>
<tr>
<td>Passenger capacity: 5 person</td>
</tr>
</tbody>
</table>

EVS25 World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium
on the Japanese market that had model years after 2000.

4 Estimation of Consumer Preference for EVs

4.1 Data Preprocessing and Estimation Scheme

Table 3 summarises the sample number of respondents used for conjoint analysis. Some respondents selected the same choice 8 times in the CE part of the survey. Although it is difficult to distinguish whether they really chose the same vehicle after considering all the profiles from the collected CE data, the results estimated by the conjoint analysis will be different if these data are not included. We measured the time required to answer all the questionnaire items for each respondent. The minimum, lower quartile, median, upper quartile and maximum amounts of time required were 73, 399, 574, 859 and 42048 s for 2009 survey and 87, 423, 602, 897, 78175 s for 2010 survey, respectively. In this paper, we assumed that the 1727 respondents whose required answer time was in the lowest quartile (≤398 s for 2009 survey and ≤422 s for 2010 survey) had answered the questions without careful consideration, and we therefore eliminated those responses from the total samples collected. The total number of respondents in the analyses was thereby reduced to 5208 and 7254 for 2009 and 2010 survey, respectively, as shown in Table 3.

Although the configured profiles and choice sets for CE parts are exactly the same for 2009 and 2010 surveys, a question item has been set after the CE questions in 2010 survey to ask respondents whether they had selected their preferable vehicle with the consideration that vehicle price should be reduced from the given price of the profile by implementation of governmental subsidy for environmental friendly vehicles.

Setting the vehicles shown in Table 2 as baseline, utility parameters are estimated using conditional logit model by assuming that the observable components of the random utility function in Eq. (1) can be explained as Eq. (8) by linear combinations of the settled attributes.

\[
V = \beta_j \text{BEV} + \beta_j \text{HEV} + \beta_j \text{PHPEV} + \beta_j (\text{VR} - \text{VR}_b) + \beta_j (\text{DC} - \text{DC}_b) + \beta_j (\text{PC} - \text{PC}_b) + \beta_j (\text{VP} - \text{VP}_b)
\]  

where BEV, HEV, PHEV are the dummy variables for each type of powertrains, VR is vehicle range, DC is driving cost, PC is passenger capacity, VP vehicle price and suffix b baseline vehicle, respectively.

One of the indices to measure the goodness-of-fit of the model is the McFadden’s likelihood ratio index (LRI), which can be calculated as Eq. (9).

\[
\text{LRI} = 1 - \frac{LL_\beta}{LL_0}
\]  

where \(LL_\beta\) is the log likelihood of the estimated model and \(LL_0\) is the log likelihood of the model when all of the coefficients are restricted to be zero. It is said that the model can be regarded to have high goodness-to-fit if LRI is from 0.2 to 0.4 [8].

4.2 Representativeness of Data Collected by Internet Survey

In terms of CE data collection, an internet survey is a quick and effective way of collecting a large number of samples at a low cost. However, because of existing bias of internet users, the collected data may not be representative of consumers and may be of lower quality as compared with data collected by other methods such as mail or in-person interviews.

As of March 2009, the number of internet monitors in the Nikkei Research Inc. Access Panel, from which the respondents of the survey were chosen, was about 155000, with a gender composition of 43% and 57% for males and females, respectively. The age composition is as follows: teens, 13%; 20–29, 35%; 30–39, 30%; 40–49, 14%; and ≥50, 8%. In addition, to ensure that respondents read the provided characteristics of each kind of powertrain (shown in subsection 3.3) and then carefully chose the preferred profile, some of the data were excluded, as described in subsection 4.1.

Fig.3 depicts the age and gender composition of 2009 and 2010 survey. The number of vehicles held per 1000 households, as provided by the

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2044</td>
<td>1947</td>
</tr>
<tr>
<td>No</td>
<td>508</td>
<td>1439</td>
</tr>
<tr>
<td>Kei passenger vehicle</td>
<td>3164</td>
<td>5307</td>
</tr>
<tr>
<td>Passenger vehicle</td>
<td>1665</td>
<td>3642</td>
</tr>
</tbody>
</table>

Table 3: Sample number of respondents used for conjoint analysis
FY2009 National Survey of Family Income and Expenditure (NSFIE) [9], is also shown in Fig.3. The respondents were not predominantly in any specific gender or age group, but they were mainly over 30. According to the FY2009 NSFIE, however, the number of HEVs and BEVs held per 1000 households is 7, 12, 18, and 26 for people in their 20s, 30s, 40s, and 50s, respectively; this indicates that the primary users of HEVs and BEVs are currently over the age of 30.

