Exploring the Adoption of Hybrid Electric Vehicles in Taiwan: An Environmental Benefits Perspective

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ABSTRACT

In 2010, there were about 1.02 billion vehicles worldwide, and we can expect this number to reach 1.7 billion by 2035 (IEA, 2011). The Bureau of Energy (2013) pointed out that 17.6% of the total energy in Taiwan is mostly (94%) used in cars and motorcycles. Former Vice President of the United States, Al Gore, advocated “saving the earth by reducing carbon dioxide usage” in his famous video “An Inconvenient Truth” which demonstrates the fact that the health of our earth is getting worse, and that there must be some ways in which people can stop or alleviate environmental destruction.

The term “Hybrid vehicle” signifies that a vehicle uses two or more distinct power sources (e.g., electricity and gasoline). In some cases, both electricity and fuel are consumed interchangeably for the purpose of power complementarity, leading to the hybrid vehicle achieving greater fuel economy. Data collected from 151 users were empirically tested against the research model using regression analysis. The results reveal that symbolic benefits and motivational benefits were significant antecedents of environmental benefits, whereas functional benefits and economic benefits were not. Several recommendations for research and practice have been derived from these findings.

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I. INTRODUCTION

In Taiwan, among the 10 leading cause of death, 7 are associated with air pollution (CommonWealth Magazine, 2013). Based on Environment Protection Administration (2013), most air pollution is caused by automobiles. Because oil is used by all automobiles and is highly related to air pollution, it is important to develop energy-saving technologies that significantly alleviate carbon dioxide emissions, to improve environmental protection (Hsu, 2005). The number of automobiles worldwide reached nearly 1.02 billion in 2010 and is expected to increase continually to 1.7 billion in 2035 (IEA, 2011). The increasing numbers of automobiles also result in more oil consumption than ever before. For example, oil consumption by automobiles was 57% in 2001 and the estimation will increase to 62% by 2020. Domestically, it has been estimated that 17.6% of the total energy is used mostly (94%) by cars and motorcycles (Bureau of Energy, 2013).

Recently, 84 countries signed the Agreement of Kyoto Protocol. In 2006, former U.S. Vice President Al Gore released a documentary called “An Inconvenient Truth”, which emphasized the seriousness of global warming. He believes in energy conservation, i.e. using more of public transportation and developing more alternative energy technologies; innovative products need to be invented to slow down global warming (Hsu, 2011). Therefore, environmental protection has been gradually accepted by most people and emphasized by all nations in the world. Among greenhouse gases, carbon dioxide is the main culprit; it causes global warming and climate variations, leading to nearly irreversible changes on earth. However, the extra amount of carbon dioxide has been generated mostly by motor vehicles.

Various industries are beginning to take action. The automobile industry has started to develop innovative products (i.e. Hybrid Electric Vehicles, HEVs) which greatly help to lessen the emission of polluting gases. Especially, Toyota’s Prius automobiles are quite commonly driven in the USA and have almost become a household brand name for energy saving motor vehicles. Moreover, according to Taiwan's Ministry of Economic Affairs Bureau of Energy (2013), among the top 5 energy-saving cars in Taiwan, three are hybrid vehicles.

II. LITERATURE REVIEW

2.1 Hybrid Electric Vehicles

In 2003, a hybrid vehicle was defined by the United Nations as “an innovative vehicle which contains two or more driving energy converters and two or more energy storage systems.” Toyota built a Hybrid Electric Vehicle (HEV) which includes a driving system which combines a gasoline ignition device with an electric motor; the storage system uses a conventional gas tank together with battery cells. It set the trend for the worldwide commercialization of HEVs.

Functionally, HEV there is a gasoline engine and an electric engine combined into a “double engine”. To drive an HEV at first, the electric motor needs to be turned on so the engine starts running. Next, to drive at
low speed, the engine depends only on the battery, not the gasoline. While driving at medium and steady speeds, only electricity needs to be consumed. Rarely when there is a rare need to drive at high speed or to climb uphill will the gasoline be used to assist the electric motor. Therefore, it becomes a very quiet and smooth ride (Chang, 2011) and, most importantly, the HEV emits much less polluting gases. Both better gas mileage and less air pollution are achieved simultaneously.

2.2 Evolution and Development of HEVs

In 1901, Dr. Ferdinand Porshe who invented the first hybrid system created the first hybrid car in the automotive industry. In 1977, Toyota proposed their first hybrid model-sports 800 gas turbine hybrid in Tokyo. However, it was not until 1997 that Toyota officially presented their first mass-production car, the Prius (MediaBrilliance System, 2014).

