Study on Models of Commuter Mode Choice beyond Fuel Prices Based on Ordered Logit Models

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Abstract: To ease the traffic congestion, domestic and foreign scholars have paid more attention to the measures of an increased ridership of public traffic and some traffic management measures to reduce vehicle usage. The travel cost and availability of parking are important determinants of private automobile use and of the balance between automobile and transit use. The paper deals with the question of how travelers with private cars would react to fuel prices rising above the high fuel levels that were attained in mid-2008 for commuting purpose. Revealed and Stated Preference surveys were constructed and carried out including vehicle travelers' socio-demographic characteristics, commuter trip characteristics and potential trip mode choices in different hypothetical choice situations which includes travelers' choice under different fuel price rising. The influence factors of commuter mode choice behavior are analyzed and commuter mode choice model corresponding to fuel price was established based on ordered logit model. And the result show that Annual income, work organizations parking condition, household kids' number, and monthly fuel expenditure have marked influences on the results of commuter mode choice. Finally the margin effects of the variables are given. The forecast veracity of the model is satisfied and the precision of this model is high which can provide the datum sustain for the traffic management measures to reduce vehicle usage. [Journal of American Science 2010; 6(8):230-235]. (ISSN: 1545-1003).

Key words: Fuel prices; ordered logit model; Stated Preference survey; commuter characteristics

1 Introduction

With the development of the economy and the rapid increase of vehicle in China, more and more commuters' arrivals are made by private cars, hence creating traffic congestion. To solve this problem, domestic and foreign scholars have paid more attention to the measures which can establish an effective accessibility public traffic system, and especially an encouraging trend is an increased ridership in rail transit and BRT in recent time (Han, 2009). On the other hand, some traffic management measures to reduce vehicle usage such as license plate rule restriction measure, cost increase, parking policy (Qing, 2009) and etc. have been taken to encourage the travelers to transfer from car to public transport. Fuel prices rising and fax is one of the methods to reduce vehicle usage which is applied in China recently. The motivation for the present study were the rising fuel prices in recent time and an interest in how private car travelers would react to further fuel cost increases during the commuter course. The price for a liter of regular non-leaded fuel was 5.6RMB at July 2009, and now is about around 6.92 RMB in April 2010 which gets to the highest in Beijing. This circumstance provided the opportunity to conduct Stated Preference (SP) experiments implementing a much greater bandwidth in pricing schemes than was the case in the previous studies during the world economic recovery period.

Foreign scholars paid attention to those researches on the fuel elasticities and the relationship between fuel and households' vehicle utilization and usage choices. Acutt and Dodgson (1996) derives that the car cross-elasticities of demand with respect to the public transport fares range from 0.0005 for London Buses to 0.0118 for intercity rail. The public transport cross-elasticities with respect to the price of petrol range from 0.013 for local buses to 0.094 for intercity rail, within the range reported for studies from the 1970s and 1980s. Golob and Brownstone (2005) reveal that annual fuel consumption per vehicle declines a bit more sharply with increasing housing density than does annual miles driven, generating a positive relationship between fuel efficiency and density. Vrtic et al. (2007) investigate the effects that potential mobility pricing schemes would have on travelers' tactical (mode choice) and strategic (long-term) decisions. Hao Audrey Fang（2008）develops a Bayesian Multivariate Ordered Probit & Tobit (BMOPT) model to estimate a joint system of vehicle fuel efficiency choice and vehicle utilization in response to varying residential density. Claude WEIS（2009）estimated multinomial logit models for mode and fleet choice based on the SP data While demand elasticity are expected to increase non-linearly with rising prices. From the introduction above, it can be seen foreign scholars have done some studies on fuel prices which are in low fuel price level and do not focus on the price elasticity of high fuel price level. And whether the results are suitable for

China has not been confirmed yet. Domestic scholars pay more attention to the parking policy and fuel fax policy. Whether or not fuel fee rising will induce the reduction of vehicle usage and a compositional shift from car to public transport has not been widely studied in China. And also at what fuel price will the commuters reduce vehicle usage for one day in one week or even give up driving has not been studied. This paper tries to solve this question and emphasizes the impact of both individual and household attributes and relevant variables such as parking and public transport accessibility on the vehicle commuter behavior.

The research comprises of a number of sections. Section 2 presents the vehicle commuter behavior survey and analysis consisting of the structure and design of the stated preference experiments. Section 3 provides explorative statistics of the sample. Section 4 covers the mode choice model of vehicle commuters based on Ordered Logit model. Section 5 presents the results of the model, followed by summary and conclusions.

