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Comparative discrete-continuous analysis

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VALUATION OF LEISURE TIME OF NON-WORK DAYS: COMPARATIVE DISCRETE-CONTINUOUS ANALYSIS

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Abstract

This paper estimates empirically the value of leisure time of weekend non-work days by a resource allocation model. After pointing out a technical problem in estimating a resource allocation model with an additive separable utility function, we develop a discrete-continuous model in the context of individual’s time and cost allocation to two types of discretionary activities, out-of-home leisure activity and in-home leisure activity. We apply it to two individual activity diary surveys collected in the cities of Tokyo, Japan and Karlsruhe, Germany. We empirically valuate the values of leisure time of two cities based on the estimated parameters. The results show that the value of out-of-home leisure time is nearly equal to the wage rate in both cities while the value in-home leisure time is about 84% in Tokyo and 45% in Karlsruhe of the wage rate respectively.

Keywords

Value of leisure time, discrete-continuous analysis, comparative analysis, Tokyo, Karlsruhe, Mobidrive

Preferred citation style

1 INTRODUCTION

In general, the value of time is one of the most important statistics in transport planning, which is used for the economic evaluation of various types of transport policies such as the new transport facilities and the improvement of existing transport service. Thus to estimate the value of time with as a high accuracy as possible is essential to evaluate transport policy appropriately. Due to this policy requirement, there have been many studies on calculating and estimating the value of time. One of the most popular techniques for valuation of time is the discrete choice modeling. The pioneering work of Train and McFadden (1978) is aimed at modeling modal choice by using a goods-leisure trade off framework that is originating from the model proposed by Becker (1965). In this framework, the value of time is estimated from the substitution rate of marginal utility with respect to time to that of cost by applying the conditional indirect utility function. Although the discrete choice modeling for travel behavior is widely used for estimating the value of time (for example, Truong and Hensher, 1985; Hague Consulting Group, 1996; Axhausen et al., 2004), the results of those models should be seen as values of time of travelers only. Trip-based models, like travel demand models of modal choice and route choice, deal with the behavior of travelers only. On the other hand, there are many transport policies affecting not only the travelers but also the non-travelers, some of which may make the non-traveler to start travel or/and other of which may make the travelers to stop traveling. To evaluate such transport policies, we need to know the value of time estimated from the people’s choice on whether to travel or not to travel. In addition, from the viewpoint of strategic transport planning, the importance of the value of leisure time will be increasing further. There are two reasons. One is because leisure activities play an increasingly dominant role in our daily lives, as Schlich et al. (2004) point out. The other is that transport policy impacts the travel generation for leisure activities on non-work day more significantly than that for work activities on work day. This is caused by the fact that leisure activities are less obligatory than work activities. Therefore, in this paper we will focus on the value of leisure time.

In past research, there were two approaches respect to the value of time. First, the travel behavior models have recently been inserted into more generalized consumer behavioral models based on microeconomic theory. The economic approach to consumer behavior is based on the assumption that individuals consume time and goods so that the utility derived from all the activities is maximized. Jara-Diaz and Guerra (2003) develop a model incorporating the allocation of time and goods under the constraints of available time and budget by applying
the framework proposed by DeSerpa (1971). This approach is comprehensive, but most of the studies are rather theoretical in nature. As an exception, Jara-Diaz et al. (2004) tried to estimate the value of work and leisure empirically, but this focuses on the value of time on work days. On the other hand, in the past decade, the activity-based approach to travel demand has received much intention and seen considerable progress (see Kitamura, 1988; Axhausen and Garling, 1992, and Bhat and Koppelman, 1999). In the conventional trip-based approach, time and cost are dealt with as the cost of making a trip, while in the activity-based approach the time and cost are considered as the resources for generating the utility by which the individual make the decision on activity participation. Several researchers have analyzed the individual behavior based on the activity-based approach (for example, see Kitamura, 1984; Yamamoto and Kitamura, 1999, and Bhat, 2005), however, most of them consider the allocation of time only. Although the time-allocation model provides important insights into individual behavior, it is impossible to estimate the value of time unless both of time and cost are treated in one model framework.

In the current paper, we develop a discrete-continuous model in the context of individual time and cost allocation to two types of activities, out-of-home leisure activity and in-home leisure activities, and apply it to data sets collected in the cities of Tokyo, Japan and Karlsruhe, Germany. In the next section, the basic model structure is formulated and the technical problem of estimating the time and cost allocation model with the additive separable utility function is pointed out. The solutions for the technical problems are shown and the discrete-continuous model is formulated in section 3. In section 4, the unknown coefficients in the model are estimated for activity-diary surveys in Tokyo and in Karlsruhe and the estimated results of value of leisure time are discussed. Finally, we conclude further research topics.

2. RESOURCE ALLOCATION MODEL AND VALUE OF LEISURE TIME

As Jara-Diaz et al. (2004) pointed out, some implicit agreement has been reached regarding a fairly-complete microeconomic formulation of consumer behavior encompassing not only goods consumption but also time allocated to activities after many years of discussion and contributions from various research fields. In such a model, the individuals allocate their time and cost to activities under constraints with regards to time and cost. We call this type of model as a resource allocation model. Many types of resource allocation models have been proposed. In this paper, we focus on the resource allocation of leisure activities on non-work
days. In modeling the individual’s behavior on non-work days, we need to consider two conditions which are not taken into account in modeling the behavior of work days. One is that the individuals who work on work days do not work on non-work day. This means that time and the cost are never allocated to work on non-work days. The other is that the individuals cannot earn a wage on non-work days. This means that the budget constraint of individuals is given and fixed. Then, we assume that the individuals will maximize their utility under the constraints of the available time and monetary budget.

