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Demographic, Social, Economic, and Regional Factors Affecting the Diffusion of Hybrid Electric Vehicles in Japan

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Abstract: The transportation sector is a major contributor to carbon dioxide emissions, and the resulting climate change. The diffusion of alternative fuel vehicles, including hybrid electric vehicles (HEV), is an important solution for these issues. This study aimed to evaluate the factors affecting the ownership ratio of HEVs, particularly passenger vehicles, and the regional differences in the purchase of HEVs in Japan. This study performed a fixed-effects regression analysis with panel data for 47 prefectures during the period 2005–2015 to evaluate the factors affecting the HEV ownership ratio and conducted three cluster analyses to investigate the regional differences in diffusion in terms of price categories, body types, and drive systems of HEVs. Some demographic and social factors were found to affect the ownership ratio in Japan, whereas economic factors, including prefecture-level subsidies for purchasing HEVs, were not. Regarding regional differences, prefectures in urban areas with higher income levels tend to purchase more expensive and large-sized HEVs. These results suggest that a strategy to sell the right vehicle to the right person and region is essential for further promoting HEVs in Japan.

Keywords: hybrid electric vehicle; diffusion; fixed-effects regression analysis; cluster analysis; regional characteristics; Japan

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1. Introduction

Increasing carbon dioxide (CO_2) emissions and climate change have become global challenges. Transportation is a major contributor worldwide to energy-related greenhouse gas (GHG) emissions, accounting for 24% of global CO_2 emissions [1]. In this context, various technologies for low-carbon transportation have been developed [2]. The spread of energy-sustainable transportation, such as alternative fuel vehicles (AFV), is one possible innovation to address this issue [3–5]. The most common types of AFVs today are different types of electric vehicles (EV), including hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV), which use less fossil fuels than conventional gas or diesel vehicles.

Although registrations for EVs are increasing, a greater market share is essential for the decarbonization of society. A growing body of literature has investigated the adaptation factors in the market for EVs and classified some of the major obstacles to the widespread adoption of EVs into vehicle attributes, consumer characteristics, and external factors [5,6].

Vehicle attributes related to vehicle performance, battery cost, driving range, and charging time are the main factors affecting EV adoption [3,7–9]. Because of the limited driving range and charging time of BEVs, several studies have reported higher preferences for HEVs and PHEVs [10,11]. Consumers also have various preferences for the design characteristics of vehicles (e.g., body type and size class), and designing vehicles to meet the demands for different preferences affects the market share of EVs [7,12]. There is also a study on obsolete EV management practices regarding recycling issues [13].

Factors related to consumer characteristics are likewise important for adopting EVs. The common consumer characteristics include gender, age, income, education, car ownership, household structure, and environmentalism. The findings from previous studies on the impact of these characteristics have shown mixed results. Several studies have presented the positive effects of income and education level [14,15], whereas others have shown that these factors do not significantly affect EV purchases [5,16]. External factors, including fuel prices, incentive policies, and infrastructure, can also be important factors. Many countries have used financial incentives, such as subsidies and emission-based vehicle taxes, to encourage EV adoption [5]. Many studies have investigated the effects of policy incentives [17–19] and showed that, for example, subsidies for EV purchase and charger installation have positive effects on promoting EV purchase, with the effects of charger installation being more significant [19]. By contrast, some studies have indicated that the effects of subsidies are limited [17,20].

Using regression and cluster analysis, the present study investigated the factors affecting the ownership ratio of HEVs and the regional differences in consumers' preferences for the purchase of HEVs. This study makes two primary contributions to the existing literature. First, a revealed preference approach was applied based on actual car registrations or HEV ownership. Previous studies on EV adoption have mostly used stated preference surveys to investigate the factors influencing EV adoption because of the low ownership ratio of BEVs. HEVs share similar features with BEVs, such as battery- and electric motor-based powertrains and lower environmental impacts. Although BEVs use a different charging method, technologically advanced batteries and the spread of charging stations can compensate for their battery-related disadvantages. The analysis included non-plug-in HEVs only. Second, this study also investigated regional differences in consumers' preferences for vehicle attributes. Previous studies have shown regional differences in the adoption of EVs [21,22]. Regional differences in vehicles' attributes may exist because of different weather and topologies.

Section 2 describes the materials and methods. Section 3 explains and discusses the results of affecting factors and regional differences in HEV adoption. Finally, section 4 concludes this study and describes the implications and avenues for future research.

2. Materials and Methods

In this study, a fixed-effects regression model with the panel data for 47 prefectures in the period 2005–2015 was used to evaluate the factors affecting the ownership ratio of HEVs (passenger vehicles). A cluster analysis was then conducted to evaluate regional differences in the purchase of HEVs. R software (version 4.0.0) and its package (plm) were used for these analyses.

2.1. Panel Data Regression Analysis

A fixed-effects regression model using the panel data of 47 prefectures for 11 years (from 2005 to 2015) was conducted to identify the factors affecting the ownership ratio of HEVs (Equation (1)). With this model, the factors (independent variables) affecting the ownership ratio of HEVs can be clarified by controlling for prefecture and year fixed effects.

$$hybrid\_ratio_{it} = \boldsymbol{\beta}\mathbf{X}_{it}^{-1} + \alpha_i + \delta_t + \varepsilon_{it} + C, \quad (1)$$

where $hybrid\_ratio_{it}$ is the ownership ratio of HEVs (passenger vehicles) of prefecture i in year t, $\boldsymbol{\beta}$ is the vector of coefficients, $\mathbf{X}_{it}$ is the vector of independent variables (i.e., *subsidy*, *income*, *saving*, *population_per_household*, *vehicle_number*, *vehicle_per_household*, *university*, *aging*, and *male*; see Table 1 for the description of these variables), α_i is the prefecture fixed effect, δ_t is the year fixed effect, ε_{it} is the error term, and C is a constant.

hybrid_ratio, the dependent variable, is calculated by "the number of HEVs/the number of passenger vehicles". These data were obtained from the Automobile Inspection and Registration Information Association [23]. Figure 1 depicts the time trend of the ownership ratio of HEVs. As shown in the figure, in Japan, the ratio of HEVs to the number of passenger vehicles increased during the study period, with a concurrent increase in variance.

