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Abstract

This paper models a negative impact on environment as one of the attributes of transport mode. By this modeling, we are able to examine whether individual environmental consciousness has a significant effect on his/her choice of transport mode. A survey data from Saito and Onohara Area in Northern Osaka of Japan is used to estimate the model with the Heteroscedastic Extreme Value (HEV) specification. Both of the estimated and simulated results imply that individual environmental consciousness does influence his/her decision on transport mode choice. Furthermore, the likelihood ratio tests indicate that both the utility and scale parameters are not equal across sub-samples of university commuters, research-facility commuters, and residents. The details of the comparison across sub-samples suggest that we may learn more from subdividing a whole sample into several sub-samples if we could select them based on their characteristics.

Keywords: Environmental consciousness; Transport mode choice; Stated choice experiment; Heteroscedastic Extreme Value (HEV) model; Value of time saving (VOTS)

JEL classification: C35, D12, Q51, R41

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1. Introduction

This paper examines variations in individuals' choice of transport mode for their dairy trips from and to a newly developed metropolis in Northern Osaka of Japan, when transport condition is changed due to the monorail line being extended to this metropolis. We consider the most important route from a currently developed area (Saito West Center) to Senri-chuou which is terminal connecting from Northern Osaka to Central Osaka. Three transport modes are selected for our analysis: monorail, bus, and car. Among these modes, bus is currently run directly from Saito West Center to Senri-chuou, while monorail is not directly connected to Saito until the extension from Handai Byoin Mae to Saito West Center operates in spring of 2007.

In previous studies on transport mode choice, several common attributes such as in-vehicle time, access and excess time, Fare or cost, frequency of the service, etc. are proved to be the key determinants of making decision on selecting which transport mode to use. In recent years, people's environmental consciousness has been greatly enhanced with the income growth. In Japan, due to Kyoto Protocol, Japanese government has made and will still make a great endeavor to attain the aim of the protocol. Reconsideration of current transport policy is one of these targets.

Under this consideration, however, whether individual environmental consciousness affects his/her decision on transport mode selection still remains an unknown issue. Limited to our knowledge, we cannot find any literature currently discussing about this issue, therefore, the first purpose of this paper is to manipulate an attribute of individual environmental consciousness into a transport mode choice experiment and examine whether it really has impact on determining which mode to choose. A further simulation experiment on choice share changes of each transport mode based on an increase of its negative impact on environment also provides useful information to the policy makers.

The second purpose of this paper is that we observe three sub-samples and examine the differences among them on values of time saving, direct choice elasticities, influences of individual socio-economic characteristics, and so on. The significant differences in some cases indicate that we may learn more from subdividing a whole sample into several sub-samples, at least in the case like this study.

A Heteroscedastic Extreme Value (HEV) model is used to derive the results of this paper. The HEV model is based on the same random utility theory as the Multinomial Logit (MNL) model, which is normally applied in discrete choice model. However, the HEV model is more plausible than the basic MNL model since it relaxes the assumption of equal variances across alternatives and avoids the independence of irrelevant alternatives (IIA) assumption in the MNL model. It is especially valid in the case that the tree for a nested model is difficult to be specified.

The rest of the paper is organized as follows. In Section 2, the random utility theory, the MNL specification and the HEV specification of the model are discussed. Section 3 describes the survey issues, focusing on the basic information of the survey, experimental design, and sampling strategy and data collection. Alternative-specific and attribute-specific individual socio-economic characteristic variables are defined in Section 4. Section 5 presents the estimated results based on the HEV model specification. Finally, our general conclusions are discussed in Section 6.