Let $I_n$ be the set of freely chosen leisure activities of individual $n$, $J_n$ the set of out-of-home leisure activities which require travel, $T_n^o$ the available free time, $Y_n$ the available budget, $T_{ni}$ the time allocated to the leisure activity $i$, $C_{ni}$ the cost associated with the leisure activity, $t_{nj}$ the travel time corresponding to the out-of-home leisure activity $j$ and $c_{nj}$ is travel cost. The utility-maximization behavior of consumer under time and cost constraints can then be formulated as

$$\max_{\{T_n, C_n\}} U_n = U(T_n, C_n)$$

(subject to)

$$\sum_{i \in I} T_{ni} + \sum_{j \in J} t_{nj} = T_n^o$$

(2a)

$$\sum_{i \in I} C_{ni} + \sum_{j \in J} c_{nj} = Y_n$$

(2b)

$$T_{ni} \geq 0, \quad C_{ni} \geq 0 \quad (\forall i)$$

(2c,d).

Note that the allocated times and expenditures have to be non-negative. Besides, the marginal utilities with respect to allocated time and cost should be positive, otherwise activities would not be undertaken. Then let the Lagrange function be:

$$L = U(T_n^*, C_n^*) + \lambda_n \left( T_n^o - \sum T_{ni} - \sum t_{nj} \right) + \mu_n \left( Y_n - \sum C_{ni} - \sum c_{nj} \right) + \sum \kappa_n^T T_{ni} + \sum \kappa_n^C C_{ni}$$

(3)

where $\lambda_n, \mu_n, \kappa_n^T, \kappa_n^C$ are multipliers. The first-order optimality conditions are:

$$\frac{\partial U(T_n^*, C_n^*)}{\partial T_{ni}} = \frac{\partial U(T_n^*, C_n^*)}{\partial T_{ni}} - \lambda_n + \kappa_n^T T_{ni} = 0$$

(4a)

$$\kappa_n^T \cdot T_{ni}^* = 0, \quad \kappa_n^T \geq 0 \quad for \ \forall i$$

(4b,c)
On the other hand, the value of time allocated to a specific leisure activity $i$ of individual $n$ is defined as

$$VOT_{ni} = \frac{\partial U}{\partial T_{ni}} \bigg|_{U = U_{max}}$$

(5).

We note that all the activities must have equal marginal utilities with respect to time and cost if time and the cost is allocated to an activity. One obtains:

$$VOT_n = \frac{\lambda_n}{\mu_n} = \frac{\partial U}{\partial T_{ni}} \bigg|_{U = U_{max}} \quad \text{for } \forall i$$

(6).

Else if no time or cost is allocated to a specific activities, then their marginal utilities with respect to time and cost may be equal to or less than $\lambda_n, \mu_n$ respectively. This leads to different values of time for constrained activities than for unconstrained activities. Therefore, we must take the case of zero-allocation into consideration in any analysis of the value of time. Actually, we often observe that individuals do not choose all activities but choose only a part of activities. When estimating the unknown coefficients by the econometric analysis, we may need to apply a technique which can deal with the error components resulting from a truncated distribution function like the Tobit model (Tobin, 1958).

### Technical problem of using an additive separable utility function

Generally speaking, a parametric modeling approach is used in activity-based modeling, in which the utility function will be specified by the researcher. The choice of the type of utility function is crucial here. In our analysis, we assume an additive separable function. While this type of utility structure is very popular in the choice literature, this assumption is so strong that it may cause technical problems for estimating the value of time. Let $U_n^T(T_n)$ be the partial utility function with respect to time and $U_n^C(C_n)$ the partial utility function with respect to cost. Then the utility-maximization behavior can be presented as
\[ Max \ U_n = U_n^T(T_n) + U_n^C(C_n) \]  \hspace{1cm} (7)

subject to

\[ \sum_{i=1}^{n} T_{ni} + \sum_{j=1}^{J} t_{nj} = T_n^o \]  \hspace{1cm} (8a)

\[ \sum_{i=1}^{n} C_{ni} + \sum_{j=1}^{J} c_{nj} = Y_n \]  \hspace{1cm} (8b)

\[ T_{ni} \geq 0, \ C_{ni} \geq 0 \hspace{0.5cm} (\forall i) \]  \hspace{1cm} (8c,d).

Since the utility function can be divided into two separate partial utility functions with independent time and cost constraints, two partial utility functions can be maximized also independently. In other words, time can be allocated to meet the available time budget while cost can be allocated under the budget constraint. Therefore, we can only estimate the coefficients of time and cost independently. On the other hand, what is required for a value of time estimation is the relation between the marginal utility with respect to time and the marginal utility with respect to cost. This means we need a relationship of the two parameters in order to obtain the ratio of the two marginal utilities. Therefore, we cannot use the results of independently estimated coefficients based on the above model.

