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Using a discrete choice experiment to predict the penetration possibility of environmentally friendly vehicles

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ABSTRACT

Amid the expansion of environmentally friendly vehicles as a strategy to cope with climate change and avoid fine particles, South Korea has set a penetration goal and implemented a support policy. The present study uses a discrete choice experiment and a mixed logit model to analyze consumer preferences for vehicles and predict the dynamic market share of environmentally friendly vehicles. The estimated results show that under given conditions, it is implausible to meet the target for the penetration of eco-vehicles (6.13% for electric vehicles and 2.6% for hydrogen fuel cell vehicles by 2025). The scenario analysis suggests that it is possible to meet the penetration target if a subsidy is provided for eco-vehicles to the extent that the price drops to the level of gasoline vehicles and the number of charging stations is increased more than threefold compared to the target. However, the study found that stronger support is required to accomplish the penetration target for hydrogen fuel cell vehicles.

1. Introduction

Petroleum-based substances such as gasoline and diesel, which are automotive fuels, produce toxic substances during combustion. Carbon dioxide and others—carbon monoxide, hydrocarbon, nitrogen oxide and, in the case of diesel engine, exhaust gas—are emitted by cars. These pollutants cause global warming and are also culprits of air pollution. According to World Health Organization [1], a total of 8.2 million deaths, 16% of global deaths, were attributed to air pollution in 2012.

Under these circumstances, the automotive industry is developing eco-friendly cars as next-generation models, moving away from the existing petroleum-powered cars. This is because regulations on automobile emissions have been under constant discussion since the 1990s, and the use of fossil fuels as a power source is increasingly difficult. Since the discovery that nitrogen oxide emissions of “eco-friendly diesel” cars, which were considered low emitters, had been rigged and far exceeded the legal limits, the technological development of eco-vehicles has gained momentum.

Electric vehicles (EV) and hydrogen fuel cell vehicles (HFCV) are representative green cars. An EV, a zero-emission car, produces driving force from electric energy that passes from the battery to the engine without burning any fossil fuels. Compared to internal combustion engines, EVs use electric motors and batteries, not engines, for power and produce no exhaust and greenhouse gases. When the Smart Grid is built, consumers will be able to buy and sell electricity through EVs. However, EVs have a shortcoming; they take a long time to charge. On the other hand, HFCVs use hydrogen to make electricity. When hydrogen is supplied to the fuel cell, electrons generated in the process of separating electrons and hydrogen ions are used as electric energy. Hydrogen ions separated from hydrogen react with oxygen in the air and are supplied to the fuel cell to generate water, and the generated water is discharged to the atmosphere.

It remains to be seen which vehicle will dominate the green car market. One of the more active research areas investigates whether EVs or hydrogen vehicles are preferable in terms of energy use and greenhouse gas emissions as eco-friendly vehicles [2]. In the case of EVs, compared to HFCVs, the charging infrastructure is relatively well established, and the expandability of infrastructure is greater because the cost of installing charging stations is cheaper. Another advantage of EVs is that they are relatively cheap. Therefore, these

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are considered an attractive alternative to consumers in the higher end car market [3]. On the other hand, HFCVs are quicker to charge and produce no byproducts other than water. Therefore, they are considered the true green vehicle.

As EVs and HFCVs each possess different characteristics, the vehicle that will dominate the automotive market is still unknown. In Sweden and elsewhere, early adopters, mainly men and middle-class, highly educated people, started using EVs, but HFCVs have not yet been used [4]. However, because of the advantages of the latter, many countries worldwide are implementing policies to promote both types of vehicle rather than choosing just one, and automakers are developing technologies for both. South Korea is also designing a roadmap for EV and HFCV penetration and is attempting to expand the use of green cars by providing subsidies and installing infrastructure. South Korea's targets for market share of new EV and HFCV car sales are 6.13% and 2.6%, respectively, by 2025. Accordingly, the present study analyzes consumer preferences for environmentally friendly vehicles—EV and HFCV—using a discrete choice experiment and, based on consumer preferences, attempts to predict the penetration possibility of EV and HFCV in Korea's market. The study offers marginal contributions in two aspects. First, while previous studies described in the next section only focused on consumer preference analysis of eco-vehicle attributes, this study estimates market share by considering the competitive relationship between conventional vehicles (gasoline vehicles (GV), diesel vehicles (DV), and eco-friendly vehicles (EV, HFCV)). Second, the study attempts to conduct dynamic forecasting using static survey results and a dynamic technology roadmap. In short, the study analyzes the feasibility of the Korean government's penetration goal for environmentally friendly vehicles by 2025 and suggests implications to achieving that goal. As cars are used for a long time—a durable good—consumer preferences are not promptly reflected in the market. Thus, purchase prediction using stated preferences will be an effective indicator for anticipating the future of the automotive industry.

