

Can subsidy programs change the customer base of next-generation vehicles?

Jiaxing Wang^{*} and Shigeru Matsumoto^{1*}

Abstract

Although many countries have implemented subsidy programs for next-generation vehicles in order to reduce energy consumption and greenhouse gas emissions from the transportation sector, the effect of such programs has not yet been fully investigated in terms of their influence of households' vehicle selection. The Japanese government introduced a subsidy program entitled "Eco-car" during 2009 and 2012. In this study, we apply multinomial logit models to micro-level data of vehicle selection from the National Survey of Family Income and Expenditure in order to identify the types of households who switched from conventional gasoline vehicles to hybrid electric vehicles (HEVs) using this subsidy program. Our analyses demonstrate that higher income households who used compact gasoline vehicles (CGVs) before the Eco-car program switched to HEVs using the subsidy, whereas those who used regular gasoline vehicles (RGVs) did not switch to HEVs. Although seniors chose HEVs over CGVs before the Eco-car program, younger consumers began choosing HEVs over CGVs after the Eco-car program. We also find that gasoline price became a less important factor on HEV purchase after the Eco-car program.

^{*} Department of Economics, Aoyama Gakuin University. 4-4-25 Shibuya, Shibuya-ku, Tokyo, 150-8366, Japan.

¹ Corresponding author: shmatsumoto@aoyamagakuin.jp

Keywords: Eco-car program; Hybrid electric vehicles; Micro-level data; Multinomial logit model

1. Background and research objective

Countries have implemented various energy conservation measures aimed at reducing energy consumption and greenhouse gas (GHG) emissions from the transportation sector for many years. Despite such efforts, GHG emissions from the transportation sector have continued to increase steadily and its share in global energy-related CO₂ emissions has reached 23% according to statistics from the International Energy Agency (2015).

Graham and Glaister (2002) surveyed the international fuel demand literature and found the long-run income elasticity of fuel demand to range from 1.1 to 1.3. Their result suggests that fuel demand increases as the economy grows if necessary curtailment measures are not taken. To reduce GHG emissions and maintain economic growth, many governments have begun promoting next-generation vehicles in recent years through measures such as preferential tax treatment and/or subsidies.

Although both electric and hydrogen vehicles are on the market, HEVs remain the most popular next-generation vehicle due to their cost and usage advantages². In the early 2000s, many countries introduced various subsidy programs for the promotion of HEVs. The impacts of those subsidy programs on HEV sales were examined in Canada (Chandra et al. 2010), in the

² According to the data by Next Generation Vehicle Promotion Center (2018), the number of electric vehicles registered in Japan was 103,569 while the number of HEVs registered was 8,207,458.

United States (Gallagher and Muehlegger 2011), and in Japan (Iwata and Matsumoto 2016). All of these studies reported that the subsidy programs increased HEV sales³.

Previous studies have identified the types of households that adopt HEVs. Hackbarth and Madlener (2013) conducted the stated preferences discrete choice experiment for German households. They considered a vehicle choice among seven fuel-type vehicles: 1) natural gas; 2) hybrid electric; 3) plug-in hybrid electric; 4) fully battery electric; 5) hydrogen vehicles; 6) conventional gasoline; and 7) conventional diesel. They reported that younger, well-educated, and environmentally aware consumers tend to choose alternative fuel vehicles.

He et al. (2011) used both National Household Travel Survey and Vehicle Quality Survey data to understand the impact of vehicle usage upon consumers' choices of HEVs in the US. Similar to Hackbarth and Madlener (2013), they found that income and education both contribute to the HEV choice. They also found that younger households with children are less likely to purchase HEVs.

Liu (2014) estimated consumers' willingness to pay for HEVs based on an analysis of micro-level data from National Household Travel Survey 2009 of the US. She showed that the sum of the consumers' willingness to pay (WTP) and the fuel cost savings from HEV is smaller

³ Konish and Zao (2017) reported that the subsidy program in Japan expanded economic surplus substantially but improved the sales-weighted average fuel efficiency only slightly.

than the price difference between HEVs and conventional gasoline vehicles. Hence, the average US consumer will not choose an HEV. However, she showed that the taste for HEVs varies across households. In particular, she showed that households with higher income are more likely to purchase HEVs but large households are less likely to purchase them.

Ozaki and Sevastyanova (2011) analyzed survey data from UK households to understand the motivations of HEV purchase. They find that financial benefits related to transport policies are important factors on HEV purchase decisions. Kahn (2007) compared hybrid vehicle choices between environmentalists and non-environmentalists and found that the former are more likely to purchase HEVs than the latter.

Previous studies commonly found that households traveling a long distance choose HEVs. In contrast, there is variation in terms of the impact of fuel cost on HEV purchase. Although Gallagher and Muehlegger (2011) and Su (2014) found that fuel cost has a significant positive impact on HEV purchase, Liu (2014) found that it has only a minor impact.

Hamamoto (2019) examined the factors influencing HEV selection among Japanese households and found that higher-income households tend to choose HEVs. However, contrary to other studies, he found that households whose annual mileages are shorter tend to choose HEVs in Japan. He also reported that awareness of global warming does not explain the

variation in HEV selection⁴.

By introducing subsidy programs for a limited period of time, governments intend to disseminate new products with desirable features. Households that hesitate to purchase a new product may decide to purchase it if a subsidy becomes available. However, not all households would be equally motivated by a specific subsidy program. Therefore, it is important to identify the types of households likely to be attracted by a subsidy program. In particular, given the popularity of subsidy programs for next-generation vehicles, it would be worthwhile to identify households who are likely to adopt next-generation vehicles when subsidy programs are introduced. Previous studies identified socioeconomic characteristics of early HEV adopters and confirmed that subsidy programs increased the sales of HEV. However, it has not been verified whether HEV evaluation by households returned to the previous position once the policy ended. In this study, we analyze micro-level data to answer these questions.

The paper focuses on the Japanese subsidy program called the “Eco-car program”. In Section 2, we explain this program and show how the program changed HEV sales in Japan. For the empirical analysis, we use micro-level data from the Japanese National Survey of Family Income and Expenditure (NSFE). Section 3 explains this survey and provides summary

⁴ He evaluated households’ environmental consciousness based on the installation condition of a solar power system.

statistics. In Section 4, we describe a multinomial logit model that is used to test whether the types of households purchasing HEV changed after the introduction of the subsidy policy. Details on the empirical results are reported in Section 5. The empirical results of this study show that higher-income households switched from CGVs to HEVs during the Eco-car program period. While seniors used to lead in the purchase of HEVs, after the Eco-car program was implemented, younger people began to purchase HEVs. Section 6 provides conclusions and policy implications.