This problem can be illustrated with a simple example. Assume a Cobb-Douglass type as a typical additive separable function. Then suppose that leisure activities can be categorized into two discrete types: out-of-home activity and in-home activity. Then consumer’s resource allocation problem can be formulated as

\[ \text{max} \quad U_n = \xi_1^T \ln T_{n1} + \xi_2^T \ln T_{n2} + \xi_1^C \ln C_{n1} + \xi_2^C \ln C_{n2} \]  \hspace{1cm} (9)

subject to

\[ T_{n1} + T_{n2} + t_{ni} = T_n^o \]  \hspace{1cm} (10a)

\[ C_{n1} + C_{n2} + c_{ni} = Y_n \]  \hspace{1cm} (10b)

\[ T_{ni} \geq 0, \ C_{ni} \geq 0 \hspace{0.5cm} (\forall i) \]  \hspace{1cm} (10c,d)

where \( i = 1 \) means the out-of-home activity and \( i = 2 \) means the in-home activity. \( \xi_1^T, \xi_2^T, \xi_1^C, \xi_2^C \) are the unknown coefficients. The solutions of this problem are:
Then, we may introduce error terms into the above equations. Censored regression models can be derived from this approach. If the error terms follow independent normal distributions, the model can be estimated with the Tobit approach. However, within this framework, we can estimate only $\xi_1^T$ and $\xi_2^C$. On the other hand, to evaluate the value of time, the ratio of the coefficient of time to the coefficient of cost is required as shown in equation (12):

$$VOT_{ni} = \frac{\partial U/\partial T_{ni}}{\partial U/\partial C_{ni}} \bigg|_{U = U_{max}} = \frac{C_{ni}}{T_{ni}} \cdot \frac{\xi_1^T}{\xi_2^C}$$

(12).

Therefore, we need to improve or reconsider the model in order to calculate the value of time.

3. DISCRETE-CONTINUOUS MODEL FOR LEISURE ACTIVITIES

The model

The technical problem pointed out in the previous section is due to the independent time and the cost allocation in the simple model. Thus we can solve this problem by introducing an interaction between time and cost into the model. Therefore, we formulate a discrete-continuous choice model of joint decision-making on activity type choice and time and cost allocation for their activities. The basic formulation and estimation method of the discrete-continuous model are discussed in the econometric literatures, for example, Hanneman (1984) and Dubin and McFadden (1984). The discrete-continuous model has been applied in transportation, for example, for the choice of vehicle type holdings and usage (see De Jong, 1997) and activity type choice and duration of allocated time (see Kitamura et al. 1996).

First, consider the consumer’s resource allocation on non-work days. Next, we assume that the consumers will choose if out-of-home leisure activities or not on a given non-work day. They will conduct both in-home leisure activity and the out-of-home leisure activity if they choose to participate in an out-of-leisure activity, whereas they will conduct only in-home lei-
sure if they do not choose to participate the out-of-home leisure activity. This decision-making behavior can be formulated as a discrete choice model. We assume the functional form of utility function to be of Cobb-Douglass-type function eq.(13):

$$\max \ U_n = \xi_1^T \ln(t_n + 1) + \xi_2^T \ln T_{n2} + \xi_1^C \ln(C_{n1} + 1) + \xi_2^C \ln C_{n2} \tag{13}$$

Note that one is added to both the time and the cost which are allocated to out-of-home leisure. This is because it becomes impossible to calculate the utility and the marginal utility when zero time and cost are allocated to the out-of-home activities otherwise. Then, the consumer’s utility-maximization under the condition that the individual conducts out-of-home leisure can be formulated as follows:

$$\max \ U_{n\text{out}} = \xi_1^T \ln(t_n + 1) + \xi_2^T \ln T_{n2} + \xi_1^C \ln(C_{n1} + 1) + \xi_2^C \ln C_{n2} \tag{14}$$

subject to

$$T_{n1} + T_{n2} + t_{n1} = T_n^o \tag{15a}$$

$$C_{n1} + C_{n2} + c_{n1} = Y_n \tag{15b}$$

$$T_{ni} > 0, \ C_{ni} > 0 \quad (\forall i) \tag{15c,d}.$$

Note that the allocated time and cost under this condition should be positive because the consumer must allocate some to the out-of-home leisure activity. The solutions can be derived from the first-order conditions as follows:

$$T_{n1} = \frac{\eta_1^T}{\eta_1 + \eta_2} \left[ T_n^o - t_{n1} - \frac{\eta_2^T}{\eta_1 + \eta_2} \right], \quad T_{n2} = \frac{\eta_2^T}{\eta_1 + \eta_2} \left[ T_n^o - t_{n1} + 1 \right] \tag{16a}$$

$$C_{n1}^* = \left[ Y_n - c_{n1} - \frac{\eta_2^C}{\eta_1 + \eta_2} \right], \quad C_{n2}^* = \frac{\eta_2^C}{\eta_1 + \eta_2} \left[ Y_n - c_{n1} + 1 \right] \tag{16b}.$$