2. Model structure and specification

Stated Choice (SC) model is based on random utility theory. The basic assumption embodied in the random utility approach to choice modeling is that decision makers are utility maximizers, i.e., given a set of alternatives the decision maker will choose the alternative that maximizes his/her utility. Since the utility of an alternative for an individual (U) cannot be observed, however, it could be assumed to consist of a deterministic component (V) and a random error term (ε). Formally, individual q's utility of alternative i can be expresses as:

$$U_{iq} = V_{iq} + \varepsilon_{iq} \tag{1}$$

Hence the probability that individual q chooses alternative i from a particular set J, which comprises j alternatives, can be written as:

$$P_{iq} = P(U_{iq} > U_{jq}; \forall \quad j(\neq i) \in J) = P(\varepsilon_{jq} < \varepsilon_{iq} + V_{iq} - V_{jq}; \forall \quad j(\neq i) \in J) \tag{2}$$

To transform the random utility model into a choice model, certain assumption about the joint distribution of the vector of random error terms are required. If the random error terms are assumed to follow the extreme value type I (EV1) distribution and be independently and identically distributed (IID) across alternatives and cases (or observations), the multinomial (or sometimes called conditional) logit (MNL) model (McFadden 1974) is obtained. In the MNL model, the choice probability in Equation (2) is expressed as:

$$P_{iq} = \exp(\mu V_{iq}) / \sum_{j=1}^{J} \exp(\mu V_{jq}) \tag{3}$$

Then, making further assumption for the deterministic component of utility to be linear in parameters, $V_{iq} = \beta' X_{iq}$, the probability in Equation (3) is given as:

$$P_{iq} = \exp(\mu\beta' X_{iq}) / \sum_{j=1}^{J} \exp(\mu\beta' X_{jq}) \qquad (4)$$

where μ represents a scale parameter that determines the scale of the utilities, which is proportional to the inverse of the distribution of the error terms. It is typically normalized to 1 in MNL model. X_{iq} are explanatory variables of V_{iq}, normally including alternative-specific constants (ASCs), the attributes of the alternative i and the social-economic characteristics of the individual q, β' is the parameter vector associated with the matrix X_{iq}.

An important assumption of the MNL model is the independence of irrelevant alternatives (IIA) property. This property, which follows from the assumption of independently and identically distributed (IID) across alternatives and cases, implies that the relative choice probabilities between any two alternatives of choice set J are not affected by the inclusion or exclusion of other alternatives in that set. The IIA property is a strict assumption of the MNL model and a "reasonable approximation of more complex relationships" (Ben-Akiva and Lerman 1985). Although the inclusion of ASCs, to some extents, helps mitigate inaccuracies caused by IIA in the MNL model, it is not enough in most cases if the IIA assumption is violated.

One way of circumventing the IIA property is to allow alternatives having different scale parameters by estimating a Heteroscedastic Extreme Value (HEV) model (Bhat, 1995; Allenby and Ginter, 1995). The HEV model is based on the same random utility structure discussed above and simply relaxes the assumption of equal variances across alternatives. A frequently used Nested Logit (NL) model with a unique inclusive value parameter for each alternative (with one arbitrarily chosen variance to 1 for identification) is equivalent to a HEV specification (Louviere et al. 2000). However, compared with the NL model, the HEV model is obviously valid when the tree for a nested model is difficult to be specified. Moreover, the magnitude of the estimated alternative-specific scale parameters and their standard deviations may help analysts determine the tree structure of a nested model.

In mathematical term for the HEV model, the choice probability of alternative i from a choice set J by individual q is expressed as

$$P_{iq} = \exp(\mu_i\beta' X_{iq}) / \sum_{j=1}^{J} \exp(\mu_j\beta' X_{jq}) \qquad (5)$$

where μ_i denotes the different scale parameters across alternatives. Intuitively, this scale parameter represents uncertainty associated with the expected utility (or the observed part of utility) of an alternative. Therefore, the lower the scale parameter is, the higher the uncertainty would be (Louviere et al. 2000).

3. Stated choice survey

3.1 Basic information on a new metropolis－Saito

Saito (International Culture-Park City) is aimed at developing a new and unique metropolis on hills in the Northern Osaka of Japan, which is planned to be equipped with such distinctive functions as culture and academic center, research and development, and international exchange. As the process of this development, a part of the West Center in the metropolis has started to be sold as its residential areas since May 2003. By the end of May 2005, about 600 households have been located with a bit more than 1800 people. In addition, two research facilities, i.e. Saito Bio-Incubator since the end of 2004 and Pharmaceutical Basic Technology Research Facility since the beginning of 2005, have started to operate, with a total number of 180 staffs in current.