2. Eco-car program

According to statistics from the Automobile Inspection and Registration Information Association (2018), the number of registered passenger vehicles increased from 55.3 million in 2004 to 61.6 million in 2018 (Figures 1a and 1b). However, the growth rate of vehicle registration has gradually slowed due to the aging Japanese population. On the other hand, the number of HEVs increased from 0.13 million in 2004 to 7.5 million in 2018. Therefore, the growth rate of HEVs is much higher than that of conventional gasoline vehicles.

There are several potential reasons for this rapid HEV sales expansion. The first major reason is the improvement in fuel economy; e.g., the fuel efficiency of the Prius released improved from 27 km/L in 1997 to 40 km/L in 2018. An increasing number of households

began to purchase HEVs for the purpose of saving gasoline costs.

The second reason is the increase in HEV variety. Initially, only a few models were equipped with the HEV engine. However, HEV engines are now installed in a variety of vehicles, expanding the range of utility. As a result, households are able to use HEVs for various purposes, stimulating the purchase of HEVs.

The last reason is the implementation of a series of Eco-car programs by the Japanese government. The rebate offered to HEV consumers during the program period made HEVs more attractive economically than conventional gasoline vehicles. The Japanese government spent JPY 589.9 billion in the first program period and JPY 300 billion in the second. Immediately following implementation of the first program (April 10, 2009) the sales share of HEVs increased from 5% to 15%. After the first program ended (September 7, 2010), the market share temporarily fell to 10%. However, it climbed again to 30% when the second program was launched on December 20, 2011.

3. Data

For the empirical analysis, we use micro-level data from the Japanese National Survey of Family Income and Expenditure (NSFE). The NSFE is a nationwide cross-sectional survey initiated in 1959 and conducted every five years. NSFE collects data on households'

socioeconomic characteristics, such as income/expenditure, savings/liabilities, and ownership of durable goods, as well as information related to houses such as dwelling characteristics and site area. In addition, the NSFE collects vehicle-related information such as the number of vehicles owned, the year of purchase of each vehicle, and vehicle type. The 2009 and 2014 surveys also asked households whether their vehicles were HEVs or conventional gasoline vehicles. Because households were randomly selected in the survey, we assume no bias in the vehicle ownership condition.

In the NSFE 2009 and 2014 surveys, 98,506 households out of 116,337 owned at least one vehicle. This rate of vehicle ownership (84.67%) indicates that the great majority of households in Japan own vehicles. Because the socioeconomic characteristics of single-vehicle households greatly differ from those of multi-vehicle households (Wang 2019), we focus on single-vehicle households in this study. The NSFE categorizes household vehicles into five types: 1) hybrid electric vehicles (HEVs); 2) battery electric vehicles (BEVs); 3) light-duty vehicles (LDVs) with an engine size less than 660 cc; 4) compact gasoline vehicles (CGVs) with an engine size between 660 and 2000 cc; and 5) regular gasoline vehicles (RGVs) with an engine size greater than 2000 cc. We removed BEV households as they numbered only 107. We also removed LDV households because the prices and usage of LDVs are much different from those of other types of vehicles. After remaining households that purchased only one new vehicle between 2004 and

2014, a total of 17,658 samples remained in our dataset.

Table 1 shows the descriptive statistics of characteristics of HEV/CGV/RGV households. The average household income is JPY 4.39 million. Among the three types of households, the average income of RGV households is the highest (JPY 5.24 million) while that of CGV households is the lowest (JPY 3.87 million). The result suggests that households with higher income tend to purchase bigger vehicles. The average income of HEV households is 4,415,000 JPY, which is above the average income of all households.

In addition to household income, the NSFE ask households about their savings and liabilities. We subtracted liabilities from the savings to calculate net wealth of each household. Table 1 shows that the average net wealth is JPY 10.93 million: the average net wealth of HEV households is JPY 17.36 million and that of RGV households is JPY 8.68 million. The result suggests that households with higher net wealth tend to purchase HEVs.

The NSFE surveys define the main income earner as the household head. We examine whether gender of the household head affects vehicle selection in Table 1. About 87.8% of household heads are males. Although the share of male household heads is 89.5% among HEV households, it is 91% among RGV households. This result means that male household heads tend to purchase larger vehicles and appreciate hybrid technologies. The average age of

household head is 55.9 years old. The average age of the household head of HEV households is 59.3 years old and of RGV households is 53.4 years old. Therefore, seniors purchase HEVs more frequently in Japan. This result is contrary to the findings of previous studies in which younger consumers are reported to purchase next-generation vehicles. The average household has approximately 2.8 members. The size of RGV households is the biggest with about 3 members, while that of HEV households is the smallest with about 2.56 members.

With respect to housing characteristics, most households live in detached houses (about 71.81%). About 75.51% of HEV households live in detached houses; this percentage is higher than those of CGV and RGV households. Approximately 81.24% of households are homeowners with the remainder (18.76%) being renters. The homeowner ratios are similar between CGV households (80.44%) and RGV households (80.38%) and these ratios are below the homeowner ratio of HEV households (87.07%).

The NSFE surveys also collect electricity usage data of households. We divide the electricity bill amount by the number of household members to calculate electricity cost per capita. To examine whether households who save electricity try to consume less gasoline, we examine whether household electricity usage is correlated to vehicle choice. Table 1 shows that average electricity cost per capita is 3484.5 JPY, whereas that of the average HEV household is

3979.6 JPY and that of the average CGV household is 3375.2 JPY. Therefore, HEV households use more electricity than CGV households.

4. Empirical method

4.1. Effect of the Eco-car program on vehicle selection

We remove households that owned multiple vehicles and focus on households that only own one vehicle. We further focus on households that purchased a new vehicle between 2004 and 2014. Then we conduct two types of empirical analyses. In the first analysis, we pool all the households and identify the type of households that purchase HEVs. In addition, we assess the impact of the Eco-car program on the vehicle selection.