Previous studies on consumer preferences for green cars or alternative fuel cars have mostly conducted a discrete choice experiment based on stated preferences. Because there are few cases where a consumer buys a green car, there is a limitation to an analysis based on revealed preferences. The relatively recent studies on green car preferences using a discrete choice experiment are as follows.

Hackbarth and Madlener [5] analyzed Germans' potential demand for alternative fuel cars using a discrete choice experiment and a mixed logit model. The discrete choice experiment was composed of seven car types (gasoline/diesel, natural gas, hybrid, biofuel, plug-in hybrid, electric, hydrogen) and eight attributes (purchasing price, fuel cost, driving range, fuel availability, CO2 emissions, fuel refilling times, battery charging times, government subsidy), and an online survey was conducted among 711 Germans in 2011. It was found that all alternative cars were less preferable than diesel/gasoline cars, and preference for conventional fuel cars was strongest although simulations under various conditions—lower prices and improvements in driving range and charging times—were conducted, indicating high consumer resistance toward green cars.

Hong et al. [6] considered that the diffusion of EVs as an alternative fuel car was limited because of the lack of infrastructure and high costs. The authors tried to assess the penetration possibility of EV if those issues were resolved by conducting a discrete choice experiment on the purchase of EVs with 250 car owners. The estimated results showed that the preference for EV was not significant, and the provision of a temporary subsidy was found to be an effective measure to raise the probability of EV selection.

Achtnicht et al. [7] conducted a discrete choice experiment to analyze the effect of fuel availability on vehicle choice. A survey consisting of six attributes (fuel type, car purchasing price, engine horsepower, fuel cost, CO2 emissions, fuel availability) was conducted among 598 consumers who owned various types of cars and was analyzed using a logit model. The estimated results showed that when fuel availability is high, the utility increases but the marginal utility diminishes because the squared term has a negative value. When the network of charging stations for alternative cars was 10% of gas stations, the market share of green cars was found to be 11.3%, and when the network was 33% and 100%, the market shares reached 17.4% and 33%, respectively.

Eggers and Eggers [8] estimated preferences using a discrete choice model and monitored purchasing behaviors over time to predict the market acceptance of EV. As the attributes of the discrete choice experiment, vehicle types, driving range, and cost were compared to gasoline, and a hierarchical Bayesian logit model was used. The estimated market share of EVs was found to be sensitive to price and not sensitive to driving range when a certain amount of driving range is guaranteed, but the market share was predicted to be low when the driving range is lower than a certain amount (150 km).

Qian and Soopramanien [9] analyzed Chinese consumers' preferences for vehicle types using a multinomial logit model and nested logit model. The results of an online survey among 527 people suggested that Chinese consumers preferred hybrid vehicles over EVs. In addition, as the price and cost were lower and the number of charging facilities and the driving range were higher, the preference was stronger, and policy measures had no significant effect.

Hoen and Koeste [10] used a discrete choice experiment and a mixed logit model to analyze Dutch car owners' preferences for green cars. Vehicle type, purchasing price, maintenance cost, driving range, charging times, detour times for charging, the number of available models according to fuel type, and promotion policy alternatives were chosen as the attributes for the discrete choice experiment. The analysis results found that preference for green cars was weak due to limited driving range and charging times. The preference for alternative fuel cars increased significantly when driving range, charging times, and fuel availability increased. Moreover, in a later study targeting business car owners, the direction of preference was almost identical, but willingness to pay differed significantly according to the amount of money individuals pay [11].

Table 1 summarizes the attribute classifications used in previous studies on environmentally friendly vehicles using discrete choice experiments. Fuel type, purchasing price, and fuel cost were used in all studies and driving range, fuel availability, CO2 emissions, and charging times were considered major factors.

Previous studies on green cars focused on the diffusion possibility of EVs or analyzed consumer preferences for various types of vehicles such as hybrid and biofuel cars. However, the future of green motoring is anticipated to be EV or HFCV technology and, accordingly, countries across the globe including South Korea are building infrastructure and attempting to build policy support in preparation for the widespread adoption of EV and HFCV. Thus, the present study predicts the market shares of EV and HFCV vehicles based on consumer preferences by considering the competitive relationship between GV and DV. Thus, consumer preferences for green car attributes are analyzed using a discrete choice experiment, and the trends of dynamic choice probabilities are drawn by applying a car attribute roadmap. The employed method in this study predicts market shares by analyzing choice probabilities in widely used choice experiments [12].