Osaka Monorail Saito Line, as a main transportation access to Saito, is planed to run a total of 9 kilometers from Saito East Center to Bampaku Kinenkoen (Expo'70 Commemoration Park). The line is planned to have totally 7 stations from south to north: Bampaku Kinenkoen → Koen Higashiguchi → Handai Byoin Mae → Toyokawa → Saito West Center (Saito Nishi Center) → Saito Central (Saito Chuou) → Saito East Center (Saito Higashi Center). The first part from Bampaku Kinenkoen to Handai Byoin Mae has already operated since October 1st 1998 and the second part from Handai Byoin Mae to Saito West Center will be operating in the spring of 2007. The survey is based on the extension of the second part of the line to examine how individuals choose their transport mode from Saito West Center to Senri-chuou due to the coming operation of this extension.

3.2 Design of the stated choice experiment

In the stated choice experiment, a number of attributes and assigned levels are used to generate hypothetical scenarios. The attributes and their levels included in each scenario for this study are summarized in Table 1. We have three alternatives (transport modes), with each five common attributes. For each attribute, we adopt a 2-level design with an exception of access time and frequency in car and a negative impact on environment in monorail. Therefore, in full factorial design, there are totally 2^{12} ($=2^4 \cdot 2^3 \cdot 2^5$) choice sets. Obviously, it is too much for respondents to answer. Then, fractional factorial designs were used to reduce the number of choice sets to a manageable level. Thirty-two choice sets were constructed in such a way that orthogonality both between and within alternatives was ensured. These choice sets were further systematically blocked into four versions to avoid dominant selection. Each surveyed respondent was presented with one version of eight choice sets and asked to

Table 1 Transport attributes and their levels used in the survey

Attributes	Levels of attributes		
	Monorail	Car	Bus
In-vehicle time including delay time caused by traffic jam	15 minutes 20 minutes	20 minutes 40 minutes	25 minutes 50 minutes
Access time	10 minutes 15 minutes	almost 0	3 minutes 6 minutes
Frequency	10 minutes 20 minutes	at any time	15 minutes 30 minutes
Fare or cost	360 JP yen 420 JP yen	400 JP yen 800 JP yen	220 JP yen 280 JP yen
Negative impact on environment (such as CO_2 emission)	low	2 times as monorail 3 times as monorail	1.5 times as monorail 2.5 times as monorail

Table 2 An example of choice sets

Transport mode	Monorail	Car	Bus
In-vehicle time including delay time caused by traffic jam (minutes)	15	40	50
Access time (minutes)	15	almost 0	3
Frequency (minutes)	10	at any time	15
Fare or cost (JP yen)	360	800	280
Negative impact on environment (such as CO_2 emission)	Low	3 times as monorail	2.5 times as monorail
Please choose one most desirable transport mode and ✔ in □	□	□	□

select the most favorite mode in the choice sets, with several questions related to individual socio-economic characteristics.

A pilot test of six residents from Saito West Center has been executed on May 21st 2005. According to the pilot test, the context and presentation of the questionnaire have been modified. Then, with a further reconsideration on the questionnaire based on the comments from transport planner and monorail operator, we finally fixed the form. Table 2 provides an example of choice sets for the final questionnaire.

3.3 Sampling and data collection

We consider three sub-samples in the survey. The first one is the residents in Saito West Center and Onohara Area in the neighborhood of Toyokawa, another new monorail station. We apply a method called posting[1] for this sub-sample. To avoid the possible result that most of the respondents are housewives, we deliver two different versions of questionnaires and two self-addressed postage-prepaid envelopes to each household, and ask two different household members older than 15 years to answer the questions respectively. Of 2440 questionnaires distributed on July 7th 2005, 467 valid responses were returned, with a response rate at 19.14%.[2]

The second sub-sample is selected as work commuters to Saito Bio-Incubator and Pharmaceutical Basic Technology Research Facility. Since there are currently 180 staffs in these two facilities, 180 questionnaires with self-addressed postage-prepaid envelopes were distributed on July 7th 2005. As a result, 85 responses were obtained, with a response rate at 47.22%.