According to the latest information [10], the internet diffusion rate in Japan was 75.3% of the population in March 2009. Taking the nature of internet surveys and all the above facts into consideration, we concluded that the collected data are representative enough of the population to evaluate Japanese consumer preference for EVs.

4.3 Kei Passenger Vehicle Estimates

Table 4 shows the estimates for Kei passenger vehicle. Each marginal utility in Table 4 stands for the valuation weights of each attribute. The Student’s two-tailed t-tests have also been performed to evaluate the difference of each marginal utility by 2009 and 2010 survey, whose results are shown in the 6th row of Table 4. The marginal utilities can be converted into monetary units as MWTP, as shown in Eqs. (5) – (7).

From the estimated results in Table 4, we drew the following conclusions.

- Population respondents evaluate that a vehicle price increase of 1 million yen causes a utility decrease of 0.0169 on average in 2010 survey.

- The marginal utility of the HEV powertrain is the highest, followed by that of the BEV. This can be explained as follows. (1) Although the current lineups of HEVs in the Japanese brand-new vehicle market are only for passenger vehicles, consumers now widely recognise the merits and environmental friendliness of HEVs, and they have the same high expectations for Kei-car-type HEVs as well. (2) Owing to the announcements of the sale of Kei-car-type BEVs for fleet users, consumers evaluated BEVs as an environmentally friendly Kei passenger vehicle. On the other hand, the estimated marginal utility of PHEVs was significantly negative at the 5% level. Although respondents were asked to read and understand the provided basic characteristics for each powertrain before they chose their preferred profile from each choice set, they either did not see the merit of choosing a PHEV as compared with an HEV or BEV or they could not envision the merits of a PHEV from the information provided.

- Since significant differences are observed for marginal utilities of HEV and BEV between 2009 and 2010 survey, the breakdowns of marginal utilities for 2010 survey are evaluated by the respondents who had considered or not that vehicle price should be reduced from the given price of the profile by implementation of subsidy, whose results are shown in Table 5. If we compare utility of BEV to HEV by each group (the 4th line of Table 5), it can be found that it has been dropped by 66% from 0.32 for 2009 survey to 0.21 for 2010, which means that by expansion of HEV line-ups, recognition for HEVs as environmentally friendly vehicles has been strengthened. However, if we focus upon the group that considered the effect of subsidy in 2010 survey, the utility has risen by twice from 0.32 in 2009 survey to 0.61 in 2010. This indicates that by the effect of commercialisation of BEV for fleet users and implementation of subsidy, BEVs have received greater recognition as environmental friendly vehicles.
Table 4: Estimates for Kei passenger vehicle

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle price [mil. yen]</td>
<td>-0.0166* (2.54×10^{-4})</td>
<td>0.0114</td>
<td>-0.0169* (2.69×10^{-4})</td>
<td>0.0551</td>
<td>2.92×10^{-4}</td>
</tr>
<tr>
<td>Powertrain: BEV</td>
<td>0.188* (2.46×10^{-3})</td>
<td>0.351</td>
<td>0.0928* (2.57×10^{-3})</td>
<td>0.259</td>
<td>0.954*</td>
</tr>
<tr>
<td>Powertrain: HEV</td>
<td>0.581* (3.92×10^{-3})</td>
<td>0.351</td>
<td>0.437* (4.04×10^{-3})</td>
<td>0.259</td>
<td>0.145*</td>
</tr>
<tr>
<td>Powertrain: PHEV</td>
<td>-0.585* (5.08×10^{-3})</td>
<td>-0.353</td>
<td>-0.657* (5.31×10^{-3})</td>
<td>-0.390</td>
<td>0.0717</td>
</tr>
<tr>
<td>Vehicle range [100km]</td>
<td>0.238* (7.73×10^{-3})</td>
<td>0.143</td>
<td>0.256* (8.07×10^{-3})</td>
<td>0.152</td>
<td>-0.0183</td>
</tr>
<tr>
<td>Driving cost [yen/km]</td>
<td>-0.264* (5.99×10^{-3})</td>
<td>-0.159</td>
<td>-0.249* (6.37×10^{-3})</td>
<td>-0.148</td>
<td>-0.0142</td>
</tr>
<tr>
<td>Passenger capacity [person]</td>
<td>0.746* (1.19×10^{-3})</td>
<td>0.450</td>
<td>0.728* (1.24×10^{-3})</td>
<td>0.432</td>
<td>0.0184</td>
</tr>
<tr>
<td>Sample number</td>
<td>2044×8 = 16352</td>
<td></td>
<td>1947×8 = 15576</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-15007</td>
<td></td>
<td>-14057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LRI</td>
<td>0.338</td>
<td></td>
<td>0.349</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significance at 5% level.

