THE FACTORS AFFECTING THE DEMAND FOR ELECTRIC MOTORCYCLE

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Abstract: This paper discusses the factors affecting the demand for electric motorcycle. Stated preference approach was used to collect the choice data and binary logit model was used to estimate the utility function of demand. We used factor analysis and cluster analysis to group respondents into different market segments. The results showed that purchase price, operating cost, social cost (level of emissions), top speed, maximum driving range, and recharging method had significant effects on the demand for electric motorcycle. However, the coefficients of social cost variable were not significantly different for respondents with different environment related behavior and different opinions about environmental protection. The respondents with higher performance and convenience requirement for motorcycle put higher value on the top speed and maximum driving range.

Key Words: electric motorcycle, environmental protection, binary logit, stated preference, market segmentation

1. INTRODUCTION

The Air Pollution Control Act of Republic of China (ROC) was amended in 1992 to include economic incentives. Specifically, Article 10 of the amended Act states, "The authorities at various levels shall levy air pollution control fees based on the type and amount of air pollutants discharged from pollution sources. The classification of pollution sources and the rule for collection of air pollution control fees should be performed by the central authority after consulting with relevant government authorities". The Environmental Protection Administration (EPA) of ROC initiated the charge on fuels (coal, fuel oil, gasoline and diesel) in July 1995. The fee is 0.2 N.T.$ per liter for gasoline and diesel. The EPA launched several projects with the collected fees. One of them is to promote the use of electric motorcycle.

To reduce the exhaust emission from the two-stoke motorcycles, the Execute Yuan of ROC approved "the Action Plan for the Development of Electric Motorcycle" in March 1998. After the approval, the EPA stipulated regulation that two percent of motorcycles sold should be electric powered starting from year 2000. The EPA provided subsidies to encourage consumers to purchase electric motorcycles. These subsidies made the prices of electric motorcycles to be close to or even lower than those of gasoline motorcycles of similar size. Furthermore, the EPA put on advertisements to promote electric motorcycle. The advertisements stated that the electric motorcycle had zero emission and was very economic. It cost only 0.1NT$ /km for electricity without considering the replacement cost of battery while the gasoline motorcycle cost 0.5NT$ /km (Environmental Protection Administration of ROC, 2000). The EPA also ran demonstration projects to show that driving range and power of electric motorcycle had significantly enhanced. However, these demonstrations did not change the common perception that the performances of electric motorcycles are inferior to those of gasoline motorcycle.

Under this circumstance, the manufactures of electric motorcycles had to focus mostly on their social merits to sell these products. They claimed that the electric motorcycle was a mode of zero pollution, zero noise, low energy usage, and high performance (Shang Wei EV Tech Inc., 1999). Do they find the right market niche for their products? Will the environmental appeal help the sale of electric motorcycles? Who will be the potential buyer? These are the questions need to be answered.

They are few literatures about the demand for electric motorcycle. The literatures about the demand for electric vehicles mostly put emphases on their purchase price and performance, such as operating cost, range, top speed, refueling duration and location, etc. For example, Beggs and Cardell (1980) used different functional forms of attributes to analyze the households' tradeoffs among price, operating cost, and size of cars. Calfee (1985) used fully disaggregate data to discuss the tradeoffs among price, capacity, speed, range, and operating cost. Bunch, D.S. *et al.* (1993) used emission level (fraction of the current pollution) and fuel availability (fraction of gasoline stations) in addition to purchase price, range, and fuel cost to estimate the demand for clean-fuel vehicles. They also used interaction variables to find the effect of respondents' socioeconomic characteristics. Segal (1995) emphasized the effect of refueling. He used refueling duration, refueling location, and refueling time of the day besides range, fuel type, purchase price, and fuel cost to forecast the market for electric vehicles. The last three papers used stated preference approach (Kroes and Sheldon, 1988; Hensher, 1994)) to conduct their researches. Brownstone, D. *et al.* (2000) discussed the pros and cons of stated preference data and revealed preference data in forecasting the demand for alternative-fuel vehicles. The attributes used were similar to those of the aforementioned studies. Chéron and Zins (1997) used nominal group technique to find the tradeoffs among range, maximum speed, recharging time, and cost/delay in the case of a battery rundown.