The third sub-sample is for students commuting to Osaka University of Foreign Studies which is quite near to Saito West Center. A total of 300 questionnaires with self-addressed postage-prepaid envelopes were distributed face-to-face to the students at the campus of the university on July 7th 2005. A response rate at 28.33% was reached upon 85 responses being mailed back.

4. Individual socio-economic variables

Table 3 defines the alternative-specific constants and the individual socio-economic interaction variables included in the stated choice model's estimation. The individual socio-economic characteristics are manipulated in two ways: an alternative-specific way and an attribute-specific way. In the alternative-specific way, such individual socio-economic characteristics as current bus users, current car users, car numbers held by each household, and work commuters are interacted with ASCs of monorail and car. In addition, the average number of days traveling in the surveyed section in a week is

[1] It is a similar method to mail survey, which can be used in some simple and familiar products choice experiments. It is executed by delivering questionnaires into the surveyed respondents' posts and asking the respondents to mail them back in self-addressed postage-prepaid envelopes after they completing the questions.

[2] Two questions involving the number of household members and the number of children below 15 years in the household are designed partly to accurately calculate the response rate, since several families may probably be single-parent with children or just single. After considering this issue, we estimate that the valid response rate is adjusted to 19.71%.

Table 3 Definitions of individual socio-economic interaction variables

Variable	Definition
ASC_mono	Dummy variable taking on a value of 1 for monorail, and 0 for others
ASC_car	Dummy variable taking on a value of 1 for car, and 0 for others
Busnow_mono	An interaction term of ASC_mono with a dummy variable taking on value of 1 for current bus users and 0 for others
Carnow_mono	An interaction term of ASC_mono with a dummy variable taking on value of 1 for current car users and 0 for others
No.Car_mono	An interaction term of ASC_mono with car numbers held by household
Work-commuter_mono	An interaction term of ASC_mono with a dummy variable taking on value of 1 for work commuters and 0 for others
Busnow_car	An interaction term of ASC_car with a dummy variable taking on value of 1 for current bus users and 0 for others
Carnow_car	An interaction term of ASC_car with a dummy variable taking on value of 1 for current car users and 0 for others
No.Car_car	An interaction term of ASC_car with car numbers held by household
Work-commuter_car	An interaction term of ASC_car with a dummy variable taking on value of 1 for work commuters and 0 for others
Days_car	An interaction term of ASC_car with average number of days traveling in the surveyed section in a week
Envi_higheduc.	An interaction term of environmental attribute with a dummy variable taking on a value of 1 for higher education above university and 0 for others
Envi_inc.abo.600	An interaction term of environmental attribute with a dummy variable taking on a value of 1 for household's annual income above six million JP yen and 0 for others
Envi_age.bel.49	An interaction term of environmental attribute with a dummy variable taking on a value of 1 for age below 49 and 0 for others

also interacted with ASC of car. In the attribute-specific way, respondent's education, age, and household's income were interacted with the key attribute of this study— transport mode's negative impact on environment. After counting these individual socio-economic characteristics into the choice model, we employ both the MNL and HEV specifications for estimation.

5. Results and analysis

5.1 Specification issue

Tables 4 and 5 report the results estimated by the MNL model and the HEV model for three sub-samples mentioned in section 3.3 and wholly pooled sample. All the results are obtained using NLOGIT Version 3.0 (Econometric Software 2002).

The first issue concerning on the model specification is whether the IIA property of the MNL model is violated or not. The results of Hausman test in all cases provided in Table 4 significantly reject the IIA assumption in all sub-samples and wholly pooled sample. It is to say that the MNL model is inappropriate in this sense. The violation of IIA in the MNL model can also be confirmed from the estimated alternatives' scale parameters in the HEV specification. Results for the estimated scale parameters for monorail and car in all cases indicate that they are significantly different from 1.0 at either 1% or 5% level[3], implying that the assumption of independently and identically distributed (IID) across alternatives is violated.