Table 1. Selection of independent variables and their data sources.

Independent Variables	Definition	Sources
subsidy	Prefecture-level subsidy for purchasing HEVs. A dummy variable that takes a value of one if a subsidy exists and zero otherwise.	Website of and inquiry from each prefecture
income (thousand JPY)	Annual income per capita	[24]
saving (thousand JPY)	Savings per household	[25]
population_per_household	Number of people per household	Calculated based on the data from [26]
vehicle_number	Number of passenger vehicles	[23]
vehicle_per_household	Number of passenger vehicles per household	Calculated based on the data from [23] and [26]
university	Ratio of university entrance (i.e., indicator of higher education)	[27]
aging	Ratio of elderly people (over 65 years old)	[26]
male	Ratio of males	[26]

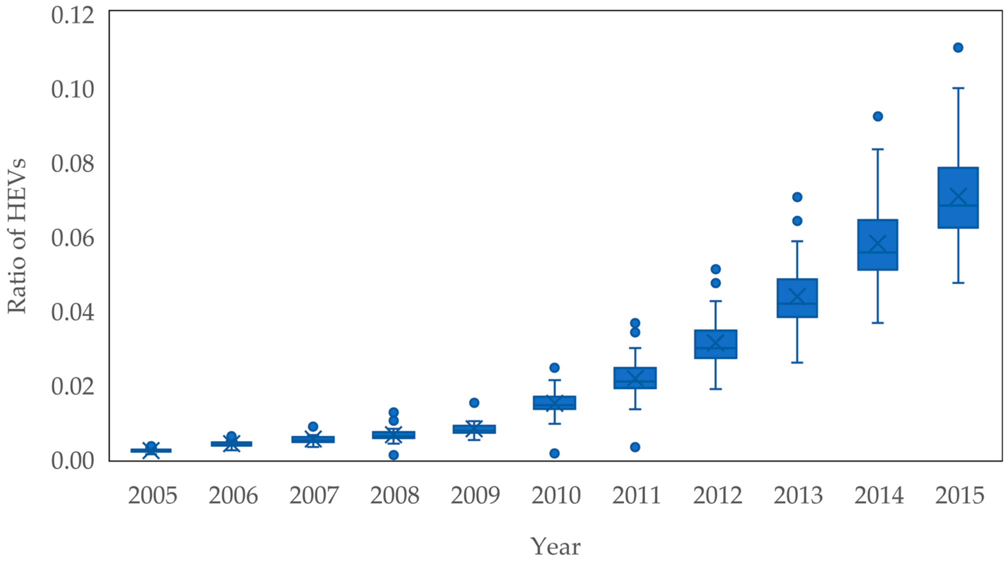

Figure 1. Trend of the ownership ratio of HEVs at the prefecture level. Each box shows the 75th percentile, median, and 25th percentile of the samples (from the top). The whiskers show the maximum and minimum values (excluding the outliers). The cross marks show the mean values, whereas the circles show the outlier points.

The following independent variables ($\mathbf{X}$) were selected: *subsidy* for the dummy variable that takes a value of one if a subsidy for purchasing HEVs exists in the prefecture in that year and zero otherwise, *income* for annual income per capita, *saving* for savings per household, *population_per_household* for the population per household, *vehicle_number* for the number of passenger vehicles, *vehicle_per_household* for the number of passenger vehicles per household, *university* for the ratio of university entrance, *aging* for the population aging rate, and *male* for the ratio of the male population. The number of observations was 517 (47 prefectures × 11 years). The definitions and sources of the independent variables are shown in Table 1, and the descriptive statistics are indicated in Table 2.

Table 2. Descriptive statistics of the variables for the whole samples.

Variables	Mean	S.D.	Min.	Max.
hybrid_ratio	0.024	0.024	0.00094	0.11
subsidy	0.077	0.088	0	1
income	4359.75	449.01	3365.24	6360.33
saving	11910.89	3020.89	3510	20390
populaion_per_household	2.50	0.23	1.97	3.13
vehicle_number	1239511.54	892405.18	310522	4064359
vehicle_per_household	1.42	0.82	0.26	5.24
university	0.50	0.072	0.31	0.67
aging	0.25	0.034	0.16	0.34
male	0.48	0.010	0.47	0.51

Note: The number of observations is 517 (47 prefectures × 11 years).

In some prefectures (Fukui, Miyagi, and Iwate), subsidies for purchasing HEVs were implemented during the study period (used as *subsidy* in the regression analysis). These subsidies were introduced to promote the purchase of HEVs. The information was obtained by inquiring from each prefecture. As described below, the subsidy schemes were different by prefecture, so a dummy variable was applied to the subsidies.

In Fukui Prefecture, the "Fukui eco-friendly car promotion subsidy" was implemented during the period FY 2003–2006. With the subsidy provided by cities under the prefecture, citizens, and companies within the prefecture could receive subsidies of one-fourth of the price difference between HEVs and non-HEVs (the upper limit is JPY 60,000 (USD 1≈JPY 110 and EUR 1≈JPY 130)).

In Miyagi Prefecture, the "subsidy to promote the use of clean energy vehicles" was implemented in FY 2009. This scheme provided a subsidy of JPY 100,000 for purchasing one HEV.

Finally, in Iwate Prefecture, the "Iwate subsidy to promote eco-friendly vehicles" was implemented in FY 2009. This scheme provided a subsidy of JPY 100,000 for purchasing a new HEV and for scrapping cars that were 13 years old or above, or of JPY 60,000 for purchasing a new HEV without scrapping such cars.