2 Mode choice behavior survey and analysis

2.1 Recruitment of Respondents

The customers' reactions to further fuel cost increases can be divided into short- and long-term (C.Weis, 2009). In the short term, the interest focuses on modeling individuals' mode choice under the modified pricing schemes. In long-term (strategic) choices, the interest focuses on customers' sets of mobility tools, such as new vehicle purchase and a re-distribution of yearly mileages. Also as we all know mode choice behaviors of the travelers are different according to the trip objects such as commuter, shopping and etc. The survey discussed in this paper only considered the traveler's short term reaction. And trips for commuter purpose over the past week are recorded along with their relevant characteristics such ad origin and destination, travel and waiting times, distances, and so on.

During the survey, respondents owning a car driving license were recruited for the SP survey. Limiting the recruitment process to driving license owners made sure that the car alternative presented in the mode choice experiments was realistic to the respondents.

2.2 Design of Stated Preference Survey

According to the above analysis, the subject of this survey was the stated preference of vehicle commuters in short-term under different hypothetical fuel fee prices assumed the customers' reactions vary with the costs. The survey was conducted in Beijing over the time period from September 8th through April 9th, 2010. The survey consisted of three parts, and the first part concerned respondents' socio-demographic characteristics such as age, gender, occupation, number of adults, number of family driving license adults, number of children, car possession, annual income, zone type of the residence area and work organization. The second part encompasses questions on respondents' commuter trip characteristics such as origin and destination, travel times, distances, weekly workday number, month mileages, parking characteristics of the residence and work organization, parking fee, pay condition of the trip cost, month fuel fee and etc. The third part yielded information about the respondents' potential trip mode choices in different hypothetical choice situations which includes travelers' choice under different fuel price increases by 10%, 20% , 50%, 70%, 100%, 150% and no thinking about the fuel price respectively, and their substitute mode when they do not go to work with private car. In the Stated Preference Survey(Guan,2004), the respondent was faced with 7 mode choice situations, and for each choice situation, explanations on how the car trip costs were computed were displayed in order to clarify the underlying assumptions to the respondents.

The survey takes the mode of quiz face to face mainly (Yao, 2007). And there are about 230 participants to which the questionnaires were sent by internet investigation. A total of 1200 respondents were selected.

3 Sample statistics

Descriptive statistics for the data used in the application are all analyzed.

3.1 Statistics of Revealed Preference survey

Monthly fuel expenditures of respondents and the commuting distance distribution are demonstrated in figure 1 and figure 2.

As shown in Figure 1, the proportions of the respondents of whose monthly fuel expenditure are below 300 RMB and higher than 1500 RMB are 10% and 5% respectively. Most of monthly fuel expenditures of the respondents are between 500 and 1500 RMB. And 46% of monthly fuel expenditures of the respondents are between 500 and 1000 RMB for commuting purpose.

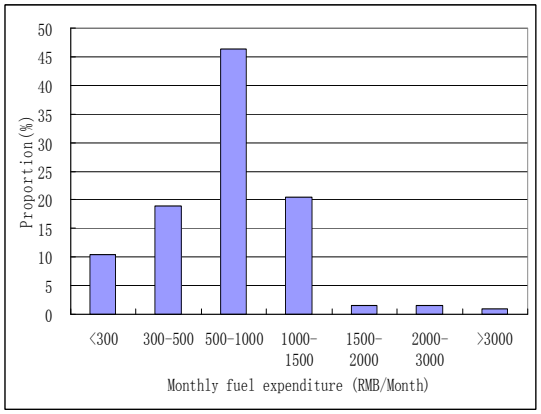

Figure 1. Proportion of the commuter monthly fuel expenditure

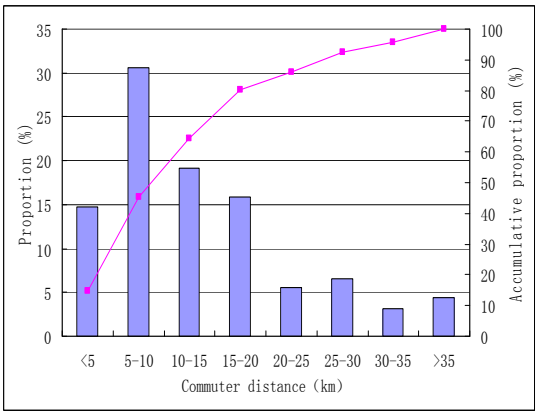

Figure 2. Accumulative proportion of the commuter distances

Figure 2 indicates that, the proportion of the respondents whose everyday commuting distance is below 25 km is about 85%. And the proportion of commuting distance about 5~10, 10~15, 15~20 km are 30.6%, 19.1% and 15.9% respectively.

