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Analysis of product efficiency of hybrid vehicles and promotion policies ☆

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ABSTRACT

The key aim of this study is to evaluate the product efficiency of current hybrid vehicles and suggest effective policies to promote hybrid vehicles in the Korean automobile market and development trends of hybrid vehicles. The efficiency levels for car models sold in Korea, including hybrid ones, were measured using the recently developed discrete additive data envelopment analysis (DEA) model that reflects consumer preference. The result of the analysis shows that current hybrid vehicles on the market are still at lower competitive advantage than traditional car models with conventional combustion engines and we can suggest a mix of incentive policies to promote the competitiveness of hybrid vehicles. In addition, we also identify two distinctive trends of hybrid vehicle development: environment-oriented hybrid vehicles and performance-oriented hybrid vehicles. It implies that the government should take account of development trends of hybrid vehicles to achieve the policy goals in designing support schemes and automobile companies that are willing to develop hybrid vehicles can also gain some insights for making strategic decisions.

1. Introduction

Environmental issues have attracted the attention of the automobile industry, as public concern has been growing over high energy prices and global warming. Moreover, developing environment-friendly and energy-saving cars has become indispensable for automobile manufacturers that wish to survive in the increasingly competitive market. In this context, highly advanced technologies are applied to achieve greater fuel efficiency.

Hybrid vehicles, which utilize a combination of a combustion engine and an electrical motor, have become possible with modern advances in technology. A battery charged in regenerative braking mode provides power to the electrical motor to assist the engine through various driving conditions; this mechanism greatly reduces on fuel consumption. In general, it is said that fuel efficiency of the hybrid vehicle is as much as up to twice that of traditional cars with combustion engines (US Department of Energy, 2007; The Times, 2009).

Even with this higher fuel efficiency, hybrid vehicles are still less attractive than gasoline or diesel-driven vehicles because of their higher costs (US Department of Energy, 2007). Under these circumstances, various hybrid vehicle-promotion policies, such as tax or monetary incentives, could be effective in reducing exhaust gas and the total consumption of energy (Nakata, 2000; Diamond, 2008). However, the questions as to which forms of supporting policies are the most effective and how much government supports should be applied are still debatable.

The key aim of this study is to evaluate the product efficiency of current hybrid vehicles and present an effective mix of policies to promote hybrid vehicles in the Korean automobile market. Analysis of the product efficiency advances the understanding of the development trends in hybrid vehicles to a deeper level as well.

In this study, we utilize the novel data envelopment analysis (DEA) model developed in Oh et al. (2009) to estimate the product efficiencies of car models sold in Korea as well as of hybrid vehicles that have not yet emerged on the Korean market. The model in Oh et al. (2009) has the advantage of being able to reflect consumer preference in measuring car efficiencies.

We can expect two outcomes as a result of the analysis. First, we can examine the relative competitiveness of hybrid vehicles when compared with traditional ones. This information can aid policy makers in designing measures that will stimulate the distribution of hybrid vehicles into the market. They can recognize which levels of attributes fulfill the satisfaction of consumers to determine the most apt policy instruments to benefit consumers and meet larger policy objectives. Second, we can investigate the trends in the development of hybrid vehicles and draw important strategic conclusions. This is expected to provide pertinent insight to automobile companies; particularly

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those in places like Korea, whose technology for environment-friendly vehicles, including hybrids, is currently far behind leading global companies.

In the following section, we briefly describe the current status of hybrid vehicles. We then argue for the need to consider product efficiency from a consumer's perspective in contrast to the view from the production side, and explain how to measure production efficiency in the methodology section. In the next two sections, we present the data and variables, and the empirical results, respectively. Finally, we suggest policy implications based on the empirical results; and thereafter, summarize our model and results in the last section.

2. Current status of hybrid vehicles

The hybrid vehicle market has been experiencing a surge of growth. Sales have significantly increased from around 9000 vehicles in 2000 to 312,000 vehicles in 2008, and the lineup of publicly available models has also expanded from two in 2000 to 16 in 2008 in the US market, according to the US Department of Energy database.[1] However, sales of hybrid vehicles still greatly depend on economic conditions and the price of oil. For example, the economic recession and lower oil prices in late 2008 negatively impacted the sales of hybrid vehicles. Hybrid sales in November 2008 experienced a sharp decline to 53% of the previous year sales, compared with a 37% decline from the previous calendar year for overall automobile sales (Financial Times, 2009). The hybrid vehicle market, thus, took a larger hit from economic fluctuations than that of its traditional counterparts.