Based on the multinomial logit model, we estimate the probability of selecting one of the following three types of vehicles: HEVs, CGVs, and RGVs. Specifically, we assume that the probability that household i chooses type j a vehicle at time of purchase t is given by

$$\Pr(y_i^t = j) = \frac{\exp(\mathbf{B}_j \mathbf{X}_i - \gamma_j p_j^t + \theta_j g^t + \mathbf{H} \mathbf{I}_t + \mathbf{\Gamma} \mathbf{Z}_t)}{\sum_{j=1}^3 \exp(\mathbf{B}_j \mathbf{X}_i - \gamma_j p_j^t + \theta_j g^t + \mathbf{H} \mathbf{I}_t + \mathbf{\Gamma} \mathbf{Z}_t)}, \quad (1)$$

where $\mathbf{X}_i$ is the vector of socioeconomic characteristics of household i , p_j^t is the weighted average price (WAP) of type j vehicles at time of purchase t , and g^t is the gasoline price at time of purchase t . $\mathbf{I}_t$ is the vector of two year dummies. A 2011 year dummy is included to control the impact of the Tohoku Great Earthquake and a 2014 year dummy is included to

control the impact of the increase in consumption tax⁵. Finally, we include two purchase period dummies Z_t to assess the impact of the Eco-car program on vehicle selection. We choose the period before the Eco-car program as the base and include two period dummies during and after the Eco-car program.

In the above estimation, we choose HEV as the base outcome for the identification purpose and estimate the parameters $B_j, \gamma_j, \theta_j, H$, and Γ based on the maximum likelihood estimation. We assume that the impacts of sociodemographic characteristics, vehicle price, and gasoline price are retained throughout the sampling period. We then examine whether the Eco-car program affected the vehicle selection by estimating the parameter Γ .

4.2. Effect of the Eco-car program on the customer base

Once a person purchases and uses a new product, he or she recognizes the beneficial features of it. One of the main motivations of subsidy programs is to provide a purchase opportunity to a person who did not have an experience to purchase a new product. The second purpose of this study is to examine whether new types of households began purchasing HEVs with the Eco-car program. In the second analysis, we divide the data into three sampling periods: before, during, and after the Eco-car program. We then estimate the following equation

⁵ The consumption tax increased from 5% to 8% in this year.

for three sampling periods separately,

$$\Pr(y_i^t = j) = \frac{\exp(B_j^s X_i - \gamma_j^s p_j^t + \theta_j^s g^t)}{\sum_{j=1}^3 \exp(B_j^s X_i - \gamma_j^s p_j^t + \theta_j^s g^t)}, \quad (2)$$

where B_j^s , γ_j^s , and θ_j^s are period-specific coefficients. Based on this estimation, we examine whether the marginal impact of covariates has changed over three sampling periods. For example, we examine whether the marginal income effect on the choice of HEV has changed before and after the Eco-car program.

5. Empirical results

5.1. Effect of the Eco-car program on vehicle selection

Table 2 presents the results of the MLN model of Equation (1), which pools the samples of all sampling periods. Because the precise purchase price is not available, we estimated the weighted average price (WAP) of three types of vehicles (HEV, CGV, and RGV) from the market data and used it for the following estimation. Although there are many grades within each vehicle type, the price of the high-grade model is very expensive in many cases. Manufacturers do not supply high-grade models for all vehicle types; e.g., high-grade models may not be available among CGVs. In this study, we use WAPs calculated from the prices of the lowest grade models and those of the second lowest grade models. The detailed calculation method of WAPs is described in the Appendix.

Model 1 is the estimation result that does not include WAPs. While Model 2 uses the WAPs calculated from the prices of the lowest grade models, Model 3 uses the WAPs calculated from the prices of the second lowest grade models.

The table shows that the relative-risk ratios (RRRs) of the purchase period dummy after the Eco-car program are all less than one. The results suggest that the positive impact of the Eco-car program on HEV selection remained even after the program ended.

Many covariates present almost the same pattern among the three models; that is, the effect of their impacts on households' HEV selection is robust. Like Gallagher and Muehlegger (2011) and Su (2014), we find that the gasoline price at the time of vehicle purchase has a positive impact on HEV purchase. Specifically, the gasoline price increase by JPY 1 increases the likelihood that an HEV is chosen over a CGV/RGV by about 3%.

In addition, Table 2 shows that financial factors play an important role in vehicle selection. Households with higher income tend to purchase HEVs over CGVs, whereas this tendency is not observed in the selection between HEVs and RGVs. On the other hand, households with larger net wealth tend to purchase HEVs not only over CGVs but also over RGVs. The net wealth increase by JPY 10 million increases the likelihood of HEV selection over CGV/RGV by about 5%.

Gender of the household head affects the vehicle selection. If the household head is male, then the probability that an HEV is chosen becomes 1.7 times higher than for CGVs. We also find that age of household head affects the vehicle selection between HEVs and RGVs. Compared with younger households, elder households choose HEV over RGV.

Like Liu (2014), we find that large households do not choose HEVs and this effect is stronger on the choice between HEVs and RGVs. Households who live in their own house tend to choose HEVs. The likelihood that the HEV is chosen over the CGV increases by a factor of about 1.56 when households live in their own house, whereas the choice of HEV over the RGV increases by a factor of about 1.27.

We also evaluate whether electricity consumption affects vehicle selection. In Table 2, we observed opposite results between the choice of HEVs/CGVs and the choice of HEVs/RGVs. In the choice between HEVs and CGVs, households that use “relatively more” electricity tend to purchase HEVs, whereas in the choice between HEVs and RGVs, households that use “relatively less” electricity tend to choose HEVs. This result implies that the consumer base of CGVs and RGVs is different: the most energy-efficient households choose CGVs, the most energy-consuming households choose RGVs, and households with average energy consumption choose HEVs.

Through the multinomial logit model analysis, we confirmed the positive impact of the Eco-car program on HEV selection. The likelihood that households choose HEVs over CGVs and RGVs increased greatly during the Eco-car program. We also identified factors that affect households' vehicle choice. We obtained that elder homeowners with high income and large net wealth tend to choose HEVs when the gasoline price is high while large families tend not to choose an HEV. Male household heads are more likely to purchase an HEV. Finally, we found that the usage of electricity is associated with vehicle selection.

5.2. Effect of the Eco-car program on the customer base

In this sub-section, we classify the households into three groups according to their vehicle purchase period: Period 1 (before the Eco-car program), Period 2 (during the program), and Period 3 (after the program). By using the multinomial logit model of Equation (2), we estimate the ratios of the vehicle choice probabilities in each period and examine how the impact of household characteristics on HEV selection has changed during three purchase periods.

Table 3 presents the estimation results when using WAPs calculated based on the lowest grade vehicles⁶. Gasoline price becomes significant only in Period 1, which suggests that gasoline price used to be an important factor before the Eco-car program but became a less

⁶ Because the results of the models with/without WAPs are similar, we omit the other two tables.

important factor during the Eco-car program period⁷.