The parking condition of the residence and work organization such as parking price, supply condition of the parking spaces and average parking time are all investigated to discuss how parking condition will affect commuters' choices. The survey result shows that 45% of commuters choose to drive because they are supplied with abundant employee parking and it will take about 25% of the commuters more than 5 minutes to park. And also 58% of the commuters choose to drive alone because employee parking is free which will stimulate and induce the usage of the vehicles for commuting purpose.

3.2 Statistics of Stated Preference survey

The fuel fee is one of the important factors which influence the trip mode choice of the commuters whose reactions are assumed to vary with the costs. In the survey the stated preference of the commuters by vehicle mode were asked that at what fuel price they will reduce car usage for one day every week considering the increase of fuel price. Using the investigate datum, the proportion of the commuters who will reduce car usage one day per week under different fuel prices were given in Figure 3 and Figure 4.

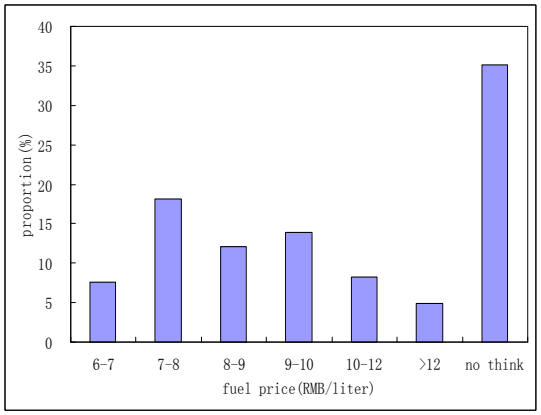

Figure 3. Proportion of the commuters who will reduce car usage for one day per week under different fuel prices

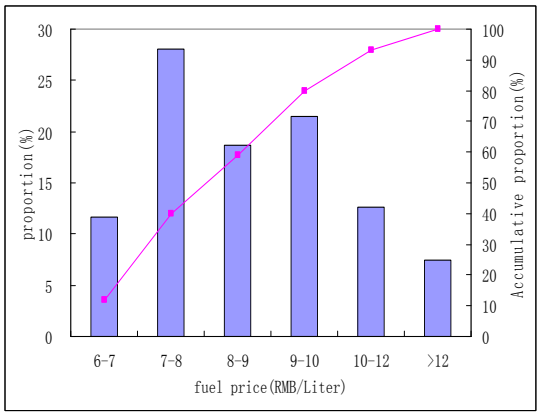

Figure 4. Accumulative proportion of the commuters who will reduce car usage for one day per week under different fuel prices

As shown in Figure 3, about 35% of the respondents will not reduce the car usage for one day every week no matter what the fuel price is. These travelers are defined as rigid travelers who do not have any elasticity with the fuel price and their commuter behaviors will not change with the fuel price. And 65% of the respondents have elasticity with the fuel price. And it can be seen from Figure 4 that when the fuel price gets to 9-10 RMB/liter, 80 % of them will reduce the car usage for one day every week.

4 Formulation and estimation of the discrete choice models

To illustrate the relationship between the travel behavior character of commuters to reduce car usage for one day every week and fuel prices, fuel price choice decisions are modeled as ordered and the ordered choice for fuel price would be zero, one, two, three, four, five and six, which represents fuel price increases by 10%, 20%, 50%, 70%, 100%, more than150% and no thinking about the fuel price respectively for each commuter in the sample.

4.1 Model Specifications

The Ordered model platform is an underlying random utility model or latent regression model. (William H.Greene, 2009)

$$y_i^* = V_i + \varepsilon_i = \beta' x_i + \varepsilon_i,\ i = 1,..., n, \quad (1)$$

Where: $\mathbf{x}_i$ is a set of K covariates that are assumed to be strictly independent of ε_i; β' is a vector of K parameters that is the object of estimation and inference. V_i is the deterministic component of utility for user i (fixed item).

In which the continuous latent utility or measure, y_i^* is observed in discrete form through a censoring mechanisms;

$$\begin{aligned} y_i &= 0 \text{ if } \mu_{-1} < y_i^* < \mu_0, \\ &= 1 \text{ if } \mu_0 < y_i^* < \mu_1, \\ &= 2 \text{ if } \mu_1 < y_i^* < \mu_2 \\ &= ... \\ &= 6 \text{ if } \mu_5 < y_i^* \end{aligned} \quad (2)$$

The thresholds, μ_j are specific to the person and number (J-1) where J is the number of possible ratings (here, six) – J-1 values are needed to divide the range of utility into J cells. The thresholds are an important element of the model; they divide the range of utility into cells that are then identified with the observed ratings.