The coefficients for *subsidy* will be positive if the prefecture-level subsidy promoted the purchase of HEVs. It should be noted that although subsidies and tax deductions for purchasing HEVs existed at the national level in Japan to promote the purchase of HEVs, they were not included as an independent variable of the regression analysis; this model could not estimate the coefficients for national-level subsidies and tax deductions because of the prefecture fixed effect.

2.2. Cluster Analysis

A cluster analysis was then conducted to clarify the regional characteristics (or regional differences) in the possession of HEVs by prefecture. Hierarchy clustering using Ward's method was applied. The variables used for the cluster analysis were the percentages of price categories, body types, and drive systems of HEVs (as of March 2018). With this analysis, similar prefectures in terms of the selected variables (the percentage of each category of each variable) can be found.

Vehicle price categories were based on the base grade at the time the vehicles were first sold. The prices were classified into the following six categories: less than JPY 2 million, JPY 2–2.5 million, JPY 2.5–3 million, JPY 3–3.5 million, JPY 3.5–4 million, and JPY 4 million or higher. Body types were classified into five types: sport utility vehicle (SUV), compact, sedan, minivan, and wagon. The drive systems were classified into four types: front-wheel drive, front-wheel/four-wheel drive, four-wheel drive, and rear-wheel drive. These data were obtained from the Automobile Inspection and Registration Information Association [23].

3. Results and Discussion

This section describes the results of the fixed-effects regression analysis of factors affecting the possession of HEVs and the cluster analysis of regional differences.

3.1. Factors Affecting the Possession of HEVs

The results of the panel data regression analysis are shown in Table 3. Column 1 shows the estimation using the pooled ordinary least square (OLS); Column 2 shows the estimation with the fixed-effects model considering only the prefecture fixed effect; and Column 3 shows the estimation with the fixed-effects model considering both prefecture and year fixed effects. Column 3 presents the main results of this study. Table 4 shows the coefficients of the year fixed effect corresponding to column 3 of Table 3.

Table 3. Results of the panel data regression analysis.

	(1) Pooled OLS	(2) One-Way Fixed Effects	(3) Two-Way Fixed Effects
subsidy	0.00298	0.000601	−0.00196
	(0.00737)	(0.00405)	(0.00190)
income	4.32×10^{-7}	$1.40e\times10^{-5}$***	-1.08×10^{-6}
	($2.34e\times10^{-6}$)	(2.85×10^{-6})	(1.50×10^{-6})
saving	1.88×10^{-8}	5.72×10^{-7}***	2.27×10^{-8}
	(2.97×10^{-7})	(1.89×10^{-7})	(9.03×10^{-8})
population_per_household	−0.0342***	0.0148	0.0603***
	(0.00403)	(0.0144)	(0.00952)
vehicle_number	2.38×10^{-9}**	5.51×10^{-8}***	3.06×10^{-8}***
	(1.16×10^{-9})	(1.50×10^{-8})	(7.14×10^{-9})
vehicle_per_household	−0.00130	−0.0143	−0.174***
	(0.000876)	(0.0250)	(0.0133)
university	0.0315**	−0.170***	0.0221
	(0.0140)	(0.0214)	(0.0160)
aging	0.562***	1.158***	−0.176***
	(0.0265)	(0.0695)	(0.0525)
male	1.280***	0.328	0.636**
	(0.102)	(0.549)	(0.262)
Constant	−0.666***	−0.489*	−0.220*
	(0.0466)	(0.273)	(0.131)
R-squared	0.629	0.909	0.981
Prefecture fixed effect	No	Yes	Yes
Year fixed effect	No	No	Yes

Note: The number of observations is 517. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4. Coefficients of the year fixed effect corresponding to the two-way fixed effects.

	Coefficients (Standard Errors)		Coefficients (Standard Errors)
year2006	0.00509 (0.000935)	*year2011*	0.0315 (0.00276)
year2007	0.00831 (0.00132)	*year2012*	0.0448 (0.00313)
year2008	0.0103 (0.00171)	*year2013*	0.0598 (0.00365)
year2009	0.0135 (0.00212)	*year2014*	0.0780 (0.00413)
year2010	0.0222 (0.00246)	*year2015*	0.0938 (0.00461)

Note: Year 2005 is the base year. All coefficients were statistically significant at the 1% level.

From the result, *population_per_household* was positive and statistically significant at the 1% level. This indicates that the ownership ratio of HEVs increased with an increase in the population per household. This may be because households with more members would prefer normal-sized passenger vehicles to Kei cars (light cars, which do not have HEV options), which increased the proportion of HEVs. *vehicle_number* was also positive and statistically significant at the 1% level, indicating that the ownership ratio of HEVs increased with an increase in the number of vehicles. This can be interpreted that consumers who purchased new vehicles chose HEVs at a greater rate than those who purchased new vehicles in the past. However, *vehicle_per_household* was negative and statistically significant at the 1% level. This may be because households with multiple cars tend to buy Kei cars, which are not HEVs, as their second cars [28]. As a result, the ownership ratio of HEVs decreased with an increase in the number of vehicles per household.

The other factors, *aging* (negative) and *male* (positive), were statistically significant at the 1 and 5% levels, respectively. These results indicate that younger people and males tended to accept HEVs, as they were receptive to accepting new technology [29]. Targeting the younger generation and males is therefore reasonable to promote the diffusion of HEVs.

By contrast, economic variables, including *subsidy*, *income*, and *saving*, were not statistically significant. Regarding prefecture-level subsidy, the prefectures that introduced the subsidy and the length of time it was given were limited; the amount of the subsidy was also too small to be competitive with non-HEVs, so these did not motivate people to purchase HEVs. In terms of per capita annual income and per-household savings, the reason for their insignificance is that consumers with high income and savings may prefer to purchase high-priced luxury vehicles rather than HEVs.