In the comparison between HEVs and CGVs, the RRR of household income becomes less than 1 in all three periods. This result suggests that household income has been an important factor throughout the sampling periods. Although HEVs have become quite popular in the Japanese market already, they are still more popular among high-income than low-income households. The value of RRR of household income decreased from Period 1 to Period 2 and then increased from Period 2 to Period 3. This means that household income became an important factor in the comparison between HEVs and CGVs during the Eco-car program period; thus, households with higher incomes switched from CGVs to HEVs.

In the comparison between HEVs and RGVs, the RRR of household income does not become statistically significant in all three periods. Therefore, household income is not an important factor in the comparison between HEVs and RGVs.

The RRRs of net wealth become less than 1 and statistically significant in the last two periods. This suggests that net wealth used to be a less important factor before the Eco-car program but became an important factor after the program. Households with large net wealth began choosing HEVs over CGVs or RGVs.

⁷ Wald test regarding if coefficients are equal to a specific value between before and during, before and after, and during and after were carried out, and the hypotheses are all rejected at 1%.

In the comparison between HEVs and CGVs, gender of the household head becomes a powerful predictor about HEV selection. Although the RRR is less than 1 in all three periods, it takes the smallest value in Period 2. The RRR in Period 3 is larger than that in Period 1. These results suggest that although HEVs were more popular among male head households, female head households began choosing HEVs in more recent years.

With respect to age of household head, on the choice between HEVs and RGVs, the RRRs became statistically significant and take the value less than 1 in all three periods. Thus, seniors choose HEVs over RGVs. In contrast, on the choice between HEVs and CGVs, the RRRs become significant only in Periods 1 and 3. In addition, the value of RRR is smaller than 1 in Period 1 but is larger than 1 in Period 3. This means that the Eco-car program changed the age bracket of the consumers of HEVs. Although seniors chose HEVs over CGVs before the Eco-car program, younger consumers began choosing HEVs over CGVs after the Eco-car program.

Large families do not to choose HEVs over RGVs in all three periods. In the comparison between HEVs and CGVs, household size is not statistically significant in Period 1. However, it becomes statistically in Periods 2 and 3. Hence, large families began avoiding HEVs.

The RRR of detached house dummy becomes statistically significant only in the

comparison between HEVs and CGVs in Period 2. The value of RRR is larger than 1, meaning that households living in a detached house chose CGVs over HEVs during the Eco-car program period. Home ownership became an important factor on vehicle selection particularly during the Eco-car program period; homeowners chose HEVs over both CGVs and RGVs during the Eco-car program period.

Finally, in terms of household electricity usage, in the comparison between HEVs and CGVs, electricity cost per capita became less than 1 and statistically significant at 1% level in Periods 1 and 3. This suggests that households that consume more electricity tend to choose HEVs over CGVs. In the comparison of HEVs and RGVs, the electricity usage becomes significant only in Period 2. The result shows that households consuming more electricity chose RGVs over HEVs during the Eco-car period.

6. Conclusions and policy implications

In this study, we analyzed the micro-level data of vehicle selection from the NSFE and examined how the Eco-car program affected households' vehicle selection. The empirical results demonstrate that the likelihood of HEV selection increased substantially during the program period and remained at a high level after the program ended.

Household income has been an important factor on the choice between HEVs and CGVs.

Households with higher income tend to choose HEVs over CGVs, whereas household income does not play an important role in the choice between HEVs and RGVs. We also found that higher-income households that used CGVs before the Eco-car program switched to HEVs during the Eco-car program but those that used RGVs did not switch to HEVs. These results suggest that the customer bases of CGV and HEV are different from that of RGV.

We find that households with large net wealth tend to choose HEVs over both CGVs and RGVs. In addition, we find that RGV households consume more electricity than the other two households. These results suggest that RGV households would have different preferences about energy consumption from the other two types of households and they may be reluctant on energy saving. Since households using a compact vehicle have already switched their gasoline vehicle to a HEV, the next challenge is to introduce a policy to change the behavior of households using a large vehicle.

Finally, we find that the impact of gasoline price has become smaller since the Eco-car program. As automobile fuel economy improves, households pay less attention to the fuel cost. To provide households with a further incentive to purchase a next-generation vehicle, governments would need to increase the effective price of gasoline.

Acknowledgment

This research was supported by the Environment Research and Technology Development Fund (2-1707) of the Environmental Restoration and Conservation Agency and KAKENHI (18K01578) of the Japan Society for the Promotion of Science.

Appendix

Derivation of the weighted average of vehicle prices

The price ranges of HEVs, CGVs, and RGVs are different. For example, the sales price of RGVs is generally higher than for CGVs due to more horsepower, interior space, etc. Although the price of vehicles is considered to play an important role when choosing vehicles, the purchase prices of vehicles are not available in the NSFE data. We calculated weighted average price (WAP) of RGVs/CGVs/HEVs between 2004 and 2014 according to the following procedure.

First, referring to the vehicle sales ranking (Sony Assurance Inc. 2018), we obtained information about vehicle sales between 2004 and 2014. We focus on popular vehicle types that sold more than 50,000 in one year.

Second, we collected sales price data of these vehicles from Yahoo Carview⁸. Third, by combining sales and price data, we calculated the WAPs of HEVs, CGVs, and RGVs. Because

⁸ Yahoo Carview is the largest information site about vehicles in Japan. The purchase price of each maker's vehicles is provided by model.

the sales price of vehicles depends on the grade, we calculated two types of WAPs: one for the lowest price grade and one for the second lowest price grade.

Figure A1 and A2 shows the change in WAPs. While WAPs of CGVs are the lowest throughout the sampling periods, those of RGVs are the highest. The fluctuations of WAPs of RGVs and HEVs are larger than for CGVs. After reaching a peak in 2007, the WAPs of HEVs and RGVs began to decrease.

References

- Automobile Inspection and Registration Information Association. 2018. Vehicle ownership trend of Japan. <<https://www.airia.or.jp/publish/statistics/trend.html>> Accessed 23 May 2019.
- Chandra, A; Gulati, S; Kandlikar, M 2010. "Green drivers or free riders? An analysis of tax rebates for hybrid vehicles." *Journal of Environmental Economics and Management* 60: 78-93.
- Coad, A.; Haan, P; Woersdorfer, JS 2009. "Consumer support for environmental policies: An application to purchases of green cars." *Ecological Economics* 68: 2078-2086.
- Gallagher, K and Muehlegger, E 2011. "Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology." *Journal of Environmental Economics and*

Management 61(1): 1-15.