It is clear that none of the above studies discussed two important factors that may have great impacts on the demand for electric motorcycle. One is the potential buyer's tendency of environmental protection. A user with environmental protection in mind or having the environment related knowledge might have better probability of buying electric motorcycle. The other is the potential buyer's existing status of motorcycle usage. A user needs motorcycle for long travel distance or frequent usage may put more emphasis on its performance (maximum driving range, top speed, etc.). This will make him less probable of choosing electric motorcycle. Hence, the main purpose of this paper is to test the following two hypotheses:

1. The motorcycle user who cares about environmental protection or has the related knowledge will place higher value on the social merits of electric motorcycle.
2. The long distance or frequent user of motorcycle will place higher value on the performance

of electric motorcycle.

If the first hypothesis is true, the manufactures of electric motorcycles should continue their advertising based on the social merits of their products. If it is not, they should change their advertising strategies. If the second hypothesis is true, the only way to increase the sale is to improve the performance of electric motorcycle. If it is not, the manufactures can put their efforts on other things, such as cutting the manufacturing cost.

The rest of the paper is arranged as followed. First, we will describe the survey design procedure. That will include the content of questionnaire and the levels of attributes used. Then, we will discuss the model estimation and market segmentation results. The factor analysis and cluster analysis will be used to group the respondents into segments. The factors affecting the demand for electric motorcycles will be discussed in detail. Finally, we will present the conclusion.

2. SURVEY DESIGN

Due to the fact that only a very limited people own electric motorcycles, it is not practical to adopt the revealed preference approach. We used stated preference approach instead. Interviewers surveyed 124 present 50 cc gasoline motorcycle user in the gas station and parking lot in the city of Tainan, Taiwan. The survey questionnaire is separated into three parts. The first part is the respondents' behavior and opinions toward environment and their motorcycle usage status. There are 17 questions and are grouped into the following three groups:

Group A: Respondents' daily environment related behavior
1. I bring my own bag for daily shopping.
2. I return recyclable goods (battery, plastic bottle, etc.) to designated place.
3. I turn off the light and running water when not needed.
4. I walk or ride a bike to a destination within 500 meters of my residence.
5. I buy commercial goods with environmental protection mark.
6. I bring my own cutlery to a cafeteria supplying only disposable tableware.
7. I regularly have my motorcycle serviced to get the emissions under regulated standard.

Group B: Respondents' opinions about environmental protection
1. I am willing to spend more money for green goods.
2. The pollution caused by motorized vehicles is harming the environment.
3. The saving of energy will decrease the global warming effect.
4. I am willing to pay for my pollutants.
5. I should only use motorized vehicles when absolutely necessary.

Group C: Daily motorcycle usage
1. It is very important to have gas station around for the convenience of refueling.
2. I need motorcycle for most of my trips.
3. My daily travel distance is quite long.
4. A well-performed motorcycle should be able to achieve at least 60 km per hour.
5. I use motorcycle at least four times a day.

We used Likert 5 point scale to get the behavior and opinions of respondents. For group A questions, 5 is for always and 1 is for never. For group B and C questions, 5 is for strongly agree and 1 is for strongly disagree.

The second part is stated preference combinations. Each respondent faced three binary choice situations, i.e., light-type electric motorcycle and 50 c.c. gasoline motorcycle. We used the first preference approach to obtain the preference data. The attributes include purchase price, top speed, maximum driving range, operating cost (the cost of gasoline for gasoline motorcycle; the cost of electricity and battery replacement for electric motorcycle), social cost (calculated from the level of emissions from motorcycle and electricity), and recharging method (electric motorcycle only). Each combination includes three attributes. Each attribute has three different levels. The medium level of operating cost and social cost were obtained from the "the Action Plan for the Development of Electric Motorcycle" of EPA assuming driving distance of 3000km per year. The medium levels of other attributes were obtained from the average value of status quo. Table 1 shows the level of attributes used.

