Intra-household interaction in a nuclear family: A utility-maximizing approach

Hironori Kato[a,*] and Manabu Matsumoto[b]

[a] *Department of Civil Engineering, School of Engineering, University of Tokyo,*

7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

[b] *West Japan Railway Company*

2-4-24 Shibata, Kita-ku, Osaka 530-8341, Japan

Abstract

This paper investigates the joint resource allocation of households using a utility-maximizing model. The joint time-allocation model is formulated, from which a nonlinear Tobit model is derived. The model parameters are estimated using empirical data collected through household time allocation surveys held in 2003 in Tokyo and Toyama, Japan. Four models—a weekday model and a weekend day model for Tokyo and Toyama each—are estimated. The empirical analysis reveals the common characteristics between the two cities—with respect to the child's gender; the husband's weekly non-working days, allowance, and job; and the wife's age and job—that significantly influence the household's welfare. The empirical analysis also reveals different characteristics between the two cities. First, the greater the number of children in a household, the higher is the significance of the husband and wife's joint out-of-home leisure activity on a weekday for household welfare in Tokyo, and the lower is the same in Toyama. Second, the greater the non-working days of the husbands, the lower is the significance of their individual out-of-home leisure activities on a weekday for household welfare in Tokyo and the higher is the same in Toyama. These characteristics may reflect the local's attitudes in intra-household interaction.

Keywords: Intra-household interaction; Utility-maximizing model; Nuclear family

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[*] Corresponding author. TEL: +81-3-5841-7451; FAX: +81-3-5841-8506

E-mail address: kato@civil.t.u-tokyo.ac.jp

1.1 Introduction

Thus far, activity-based travel models have typically assumed that an individual makes a decision on its own activities. Although the assumption of individual decision-making is reasonable for some personal activities, it may not be suitable for, for example, social activities in which more than one individual participates. The joint decision-making of household members is also important from the viewpoint of transportation planning. This is because a transportation policy will impact an individual's behavior not only directly but also indirectly through a change in household behavior. This paper aims to investigate intra-household interaction through the development of a household time allocation model using empirical activity diary data. This paper focuses on non-obligatory activities. The model proposed in this paper uses the approach similar to Zhang and Fujiwara (2006), which assumes the household utility maximization. It enjoys three refinements over their research. First, we explicitly consider a child in the model. This is because we expect the existence of children to significantly influence the household resource allocation (Jones et al., 1983; Chandraskharan and Goulias, 1999). This paper covers a household with three members: a husband, wife, and child. Second, the model considers not only time allocation but also the monetary budget allocation of a household. This is because the intra-household interactions and group dynamics in activity-travel scheduling and the utility derived from such interactions are inextricably linked to monetary expenditures (Meister et al., 2005). Third, we empirically compare the intra-household interactions between a weekday and a weekend day, between two different cities.

The paper is organized as follows. Section 2 presents a brief review of past researches that examined intra-household interaction. Section 3 describes a household joint resource allocation model with a microeconomic model framework. Section 4 describes an activity diary survey conducted in two cities in Japan, and Section 5 examines the application of the proposed model. The final section briefly summarizes the study and presents topics for further research.

2.1 Literature Review on Intra-household Interaction

Although the importance of interpersonal dependencies is widely recognized in transportation planning, most of the research efforts to date have accommodated household interaction effects, at best, by using household-level characteristics as explanatory variables in individual-level models (Srinivasan and Bhat, 2004). An activity-based travel model incorporating household decision mechanisms has gradually been studied by transportation researchers. Timmermans (2006) extensively reviews the past research dealing with household activity analysis with an explicit consideration of intra-household interactions. He classifies them into the following three models: micro-simulation models (Pribyl and Goulias, 2005), rule-based models (Arentze and Timmermans, 2000, 2004; Miller and Roorda, 2003), and utility-maximizing models. The amount of analytical research—especially in conjunction with the utility-maximizing concept—has increased rapidly over the last couple of years. There are two approaches to the utility-maximizing model. One approach is the discrete choice model that was addressed by Vovsha et al. (2004), Bradley and Vovsha (2005), Scott and Kanaroglou (2002), Wen and Koppelman (1999), Gliebe and Koppelman (2002), Srinivasan and Bhat (2005), and Srinivasan and Athuru (2005), among others. The other approach is the time-allocation model that has been explored in works including Zhang et al. (2003), Zhang and Fujiwara (2006), and Zhang et al. (2005). The present research belongs to the category of studies adopting the time-allocation model approach.