Graham, D; Glaister, S 2002. "The demand for automobile fuel: a survey of elasticities."

Journal of Transport Economics and Policy 36: 1-26.

Hamamoto, M. 2019. "An empirical study on the behavior of hybrid-electric vehicle purchasers."

Energy Policy 125: 286-292.

Hackbarth, A; Madlener, R 2013. "Consumer preferences for alternative fuel vehicles: a discrete

choice analysis." *Transportation Research Part D* 25: 5-17.

He, L; Chen, W; Conzelmann, G 2012. "Impact of vehicle usage on consumer choice of hybrid

electric vehicles." *Transportation Research Part D* 17: 208-214.

International Energy Agency. 2019. Tracking Progress: Transport. <[https://www.iea.org/etp/](https://www.iea.org/etp/tracking2017/transport/)

[tracking2017/transport/](https://www.iea.org/etp/tracking2017/transport/)> Accessed 12 May 2019.

Iwata, K and Matsumoto, S. 2016. "Use of hybrid vehicle in Japan: An analysis of used car

market data." *Transportation Research Part D* 46: 200-206.

Kahn, ME 2007. "Do greens drive hummers or hybrids? Environmental ideology as a

determinant of consumer choice and the aggregate ecological footprint." *Journal of*

Environmental Economics and Management 54: 129-145.

Konishi, Y; Zhao, M 2017. "Can green car taxes restore efficiency? Evidence from the Japanese

New Car Market." *Journal of the Association of Environmental and Resource Economists* 4:

51-87.

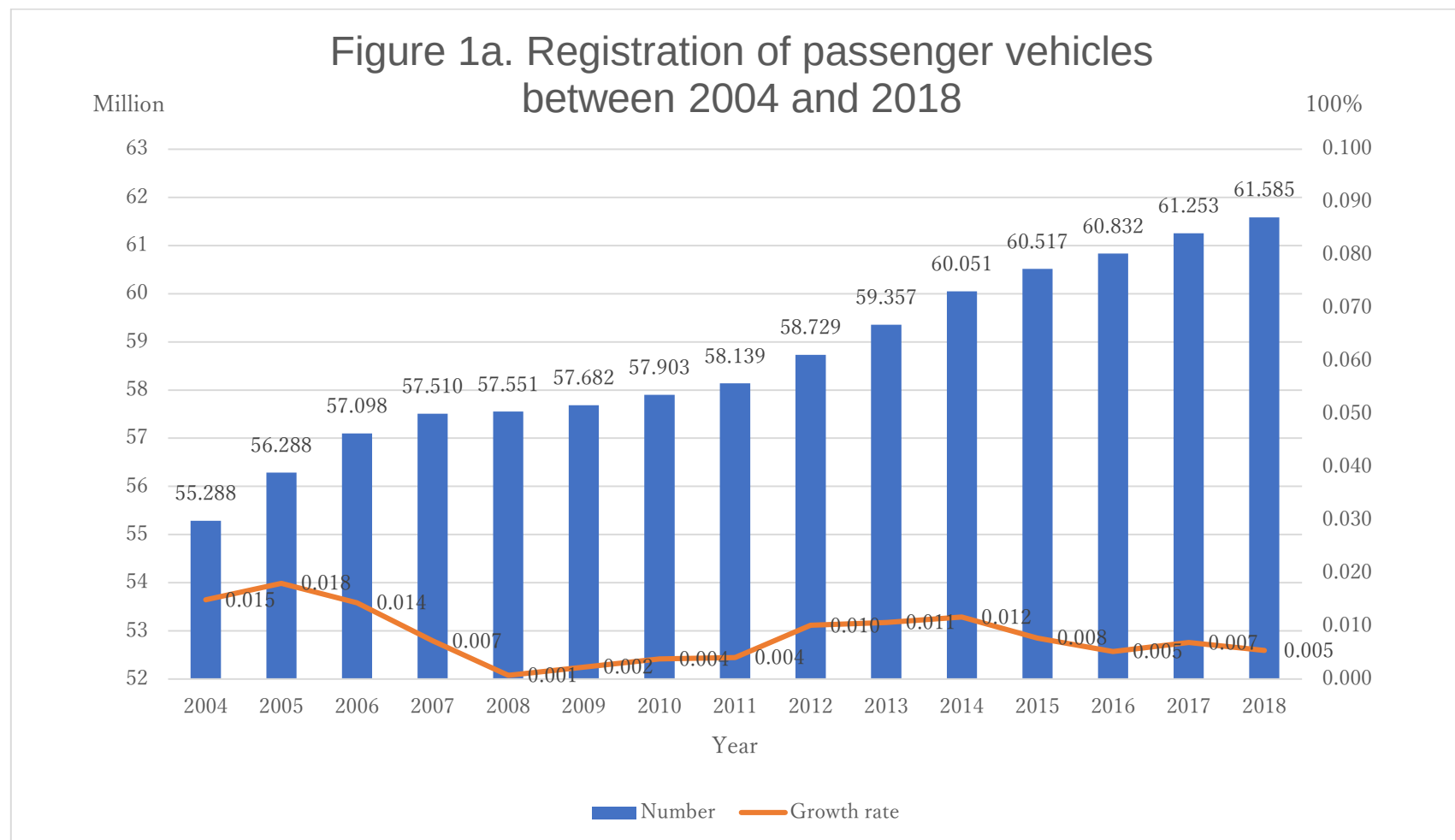
Liu, Y. 2014. “Household demand and willingness to pay for hybrid vehicles.” *Energy Economics* 44: 191-197.