These statistics imply that hybrid vehicles still have barriers to overcome. Many scholars have proposed solutions to deal with these barriers. Kazimi (1997) utilized a dynamic micro-simulation model to examine total emissions when alternative vehicles were introduced. This showed that reducing prices for alternative vehicles was effective in reducing emissions. Nakata (2000) and Diamond (2008) investigated hybrid vehicles in the market. Nakata (2000) showed that hybrid vehicles had a significant impact on reducing the consumption of fossil fuels and carbon dioxide emissions, and taxes on fossil fuels could be used to raise the market share of hybrid vehicles. Diamond (2008) also explained several factors that could influence the adoption of hybrid vehicle in large, including gasoline prices and government incentives. However, little is known about the effectiveness of policies and the development trends of hybrid vehicles.

The US market has indicated that there are barriers preventing the mass distribution of hybrid vehicles; and so, the US government has tried to diminish the distinct gap between traditional and hybrid vehicles through a variety of policies implemented to stimulate the hybrid vehicle market. These efforts may result in positive growth for hybrid vehicles in the US market.

Unfortunately, the Korean market is far behind the US market. The Hyundai and Kia automobile groups, which have dominated the domestic market, had not yet succeeded in commercializing hybrid vehicles and few hybrid models were being imported as of 2006; as a result, the volume of hybrid vehicle sales was quite low. The number of new registrations for hybrid vehicles in 2008 was 637 vehicles in Korea, according to the Korea Automobile Importers and Distributors Association. It represented a small portion of the total Korean auto market, in which around 1.2 million new cars were registered in 2008, according to the Korea Automobile Manufacturers Association.

[1] www.afdc.energy.gov/afdc/data/.

The Hyundai automobile company recently launched its first domestic hybrid model in July 2009 in Korea. The model is a liquefied petroleum gas (LPG)-electric hybrid car which has merit in low operation cost. However, as of yet, the LPG-electric hybrid car is not very commonly seen in the market.

3. Methodology

To evaluate vehicle efficiencies and the effect of promotion policies, we utilized the DEA model (Charnes et al., 1978, 1979, 1981; Banker et al., 1984). The DEA is a non-parametric methodology, primarily used to estimate the efficiency of production units under study, based on multi-input and multi-output information. Using linear programming to determine the best practice frontier, the DEA calculates efficiencies as a distance or ratio between units and best practice frontier in the input–output space. However, though DEA is generally used to evaluate production units, it can also be applied to measure efficiencies of consumption when we recognize *consumption* as a household production, following Lancaster (1966). Then, the money paid to buy a product is taken as an input factor and the set of characteristics of the purchased product brought about can be considered as output factors. Similarly, the efficiencies of car models can be calculated using the DEA, regarding the money used to buy a car as an input and the various quality attributes of the car models—e.g., price, fuel efficiency, and horsepower (Hp)—as outputs (Doyle and Green, 1991; Papahristodoulou, 1997; Fernandez-Castro and Smith, 2002; Lee et al., 2005).

However, from the perspective of the consumer, not only the level of each quality attribute of a product, but also the level of utility brought about by each quality attribute is important. In this regard, Oh et al. (2009) recently developed a model which can take account of consumer preference on each quality attribute. The model depicted in Oh et al. (2009) is mimicking the methodology used to measure the allocative and overall efficiencies of production units using the DEA. Following the methodologies adopted to find the cost-minimizing best practice production unit through considering the cost of input factors in analyzing the allocative and overall efficiencies of production units (Cooper et al., 2000), the model finds the utility-maximizing best practice product through considering the level of utility brought by each quality attribute of a product. The following sections explain the methodology used in this research, in greater detail.

3.1. Data envelopment analysis

The DEA model construed how efficiently producers make their products during the manufacturing process. In the presence of cost information about multi-inputs, Cooper et al. (2000) elaborated the concept of technical efficiency, allocative efficiency, and overall efficiency on the production side. The term defined as *technical efficiency* is utilized commonly in the literature to describe the performance level of a production unit with regard to its utilization of input resources in generating a given set of outputs. Koopmans (1951) defined *technical efficiency* as a state in which it is technically impossible to increase outputs without simultaneously reducing another output or increasing inputs. Farrel (1957) showed that the *overall efficiency* of a production unit consists of two separate efficiency measures, referred to as *technical efficiency* and *allocative efficiency*. He also proposed a method by which technical efficiency could be measured as the maximum equi-proportional reduction in all inputs consistent with the equivalent production of observed output. Allocative efficiency measures the degree to which the