With the full set of normalizations in place, the likelihood function for estimation of the model parameters is based on the implied probabilities,

$$\text{Prob}[y_i = j \mid \mathbf{x}_i] = [F(\mu_j - \beta'\mathbf{x}_i) - F(\mu_{j-1} - \beta'\mathbf{x}_i)] > 0, \quad j = 0, 1, \ldots, 6. \quad (3)$$

$$\text{Prob}([y_i = 0 \mid \mathbf{x}_i] = F(\mu_0 - \beta'\mathbf{x}_i)$$
$$\text{Prob}[y_i = 1 \mid \mathbf{x}_i] = [F(\mu_1 - \beta'\mathbf{x}_i) - F(\mu_0 - \beta'\mathbf{x}_i)]$$
$$\text{Prob}[y_i = 2 \mid \mathbf{x}_i] = [F(\mu_2 - \beta'\mathbf{x}_i) - F(\mu_1 - \beta'\mathbf{x}_i)]$$
$$\text{Prob}[y_i = 3 \mid \mathbf{x}_i] = [F(\mu_3 - \beta'\mathbf{x}_i) - F(\mu_2 - \beta'\mathbf{x}_i)]$$
$$\text{Prob}[y_i = 4 \mid \mathbf{x}_i] = [F(\mu_4 - \beta'\mathbf{x}_i) - F(\mu_3 - \beta'\mathbf{x}_i)]$$
$$\text{Prob}[y_i = 5 \mid \mathbf{x}_i] = [F(\mu_5 - \beta'\mathbf{x}_i) - F(\mu_4 - \beta'\mathbf{x}_i)]$$
$$\text{Prob}[yi = 6 \mid xi] = [1 - F(\mu 5 - \beta' xi)]$$

The standard treatment in the received literature completes the ordered choice model by assuming either a standard normal distribution for εi, producing the "ordered probit" model or a standardized logistic distribution (mean zero, variance π2/3), which produces the "ordered logit" model. The ordered logit model is given in this paper. For the determination of the attribute combinations to be used in the SP experiments, the software LIMDEP was used.

4.2 Variable Filtration and Grouping

Using the survey datum, the influence of the travelers' household characteristics and trip characteristics are analyzed through crosstables chi-square test. It can be concluded that discrete parameters such as age, occupation, income, parking characteristics of the residence and work organization, and continuous parameters such as number of household children, car possession number, distances between residence and work organization, weekly driving day number, monthly fuel expenditure have marked influences on the results of fuel price choice modes, and other parameters collected in the survey are not significant to choice modes.

Variables filtration and grouping were decided as following by correlation analysis: 1)Age is divided into three groups: Age1 is between 18 and 30 years old,Age2 is between 30 and 50 years old and age3 is others; 2)Occupation is divided into three groups: Occupation1 is private owner, senior manager; Occupation2 is engineering and technical personnel, office clerk and Occupation3 is others; 3)Income is divided into three groups:Income1 is below 60000 RMB/year, Income2 is between 60000 and 150000 RMB/year and Income3 is over 150000 RMB/year.

4.3 Calibration of Model

Using the Ordered logit model and survey datum, vehicle commuter behavior model based on different fuel prices is proposed as shown in Table 1.

According to the statistic analysis, annual income, parking condition of work organization, household kids' number, and distance between residence and work organization and monthly fuel expenditure are chosen as the independent variables of the model. The parameter estimates for the final model are displayed in Table 1. Parameter values are displayed along with the corresponding t-statistics (where absolute values above 1.96 indicate significance of the parameters at the 5% level), as well as general model fit information. The absolute values of t-statistics of HHKIDS, income1, income2, WRKPARK, CARDIST,MFUEL are all higher than 1.96 at a 5 percent confidence level, which indicates that these seven influential factors are significant for the choice probability. The adjusted ρ^2 value of 0.369 indicates a good model fit, and all the included variables are of the expected sign and statistically significant.

For example , let's forecast the probability of junior manager whose household kids number is two ,annual income is between 60000 and 150000 RMB, monthly fuel expenditure is about 1000 RMB ,parking spaces in his work organization is not abundant and distance between residence and work organization is about 25km. The result is listed in table 2.