The second issue concerns on the hypothesis of equal utility parameters among each sub-samples and pooled samples. Since there are three sub-samples, four groups can be possibly pooled. They are pooled samples of university commuters + research-facility commuters, university commuters + residents, research-facility commuters + residents, and university commuters + research-facility commuters + residents[4]. Therefore, the null hypotheses can be formally stated as follows:

$$H_0^1 : \beta^{university} = \beta^{research-facility} = \beta^{university+research-facility}$$
$$H_0^2 : \beta^{university} = \beta^{resident} = \beta^{university+resident}$$
$$H_0^3 : \beta^{research-facility} = \beta^{resident} = \beta^{research-facility+resident}$$
$$H_0^4 : \beta^{university} = \beta^{research-facility} = \beta^{resident} = \beta^{whole}$$

The statistics of the likelihood ratio test suggested by Swait and Louviere (1993) are:

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[3] The scale parameter of bus is set to one for identification.

[4] The results for listed pooled sample in Tables 4 and 5 are for university commuters + research-facility commuters + residents sample. To conserve space, we do not list the results of other pooled samples. These results are available upon request.

Table 4 MNL results for sub-samples and wholly pooled sample

	University	Research-facility	Resident	Pooled sample
In-vehicle time	-0.08291***	-0.08018***	-0.07584***	-0.07636***
Access time	0.00156	-0.10604***	-0.02652**	-0.03152***
Frequency	-0.01658*	-0.04941***	-0.01555***	-0.01915***
Fare or cost	-0.00359***	-0.00267***	-0.00266***	-0.00269***
Environment	-0.641457	-1.73916**	-0.70660***	-0.91034***
Envi_higheduc.	—	-0.83308*	-0.50334***	-0.58513***
Envi_inc.abo.600	—	-0.09796	-0.49052***	-0.31021**
Envi_age.bel.49	—	0.92467*	0.35160**	0.39249***
ASC_mono	-1.64426***	-0.42016	-0.76123***	-1.03457***
Busnow_mono	0.46312**	0.05906	0.02122	0.25145**
Carnow_mono	-1.36694*	1.12373***	0.18071	0.54531***
No. Car_mono	-0.09568	0.20643	0.28616***	0.16202***
Work-commuter_mono	—	—	0.43587***	0.51315***
ASC_car	-0.88921	-1.09955**	-1.39350***	-1.43559***
Busnow_car	-0.28916	-1.27860***	-0.97117***	-0.87194***
Carnow_car	0.35611	1.14179***	0.84037***	1.10189***
No. Car_car	0.11527	0.17810	0.53534***	0.27612***
Days_car	-0.10913	—	-0.11327***	-0.06451***
Work-commuter_car	—	—	0.46454***	0.74883***
Hausman test for IIA	30.081***	33.442***	80.854***	116.257***
	(5)	(8)	(8)	(8)
LL convergence	-530.9535	-547.5648	-2853.0621	-3989.0072
ρ^2	0.1798	0.2042	0.1844	0.1830
Observation	672	664	3584	4920

Note: *t*-statistics and standard deviations are not reported to save space.
***, ** and * denote significance at the 1%, 5% and 10% significance level, respectively

$$LR_1=-2[-1128.685-(-530.9535+-547.5648)]=100.3334$$

$$LR_2=-2[-3424.773-(-530.9535+-2853.0621)]=81.5148$$

$$LR_3=-2[-3445.949-(-547.5648+-2853.0621)]=90.6442$$

$$LR_4=-2[-3989.0072-(-530.9535+-547.5648+-2853.0621)]=114.8536$$

The critical value of the χ^2 distribution is 49.80 and 67.50 at the 95% significance level on 35 and 50 degree of freedom, respectively. Therefore, the hypothesis that the vector of common utility parameters is equal across sub-samples can be rejected in all cases.

To test whether the scale parameters are equal across sub-samples requires a further likelihood ratio test. The models for four pooled samples are re-run with the restriction that the scale parameters is no longer allowed to differ across sub-samples. The LR