Table 1. Level of Attributes

	Attribute	Level		
Fuel motorcycle	Purchase price	NT$32000	NT$36500	NT$39000
	Top speed per hour	60km	70km	80km
	Maximum driving range	100km	125km	150km
	Operating cost per month	NT$125	NT$180	NT$235
	Social cost per month	NT$174	NT$248	NT$322
Electric motorcycle	Purchase price	NT$27000	NT$30000	NT$33000
	Top speed	30km	40km	50km
	Maximum driving range	30km	50km	70km
	Operating cost per month	NT$320	NT$460	NT$600
	Social cost per month	NT$14	NT$20	NT$26
	Recharging method	At home (NT$5, 8hours)	At public station (NT$20, 30 minutes)	At battery exchange station (NT$40, 10 minutes)

Note: 1US$ =30NT$.

The last part is respondent's personal characteristics, such as sex, age, education degree, household income, daily average travel distance, etc.

3. MODELS

3.1 Full Sample Model

We surveyed 124 respondents and each respondent faced three choice situations so we got 372 samples. The estimation results of binary logit (Ben-Akiva and Lerman, 1985) model were shown in Table 2. The results show that all coefficients of attributes are significant and have the correct sign. The explanatory power of the model is quite good. The social cost attribute is not significant for all respondents but is significant for the respondents with college degree. The size of coefficients show that respondents with college degree put more value on the social cost than operating cost although the difference is not statistically significant. The size of maximum driving range coefficient is significant but small compared to that of top speed. It may be due to the fact that the daily average driving distance of more than 80 percent of the respondents is less than 10km. So the pre-specified maximum driving range for electric motorcycle is enough for their requirement. Of the three recharging methods of the electric motorcycle, respondents prefer to recharge their motorcycles at home, followed by recharging at public station (specified as base). Battery exchange station is the least welcomed. This result may be caused by several reasons. First, the cost of recharging is different. Recharging at home is the cheapest, followed by recharging at public station. The cost of battery exchange is even greater than that of refueling a gasoline motorcycle. Second, recharging at home can be done at night so the longer time may not be cumbersome. Third, the respondents may worry that they will get battery of inferior quality from the exchange station.

Table 2. Logit Model Estimation Results

Attributes	Coefficients (t-values)
Electric motorcycle constant	0.496(1.2)
Purchase price ($10,000)	-0.111(-2.3)
Operating cost ($100)	-0.273(-2.9)
Social cost-college degree ($100)	-0.361(-2.6)
Top speed	-0.030(3.5)
Maximum driving range	0.010(2.9)
Recharging at home	0.556(2.2)
Battery exchange station	-0.728(-2.1)
Sample size	372
$LL(\bar{\beta})$	-223.562
ρ_c^2	0.132

3.2 Market Segmentation

The purpose of this paper is to find the factors affecting the demand for electric motorcycle. In addition to the performance of electric motorcycle, there are other factors, such as potential buyers' socioeconomic characteristics, that might affect their demand for electric motorcycle. In this paper, however, we will focus on the environmental protectionism issue. We try to understand whether the drivers' daily environment related behavior, their opinions about environmental protection, and their daily motorcycle usage would affect their demand for electric motorcycle. To achieve this objective, we have to segment the respondents into different groups according the aforementioned three factors. The basic idea of market segmentation is that a consumer market can be divided into identifiable groups (segments) sharing similar tastes, preferences, or behaviors with respect to a particular product. These segments are based on similarity among members of a given group and differences between members of different groups.