By substituting these solutions into the direct utility function, we can derive the conditional indirect utility function shown as:

$$V_{\text{out}} = \left( \xi_1^T + \xi_2^T \right) \ln \left( T_n^o - t_{n1} + 1 \right) + \left( \xi_1^C + \xi_2^C \right) \ln \left( Y_n - c_{n1} + 1 \right) + v \tag{17}$$

where $v$ means

$$v = \xi_1^T \ln \xi_1^T + \xi_2^T \ln \xi_2^T + \xi_1^C \ln \xi_1^C + \xi_2^C \ln \xi_2^C - \left( \xi_1^T + \xi_2^T \right) \ln \left( \xi_1^T + \xi_2^T \right) - \left( \xi_1^C + \xi_2^C \right) \ln \left( \xi_1^C + \xi_2^C \right)$$
Next, the conditional indirect utility function under the condition that the consumers do not conduct out-of-home leisure will be directly derived from the direct utility function, because all of available time and budget will be allocated to in-home leisure. It is

$$V_{\text{home}} = \frac{\xi^T}{\xi^T} \ln \left( r^+ \right) + \xi^C \ln \left( y_n \right)$$  \hspace{1cm} (19).$$

We introduce the error component into the above indirect utility function as

$$\tilde{V}_n = V_n + \eta_n$$ \hspace{1cm} (20)$$

where \( \eta_n \) is the error term. If we assume \( \eta_n \) independently and identically Gumbel distributed, the discrete choice of types of activities can be formulated as the binary logit model.

Then, we introduce the second error terms into the allocated time and cost equations for out-of-home leisure activities as

$$T_{n1} = \pi^T \left[ t^{n1}_n - t_{n1} \right] - \left( 1 - \pi^T \right) + \sigma^T u_{n1}$$ \hspace{1cm} (21a)$$

$$C_{n1} = \pi^C \left[ c^{n1}_n - c_{n1} \right] - \left( 1 - \pi^C \right) + \sigma^C u_{n1}$$ \hspace{1cm} (21b)$$

where \( u_{n1}^T, u_{n1}^C \) are the error components and \( \sigma^T > 0, \sigma^C > 0 \).

The time and cost allocated to out-of-home leisure activities can be observed only if the individuals participate in out-of-home leisure. We can summarize the above models into a censored regression model shown as:

$$T_{n1} = \begin{cases} \pi^T \left[ t^{n1}_n - t_{n1} \right] - \left( 1 - \pi^T \right) + \sigma^T u_{n1} & \text{if } \tilde{V}_{\text{out}} > \tilde{V}_{\text{home}} \\ 0 & \text{otherwise} \end{cases}$$ \hspace{1cm} (22a)$$

$$C_{n1} = \begin{cases} \pi^C \left[ c^{n1}_n - c_{n1} \right] - \left( 1 - \pi^C \right) + \sigma^C u_{n1} & \text{if } \tilde{V}_{\text{out}} > \tilde{V}_{\text{home}} \\ 0 & \text{otherwise} \end{cases}$$ \hspace{1cm} (22b).$$
Parameter Estimation

The above model is estimated with the method proposed by Lee (1983) and Lee and Trost (1978). First, we assume that both $T_{n1}$ and $C_{n1}$ follow mutually independent standard normal distributions. Next, since we have assumed $\eta_{n1}$ to be i.i.d. Gumbel, we obtain the following probability distribution function with respect to $\epsilon$:

$$F_{n1}(\epsilon) = \text{Prob}(\eta_{n1} < \epsilon) = \frac{\exp(\epsilon)}{\exp(\epsilon) + \exp(\eta_{n1})} \tag{23}$$

Then, we introduce a new function $J(\epsilon)$ which converts the probabilistic variable following the specific distribution function into the probabilistic variable following the standard normal distribution function. Let $\epsilon^*$ be the converted variable, then the converted probabilistic variable $\epsilon^*$ can be derived from the original variable as:

$$\epsilon^* = J(\epsilon) = \Phi^{-1}(F_{n1}(\epsilon)) \tag{24}$$

where $\Phi(\cdot)$ is the distribution function of standard normal distribution. We assume that the two pairs of error terms $(u_{n1}^T, \epsilon^*)$ and $(u_{n1}^C, \epsilon^*)$ are bivariately distributed with mean 0, covariance 1 and the correlation coefficients of $\rho^T, \rho^C$ respectively. If these two correlation coefficients are zero, the pairs of error terms $(u_{n1}^T, \epsilon^*)$ and $(u_{n1}^C, \epsilon^*)$ are independent from each other. Finally, the likelihood of the above-mentioned model with respect to time and cost can be formulated as follows:

$$\ln T_n^T = d_{n1}^T \ln \left[ \frac{1}{\sigma^T} \Phi \left( \frac{T_{n1} - \pi^T T_{n1} + (1 - \pi^T)}{\sigma^T} \right) + \ln \Phi \left( \sqrt{1 - (\rho^T)^2} \Phi \left( \frac{T_{n1} - \pi^T T_{n1} + (1 - \pi^T)}{\sigma^T} \right) \right) \right] + d_{n1}^T \ln \left[ F_{n1}(\epsilon^*) \right] \tag{25a}$$

$$\ln T_n^C = d_{n1}^C \ln \left[ \frac{1}{\sigma^C} \Phi \left( \frac{C_{n1} - \pi^C C_{n1} + (1 - \pi^C)}{\sigma^C} \right) + \ln \Phi \left( \sqrt{1 - (\rho^C)^2} \Phi \left( \frac{C_{n1} - \pi^C C_{n1} + (1 - \pi^C)}{\sigma^C} \right) \right) \right] + d_{n1}^C \ln \left[ F_{n1}(\epsilon^*) \right] \tag{25b}$$
where \( \phi(\cdot) \) is the standard normal probability density function, \( d_{q_{\text{out}}} \) is a dummy variable that is equal to one if the individual conducts an out-of-home leisure activity and is equal to zero if not \( d_{q_{\text{hom}}}=1-d_{q_{\text{out}}} \). The unknown parameters are estimated by maximizing over all individuals:

\[
\sum_{n} \left( \ln T_n^U + \ln T_n^C \right) \rightarrow \max
\]  

(26).