The household time allocation analysis originally began from the seminal work of Becker (1965). He extended a traditional individual behavioral model system to a household time allocation one by introducing time into both the utility function and the household production function. We term this type of model a unitary model. The unitary model treats a household as though it were an individual. A household has a household utility function comprising the aggregated amounts of time and goods of the household, and it has a pooled time budget and monetary budget. The model assumes the constrained maximization of the household utility function with respect to the consumption of time and goods. Although the unitary model is simple and comprehensible, it has been criticized by a number of researchers who are mainly concerned with intra-household interaction. First, they claim the unitary model is unacceptable from the viewpoint of individualism that constitutes the core of microeconomics (Chiappori, 1992). Second, they criticize that the unitary model ignores the interaction among household members and deals with the joint decision-making process as a black box. Third, the unitary model only considers allocations between households and disregards questions concerning intra-household inequalities, which may lead to incorrect welfare implications (Haddad and Kanbur, 1990). For example, a tax reform may increase the welfare of households but may not improve the inequity among household members (Apps and Rees, 1988). Fourth, although the demand functions in the unitary model are required to satisfy homogeneity, Walras' law and Slutsky equations (or the revealed preferences restriction) are often not supported by empirical analyses as in the case of an ordinary individual consumer model, (e.g., Kooreman and Kapteyn, 1986).

In order to overcome the above problems of the unitary model, three approaches have been proposed thus far. The first approach is to incorporate the difference in the preferences of household members into the unitary model. First, Samuelson (1956) proposes a household utility function comprising household members' individual utility functions with an analogy of the social welfare function. He assumes that the household utility function should be developed with a hypothetical consensus among household members. Second, Becker (1974a, b) proposes the "rotten kid theorem" that assumes the existence of a household head. If a family has a head who "cares sufficiently about all other members to transfer general resources to them, then redistribution of income among members would not affect the consumption of any member, as long as the head continues to contribute to all." "If a head exists, other members also are motivated to maximize family income and consumption, even if their welfare depends on their own consumption alone." Third, Becker (1981) proposes an introduction to altruism in the decision-making of households. He defines altruism as the direct dependence of one person's utility on another's.

The second approach is based on game theory. This type of model assumes that each household member has their own utility function and analyzes the interactions among them in terms of cooperative or non-cooperative game theory. Leuthold (1968), Browning (2000), and Chen and Woolley (2001) apply non-cooperative game theory to the decision-making of households. This model assumes the utility maximization of household members, taking other individuals' behavior as given; it analyzes, for example, a Cournot-Nash solution. However, a solution of the non-cooperative game is not always efficient from the viewpoint of Pareto efficiency (Kooreman and Kapteyn, 1990). On the other hand, cooperative game theory analyzes the negotiation on marriage between a husband and wife (Manser and Brown, 1980; McElroy and Horney, 1981). Each player has his/her own threat point, which is defined as his/her opportunity cost of being married. The opportunity cost should be derived from other models. The Nash-bargained solution to the allocation problem of two players can be obtained by the so-called Nash product (Nash 1950, 1953), that is, the product of their gains from marriage. The cooperative game model guarantees Pareto efficiency, but does not imply a unique equilibrium (Schultz, 1990).

The third approach uses a model that requires only Pareto efficiency. This model is named the collective model (Chiappori, 1988, 1992; Bourguignon and Chiappori, 1992). The collective model has been proposed as a criticism against the unitary model and as a generalization of the cooperative game model. In the collective model, no other assumption on the Pareto efficiency is made with respect to the decision-making process. This implies that no restriction is imposed a priori on which point of the Pareto frontier will be chosen. Recently, there have been empirical studies based on the collective model, including Chiappori (1997), Fortin and Lacroix (1997), and Aronsson et al. (2001). As Vermeulen (2002) points out, the collective approach has gradually found acceptance in recent microeconomic theory.

The model proposed in the present paper shares a similarity with the model suggested by Samuelson (1956). His model includes the weighted parameters assigned to each member's utility, which are independent of prices and incomes. Chiappori (1992) terms Samuelson's model as a "collective neoclassical case" among the collective models. This suggests that our model is regarded as one of the collective models.