We developed a two-step process to group respondents into different market segments. First, we used principal factor analysis (Harman, 1976) to reduce the number of measures used to describe the behavior and opinions of respondents. The principal factor solution, developed by using the set of squared multiple correlations as commonality estimates, identified common factors. We also used varimax rotation to rotate the matrices of factor loadings to get a better understanding of the relationship between factors and variables (questions in our case). Second, factor scores for these respondents were grouped using a cluster analysis algorithm (Lorr, 1983). Cluster analysis can identify groups (or clusters) of observations that are similar with respect to the variables of interest. We used K-means cluster analysis to partition the set of factors into a pre-specified number of groups based on distances between cluster centroids. We will discuss the segmentation results in the following subsections.

3.2.1 Segmentation Results of Daily Environment Related Behavior

The group A questions are about the daily environment related behavior of respondents. There are seven questions. The results of factor analysis are shown in Table 3. The results showed that these seven questions could be reduced into two factors that explained 51.29% of total variance. The factor loadings of all questions are high for one factor and low for another factor that gives these two factors clear definitions. The first factor includes own shopping bag, recycling goods, buying goods with environmental protection mark, and own cutlery. It can be defined as environmental protectionism. The second factor includes turning off light and water, walking or riding a bike, and motorcycle regularly serviced. It can be defined as energy saving.

Table 3. Factor Loadings of Group A Questions

A. Daily environment related behavior	Factor 1 Environmental protectionism	Factor 2 Energy saving
1. Own shopping bag	<u>0.777</u>	0.044
2. Recycling goods	<u>0.625</u>	0.333
3. Turning off light and water	-0.283	<u>0.760</u>
4. Walking or riding a bike	0.194	<u>0.667</u>
5. Buying goods with environmental protection mark	<u>0.613</u>	0.378
6. Own cutlery	<u>0.676</u>	-0.177
7. Motorcycle regularly serviced	0.346	<u>0.466</u>

Since there is no priori knowledge about which number of segments can best explain the difference between respondents. Different number (two, three, and four) of segments was grouped by cluster analysis using factor scores of factors and one logit model was estimated for each segment. There are nine models in total. Their results are omitted here for brevity. We obtained the following results by comparing these models:

1. The respondents with higher environmental protectionism and energy saving behavior put higher value on the operating cost. They also less favor recharging at battery exchange station than other respondents. This result suggests that the energy saving behavior may play an important role in the demand for electric motorcycle. However, this behavior may actually be the money saving behavior. This is the reason these users put higher value on the operating cost and have an aversion to the most expensive method of recharging, i.e. recharging at battery exchange station. This finding suggests that the manufactures of electric motorcycle should put more effort in reducing the cost of battery (the most part of operating cost of electric motorcycle is from the replacement cost of battery).

2. There is no significant difference for the variable of purchase price between different segments.

3. The coefficient differences of social cost variable between different segments are not significant. This result shows that the environmental protectionism of respondents might not

be able to turn into the demand for electric motorcycle.

4. The respondents with lower environmental protectionism and energy saving behavior put higher value on the top speed and maximum driving range.

3.2.2 Segmentation Results of Opinions about Environmental Protection

The group B questions are about the opinions about environmental protection of respondents. There are five questions. The results of factor analysis are shown in Table 4. The results showed that these five questions could be reduced into two factors that explained 62.66% of total variance. The factor loadings of all questions are very high for one factor and quite low for another factor that gives these two factors clear definitions. The first factor includes paying more for green goods, paying for own pollutants, and reducing the use of motorized vehicle. It can be defined as willingness to pay for environment. The second factor includes motorized vehicles harming the environment and energy saving decreasing the global warming effect. It can be defined as knowledge about air pollution.