We can calculate the values of time of the two activities with the estimated parameters:

\[
\begin{align*}
VOT_{n1} &= \frac{\partial U_1}{\partial T_{n1}} \bigg|_{U=U_{\text{max}}} = \frac{C_{n1} + 1}{T_{n1} + 1} \xi_1^T, \\
VOT_{n2} &= \frac{\partial U_2}{\partial T_{n2}} \bigg|_{U=U_{\text{max}}} = \frac{C_{n2}}{T_{n2}} \xi_2^T.
\end{align*}
\]  

(27).

There is one further technical problem for parameter estimation. For the binary logit model, we need to assume travel times and travel costs for the out-of-home activity for the individuals who did not participate in one. We impute their values with simple linear regression models based on the individual socio-demographics of the respondents. This may cause the following two problems. One is the possibility that the individuals participating in the out-of-home leisure may have different preference from the individuals not participating. However, we assume that these two types of individuals have the same preference. The other is the possibility of a correlation between the error term of the linear regression model and the error terms of the binary logit model and/or the censored regression model. The validity of this assumption should be addressed below.

The above model recognizes three types of errors introduced for the indirect utility function and the time and cost allocated. The error sources considered are summarized into the following: the measurement error, specification error and the randomness inherent to human nature. As the analyst cannot recognize these error sources in the postulated error structure, the possibility of correlation has to be judged by the empirical results.

We note that the value of time can be estimated with only the discrete-choice model, which is a part of our proposed model. However, doing so reduces the amount and the quality of information used for the estimation. The conditional indirect utility functions of two alternatives differ only in terms of travel time and travel cost. That the decision about activity participation is based only on the travel conditions may be too much simple from a practical viewpoint. Thus, we add information on people’s behavior to the discrete-choice model by introducing the censored regression model for the allocated time and cost. The second problem is caused by the low accuracy of the linear regression model for the estimation of the unobserved travel times and costs. This problem may be eased by adding behavioral information.
about the allocated time and cost. We will compare our method and the activity-type discrete-choice model to see how relevant these two problems are.

4. VALUE OF LEISURE TIME ON NON-WORK DAY

Data sources and sample construction

The data sources used for the empirical analyses are the following two: an original survey which was designed and conducted by a study team of the University of Tokyo for the ward area of Tokyo, Japan in 2002, the other is the Mobidrive survey which was designed and conducted by a study team involving the Swiss Federal Institute of Technology (ETH) for the city of Karlsruhe Germany in 1999. The Tokyo survey collected information on all activity episodes undertaken by individuals from 221 respondents over a two-week continuous period (see Kato and Kouchi, 2004 and Kouchi, 2003 for details of the survey and the sampling). The information collected on the activity episodes includes the type of activity (based on 8 categories), the duration and the expenditure for the activity, travel time and cost and individual and household socio-demographics. The Mobidrive survey collected information on all activity episodes undertaken by individuals from 159 respondents over a six-week continuous period (see Axhausen et al., 2002 for details of the survey and the sampling). The information collected on the activity episodes includes the type of activity, start and end times of activity participation, expenditure of activity participation, travel time and cost and individual and household socio-demographics.

We generated the sample for analysis with the following steps for each survey. First, we selected only weekend day data. This is done because individuals will participate in more leisure activity with longer durations for out-of-home leisure than during weekdays. Second, for comparativity, only the data of individuals of 18 years or older is used for the analysis. The Tokyo survey covers the individuals over 17 year-old whereas the Mobidrive survey covers individuals over 6 year-old. Third, only workers were selected from the original sample data. This is because the workers may have enough incentives to participate in leisure activities during weekends than non-workers. The workers include both permanent workers and part-time workers. Fourth, we selected data of one of two weekends for the Tokyo data whereas all weekends were selected for the Karlsruhe data. The weekend excluded from the Tokyo’s analysis was part of a national holiday and it is expected that individual will participate in longer duration of activities during a three-day weekend than during an ordinary weekend.
As for individual behavior, we assume that individuals allocate their resources under the two-day constraints of the weekend because individuals may consider the two days of weekend as one unit values of the activity participation decision-making. Based on this assumption, we calculate the individual constraints as follows. First, the time constraint was calculated by subtracting the duration of obligatory activities like sleeping, having meals and taking a bath from forty-eight hours in the Tokyo case, whereas for the Karlsruhe case it was calculated by subtracting the necessary time from forty-eight hours by assuming the duration of obligatory activities as nine hours per day. The budget constraint was calculated as follows. For Tokyo, we assume the budget to be one-fourth of the monthly disposable income reported by the individuals, which excludes regular expenditure such as house rent, insurance cost, commuting cost, education cost and so on. On the other hand, for Karlsruhe, we calculate the two-day budget constraint after estimating the weekly wage of individuals based on socio-demographic data.