Finally, the coefficients of the year fixed effect (Table 4) were positive and statistically significant at the 1% level, and they increased over time. This indicates that the trend of the ownership ratio of HEVs (Figure 1) was captured by the year fixed effect. However, the above results were obtained even after such effects were controlled by including the year fixed effect in the model.

3.2. Regional Characteristics in the Possession of HEVs

The panel data regression analysis showed that *population_per_household*, *vehicle_number*, and *male* were positive and statistically significant, whereas *vehicle_per_household* and *aging* were negative and statistically significant for the ownership ratio of HEVs. Economic variables, including *subsidy*, were not statistically significant. However, the regression analysis included only the factors influencing the diffusion of HEVs, in general, in Japan. To identify regional differences in the diffusion of HEVs, a cluster analysis was conducted for three selected variables.

3.2.1. Cluster Analysis of Vehicle Price Categories

Figure 2 shows the results of the cluster analysis for the percentage of vehicle price categories, and Figure 3 shows the weighted average of the percentage in each category by the identified cluster. Based on the cluster analysis, the prefectures were classified into three clusters: P-I, P-II, and P-III. Cluster P-I mainly included prefectures in urban areas with relatively high income levels, such as Tokyo (capital city and the most populated area), Kanagawa (the second most populated prefecture), Osaka (the third most populated prefecture), and Aichi (the fourth most populated prefecture). As shown in Figure 3, the proportion of HEVs in the cheapest category was lower in this cluster than in the other clusters, whereas the cluster held more expensive vehicles than in the others. For example, the proportion of HEVs over JPY 4 million was more than two percentage points higher in Cluster P-I (7.9%) than in the others (5.3–5.6%). In particular, the proportion of HEVs in the most expensive categories for Tokyo (13.5%; Tokyo belonged to Cluster P-I but was further away from the other prefectures in the cluster) was about 2.5 times the averages of Clusters P-II and P-III and twice the average of Cluster P-I. This means that prefectures with higher incomes tended to possess more expensive HEVs.

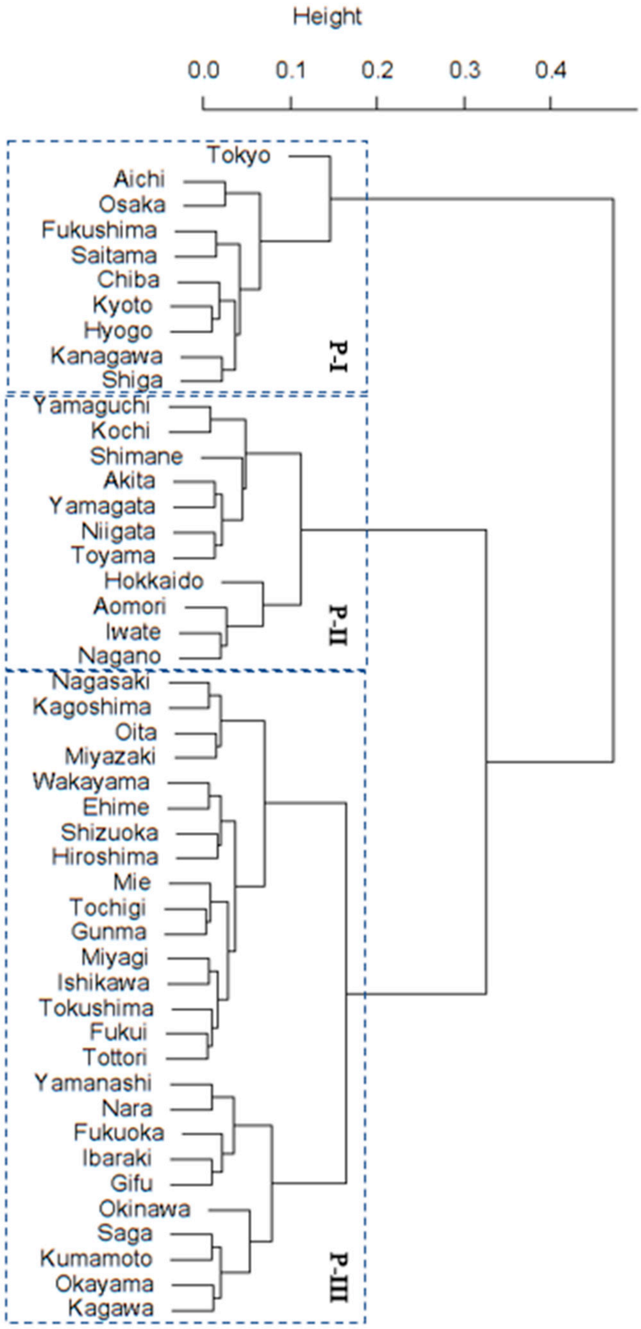

Figure 2. A dendrogram for the vehicle price categories. See Figure A1a for the mapping of the cluster analysis results.