Table 5 HEV results for sub-samples and wholly pooled sample

	University	Research facility	Resident	Pooled sample
In-vehicle time	-0.08186***	-0.09319***	-0.07593***	-0.07614***
Access time	-0.01386	-0.11303***	-0.02308*	-0.02778***
Frequency	-0.01685*	-0.05334***	-0.01476***	-0.01777***
Fare or cost	-0.00517**	-0.00335***	-0.00307***	-0.00315***
Environment	-0.78494*	-1.67719*	-0.64773**	-0.89740***
Envi_higheduc.	—	-0.88097	-0.49577***	-0.58069***
Envi_inc.abo.600	—	-0.30983**	-0.45831***	-0.30140**
Envi_age.bel.49	—	0.84831	0.35651**	0.37951**
ASC_mono	-1.17532*	-0.48238	-0.64561**	-0.85608***
Busnow_mono	0.43139**	-0.00503	0.02534	0.22838***
Carnow_mono	-1.15019	1.13661**	0.21077	0.54747***
No. Car_mono	-0.09668	0.19513	0.27535***	0.14983***
Work-commuter_mono	—	—	0.41078***	0.46764***
ASC_car	-1.52804	-1.55418**	-1.59834***	-1.70499***
Busnow_car	-0.51432	-1.78273***	-1.08142***	-1.04014***
Carnow_car	0.78124	1.23067**	0.96014***	1.26194***
No. Car_car	0.19000	0.25397	0.55632***	0.27316***
Days_car	-0.13732	—	-0.12710***	-0.06758**
Work-commuter_car	—	—	0.46974***	0.78812***
Scale parameters				
Monorail	1.46071**	1.06629**	1.24873***	1.37301***
Car	0.59376***	0.62269***	0.80387***	0.75201***
Bus	1 (fixed)	1 (fixed)	1 (fixed)	1 (fixed)
Std. deviation				
Monorail	0.87803	1.20281	1.02708	0.93412
Car	2.16003	2.05969	1.59547	1.70550
Bus	1.28255	1.28255	1.28255	1.28255
LL convergence	-489.5722	-515.057	-2627.048	-3680.383
LL constants	-647.3135	-688.0841	-3598.0438	-4882.4911
ρ^2	0.2437	0.2515	0.2699	0.2462
observation	672	664	3584	4920

Note: *t*-statistics and standard deviations are not reported to save space.
***, ** and * denote significance at the 1%, 5% and 10% significance level, respectively

statistics for this test are:

$LR_5 = -2[-1143.325-(-1128.685)] = 29.28$

$LR_6 = -2[-3445.462-(-3424.773)] = 41.378$

$LR_7 = -2[-3477.245-(-3445.949)] = 62.592$

$LR_8 = -2[-4023.733-(-3989.0072)] = 69.4516$

These LR statistics well exceed the critical value of 3.84 at the 95% significant level, indicating that the scale parameters are different across sub-samples in all cases.

5.2 Results based on the HEV model

Due to the violation of the IIA property in the MNL model, we focus, based on the HEV results, our following discussions on *fare and time-associated attributes*, *environmental consciousness attributes*, and *alternative-specific individual socio-economic variables*. We have checked the cross effects of *environmental consciousness attribute* with *fare and time-associated attributes* and found that these cross effects are not significant in all the sub-samples. Thus, we only deal with the main effects in our estimation.

・*fare and time-associated attributes*

Most of fare and time-associated attributes in each sub-sample have been estimated with significantly negative signs, which is consistent with the theoretical expectation. However, in the sub-sample of university commuters, access time is not statistically significant even at 10% level.

Evaluating the absolute parameter estimates across sub-samples is not informative because of scale differences. However comparisons of willingness to pay indicators such as values of time savings (VOTS) and elasticities are very informative. Summaries of VOTS for each sub-sample are presented in Table 6. The estimates of VOTS differ a great deal across sub-samples. Research-facility commuters have the highest VOTS in each kind of time such as in-vehicle time, access time, and frequency, whilst university commuters have the lowest VOTS among the surveyed samples. An interest and probably important result is that in the sub-sample of research-facility commuters, the VOTS of access time has the highest value, while in the other two sub-samples, in-vehicle time is the highest one. It is intuitive that work commuters evaluate access time as the most important determinant of transport mode choice probably because they dislike spending too much time on accessing the mode everyday.