The final sample for analysis includes the weekend time-and-cost-use information of 198 individuals for Tokyo and 54 individuals for Karlsruhe with 198 weekends in Tokyo and 323 weekends in Karlsruhe. Table 1 shows daily allocations of time and cost to out-of-home leisure and travel as well as the time and cost constraints. From this table we can find the following difference. First, the mean of out-of-leisure activity duration in Tokyo is shorter than that in Karlsruhe by more than one hour per day. Besides, the share of individuals participating the out-of-home leisure in Tokyo (58.6%) is smaller than that in Karlsruhe (89.7 %). These may be due to differences in definition of “out-of-home activities” between in Tokyo and in Karlsruhe. The daily out-of-door activities like walking with an dog, gardening around home, physical stretching and jogging are not included as out-of-home activities in the Tokyo data while all out-of-home activities are taken into account in the Mobidrive data. Second, the individuals in Tokyo travel less than those in Karlsruhe. This is probably because the Tokyo individuals are sampled mainly in the densely-populated core area where they can access the commercial districts quickly while the individuals in Karlsruhe are sampled randomly from all over the area. Third, the ratio of the expenditures for traveling and participating in out-of-home activities to the wage rate is smaller in Tokyo than in Karlsruhe. This may reflect a difference of people’s life style on weekend days between Japan and Germany. In Japan, as people usually go shopping almost everyday to buy foods and commodities. On the contrary, German people tend to go shopping intensively on Saturday. We note that the average wage rate of the individuals in Tokyo is higher than the average wage rate of Tokyo, 2890 yen/hour. This is partly because the sample individuals inhabit at the core area of Tokyo where many people with higher incomes choose to live.
Empirical analysis

We assume the parameters $\xi^T_{11}, \xi^T_{21}, \xi^C_{11}, \xi^C_{22}$ in the utility function eq.(9) have the following exponential function form: $\xi^T_{11} = \exp(\beta^T_{11})$, $\xi^T_{21} = \exp(\beta^T_{21})$, $\xi^C_{11} = \exp(\beta^C_{11})$, $\xi^C_{22} = \exp(\beta^C_{22})$, because the marginal utility with respect to the allocated time and cost to leisure activities should be positive. The best models for the imputation of the non-observed costs and times are shown below. They are formulated as ratios with the available budgets:

Tokyo

number of weekends with out-of-home leisure =116

<table>
<thead>
<tr>
<th>Budget</th>
<th>Unit</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out-of-home leisure time</td>
<td>hour</td>
<td>3.92</td>
<td>3.06</td>
</tr>
<tr>
<td>Out-of-home leisure expenditure</td>
<td>yen</td>
<td>6797</td>
<td>7621</td>
</tr>
<tr>
<td>Travel time for leisure activity</td>
<td>hour</td>
<td>1.72</td>
<td>1.97</td>
</tr>
<tr>
<td>Travel cost for leisure activity</td>
<td>yen</td>
<td>1578</td>
<td>3133</td>
</tr>
</tbody>
</table>

number of weekends =198

<table>
<thead>
<tr>
<th>Budget</th>
<th>Unit</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time budget</td>
<td>hour</td>
<td>30.1</td>
<td>5.57</td>
</tr>
<tr>
<td>Expenditure budget</td>
<td>yen</td>
<td>18941</td>
<td>19883</td>
</tr>
<tr>
<td>wage rate</td>
<td>yen/hour</td>
<td>3382</td>
<td>3220</td>
</tr>
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</table>

Karlsruhe

number of weekends with out-of-home leisure =290

<table>
<thead>
<tr>
<th>Budget</th>
<th>Unit</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out-of-home leisure time</td>
<td>hour</td>
<td>6.36</td>
<td>4.48</td>
</tr>
<tr>
<td>Out-of-home leisure expenditure</td>
<td>DM</td>
<td>85.3</td>
<td>97.7</td>
</tr>
<tr>
<td>Travel time for leisure activity</td>
<td>hour</td>
<td>2.63</td>
<td>1.87</td>
</tr>
<tr>
<td>Travel cost for leisure activity</td>
<td>DM</td>
<td>45.2</td>
<td>82.5</td>
</tr>
</tbody>
</table>

number of weekends =323

<table>
<thead>
<tr>
<th>Budget</th>
<th>Unit</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time budget</td>
<td>hour</td>
<td>30.0</td>
<td>-</td>
</tr>
<tr>
<td>Expenditure budget</td>
<td>DM</td>
<td>273.5</td>
<td>148.5</td>
</tr>
<tr>
<td>wage rate</td>
<td>DM/hour</td>
<td>19.2</td>
<td>12.7</td>
</tr>
</tbody>
</table>

*1 US dollar = 121.63 yen (average in November 2002) = 1.863 DM (average in September 1999)

