SIMULATION OF THE DIFFUSION OF ALTERNATIVE FUEL VEHICLES CONSIDERING THE POSSESSION OF INFORMATION

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Overview

The widespread use of alternative fuel vehicles (AFVs), such as electric vehicles (EVs) and fuel cell vehicles (FCVs), is considered to be a driving force for the transition to a decarbonized society. Tanaka et al. (2014) conducted a comparative discrete choice analysis to estimate consumers' willingness to pay for EVs and plug-in hybrid electric vehicles (PHEVs) based on the same stated preference survey conducted in the US and Japan. Khan et al. (2020) modeled consumers' preferences for FCVs by conducting a stated preference discrete choice experiment on a dataset collected from a sample of individuals in Japan. Sen et al. (2017) developed an agent-based simulation model to estimate the potential future market shares of EVs under different policy scenarios, including the Corporate Average Fuel Economy (CAFE) standards in the United States.

In this study, we adopted a multi-agent simulation to evaluate the social acceptability of innovative technologies and analyze the diffusion process of AFVs. The degree of preference for innovative technologies among individual consumers is expected to influence the purchase decision for AFVs, which are advanced products. Simultaneously, individuals' degree of awareness of environmental and energy-related information is also expected to influence the purchase decision because AFVs are highly environmentally friendly. Therefore, we conducted social surveys and experiments to clarify the relationship between individuals' possession of such information and their preference for purchasing alternative vehicles. By clarifying this relationship, we developed a consumer agent model that considers the degree of awareness of information about the environment and energy. We used the model to develop a multi-agent simulator that can quantitatively and dynamically analyze the effects of the information content provided to consumers and its propagation and recognition processes on the diffusion of AFVs.

Methods

To construct a preference model of consumers' car purchasing behavior, we conducted a discrete choice experiment on the Internet. We then performed conjoint analysis on the obtained results using a mixed logit model and calculated the utility values of consumers for each attribute of the AFVs. In the experiment, we presented participants with the values of each attribute for each option (vehicle type) and asked them to choose the most desirable option. We used five types of vehicles in the experiment, FCV, EV, PHEV, gasoline vehicle (GV), and non-purchase, and five vehicle attributes, vehicle price, fuel cost reduction, driving range, greenhouse gas (GHG) emission reduction, and percentage of refueling stations installed. When conducting the choice-type experiment, we divided the subjects into two groups: a treatment group to which we gave information on the environment and energy in advance and a control group to which we did not. The information included information on disasters caused by global warming, the Paris Agreement, domestic goals for a carbon-neutral and decarbonized society, and carbon dioxide emission reductions. We compared the calculated utility values between the two groups.

The simulation in this study consisted of three types of agents: consumers, automobile manufacturers, and refueling stations. We further classified consumer agents into two types based on their possession of environmental and energy information. A relational network exists among consumer agents and acts as a channel for information propagation, allowing them to exchange information on the environment and energy, as well as on car models owned by other consumer agents in the vicinity. Then, we considered that consumer agents' preferences change owing to the recognition of environmental and energy information in the network. Each consumer agent calculates the utility value of each car model based on their preferences, vehicle attribute values, and car models owned by other consumer agents in the vicinity at regular intervals. They then probabilistically select a new car model for purchase according to the magnitude of the value.

Results

We conducted Internet social surveys and experiments in 2021, including 1,720 men and women in their 20s to 60s throughout Japan. The sample size of the treatment and control groups was 860 participants each. Table 1 presents the marginal utility values calculated for each vehicle attribute. The values are negative for vehicle price, indicating that utility decreases as vehicle price increases. On the contrary, they are positive for other vehicle attributes, indicating that utility increases as the level of each attribute increases. We compared the results of the control and treatment groups and found that the marginal utility values for driving performance, such as fuel cost reduction and the ratio of refueling stations, decreased in the treatment group, while those for GHG emission reduction and environmental performance increased. These differences in marginal utility values were due to the provision of environmental and energy information.