3.1 Model

3.1.1 Formulation of Resource Allocation in a Nuclear Family

We assume a nuclear family with a husband, wife, and child as comprising a household. Each household member chooses one of a set of activities discretely and allocates time and expenditure continuously for a chosen activity. The classification of activities in this study follows the idea of Yamamoto and Kitamura (1999). We classify an activity into two types: obligatory and non-obligatory activities. The obligatory activity is defined as one that an individual is required to engage in within a given period, while the non-obligatory activity is defined as an activity that an individual can choose whether or not to engage in. In our analysis, we classify the above two activities further into the following four activities: non-obligatory activities include (a) out-of-home leisure, namely, activities involving travel such as going shopping and going to the theatre and (b) in-home leisure, namely, activities without travel such as watching television and reading books at home; obligatory activities include (c) required activities, that is, productive or learning activities such as working at the workplace, working at home, and learning at school and (d) fundamental activities, namely, basic activities of human beings such as sleeping, bathing, and having meals at home. We assume that both the time and expenditure allocated to obligatory activities are given and fixed, although the time and expenditure for required activities may be adjusted in the long run, for example, through a change of jobs. In this sense, our model is regarded as a short-term model. As regards out-of-home leisure, we classify it further into two: independent and joint activities. An independent activity involves a single individual alone, while a joint activity involves the collective participation of several individuals. We consider that an individual will choose a type of out-of-home joint leisure activity by selecting members with whom he/she will engage in joint out-of-home leisure.

Next, we set six basic assumptions on the choice of activities of household members. First, we assume that all household members participate in their household joint decision-making process. It may be true that a child that is too young will be unable to choose a type of activity. However, we assume that even such young children can contribute to the joint decision-making through a discussion with their parents, provided they are old enough to communicate with their parents. As the empirical analysis presented later focuses on children aged from six to twelve and who are studying at primary school, we consider this assumption to be satisfied. Second, we assume that an individual does not engage in two or more than two types of activities at one time (monochromic time use). This is due to the independence of defined activities. Kaufman et al. (1991) examine the concept of polychronic time use, such as eating while watching television. Although our model excludes this polychronic time use, it may be possible for an individual to engage in individual activities with other members. For example, a husband and a child go together to the same playground, and the child plays football while the husband watches. In this case, the husband individually watches a football game, but this activity would be meaningless without the existence of his child in the playground. In the extreme sense, any kind of activity can be considered as an individual independent activity. Thus, we define a joint activity as one in which two or more members simply have some interaction at the same location. For analytical simplification, we do not take into account the details of the type of activities each individual engages in. Third, we assume that all individuals who participate in a joint activity can gain common utility from the time and expenditure consumed in the joint activity. It is quite reasonable to consider that the same amount of time is consumed by all household members participating in the same activities; however, it may not seem reasonable to consider that the same amount of expenditure is consumed by all household members participating in the same activities. Nonetheless, we set this assumption simply because we consider that an individual consumes a kind of public good in the joint activity. When the public good is consumed, the amount of consumption should be the same for all the members. Fourth, we assume that the member's income is pooled as a single monetary budget of a household. In reality, the household income is allocated to each household member as, for example, an individual allowance. However, it may be difficult to observe the mechanism of income allocation. As Chiappori (1992) demonstrates theoretically, if we use the "collective model," we need not be concerned about the non-labor income allocation among members. As mentioned earlier, our model is considered as a type of collective model. Therefore, this assumption does not bias our model structure. Fifth, an activity space constraint is not considered explicitly. The activity space availability may impact an individual activity pattern and may be influenced by socio-demographic factors such as the travel modes available. However, for the simplification of the analysis, we ignore the dimension of activity space. Finally, we assume that an individual gains utility not from the consumption of goods but from engaging in the activity. In modeling the individual behavior, we focus on the activity rather than the goods/service consumption. This distinction enriches our resource allocation analysis. For example, consider an example where a household member A purchases a good X on behalf of another member B. Although good X is common between the two members, individual A gains utility from the activity of purchasing X, while individual B gains utility from the activity of consuming X. As these two activities are completely different in terms of their characteristics and the locations where the activities are engaged in, they cannot be considered as a joint activity. We follow an activity-based approach where the behavior of consumers is analyzed not in terms of the consumption of goods but rather in terms of the activity, as suggested by Pollak and Wachter (1975), Juster (1990), and Jara-Diaz (1998).