Summaries of the choice elasticities for in-vehicle time, access time, frequency and Fare or cost are given in Table 7. The results suggest that the choice elasticities of in-vehicle time for each transport mode are somewhat similar among sub-samples. However, for access time and frequency, sub-sample of research-facility commuters is relatively much more sensitive than the other two sub-samples, with a range from the lowest ratio of 2.405(=-0.291/-0.121) in comparing to university commuters for frequency to the highest ratio of 4.470(=-0.514/-0.115) in comparing to residents for

Table 6 Value of time savings (JP yen per hour)

	University	Research-facility	Residents
In-vehicle time	950	1669	1484
Access time	161^{ns}	2024	451
Frequency	196	955	288

Note: ns = not statistically significant. The results are based on the HEV specification.

Table 7 Choice direct elasticities (probability weighted)

	University	Research-facility	Residents
In-vehicle time			
Monorail	-0.681	-0.595	-0.527
Car	-1.169	-1.123	-1.194
Bus	-1.277	-1.593	-1.455
Access time			
Monorail	—	-0.514	-0.115
Car	—	—	—
Bus	—	-0.266	-0.061
Frequency			
Monorail	-0.121	-0.291	-0.088
Car	—	—	—
Bus	-0.165	-0.620	-0.194
Fare or cost			
Monorail	-0.964	-0.447	-0.474
Car	-1.413	-0.838	-0.986
Bus	-0.565	-0.445	-0.450

access time. This issue indicates that access time and frequency are relatively important to the work commuters other than students and residents. With respect to choice elasticity on fare, university commuters are the most sensitive in all modes, while the other two sub-samples are almost with the same elasticities. This is probably plausible because students normally have stricter constraint of income than the other two sub-samples, therefore, they are more sensitive on fare.

・*environmental consciousness attributes*

The key issue being worthy of remark in this paper is the environmental consciousness attribute. In all the sub-samples estimated by the HEV specification, the variable of transport negative impact on environment is estimated with a significantly

Table 8 Prediction of change in choice share in response to a 50% increase in negative impact on environment caused by each transport mode

	University	Research-facility	Residents
Monorail increase [a]			
Monorail	-0.836	-5.864	-2.675
Car	0.252	2.414	0.767
Bus	0.584	3.450	1.908
Car increase [b]			
Monorail	0.637	5.353	1.804
Car	-1.159	-7.306	-2.537
Bus	0.523	2.953	0.733
Bus increase [c]			
Monorail	1.148	6.250	3.681
Car	0.412	1.595	0.597
Bus	-1.560	-7.845	-4.278

Note: Share changes are in percentage (%)

[a] Corresponding to an increase in the negative impact on environment for a monorail

[b] Corresponding to an increase in the negative impact on environment for a car

[c] Corresponding to an increase in the negative impact on environment for a bus

negative sign, indicating that the more negative impact a transport mode causes on environment, the more disutility individual has when he/she chooses that mode. By interacting the individual socio-economic characteristics with the variable of environmental consciousness, we may conclude that, for those who have at least educational background over university and whose annual household incomes are more than six million JP yen, more negative impact on environment of a transport mode leads to a less choice probability of that mode. In contrast, young and middle age (below forty-nine years old) group may receive relatively more utility than old age (older than fifty) group when they choose a mode with more negative impact on environment, such as car comparing to monorail.

To examine more explicitly how environmental impact caused by a transport mode affects individual choice of it, we execute a simulation of predicting the change in choice shares of each transport mode after changing the attribute level of one mode associated with environmental consciousness. We suppose a 50% increase of the environmental negative impact to simulate its impact on each alternative, and report the results in Table 8.

It can be seen that, based on the HEV specification, a 50% increase in monorail's negative impact on environment brings about 0.836% reduction of the monorail share for university commuters, 5.864% reduction for research-facility commuters and 2.675% reduction for residents. These reductions are almost lower than any other reduction caused by the same increase for car and bus in each sub-sample, except in the scenario of car for residents. This indicates that the reduction in the choice share of a transport mode which has relatively small negative impact on environment is less than those of which have relatively more negative environmental impact. In addition, in any sub-sample, for any loss of the share from the increased negative impact, more shares go to the relatively "cleaner" mode. That is, for the reduction in monorail's share, more people change to bus than car; for the reduction in share of car, more people change to monorail than bus; and for the reduction in share of bus, more people change to monorail than bus.