The exploratory work on HEVs actually started around 1990 when petroleum was at about $20 per barrel. In addition, the battery cell technology was not as developed. So, the general public was not as interested in hybrid cars (AUTO Driver, 2008) until 2008 when the average petroleum prices reached around $100 per barrel. As the public started to pay more attention to environmental protection issues, HEVs gradually become the center of attention. Meanwhile, the automotive industry began to build innovative vehicles using alternative energy resources.

The USA, countries in Europe, and Japan set their long-term development objectives on hybrid vehicles. Initially, immature rechargeable cell techniques and lack of physical rechargeable stations really hindered the development process. Actually, hybrid vehicles can be grouped into 4 categories: Battery Electric Vehicles (BEVs), Fuel Cell Electric Vehicles (FCEVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). Among these 4 categories, the HEVs are the most commercialized and have been the focus of innovative technologies worldwide.

Although HEVs are environmentally green and financially successful, they still depend on internal combustion engines; thus, they still pollute the environment to a degree. Many experts believe that HEVs are just transitional products to save energy and reduce pollution. They should eventually be replaced by vehicles which do not require oil to operate. However, before these vehicles are invented, HEVs will remain. Hopefully, in the future, more fuel efficient with less polluting vehicles will be developed and our environment will become much cleaner (Chang, 2011).

2.3 Research on HEV Issues

Various issues of HEVs raised by several authors will be reviewed to set the main topic of this research. One basic issue is that the selling price of an HEV is higher than that of a conventional internal combustion car. However, many people are willing to pay for it because they want to save energy and protect the environment. Some consumers are just mainly interested in innovative technical items and are willing to face additional expenditures to buy an HEV. Johnson Controls (2009) examined consumer sentiment regarding HEVs to gain insight into the challenges and opportunities for broader market acceptance. In Johnson Controls'
survey, the purchase price and fuel cost were determined to be the most important factors in buying an HEV.

McCarthy and Tay (1998) found that income, race, age, gender and population density are the factors affecting hybrid vehicle acceptance. Ong and Hasselhoff (2005) studied the levels of interest in HEVs on the part of American consumers and found that 41% were willing to pay more to buy the HEVs. White consumers, people with more age, or people with annual personal income of more than $80,000 are more interested in purchasing the HEVs. Kahn (2006) carried out an empirical study on the relationship between the HEV purchasing habit and the attitude towards environmental protection. It was determined that people primarily interested in the environmental protection tend to take mass transportation systems, which would use less oil than driving HEVs, and much less than driving internal combustion vehicles. Kahn (2006) also showed that environmental protection advocates tended to take mass transportation to save energy.

Potoglou and Kanaroglou (2006) studied people in Hamilton, Canada, who would buy HEVs within the next 5 years. Based on their study, as expected, people with higher incomes were more interested in HEVs compared to people with lower incomes.

Kishi and Satoh’s (2005) research in Tokyo and Sapporo, in Japan, found that people were very interested in protecting the environment, but the factor of environmental protection alone was insufficient to encourage people to buy HEVs. Based on various studies, environmental protection could only be a modifying factor for purchasing HEVs. However, it could not be used as an absolute contributing factor. Tai and Yeh (2013) indicated that while most people care about environment policy and related issues, the gas saving and user-friendly features of hybrid cars are new to people. Therefore, if people are provided with eco-friendly knowledge, it might stimulate their motivation to purchase hybrid cars. Adler’s (2003) study in California used data from car and job registrations. The cars were partitioned into 3 groups: conventional cars, HEVs and genetically modified internal combustion cars. His research showed that savings in gasoline, taxes and parking fees would encourage people to buy HEVs or genetically modified internal combustion cars.

Tai (2005) pointed out that since HEVs were priced much higher than conventional cars, despite technical enhancements in acceleration, maximum speed, maneuverability and other features which made the HEVs very competitive, governmental subsidies were still needed to popularize the HEVs. Haan and Scholz (2007) indicated that tax reduction policies were the primary reason for the popularization of HEVs in Switzerland. Cheng (2008) proposed the impacts of governmental subsidies in Taiwan. When the government subsidy was at NT$50,000, more than half of the possible customers would not buy the HEVs. When the car dealers added more subsidies, the percentage exceeded 50%. When more subsidies were provided, HEVs would rank ahead of diesel cars, but still lag behind regular cars. HEVs were the most favored environmentally green vehicles.