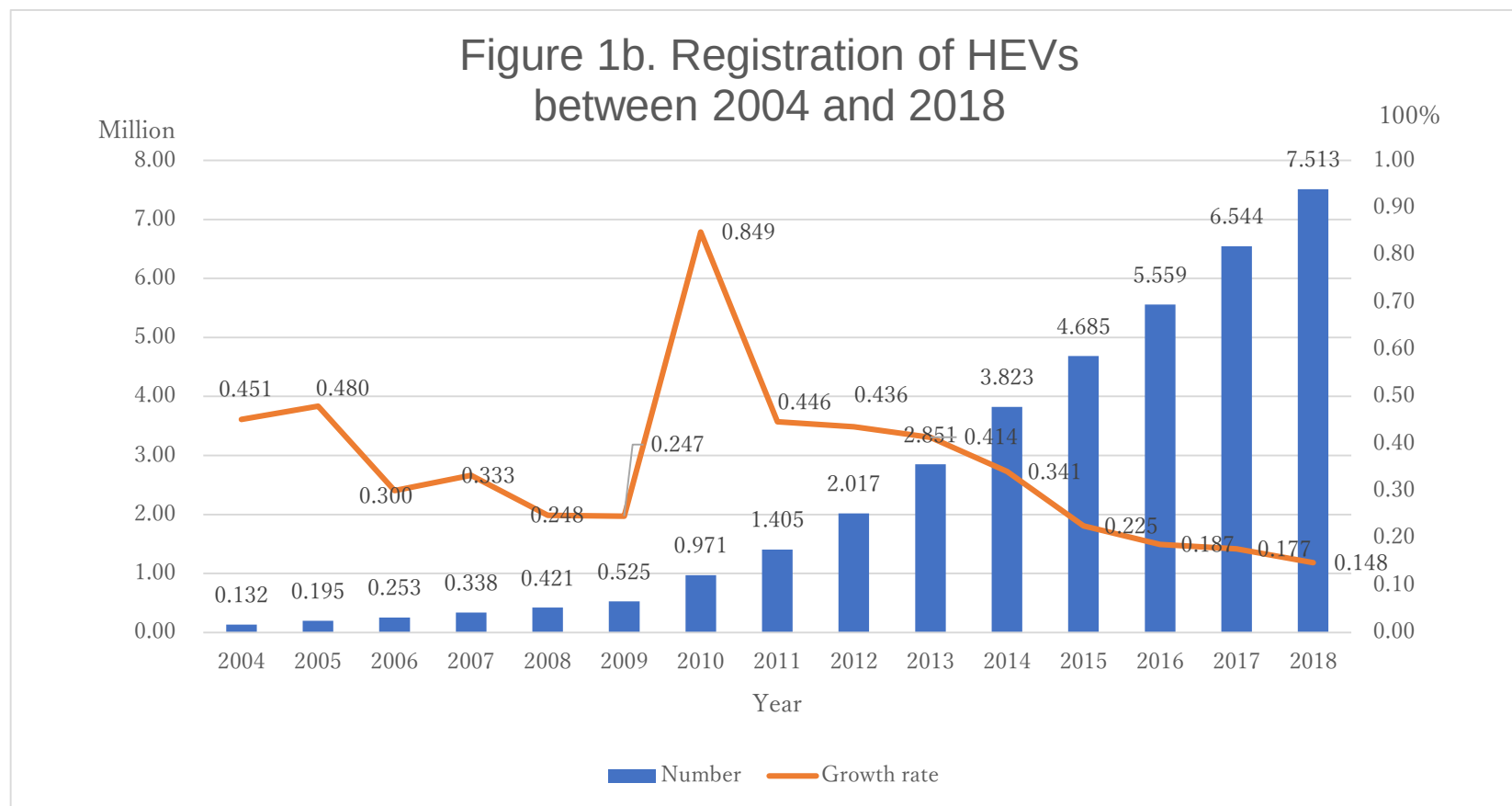
Next Generation Vehicle Promotion Center. 2018. The number of vehicle registered.
<<http://www.cev-pc.or.jp/tokei/hanbai.html>> Accessed 15 May 2019.

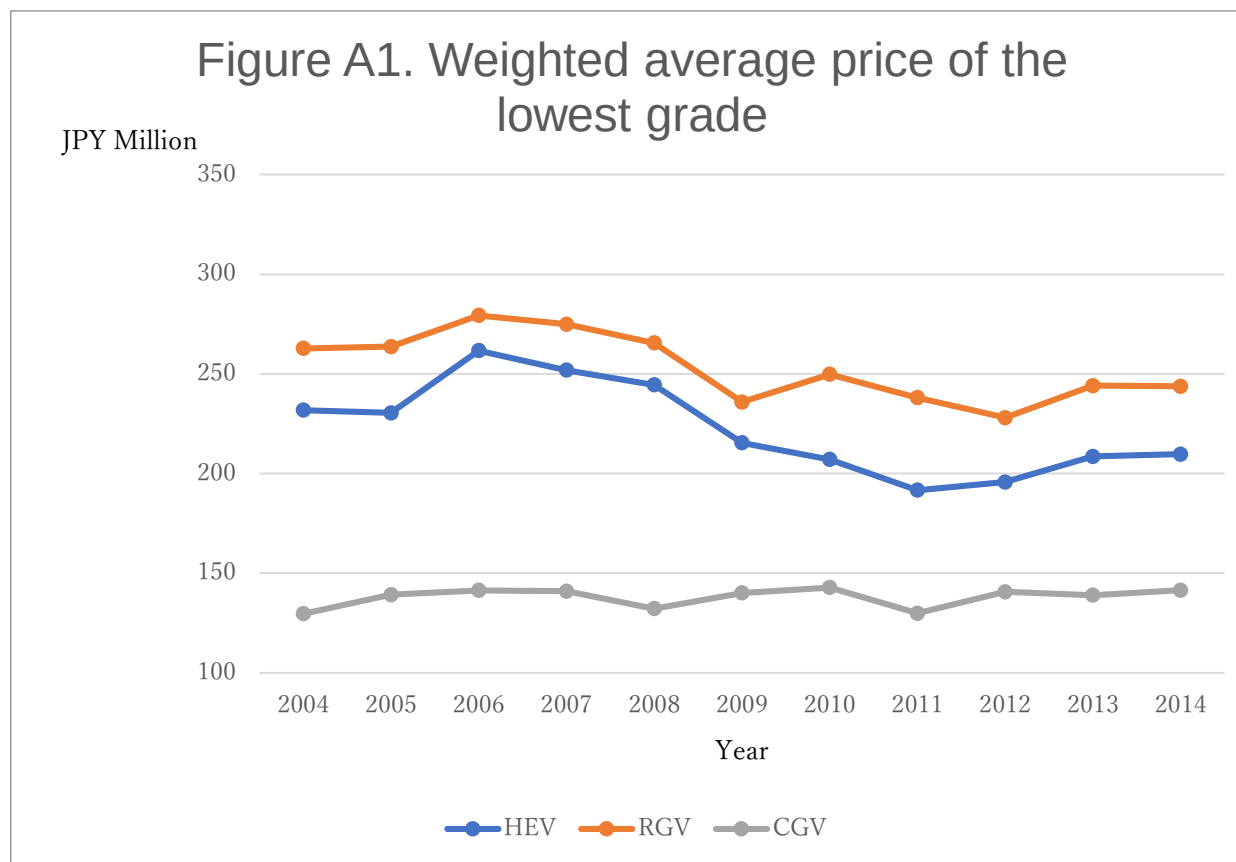
Ozaki, R; Sevastyanova, K 2011. Going hybrid: An analysis of consumer purchase motivations.
Energy Policy 39: 2217–2227.