The above two evidences from the simulation strongly support our hypothesis that individual environmental consciousness is an important determinant in his/her transport mode choice. Therefore, "cleaner" transport modes are worth being developed.

Finally, a relatively lower reduction in each mode from the increase of negative impact on environment for university commuters than for both research-facility commuters and residents is probably true in reality, since students, due to their stringent income constraint, are less substitutable any other than their usually selected transport mode.

・*alternative-specific individual socio-economic variables*

Individual social-economic variables such as current bus user, current car user, car numbers held by household, and work commuters, etc. are interacted with alternative specific constants of monorail and car. The results of these interaction terms are presented below.

＊*Busnow_mono* and *Busnow_car*

The positive and significant parameter of *Busnow_mono* in the sub-sample of university commuters implies that for university commuters, current bus users are more willing to change to monorail other than continuing taking bus. Whilst, the significantly negative parameters of *Busnow_car* in research-facility and resident sub-samples suggest that a current bus user is unwilling to change his current transport mode to car.

＊*Carnow_mono* and *Carnow_car*

Current car users in the sub-sample of research-facility commuters intend to choose either monorail or car other than bus due to the estimated positive and significant parameters of *Carnow_mono* and *Carnow_car*. However, the current car users in resident sub-sample seem only receive more utility for continuing using car.

＊*No. car._mono* and *No. car_car*

No. car._mono variable parameter is estimated with a significantly positive sign in resident sample. It indicates that for residents in Saito West Center and Onohara Area, the more cars a household has, the more utility they obtain from choosing monorail than the bus. The estimated positive sign of *No. car_car* means that more cars held by a household bring to higher possibility in which they choose car as their transport mode.

＊*Work-commuter_mono* and *Work-commuter_car*

These two variables are only interacted in the sub-sample of residents. The result is somewhat counterintuitive to us. Both the positive and significant parameters of *Work-commuter_mono* and *Work-commuter_car* imply that work commuters of those residents are more willing to choose either monorail or car other than bus. However, the magnitude of marginal utility of *work-commuter_car* is estimated slightly larger than that of *work-commuter_mono*, which is out of our expectation. The probable reason may be that some of work commuters are current car users and prefer continuing choosing car due to their habits.

＊*Days_car* is considered in sub-samples of university commuters and residents, with the result that it is only significant in residents' sample. The significantly negative parameter of this variable implies that the more days residents travel in the section, the less probably they choose car as their transport mode.[5]

All the above discussions are very intuitive to the decision makers of transport policy. The significant and substantial differences of value of time savings, elasticities of fare and time-associated attributes, environmental consciousness attributes, and individual socio-economic interaction variables across sub-samples suggest that we can learn more from subdividing a whole sample into several sub-samples if we could select them based on their characteristics.

6. Conclusion

This paper estimates various parameters of discrete transport choice model, based on the survey for Saito West Center and Onohara Area in Northern Osaka of Japan. We

[5] We have also tried interacting *days* (average number of days traveling in the surveyed section in a week) with ASC of monorail. However, this interaction term is not significant in any sub-sample. Therefore, we drop it in our final estimation.

have shown that a more general Heteroscedastic Extreme Value model than a traditional Multinomial Logit model provides a better fitness and better explanation of the data.

Our modeling on individual environmental consciousness is a try to connect transport economics with environmental economics. This modeling allows us to examine whether individual environmental consciousness is one of the determinants of transport mode choice. Our results suggest that people intend to choose a mode which has less negative impact on environment. Furthermore, the simulation of predicting the change in choice shares of each transport mode in response to a change on the level of environmental attribute brings to a result that the environmental deterioration of one mode reduces its choice share and increases more the share of a relative "cleaner" mode.

Finally, we are able to compare the model estimates across sub-samples due to our sampling strategy and data collection of the survey. The results of two different likelihood ratio tests suggest that neither utility parameters nor scale parameters are equal across sub-samples. With a detailed comparison among the estimated values of time saving, direct choice elasticities, and alternative-specific individual socio-economic variables across the sub-samples, we conclude that at least in the cases like this study, more implication can be found by subdividing a whole sample into several different sub-samples.

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