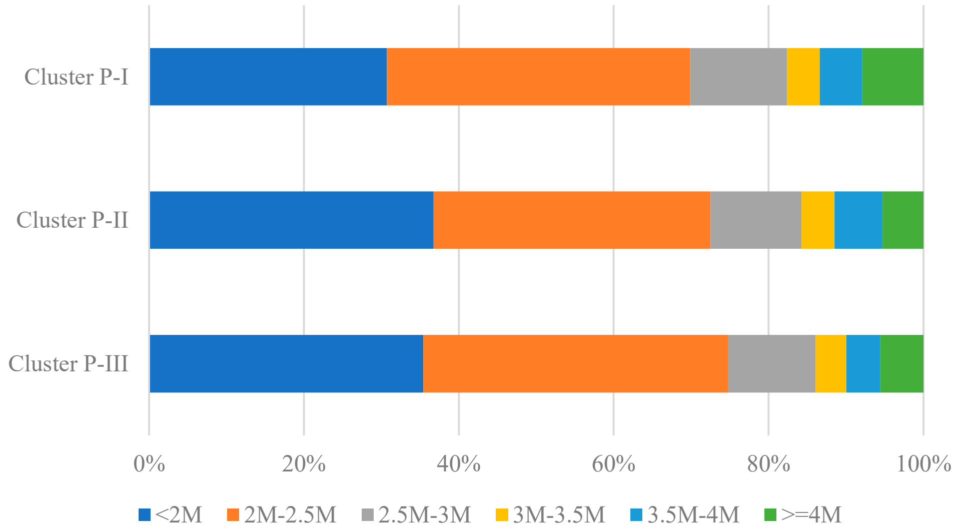

Figure 3. Percentages of HEVs by vehicle price category (in JPY) for each cluster.

Clusters P-II and P-III were relatively similar in that the proportion of cheaper vehicles was equally high in both clusters compared with Cluster P-I. The prefectures in Cluster P-III had more HEVs in the second cheapest category than those in Cluster P-II.

3.2.2. Cluster Analysis of Body Types

Figure 4 shows the results of the cluster analysis for the percentage of vehicles' body types, and Figure 5 depicts the weighted average of the percentage in each category by the identified cluster. Based on this cluster analysis, the prefectures were classified into three clusters: T-I, T-II, and T-III. The proportions of SUV- and wagon-type vehicles were similar for all three clusters; major differences were observed in the other body types of vehicles. For Clusters T-I and T-III, the percentages of the compact type were higher, whereas its percentages of the minivan type were lower than those for Cluster T-II. Comparing Clusters T-I and T-III, a large difference in sedan type, which occupies the highest percentage in every cluster, was observed; the proportion was higher for Cluster T-III than for Cluster T-I.

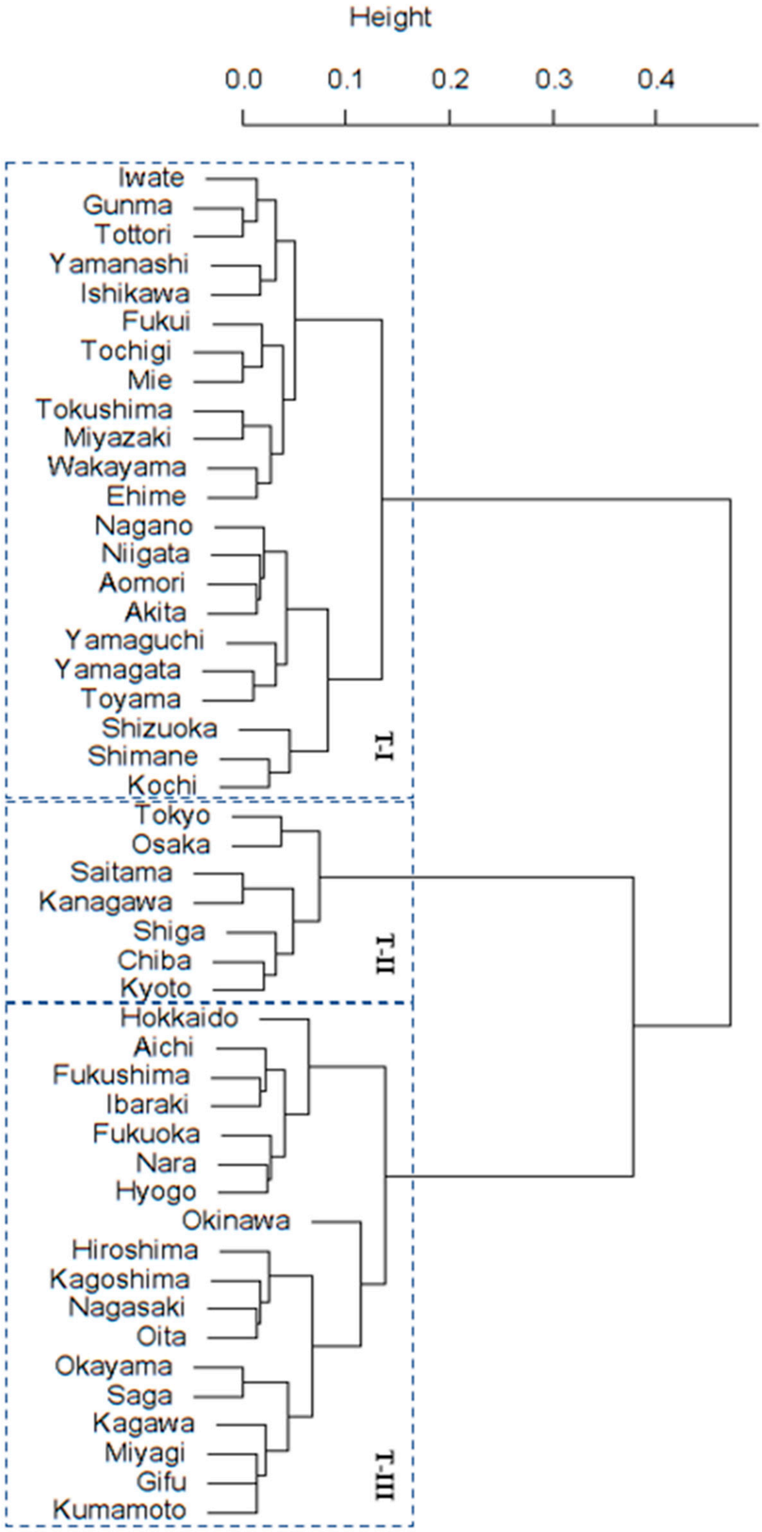

Figure 4. A dendrogram for vehicle body type. See Figure A1b for the mapping of the cluster analysis results.