Empirical analysis

We assume the parameters $\xi^T_{11}, \xi^T_{21}, \xi^C_{11}, \xi^C_{22}$ in the utility function eq.(9) have the following exponential function form: $\xi^T_{11} = \exp(\beta^T_{11})$, $\xi^T_{21} = \exp(\beta^T_{21})$, $\xi^C_{11} = \exp(\beta^C_{11})$, $\xi^C_{22} = \exp(\beta^C_{22})$, because the marginal utility with respect to the allocated time and cost to leisure activities should be positive. The best models for the imputation of the non-observed costs and times are shown below. They are formulated as ratios with the available budgets:

Tokyo

$$t/T^o = 0.0418 + 0.0177 \cdot AGE + 0.0155 \cdot PART$$

$$c/I = 0.1026 - 0.0263 \cdot LOW + 0.0280 \cdot SEX + 0.0785 \cdot AGE - 0.0372 \cdot WORK$$
Karlsruhe

\[
t/T^o = 0.0309 - 0.0122 \cdot \text{CHILD} + 0.000364 \cdot \text{AGE}^2 + 0.00477 \cdot \text{CAR} + 0.00986 \cdot \text{SEASON}
\]

\[
(3.14) \quad (-1.55) \quad (1.70) \quad (1.26) \quad (1.77)
\]

\[R = 0.18\]

\[
c/I = 0.0580 + 0.0604 \cdot \text{CHILD} + 0.0198 \cdot \text{FAMILY} + 0.0369 \cdot \text{CAR}
\]

\[
(1.43) \quad (1.57) \quad (1.84) \quad (2.11)
\]

\[R = 0.25\]

where \(\text{AGE}\) is 1 if the individual’s age is over 65 year-old and 0 otherwise; \(\text{PART}\) is 1 if the individual has a partner and 0 otherwise; \(\text{LOW}\) is 1 if the annual income is lower than five million yen and 0 otherwise; \(\text{SEX}\) is 1 if the individual is a male and 0 otherwise; \(\text{WORK}\) is 1 if the individual permanent work and 0 otherwise; \(\text{CHILD}\) is 1 if the individual has one or more children and 0 if he/she has no child; \(\text{AGE}^2\) means the age of individual; \(\text{FAMILY}\) means the number of family members; \(\text{CAR}\) means the number of private car ownership; and \(\text{SEASON}\) is 1 if the individual hold a seasonal ticket for public transport and 0 otherwise. The parentheses after the regression equations show the coefficients of determinations and the parentheses below the equations present the t-statistics of each explanatory variable.

The final leisure resource allocation models are presented in Table 2 and 3 for Tokyo and Karlsruhe, respectively. From these results, we can point out the following. First, the chi-square tests show that the null hypothesis that the estimated model is equal to the initial model with variances 1 and coefficients 0 is rejected for all four models. Second, all parameters of the discrete-continuous choice model of Tokyo are significant at the 95% level of confidence whereas only in-home leisure time parameters of the discrete choice model of Tokyo is significant at the same level. Third, the correlation coefficient between the error term of discrete choice model and the continuous time-duration model is around -0.4 with the high significance. Fourth, in the discrete-continuous choice model of Karlsruhe, two correlation coefficients are not significant at any level of confidence whereas the two parameters for out-of-home leisure time, but out-of-home leisure expenditure are not significant at 80% level of confidence and the others are significant at 99% level of confidence. Finally, in the discrete choice model of Karlsruhe, the parameters for out-of-home leisure time and the in-home leisure expenditure are significant at 90% level of confidence while those for in-home leisure time and the out-of-home leisure expenditure are not significant.
Then the values of time of in-home and out-of-home leisure are calculated based on the estimated parameters. Table 4 shows the mean values of leisure time for the two cities. The values of the out-of-home leisure time tend to be larger than the values of in-home leisure time. This is intuitive because out-of-home leisure participants have a higher incentive in participating in social activities or are more proactive than the individuals who stay at home. Here, we need to note that the expected values of the two activities should be the same for out-of-home leisure participants, because they allocate the resources so that the marginal utilities with respect to time and cost are equal among different activities. Thus the difference should be explained by the difference between the VOTs of participants and non-participants. Second, the ratio of values of out-of-home to that of in-home leisure estimated from the discrete-

<table>
<thead>
<tr>
<th>Table 2: Parameter estimation results: activity-type and resource allocation discrete-continuous model vs. activity-type discrete choice model in Tokyo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variables</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Out-of-home leisure time</td>
</tr>
<tr>
<td>In-home leisure time</td>
</tr>
<tr>
<td>Out-of-home leisure expenditure</td>
</tr>
<tr>
<td>In-home leisure expenditure</td>
</tr>
<tr>
<td>Correlation coefficient (time)</td>
</tr>
<tr>
<td>Correlation coefficient (cost)</td>
</tr>
<tr>
<td>Variance of time</td>
</tr>
<tr>
<td>Variance of cost</td>
</tr>
<tr>
<td>Initial log-likelihood</td>
</tr>
<tr>
<td>Final log-likelihood</td>
</tr>
<tr>
<td>Number of observation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3: Parameter estimation results: activity-type and resource allocation discrete-continuous model vs. activity-type discrete choice model in Karlsruhe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variables</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Out-of-home leisure time</td>
</tr>
<tr>
<td>In-home leisure time</td>
</tr>
<tr>
<td>Out-of-home leisure expenditure</td>
</tr>
<tr>
<td>In-home leisure expenditure</td>
</tr>
<tr>
<td>Correlation coefficient (time)</td>
</tr>
<tr>
<td>Correlation coefficient (cost)</td>
</tr>
<tr>
<td>Variance of time</td>
</tr>
<tr>
<td>Variance of cost</td>
</tr>
<tr>
<td>Initial log-likelihood</td>
</tr>
<tr>
<td>Final log-likelihood</td>
</tr>
<tr>
<td>Number of observation</td>
</tr>
</tbody>
</table>
The continuous model is smaller than the ratio in the discrete choice model. Especially the values of in-home leisure time estimated from the discrete choice model are much lower than the values of out-of-home leisure time. The values of leisure time estimated as 4.65 DM and 0.0092 DM from the discrete choice model in Karlsruhe is so small that we can judge these values as unrealistic. Third, the values of out-of-home leisure time estimated from discrete-continuous model are eventually almost the same as the average wage rate of sample individuals in both cities while the values of out-of-home leisure time estimated from discrete choice model are very different from the average wage rate, higher in Tokyo and lower in Karlsruhe. Fourth, the ratio of value of in-home leisure time to the average wage rate is higher in Tokyo than in Karlsruhe. This may mean that the individuals in Tokyo find more fun or interest in domestic activities than those in Karlsruhe or that those in Tokyo find less attractiveness in out-of-home activities than those in Karlsruhe.