Su, Q. 2014. Purchase and utilization of new fuel efficient vehicles in the us: evidence from the 2009 national household transportation survey data. *International Journal of Energy Economics and Policy* 4: 1-14.

Wang, J. 2019. “For the promotion of Eco-Car: Analysis of household attributes and vehicle choice”. Working Paper. (in Japanese).







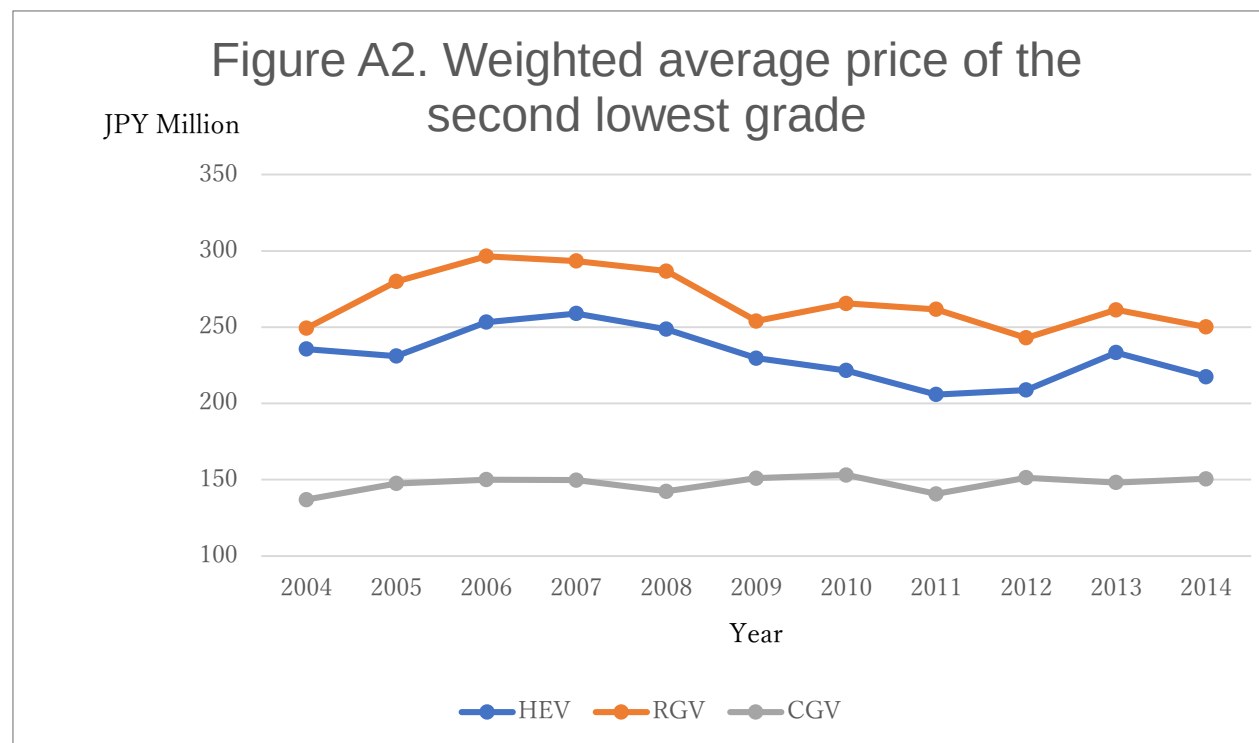


Table 1. Descriptive statistics of HEV/CGV/RGV households.

	HEV households		CGV households		RGV households		All households	
	Mean or Share	Std. Dev	Mean or Share	Std. Dev	Mean or Share	Std. Dev	Mean or Share	Std. Dev
Household income (10 million JPY)	0.4415	0.5275	0.3870	0.4656	0.5237	0.5082	0.4388	0.4918
Gender of household head dummy (if s/he is male = 1)	0.8949		0.8550		0.9102		0.8781	
Net wealth (10 million JPY)	1.7357	3.1988	1.0831	2.6285	0.8681	2.8380	1.0932	2.7866
Age of household head	59.2942	13.4892	56.6061	15.1598	53.4155	14.7643	55.8886	14.9566
Household size (number of persons in household)	2.5610	0.9739	2.7393	1.1032	3.0046	1.1542	2.8046	1.1155
Detached house dummy (if the house is a detached house = 1)	0.7551		0.7276		0.6886		0.7181	
Homeowner dummy (if s/he is a home owner = 1)	0.8707		0.8044		0.8038		0.8124	
Electricity cost per capita (1000 JPY)	3.9796	2.1623	3.3752	1.9689	3.4788	2.1833	3.4845	2.0751

Table 2. Impact of Eco-Car program on vehicle selection.