Table 5: Marginal utilities breakdown for BEV and HEV in 2010 survey

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>Subsidy consideration</th>
<th>Yes</th>
<th>No</th>
<th>BEV/HEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEV</td>
<td>0.188*</td>
<td>0.0928*</td>
<td>0.328*</td>
<td>0.00484</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEV</td>
<td>0.581*</td>
<td>0.437*</td>
<td>0.536*</td>
<td>0.416*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEV/HEV</td>
<td>0.32</td>
<td>0.21</td>
<td>0.61</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significance at 5% level.

Although the marginal utility of vehicle range seems to be of less importance than the other attributes shown in Table 4, it would strongly affect the preference for BEVs. For example, if the 2010 survey estimate is applied to the current Kei-car-type BEVs sold in Japanese market (vehicle range of 160 km under standard Japanese driving conditions) and compared with the baseline Kei passenger vehicle in Table 2 (vehicle range of 500 km), it would lead to a considerable utility decline of 0.870.

The unit driving cost decline from the baseline cost of 6 yen/km is 0.249 in 2010 survey.

The marginal utility for passenger capacity of 0.728 in 2010 survey means that respondents highly value this attribute. Given that the maximum passenger capacity for Kei passenger vehicles is already restricted to 4 people, reducing the capacity because, for example, electric motors need to be mounted would most likely not be accepted by consumers.

4.4 Passenger Vehicle Estimates

The estimates for passenger vehicle are summarised in Table 6. Significant differences are found for marginal utilities of vehicle price, HEV and vehicle range between 2009 and 2010 survey. For passenger vehicles, the marginal utilities of HEVs and BEVs were positive and negative for both 2009 and 2010 surveys, respectively. The marginal utility of a BEV for a Kei passenger vehicle was positive, whereas it was negative for passenger vehicles. It may be that respondents did not make an affirmative powertrain choice for a passenger vehicle type BEV because only the Kei passenger type BEVs were available in the market and passenger type BEV were announced to be sold in late 2010.

The breakdown of HEV utility for 2010 survey is 0.450 for those who have considered the subsidy and 0.155 for those not. (Both utilities have statistical significance at 5% level.) This means that the effect of subsidy implementation lead to utility difference by about 3 times.

The estimated coefficient for PHEVs was not statistically significant. Although respondents most
likely understood the concept and merits of PHEVs from the information provided, there was no concrete information about the commercialisation of PHEV passenger vehicles at the time of the survey. It is likely that respondents were therefore hesitant to choose a PHEV when asked which new vehicle they would buy within 3 years.

The estimates for the other attributes listed in Table 6 for passenger vehicles showed very similar trends as those for Kei passenger-type vehicles.

5 Summary

In this paper, the effect of new EV commercialisation and implementation of governmental subsidy for environmentally friendly vehicles towards the Japanese consumer preference towards EVs have been evaluated based upon the collected CE data by internet questionnaire surveys that have been conducted in February 2009 and February 2010.

From the estimated marginal utilities for the configured attributes for vehicles using conjoint analysis, the following implications are obtained for the current EV preference: (A) Marginal utility of vehicle range indicates that the vehicle range under the current battery technology level lead to range anxiety for BEVs. (B) Consumers weigh high importance for passenger capacity, which means that those EVs with fewer seats by mounting devices for electric driving would not be accepted by consumers. (C) In terms of powertrain selection, the results show that consumers express strong preference for HEVs, whereas the evaluation for BEVs and PHEVs are different by vehicle types: For Kei passenger vehicles, they show affirmative evaluation for BEVs but negative for PHEV. Meanwhile for passenger vehicles, they show negative evaluation for BEVs and hold judgment for choosing PHEVs. From the comparison of the estimated marginal utilities for powertrain in 2009 and 2010, significant statistical differences are found for HEVs and Kei passenger type BEVs. Moreover, it is confirmed that implementation of has played an important role to enhance consciousness of HEVs and Kei passenger type BEVs as environmentally friendly vehicles.

The Japanese governmental subsidy for purchasing environmentally friendly vehicles, on which we put focus in this paper, had started from April 2009 and halted in September 2010. The results of this paper indicate that it is true the current subsidy has played an important role to raise awareness of EVs, especially HEVs. However, in order to improve environment by diffusing other kinds of EVs that have higher environmental performance than HEVs, not only the commercialisation of those kinds of vehicles that satisfy consumer needs at acceptable vehicle price levels but also further...
preferential treatment schemes should be required to gain consumer recognition especially for BEVs and PHEVs.

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