Table 4. Factor Loadings of Group B Questions

B. Opinions about environmental protection	Factor 1 Willingness to pay for environment	Factor 2 Knowledge about air pollution
1. Paying more for green goods	<u>0.717</u>	0.226
2. Motorized vehicles harming the environment	0.094	<u>0.826</u>
3. Energy saving decreasing the global warming effect	0.075	<u>0.789</u>
4. Paying for own pollutants	<u>0.791</u>	0.115
5. Reducing the use of motorized vehicle	<u>0.779</u>	-0.064

Different number (two, three, and four) of segments was grouped by cluster analysis using factor scores of factors and one logit model was estimated for each segment. There are nine models in total. Their results are omitted here for brevity. We got the following results by comparing these models:

1. The respondents with higher willingness to pay for environment and more knowledge about air pollution put higher value on the operating cost. They also more favor recharging at home than other respondents. This finding suggests that the manufactures of electric motorcycle should put more effort in cutting the cost of battery to get these customers.

2. There is no significant difference for the variable of purchase price between different segments.

3. The coefficient differences of social cost variable between different segments are not significant. This result shows that the respondents' willingness to pay for environment and knowledge about air pollution might not be able to turn into the demand for electric motorcycle.

4. The respondents with less willingness to pay for environment and less knowledge about air pollution put higher value on the top speed. There is no significant difference between

different segments for maximum driving range.

3.2.3 Segmentation Results of Daily Motorcycle Usage

The group C questions are about the daily motorcycle usage of respondents. There are five questions. The results of factor analysis are shown in Table 5. The results showed that these five questions could be reduced into two factors that explained 59.67% of total variance. The factor loadings of all questions are very high for one factor and quite low for another factor that gives these two factors clear definitions. The first factor includes long travel distance, high speed performance, and high usage of motorcycle. It can be defined as performance requirement for motorcycle. The second factor includes refueling convenience and necessity of motorcycle. It can be defined as convenience of motorcycle.

Table 5. Factor Loadings of Group C Questions

C. Daily motorcycle usage	Factor 1 Performance requirement for motorcycle	Factor 2 Convenience of motorcycle
1. Refueling convenience	0.205	<u>0.711</u>
2. Necessity of motorcycle	-0.043	<u>0.831</u>
3. Long travel distance	<u>0.818</u>	0.006
4. High speed performance	<u>0.614</u>	0.218
5. High usage of motorcycle	<u>0.806</u>	0.021

Different number (two, three, and four) of segments was grouped by cluster analysis using factor scores of factors and one logit model was estimated for each segment. There are nine models in total. Their results are omitted here for brevity. We found the following results by comparing these models:

1.The respondents with lower performance and convenience requirement for motorcycle put higher value on the operating cost. They also less favor recharging at battery exchange station than other respondents. This finding suggests that the manufactures of electric motorcycle should put more effort in decreasing the cost of battery to get these customers.

2.The coefficient differences of social cost variable and purchase price variable between different segments are not significant.

3.The respondents with higher performance and convenience requirement for motorcycle put higher value on the top speed and maximum driving range. This results show that these people might not be satisfied with the present performance of electric motorcycle.

4. CONCLUSIONS

We used stated preference approach to analyze the factors affecting the demand for electric motorcycle. Market segmentation was used to group the respondents into segments to find their preference. The estimation results of binary logit models showed that purchasing price, operating cost, top speed, maximum driving range, and methods of recharging the electric motorcycle had significant effect on the demand for electric motorcycle. However, the social cost, which is the focus of promotion effort, did not have significant difference for respondents with different environment related behavior and opinions about environmental protection. The respondents with environmental protectionism or air pollution related knowledge did not put more value on the social merits of electric motorcycle than other respondents. What they emphasized is the cost of battery. The respondents with college degree did find the social cost significant for their demand. The respondents with higher performance and convenience requirement for motorcycle put higher value on the top speed and maximum driving range. These findings suggests that the manufactures of electric motorcycles ,should put more effort on reducing the cost of battery and increasing the performance rather than counting on the potential buyers' social conscience.

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