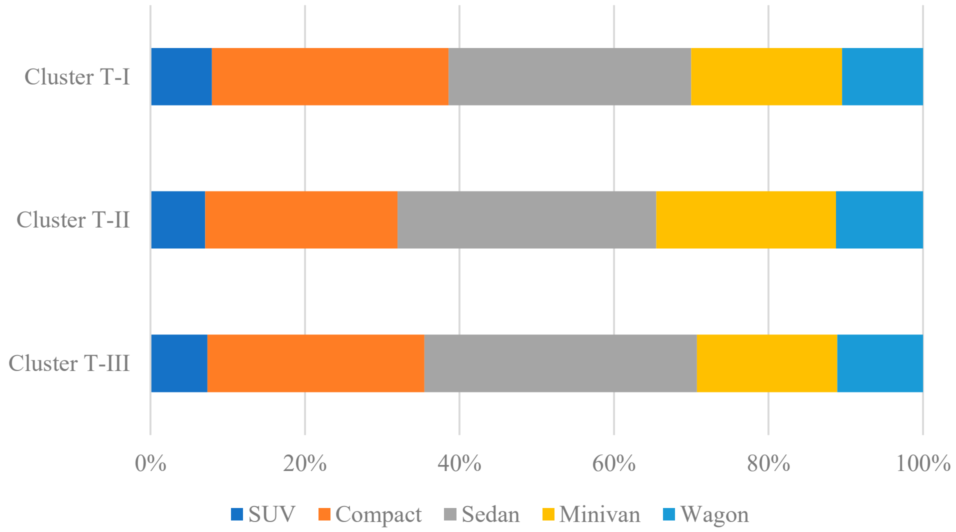

Figure 5. Percentages of HEVs by vehicle body type for each cluster.

As for Cluster T-II, as mentioned above, the percentage of the minivan type is higher, whereas that of the compact type is lower than that of the other clusters. This cluster includes prefectures in urban areas with relatively high income levels similar to Cluster P-I in section 3.2.1. Therefore, large vehicles, which are usually more expensive, are more popular in these areas.

From the analyses in section 3.2.1 and in this section, prefectures in urban areas tended to possess expensive and large-sized vehicles, probably because of their high income levels. In other prefectures, cheaper and smaller vehicles are preferred. One reason is that the income levels in these prefectures are relatively lower than those in urban areas. In addition, public transportation is less developed in such regions, so households tend to have two or more vehicles, and they possess cheaper and smaller vehicles for their second car [28]. Therefore, a strategy to sell cheaper and smaller HEVs will help promote the diffusion of HEVs in less urban areas.

3.2.3. Cluster Analysis for Drive Systems

Lastly, Figure 6 shows the result of the cluster analysis for the proportion of vehicle drive systems, and Figure 7 depicts the weighted average of the percentage in each category by the identified cluster. As shown in Figure 7, most HEVs purchased were front-wheel or four-wheel drive systems.