Table 1. Estimated Ordered Choice Model

Variable		Coef.	t statistic	P
Discrete	Income1	-1.076	-2.886	0.010
	Income2	-1.098	-2.920	0.008

	WRKPARK	-0.778	2.51	0.012
	CARDIST	-0.028	8.278	0.004
Continuous	HHKIDS	0.686	3.164	0.001
	MFUEL	0.001	3.128	0.002
Thresholds		Coef.	Thresholds	Coef.
u_0		-3.315	u_3	-0.589
u_1		-1.805	u_4	-0.250
u_2		-1.225	u_5	-0.015
$L(0)$= -1931.325 ρ^2 = 0.371		$L(\hat{\theta})$ = -1214.344	$-2(L(0)-L(\hat{\theta}))$ =1433.963 *Adjusted* $\bar{\rho}^2$ = 0.369	

HHKIDS =household kids number; Income1 = annual income is below 60000 RMB. Income2= annual income is between 60000 and 150000 RMB; MFUEL = Monthly Fuel expenditure, WRKPARK= Parking condition of work organization; CARDIST=Distance between residence and work organization.

Table 2. Estimated probabilities

yi	0	1	2	3	4	5	6
Prob.	0.020	0.063	0.099	0.132	0.163	0.180	0.343

As shown in table 2, the probability of choose y_i =6 choice is equal to 0.343 and it is the biggest in all of the choices which represents the junior manager will not reduce the car usage for one day every week no matter what the fuel price is. The elasticity of fuel price is very small and his commuter behaviors will not change with the fuel price. Suppose If the probability of choose y_i =4 choice is the biggest of all the choices, it can be concluded that the junior manager will reduce the car usage for one day every week when the fuel price increases and is about 10~12RMB/liter.

4.4 Interpretation of the Model – Partial Effects

Interpretation of the coefficients in the ordered logit model is more complicated than in the ordinary regression setting. The implication of the preceding result is that the effect of a change in one of the variables in the model depends on all the model parameters, the data, and which probability (cell) is of interest. It can be negative or positive. The partial effects are shown in Table 3.

Table 3 Summary of Marginal Effects for Ordered Probability Model

Variable	y_i =0	y_i =1	y_i =2	y_i =3	y_i =4	y_i =5	y_i =6
CARDIST	0.0000	0.0001	0.0006	0.0015	-0.0015	-0.0001	.0000
WKPARK	-.0001	-.0002	-.0031	.0032	.0001	.0001	.0000
INCOME1	.0001	.0002	.0050	-.0050	-.0002	-.0001	.0000
INCOME2	.0000	.0001	.0021	-.0021	-.0001	.0000	.0000
MFUEL	-.0001	-.0006	-.0016	.0015	.0001	.0000	.0000
HHKIDS	.0000	-.0002	-.0020	-.0510	.0499	.0030	.0002

HHKIDS =household kids number; Income1 = annual income is below 60000 RMB. Income2= annual income is between 60000 and 150000 RMB; MFUEL = Monthly Fuel expenditure, WRKPARK= Parking condition of work organization; CARDIST=Distance between residence and work organization.

The partial effects give the impacts on the specific probabilities per unit change in the stimulus or repressors. For example, for continuous variable HHKIDS, we find partial effects for the ordered logit model for the seven cells of 0.000，-0.0002, -0.0020, -0.0510, 0.0499, 0.0030, 0.0002 respectively, which give the expected change on the probabilities per additional number of household kid. For the WKPARK variable, for the (y_i =5) cell, the estimated partial effect is 0.0001; however, some care is needed in interpreting this in terms of a unit change. The WKPARK variable has a mean of 0.8875 and a standard deviation of 0.2601. A full unit change in WKPARK would put the average individual nearly six standard deviations above the mean. Thus, for the marginal impact of WKPARK, one might want to measure a change in standard deviation units. Thus, an assessment of the impact of a change in WKPARK on the probability of the (y_i =5) cell probability might be 0.0001×0.2601 = 0.00026. Precisely how this computation should be done will vary from one application to another.

5 Conclusions

Based on survey data and ordered logit model, commuter mode choice model corresponding to fuel price was established. Conclusions following can be obtained by analyzing the mode. About 35% of the respondents who are defined as rigid travelers will not reduce the car usage for one day every week no matter what the fuel price is. 65% of the respondents have elasticity with the fuel price. And when the fuel price get to 9-10RMB/liter, 80 % of them will reduce the car usage for one day every week. Annual income, work organizations parking condition, household kids' number, and monthly fuel expenditure have marked influences on the results of commuter choice. The forecast veracity of the model is satisfied and the

precision of this model is high. For advanced research we could take advantage of SP (Stated Preference) survey data to establish choice behavior models which include more convenient factors.

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