Then, we formulate the household joint decision-making with the weighted linear group utility function as

$$\max U(U_h, U_w, U_c) = w_h \cdot U_h + w_w \cdot U_w + w_c \cdot U_c \tag{1}$$

subject to

$$t_i^{ind} + t_i^{hwc} + t_i^{hc} + t_i^{wc} + t_i^{hw} + t_i^{\mathrm{home}} = T_i \tag{2}$$

$$\sum_i c_i^{ind} + c^{hwc} + c^{hc} + c^{wc} + c^{hw} = Y \tag{3}$$

$$t^{hwc} = t_h^{hwc} = t_w^{hwc} = t_c^{hwc} \tag{4}$$

$$t^{hc} = t_h^{hc} = t_c^{hc}, t^{wc} = t_w^{wc} = t_c^{wc}, t^{hw} = t_h^{hw} = t_w^{hw} \tag{5}$$

$$t_i^{ind} \geq 0 \, , t^{hwc} \geq 0 \, , t^{hw} \geq 0 \, , t^{hc} \geq 0 \, , t^{wc} \geq 0 \, , t_i^{\mathrm{hom}e} \geq 0 \tag{6}$$

$$c^{hwc} = c_h^{hwc} = c_w^{hwc} = c_c^{hwc} \tag{7}$$

$$c^{hc} = c_h^{hc} = c_c^{hc} \, , c^{wc} = c_w^{wc} = c_c^{wc} \, , c^{hw} = c_h^{hw} = c_w^{hw} \tag{8}$$

$$c_i^{ind} \geq 0 \, , c^{hwc} \geq 0 \, , c^{hw} \geq 0 \, , c^{hc} \geq 0 \, , c^{wc} \geq 0 \tag{9}$$

where i denotes an individual; h, w, and c represent a husband, wife, and child, respectively; t_i^{ind} and c_i^{ind} are the time and the expenditure, respectively, for an independent out-of-home leisure activity for an individual i; t_i^{hwc} and c_i^{hwc} are the time and the expenditure, respectively, for a joint out-of-home leisure activity of all household members for an individual i; t_i^{wc} and c_i^{wc} are the time and the expenditure, respectively, for joint out-of-home leisure activity of a wife and child for an individual i; t_i^{hc} and c_i^{hc} are the time and the expenditure, respectively, for a joint out-of-home leisure activity of a husband and child for an individual i; t_i^{hw} and c_i^{hw} are the time and the expenditure, respectively, for a joint out-of-home leisure activity of a husband and wife for an individual i; $t_i^{\mathrm{hom}e}$ is the in-home leisure time for an individual i; T_i is an available time in a day for an individual i; and Y is the available household income in a day. The rationale behind selecting the weighted linear group utility function is discussed in Kato and Matsumoto (2007).

3.1.2 Specification of the Individual Utility Function

We assume that an individual utility function comprises "sub-utility functions" associated with the types of activities and that the sub-utility functions of each activity is a linear function of the "utility elements" associated with the time and expenditure consumed for each activity. We also assume that the sub-utility of in-home leisure stems from the time consumption only. Then, the utility function of each household member is expressed as

$$U_h = U_h^{ind}\left(t_h^{ind}, c_h^{ind}\right) + U_h^{hwc}\left(t_h^{hwc}, c_h^{hwc}\right) + U_h^{hw}\left(t_h^{hw}, c_h^{hw}\right) + U_h^{hc}\left(t_h^{hc}, c_h^{hc}\right) + U_h^{\mathrm{hom}e}\left(t_h^{\mathrm{hom}e}\right) \tag{10}$$

$$U_w = U_w^{ind}\left(t_w^{ind}, c_w^{ind}\right) + U_w^{hwc}\left(t_w^{hwc}, c_w^{hwc}\right) + U_w^{hw}\left(t_w^{hw}, c_w^{hw}\right) + U_w^{wc}\left(t_w^{wc}, c_w^{wc}\right) + U_w^{\mathrm{hom}\,e}\left(t_w^{\mathrm{hom}\,e}\right) \quad (11)$$

$$U_c = U_c^{ind}\left(t_c^{ind}, c_c^{ind}\right) + U_h^{hwc}\left(t_c^{hwc}, c_c^{hwc}\right) + U_c^{hc}\left(t_c^{hc}, c_c^{hc}\right) + U_c^{wc}\left(t_c^{wc}, c_c^{wc}\right) + U_c^{\mathrm{hom}\,e}\left(t_c^{\mathrm{hom}\,e}\right) \quad (12)$$

where $U_i^{\mathrm{a}}\left(t_i^{\mathrm{a}}, c_i^{\mathrm{a}}\right)$ denotes the sub-utility function of activity a (ind, hw, hc , wc , $hwc, \mathrm{hom}\,e$) of an individual i .