Dagsvik and Wennemo (2002) performed a study on the potential market for alternative energy motor vehicles in Norway; they found that alternative energy vehicles were quite favored compared to regular cars. Sun (2006) found that the major issue in buying an HEV was the price. In Taiwan, Chou (2006) found that the prices for HEVs by environmental protection enthusiasts were between NT$1,400,000 and NT$1,700,000 for financially sound buyers and NT$700,000 for performance oriented customers. Diamond’s (2009) study in the USA found that gasoline prices had more influence than government promotion policies for people choosing to buy the HEVs. Li (2007), under the framework of The Small World website, studied the factors of price of car, gas efficiency, price of gas per liter and car performance in relation to HEV buying. When the
subsidy was raised to 10% of the car price, the acceptance level would rise to 4.5%. People earning more than NT$1,000,000 annually would comprise 18.2% for HEV buying, naturally at a higher level than the people earning less.

The foundation of this research is based on the studies performed by Heffner, Kurani and Turrentine (2005). This research emphasizes that many people would trade off functional performances for outstanding ‘Symbolic Benefits’ for HEVs. The concept of ‘Symbolic Benefits’ means benefits of symbolic impressions of the HEVs. When buying HEVs, customers would consider factors such as price, performances, etc. However, among the factors, we propose that the central factor is ‘positive personality impressions’. The factor of ‘positive personality impressions’ often exceeds the car price and performance factors, i.e. the car displaying an ‘image of personal character’, or creating a ‘feeling of personal aura’, reflecting its owner’s personality. This research also proposes other benefits, such as ‘Functional Benefits’, ‘Economic Benefits’ and ‘Motivational Benefits’ for buying HEVs.

Referring to the ‘Functional Benefits’, Greene, Duleep and McManus (2004) pointed out that HEV owners often emphasize horsepower and acceleration. In addition, Heffner et al. (2005) concluded that the HEV vehicles are very quiet and move smoothly during driving. Besides the ‘Functional Benefits’, another factor is the ‘Economic Benefits’. Though HEVs tend to be priced higher than conventional vehicles, they do have better gas mileage. After long periods of time, it will even out the initial higher buying costs. Thus, it’s also economically positive to buy HEVs. Finally, the factor of ‘Motivational Benefits’ should be stated, i.e. HEVs offer positive factors for our living environment. The HEVs use much less oil and expel much less polluting gases, which will make our cities quieter and cleaner (Heffner et al., 2005).

Functionally, though the HEVs are often not better than conventional vehicles, they do provide more benefits such as improving our environment, etc. Therefore, customers are mostly willing to sacrifice a little on the functionalities to gain largely on other benefits by purchasing HEVs. Thus, the symbolic, functional, economic and environmental factors are motivational benefits; these have been proposed and will be thoroughly analyzed in this research on HEVs.

III. DATA ANALYSIS

3.1 Data

There are 151 participants in this research: 78 (51.7%) are male and 73 (48.3%) are female. Participants’ aged between 21 and 30 number 88 (58.2%), 31 to 50 number 49 (32.5%) and those over 50 number 14 (9.3%). Regarding the education background of participants: 11 (7.3%) hold a senior high diploma, 78 (51.7%) graduated from undergraduate college and 62 (41%) have a master’s degree. Regarding the participants’ occupations: 34 (22.5%) are in manufacturing, 7 (4.6%) are in information industry, 57 (37.7%) are in service, 21 (13.9%) are in Military/Public/Teaching position, 17 (11.3%) are students and 15 (10%) are in other industries. Regarding the average monthly income of participants, 98 (64.9%) earn under NT$20,000, 21 (13.9%) earn between NT$40,000 and NT$60,000, and 32 (21.2%) earn over NT$60,000. Regarding the
participants’ driving experience: for 63 (41.7%) it is under 5 years, for 37 (24.5%) it is between 6 to 10 years, and for 51 (33.8%) it is over 10 years. As for car types: 137 (90.7%) drive gasoline cars, 11 (7.3%) use diesel vehicles and 3 (2%) drive hybrid electric vehicles. As for the car prices that participants are willing to pay: for 100 (66.2%) it is under NT$900,000, for 33 (21.9%) it is between NT$900,000 and NT$1,000,000, and for 18 (11.9%) it is over NT$1,000,000.

3.2 Measurement

The research methodology is based on statistical analysis, which in this paper includes multiple regression analysis. This type of analysis is used for modeling and analyzing several variables. Tabulations of the information and results are partitioned according to the formats used by Chang (2012) in his studies on HEVs. Symbolic Benefits, Functional Benefits, Economic Benefits, Motivational Benefits and Environmental Benefits were measured using a five-point Likert scale ranging from 1 = “strongly disagree” to 5 = “strongly agree.