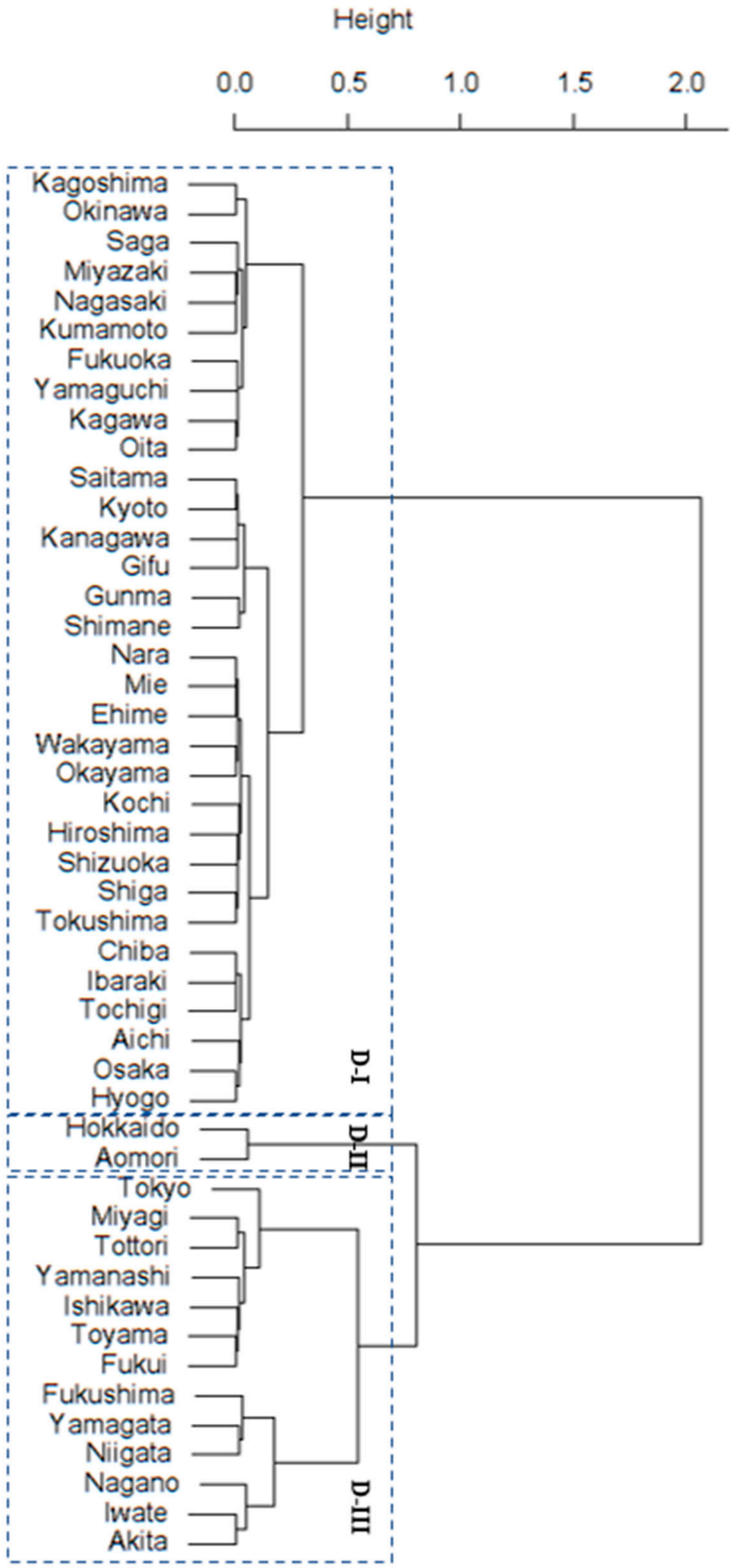

Figure 6. A dendrogram for the drive systems. See Figure A1c for the mapping of the cluster analysis results.

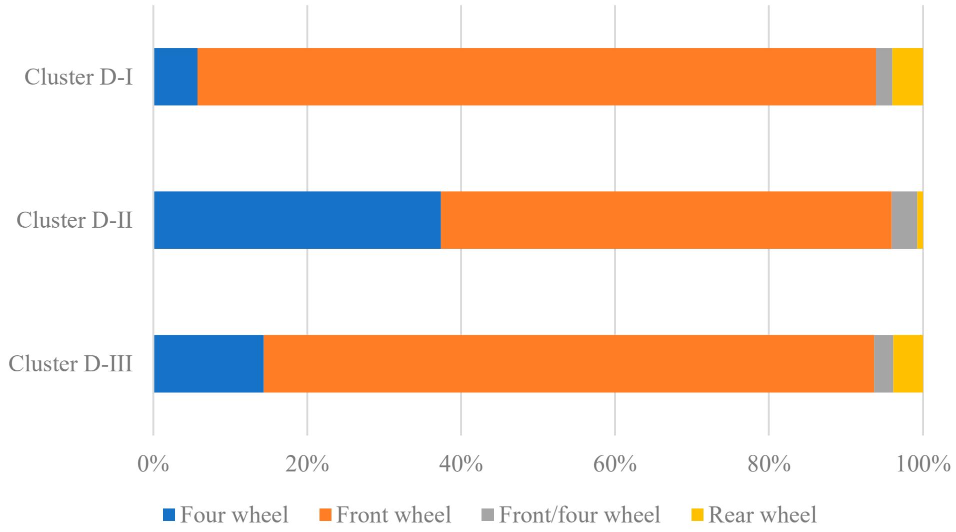

Figure 7. Percentages of HEVs by drive system for each cluster. Note that front-/four-wheel is a classification that could not distinguish between the front-wheel and four-wheel drive vehicle types.

Based on the cluster analysis, the prefectures were classified into three clusters: D-I, D-II, and D-III. The most interesting characteristic of the distribution was that the percentage of four-wheel drive vehicles was much higher for Cluster D-II (37.4%) than for the other clusters (5.7–14.3%). This cluster included Hokkaido and Aomori, which are located in the northern part of Japan (Hokkaido is the northernmost region). These areas are snowy, and the road surface is frozen in winter, so a stable four-wheel drive system is preferred. Furthermore, most of the prefectures included in Cluster D-III are located in the northern part of Japan, so the percentage of the four-wheel drive system was higher for Cluster D-III than for the prefectures in Cluster D-I.

From the cluster analysis described in sections 3.2.1–3.2.3, it was found that there were apparent regional characteristics in the distribution of HEVs. Thus, spreading the same types of HEVs uniformly throughout the country is not appropriate. Considering regional differences will help further promote the diffusion of HEVs.

4. Conclusions

The Intergovernmental Panel on Climate Change highlighted the necessity for GHG emission reduction, particularly in the energy and transport sectors [30]. Considering the contribution of the transportation sector to fossil fuel consumption and CO_2 emissions and the resulting climate change, understanding how AFVs can be diffused and developing technology for energy-sustainable transportation are urgent. This study evaluated the factors affecting the ownership ratio of HEVs (the high diffusion among AFVs) using a fixed-effects regression model, as well as the regional differences in the purchase of HEVs using cluster analysis. The main findings of this study can be summarized as follows. The regression analysis showed that demographic and social factors, such as population per household, population aging, and gender, affected the ownership ratio of these vehicles, but economic factors, such as prefecture-level subsidies for purchasing HEVs, income, and savings, had no effects. From the regional differences, the findings indicate that prefectures in urban areas tended to purchase more expensive and large-sized HEVs, whereas other areas preferred smaller and cheaper vehicles. Northern regions preferred four-wheel vehicles because of their meteorological conditions. These results suggest that economic incentives or subsidies were generally not effective in promoting HEVs, but considering regional differences is essential for the diffusion of HEVs. This means that a strategy to sell the right vehicle to the right person or region (e.g., targeting younger people/males, in general, and selling expensive/larger HEVs in urban areas and cheaper/smaller HEVs in less urban areas) is important to further promote HEVs in Japan.

To further reduce CO_2 emissions and combat climate change in the transportation sector, it is essential to promote BEVs and fuel cell vehicles. Future studies need to evaluate relevant factors and regional differences in order to promote the diffusion of more environmentally friendly vehicles.

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Data Availability Statement: Data is available upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Figure A1 depicts the results of the cluster analysis on the maps. The figure is created based on the information in Figures 2, 4, and 6.