	Model 1. Without price control							Model 2. Lowest grade						Model 3. Second lowest grade										
	Vehicle = CGV			Vehicle = RGV				Vehicle = CGV			Vehicle = RGV			Vehicle = CGV			Vehicle = RGV							
	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR						
Purchase period dummies (base=before Eco-Car program period)																								
Period 2 dummy (during Eco-Car program)	0.097	0.007	***	10.329	0.146	0.011	***	6.864	0.226	0.056	***	4.424	0.449	0.113	2.226	0.243	0.052	***	4.120	0.273	0.060	***	3.660	
Period 3 dummy (After Eco-Car program)	0.104	0.009	***	9.631	0.229	0.020	***	4.371	0.173	0.033	***	5.785	0.343	0.066	***	2.917	0.170	0.023	***	5.890	0.274	0.037	***	3.654
Gasoline Price	0.965	0.002	***	1.036	0.970	0.003	***	1.031	0.968	0.003	***	1.033	0.975	0.003	***	1.025	0.964	0.003	***	1.038	0.973	0.003	***	1.028
Household income	0.691	0.041	***	1.448	0.996	0.053		1.004	0.691	0.042	***	1.446	1.002	0.054		0.998	0.690	0.041	***	1.450	0.998	0.054		1.002
Gender of household head dummy	0.592	0.052	***	1.690	0.886	0.082		1.129	0.590	0.052	***	1.694	0.883	0.082		1.133	0.587	0.052	***	1.703	0.880	0.082		1.137
Net wealth	0.950	0.010	***	1.052	0.954	0.010	***	1.048	0.950	0.010	***	1.052	0.954	0.010	***	1.048	0.951	0.010	***	1.052	0.954	0.010	***	1.048
Age of household head	0.997	0.003		1.003	0.987	0.003	***	1.014	0.997	0.003		1.003	0.986	0.003	***	1.014	0.997	0.003		1.003	0.987	0.003	***	1.014
Household size	1.162	0.038	***	0.860	1.362	0.045	***	0.734	1.163	0.039	***	0.860	1.360	0.045	***	0.735	1.162	0.039	***	0.861	1.360	0.045	***	0.735
Detached house dummy	1.161	0.089	*	0.861	0.929	0.072		1.076	1.161	0.090	*	0.861	0.931	0.072	*	1.074	1.163	0.090	*	0.860	0.931	0.072		1.074
Home owner dummy	0.643	0.063	***	1.556	0.791	0.078	**	1.265	0.643	0.063	***	1.556	0.788	0.078	*	1.269	0.640	0.063	***	1.563	0.787	0.078	**	1.271
Electricity cost per capita	0.932	0.014	***	1.072	1.049	0.015	***	0.954	0.932	0.014	***	1.073	1.046	0.015	**	0.956	0.931	0.014	***	1.074	1.046	0.015	***	0.956
Year 2014 dummy	0.890	0.096		1.123	0.974	0.099		1.027	1.026	0.123		0.975	1.316	0.152	**	0.760	1.483	0.215	***	0.674	1.359	0.193	**	0.736
Year 2011 dummy	1.160	0.438		0.862	1.496	0.568		0.669	0.998	0.381		1.002	1.123	0.432		0.891	0.812	0.312		1.232	1.035	0.400		0.967
WAP of HEV									1.001	0.004		0.999	0.984	0.004	***	1.016	0.994	0.004	*	1.006	0.990	0.004	***	1.010
WAP of RGV									1.019	0.006	***	0.981	1.045	0.007	***	0.957	1.027	0.004	***	0.974	1.020	0.004	***	0.980
WAP of CGV									0.963	0.011	***	1.039	0.948	0.011	***	1.055	0.958	0.013	***	1.043	0.964	0.013	***	1.037
Constant	5753.1	2371.9	***	0.000	729.1	307.4	***	0.001	3245.7	4599.8	***	0.000	149.6	216.1	***	0.007	7865.1	10932.1	***	0.000	3836.0	5404.7	***	0.000
N	17,311									17,311						17,311								
Log likelihood	-14723.29									-14683.40						-14689.00								

Notes: 1) ***, **, * indicate significance at 1, 5, and 10% level, respectively;

2) RRRs capture the relative risks, which are the ratios of the vehicle choice probabilities.

3) dummies of 47 prefectures are concluded in the model.

Table3. Changes in the marginal impact of households characteristics on vehicle selection.

Variables	Period 1: Before Eco-Car program						Period 2: During Eco-Car program						Period 3: After Eco-Car program											
	Vehicle = CGV			Vehicle = RGV			Vehicle = CGV			Vehicle = RGV			Vehicle = CGV			Vehicle = RGV								
	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR	RRR	Std.err	1/RRR						
Gasoline Price	0.959	0.013	***	1.043	0.968	0.014	**	1.033	1.020	0.050	0.980	0.988	0.051	1.013	0.979	0.060	1.022	0.954	0.057	1.049				
Household income	0.749	0.102	**	1.335	1.109	0.151		0.902	0.583	0.064	***	1.714	0.898	0.091	1.114	0.804	0.091	*	1.244	1.002	0.094	0.998		
Gender of household head dummy	0.602	0.115	***	1.661	0.940	0.187		1.064	0.565	0.083	***	1.771	0.823	0.134	1.215	0.646	0.097	***	1.547	0.896	0.139	1.116		
Net wealth	0.971	0.020		1.029	0.971	0.021		1.030	0.930	0.016	***	1.076	0.952	0.017	***	1.050	0.963	0.018	**	1.038	0.947	0.017	***	1.057
Age of household head	0.982	0.005	***	1.018	0.978	0.006	***	1.023	0.997	0.004		1.003	0.977	0.004	***	1.023	1.014	0.005	***	0.987	0.990	0.004	**	1.010
Household size	1.117	0.081		0.895	1.348	0.100	***	0.742	1.244	0.069	***	0.804	1.368	0.077	***	0.731	1.156	0.069	**	0.865	1.312	0.073	***	0.762
Detached house dummy	1.078	0.185		0.928	0.823	0.144		1.215	1.412	0.177	**	0.708	1.035	0.131		0.966	0.844	0.118		1.186	0.974	0.129		1.027
Home owner dummy	0.741	0.166		1.349	0.923	0.211		1.083	0.524	0.083	***	1.909	0.765	0.124	*	1.307	0.802	0.141		1.246	0.705	0.115	**	1.419
Electricity cost per capita	0.882	0.024	***	1.134	1.026	0.028		0.975	1.001	0.024		0.999	1.069	0.027	***	0.935	0.932	0.025	***	1.074	1.006	0.025		0.994
WAP of HEV	1.094	0.074		0.914	1.045	0.072		0.957	1.095	0.076		0.913	1.002	0.073		0.998	0.961	0.235		1.041	1.146	0.273		0.873
WAP of RGV	0.836	0.108		1.197	0.920	0.122		1.087	1.009	0.008		0.991	1.033	0.008	***	0.968	1.018	0.602		0.983	0.644	0.370		1.553
WAP of CGV	1.078	0.053		0.927	1.025	0.052		0.975	1.000	(omitted)			1.000	(omitted)			1.000	(omitted)			1.000	(omitted)		
Constant	3.9E+11	5.4E+12	*	0.000	5870071	8.5E+07	0.000		0.000	0.000	3.8E+09	0.004	0.091	229.242			922.143	94474.9	0.001		4E+37	4E+39		0.000
N	10158						4149						3004											
Log likelihood	-7368.137						-4046.655						-3093.565											

Notes: 1) ***, **, * indicate significance at 1, 5, and 10% level, respectively;

2) RRRs capture the relative risks, which are the ratios of the vehicle choice probabilities.

3) dummies of 47 prefectures are concluded in the model.