3.3 Sample Structure Analysis

A total of 151 participants were recruited as our respondents: 51.7% of them were male and 48.3% were female; 58.2% were within the 21-30 age group, followed by 32.5% in the 31-50 age group. Nearly all the respondents had a bachelor degree or above (92.8%) and most of them work in the service industry (37.7%) and manufacturing industry (22.5%). Based on monthly income, the majority of the participants earn under NT$40,000, at 64.9%. Participants with less than 5 years driving experience total 41.7%, and from 6 to 10 years, 24.5%. Based on cars driven, 90.7% are using gasoline cars. The participants state that prices under NT$900,000 may encourage them to buy, based on the HEV vehicle model being a Toyota Camry Hybrid, at 66.2%.

3.4 Multiple Regression Analysis

Table 1. Result of hypotheses test based on regression analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>$R^2$</th>
<th>$\beta$</th>
<th>Hypothesis result</th>
</tr>
</thead>
<tbody>
<tr>
<td>$EB = SB + FB + EB + MB$</td>
<td>0.502</td>
<td>0.596***</td>
<td>H1: supported</td>
</tr>
<tr>
<td>SB</td>
<td></td>
<td>-0.053</td>
<td>H2: not supported</td>
</tr>
<tr>
<td>FB</td>
<td></td>
<td>-0.081</td>
<td>H3: not supported</td>
</tr>
<tr>
<td>EB</td>
<td></td>
<td>0.334**</td>
<td>H4: supported</td>
</tr>
</tbody>
</table>

Notes:*** $p<0.001$; ** $p<0.01$; * $p<0.05$

SB = Symbolic Benefits; FB = Functional Benefit; EB = Economic Benefits; MB = Motivational Benefits
To test the hypotheses, we conducted multiple regression analyses using SPSS 16.0. The coefficient of determination $R^2$ indicating the percent of how much of the total variance is explained by the independent variable being 50.2%. Regression analysis was conducted to examine the survey data. The results indicate that Symbolic Benefits ($\beta = 0.596, P < 0.001$) and Motivational Benefits ($\beta = 0.334, P < 0.01$) were significant antecedents of environmental benefits, whereas Functional Benefits and Economic Benefits ($\beta = -0.053, P>0.05; \beta = -0.081, P>0.05$) were not. Among all the significant factors, Symbolic Benefits, through further commercial advertisements explaining the benefits provided by the HEVs in improving our environment, the willingness to buy HEVs will be significantly increased. Therefore, if our governments and car dealers can propose and promote more favorable policies and programs encouraging purchasing, people will buy more HEVs and our living environment will be much improved and protected.

**IV. CONCLUSIONS AND DISCUSSION**

4.1 Conclusions

The results indicated that symbolic benefits are significant antecedents of environmental benefits. It is likely that the symbolic benefits of HEVs could enhance environmental protection. Motivational Benefits were significant antecedents of environmental benefits in buying HEVs; customers believe that HEVs would help to protect our environment.

Functional Benefits were not significant antecedents of environmental benefits. Probably, people are not clear about the functions of HEV, thus, they may not understand that HEVs can benefit the environment. If
the government could pay more attention to strengthening the promotion of HEVs, people’s environment consciousness would be enhanced, thus leading to different results. Economic Benefits were not significant antecedents of environmental benefits. Due to the high price of HEVs and inconvenience of obtaining factory car repair, people may not buy HEVs in order merely to protect the environment. Prices have gone up if more people have ability to buy HEVs, they would be willing to buy HEVs to protect our environment.

4.2 Recommendations

(1) Recommendation for Car Dealers

As a result of this study, the factors of Symbolic Benefits, Motivational Benefits, and Environmental Benefits are strongly correlated. On the impression factor, the HEVs represent images of environmental protection, of being very fashionable, of social responsibility, etc. Car dealers should budget more to promote the benefits of buying and owning HEVs to potential customers. For purchase incentives, the car dealers should offer more HEV purchasing programs. If these steps are taken, protecting our environment will become a reality.

(2) Recommendation for Further Studies

This study included the factors of Symbolic Benefits, Functional Benefits, Economic Benefits and Motivational Benefits related to the factor of Environmental Benefit. More factors can be incorporated in future studies. These extra factors can be carefully analyzed and cross compared. More groups of samples can be collected to be cross checked, to increase the study accuracy. More research results and tabulations can be generated by future researchers.

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