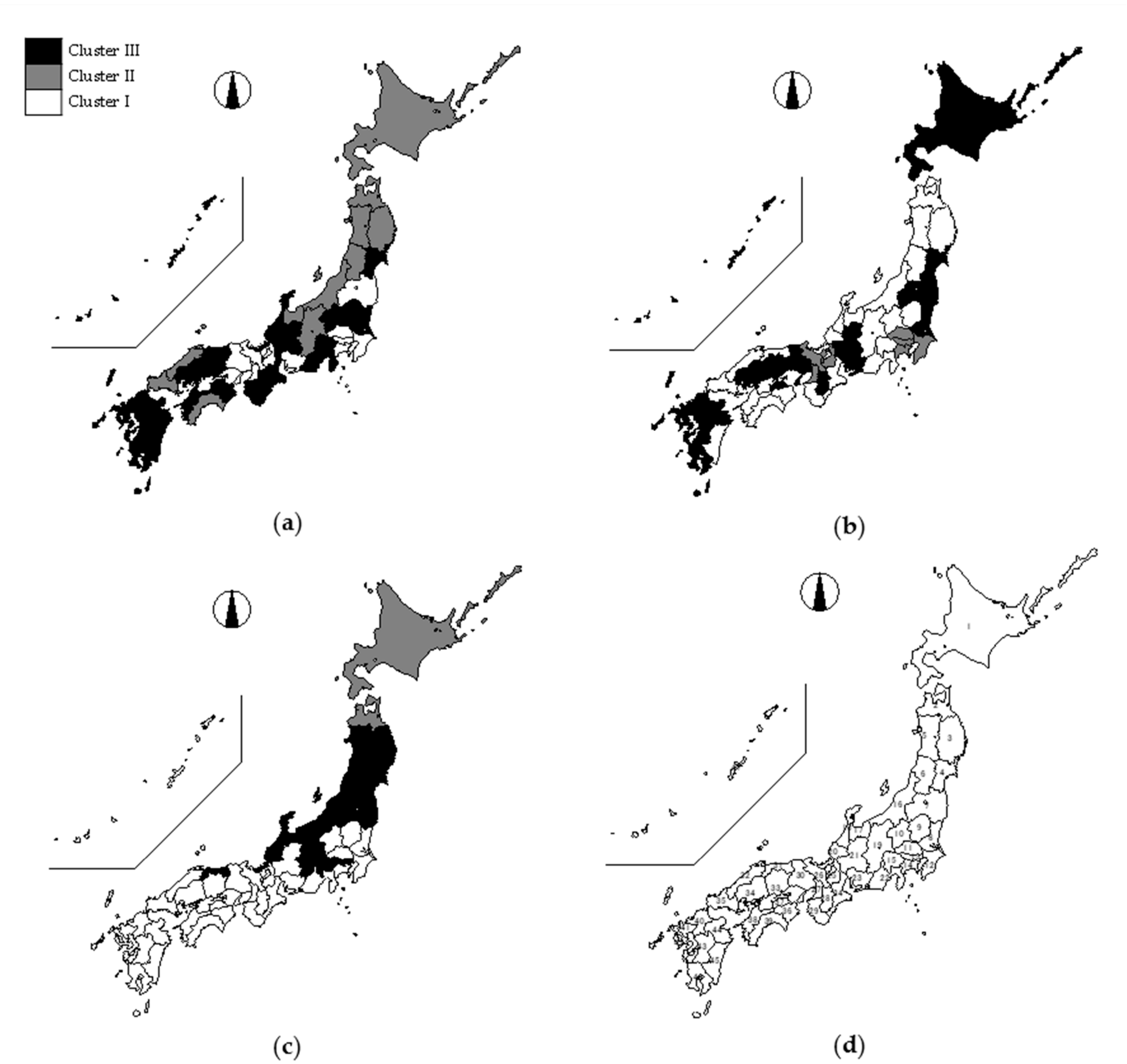

Figure A1. Maps of the results of the cluster analysis: (**a**) price category, (**b**) body type, and (**c**) drive system. (**d**) shows the name of the prefectures (1: Hokkaido, 2: Aomori, 3: Iwate, 4: Miyagi, 5: Akita, 6: Yamagata, 7: Fukushima, 8: Ibaraki, 9: Tochigi, 10: Gunma, 11: Saitama, 12: Chiba, 13: Tokyo, 14: Kanagawa, 15: Yamanashi, 16: Niigata, 17: Toyama, 18: Ishikawa, 19: Nagano, 20: Fukui, 21: Gifu, 22: Shizuoka, 23: Aichi, 24: Mie, 25: Shiga, 26: Kyoto, 27: Osaka, 28: Nara, 29: Wakayama, 30: Hyogo, 31: Tottori, 32: Shimane, 33: Okayama, 34: Hiroshima, 35: Yamaguchi, 36: Tokushima, 37: Kagawa, 38: Ehime, 39: Kochi, 40: Fukuoka, 41: Saga, 42: Nagasaki, 43: Kumamoto, 44: Oita, 45: Miyazaki, 46: Kagoshima, and 47: Okinawa).

Nomenclature

Abbreviation

AFV	Alternative fuel vehicle
BEV	Battery electric vehicle
CO_2	Carbon dioxide
EV	Electric vehicle
HEV	Hybrid electric vehicle
OLS	Ordinary least square
PHEV	Plug-in hybrid electric vehicle
SUV	Sport utility vehicle

Variable

aging	Ratio of elderly people (over 65 years old)
hybrid_ratio	Ownership ratio of HEVs (passenger vehicles)
income	Annual income per capita
male	Ratio of males
population_per_household	Number of people per household
saving	Savings per household
subsidy	Prefecture-level subsidy for purchasing HEVs
university	Ratio of university entrance
vehicle_number	Number of passenger vehicles
vehicle_per_household	Number of passenger vehicles per household
C	Constant
$\mathbf{X}$	Vector of independent variables
$\boldsymbol{\beta}$	Vector of coefficients
α	Prefecture fixed effect
δ	Year fixed effect
ε	Error term
i	Prefecture
t	Year

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