Table 1: Marginal utility values for each vehicle attribute

	Control group	Treatment group
Vehicle price (¥10,000)	-0.01337	-0.01506
Fuel cost reduction (%)	0.00527	0.00222
Driving range (km)	0.00098	0.00095
Greenhouse gas emission reduction (%)	0.00672	0.00792
Ratio of refueling stations (%)	0.00977	0.00865

Based on the consumer preference model obtained from the above analysis, we conducted a multi-agent simulation of the diffusion process of AFVs. In this calculation, we also considered future changes in fuel prices and vehicle attribute values of each vehicle type as input data that have a significant impact on the diffusion process, i.e., evaluation scenarios, in addition to the preference model. As an example of numerical experiments, we performed two simple calculations and compared them under a certain scenario to observe the impact of environmental and energy information possession on the diffusion process. In the first calculation, the consumer agents have a preference model for the control group. In the second calculation, they have a preference model of the treatment group. To clearly observe the effect of information, we assumed that all consumer agents initially owned gasoline cars. Figure 1 shows the time series of the market share of each car model in both cases, and Figure 2 shows the market share of each car model at the end of 120 months. Under this scenario, there was no significant difference in the qualitative market share trends. However, when all consumer agents possessed environmental and energy information (treatment group), the market shares of gasoline and electric vehicles reached a reversal at the 120-month mark, and we observed the effect of information awareness in promoting the diffusion of AFVs.

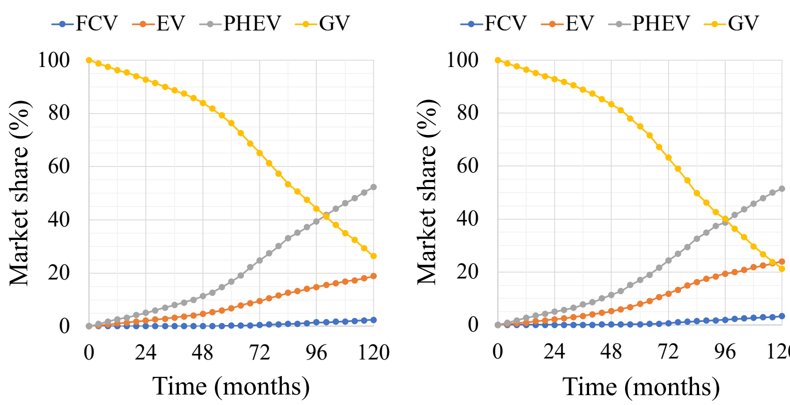

Figure 1: Time series of the market share of each car model (Left: control group, Right: treatment group)

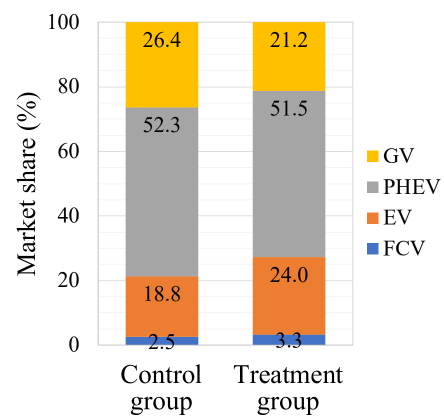

Figure 2: Market share of each car model at the end of 120 months

Conclusions

In this study, we analyzed the relationship between the possession of environment and energy information and preferences for purchasing automobiles through social surveys and experiments. The results showed that the utility values for driving performance, such as fuel cost reduction, decreased in the treatment group. In contrast, the utility values for environmental performance, i.e., GHG emissions reduction, increased in the control group. Based on the consumer preference model obtained from the analysis, we constructed an agent-based simulation model of the diffusion process of AFVs. We could quantitatively and dynamically observe the effect of information awareness on the diffusion of AFVs through simulation experiments. Future work will include a detailed sensitivity evaluation of diffusion to the technological improvement of vehicle attributes and information recognition rate. It should also incorporate policy effects for a comparison of the diffusion process by policy scenario.

References

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