From these results, we here conclude that the discrete choice models for the activity type choice provide outputs with low levels of statistical confidence and unrealistic values of time. Therefore, we will proceed to analyze the individual values of leisure time only with the discrete-continuous models.

Figure 1 presents the accumulated distributions of ratio of individuals’ simulated values of leisure time to average wage rate in Tokyo and Karlsruhe. The values of leisure time are simulated by applying the estimated parameters to the observed individual allocated times and costs. This shows that the values of leisure time vary from zero to more than several times of the average wage rate. This variety mainly stems from the various pattern of allocation of time and cost as well as the error components in the model. The distributions of two leisure times are similar in Tokyo while those are quite different in Karlsruhe. Especially, the distribution of in-home leisure in Karlsruhe shows that there are many individuals with values of in-home leisure time less than their wage rate.

<table>
<thead>
<tr>
<th></th>
<th>discrete-continuous model</th>
<th>discrete choice model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>out-of-home</td>
<td>in-home</td>
</tr>
<tr>
<td>Tokyo (yen/hour)</td>
<td>3385.2</td>
<td>2828.0</td>
</tr>
<tr>
<td>(1.00)</td>
<td>(0.84)</td>
<td>(1.50)</td>
</tr>
<tr>
<td>Karlsruhe (DM/hour)</td>
<td>19.15</td>
<td>8.57</td>
</tr>
<tr>
<td>(1.00)</td>
<td>(0.45)</td>
<td>(0.24)</td>
</tr>
</tbody>
</table>

* ( ) means the ratio of the value of time to the average wage rate
Figure 1: Simulated individual’s values of leisure time of Tokyo (upper) and Karlsruhe (lower)
Figure 2: Individual wage rate vs. ratio of value of in-home leisure time to personal wage rate

Figure 3: Individual wage rate vs. ratio of value of in-home leisure time to average wage rate
Figure 2 presents the individual wage rates versus the simulated ratio of individual values of in-home leisure time to personal wage rate, and Figure 3 presents the individual wage rates versus the simulated ratio of individual values of in-home leisure time to average wage rate. Although there seems to be some correlation between individual wage rates and value of in-home leisure time in Karlsruhe, but none in Tokyo. One of the possible reasons for this is we have more observations for the Karlsruhe respondents. Remember that the results of Schilch and Axhausen (2005) suggest very large levels of intrapersonal variability, which are visible in the Tokyo case.

5. CONCLUSIONS

This paper estimated empirically the value of leisure time on weekend days by a resource allocation model. After pointing out a technical problem in the estimation of resource allocation model with additive separable utility functions, we developed a discrete-continuous model in the context of individual’s time and cost allocation to two types of discretionary activities; out-of-home leisure and in-home leisure. We apply it to two individual’s activity diary surveys collected in Tokyo, Japan and Karlsruhe, Germany. We empirically valuate the values of leisure time in the two cities based on the estimated parameters. The results show that the value of out-of-home leisure time is nearly equal to the wage rate in both cities while the value in-home leisure time is about 84 % in Tokyo and 45 % in Karlsruhe of the wage rate respectively.

As the further research topics, we will point out four issues. First, we focused on the formulation with the Cobb-Douglas type as an additive separable utility function. However, as there is no reason for using only this type, we need to analyze with the other type as well. Especially we need to discuss the possibility of using a non additive separable utility function for the valuation of leisure time. Second, we classified the leisure activities into only two types: in-home leisure and out-of-home leisure. As out-of-home leisure includes various activities and they may have different values of time, we should analyze it further in details. Third, we did not consider the heterogeneity of individual preference. However, as Kato and Imai (2004) shows, there is possibly the diversity in preference among individuals, and this may impact on the estimated values of times. Fourth, we used the simply linear regression models for imputation of unobserved travel times and travel costs. We may estimate them better if we use the techniques of travel demand analysis such as the transport mode choice and the destination choice. In such a case, we should consider how to treat the correlation of newly introduced error terms.
ACKNOWLEDGMENTS

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REFERENCES