Next, the sub-utility function of each activity is given as

$$U_i^a\left(t_i^a, c_i^a\right) = U_{it}^a\left(t_i^a\right) + U_{ic}^a\left(c_i^a\right) \quad (13)$$

where $U_{it}^a\left(t_i^a\right)$ is the utility element associated with time and $U_{ic}^a\left(c_i^a\right)$ is the utility element associated with expenditure. We assume that the marginal utility element with respect to time and expenditure decreases following the neoclassical microeconomic theory, as follows:

$$\frac{\partial U_{it}^a\left(t_i^a\right)}{\partial t_i^a} < 0 \, , \; \frac{\partial U_{ic}^a\left(c_i^a\right)}{\partial c_i^a} < 0 \quad (14).$$

Then, we specify the utility elements as logarithmic functions, as below.

$$U_{it}^a\left(t_i^a\right) = \alpha_{it}^a \ln\left(t_i^a + 1\right) \quad (15)$$

$$U_{ic}^a\left(c_i^a\right) = \alpha_{ic}^a \ln\left(c_i^a + 1\right) \quad (16).$$

We add one to the time and expenditure of the utility element functions. There are two reasons for this. First, we add a positive constant value to the utility element function because it approaches $-\infty$ as the time or expenditure approaches zero without the addition of some positive constant. Second, we use one as the constant value because the utility element is negative unless the added positive constant is one or more than one. As regards the parameters of the utility elements expressed as logarithmic functions in equations (15) and (16), we assume that an individual has a heterogeneous preference and positive marginal utility with respect to time and expenditure. We specify the parameters as

$$\alpha_{it}^{a} = \exp\left(\boldsymbol{\theta}_{it}^{a} \cdot \mathbf{x}_{it}^{a}\right) \qquad \text{for } a = ind \tag{17}$$

$$\alpha_{ic}^{a} = \exp\left(\boldsymbol{\theta}_{ic}^{a} \cdot \mathbf{x}_{ic}^{a}\right) \qquad \text{for } a = ind \tag{18}$$

$$\alpha_{it}^{a} = \exp\left(\boldsymbol{\theta}_{it}^{a} \cdot \mathbf{x}_{it}^{a} + \varepsilon_{it}^{a}\right) \qquad \text{for } a \neq ind \tag{19}$$

$$\alpha_{ic}^{a} = \exp\left(\boldsymbol{\theta}_{ic}^{a} \cdot \mathbf{x}_{ic}^{a} + \varepsilon_{ic}^{a}\right) \qquad \text{for } a \neq ind \tag{20}$$

where $\boldsymbol{\theta}$ is a vector of unknown parameters; $\mathbf{x}$ is a vector of individual attributes; and ε_{it}^{a} and ε_{ic}^{a} are the independent error components following the normal distribution with mean zero and variances σ_{it} and σ_{ic}, respectively. These error components are introduced because the heterogeneity in the individual preference stems from not only the individual attributes $\mathbf{x}$ but also other unknown factors.

3.1.3 Parameter Estimation

We define a Lagrange function for the optimization problem of equations (1) to (9) with the specified functions in equations (10) to (20). Then, we apply the Kuhn-Tucker theorem to equations (1) to (9). The first-order optimality conditions include

$$Z_{it}^{\hom e} = \ln\left(\frac{t_i^{\hom e}}{t_i^{ind}}\right) - \left(\boldsymbol{\theta}_{it}^{\hom e} \cdot \mathbf{x}_{it}^{\hom e} - \boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right) \begin{cases} = \varepsilon_{it}^{\hom e}\left(t_i^{\hom e*} > 0\right) \\ \geq \varepsilon_{it}^{\hom e}\left(t_i^{\hom e*} = 0\right) \end{cases} \tag{21}$$

$$Z_t^{ij} = \ln\left[\frac{\exp\left(\boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right)}{t_i^{ind}} + \frac{\exp\left(\boldsymbol{\theta}_{jt}^{ind} \cdot \mathbf{x}_{jt}^{ind}\right)}{t_j^{ind}}\right] + \ln\left[\frac{t^{ij}}{\exp\left(\boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right) + \exp\left(\boldsymbol{\theta}_{jt}^{ind} \cdot \mathbf{x}_{jt}^{ind}\right)}\right] \begin{cases} = \varepsilon_t^{ij}\left(t^{ij*} > 0\right) \\ \geq \varepsilon_t^{ij}\left(t^{ij*} = 0\right) \end{cases} \tag{22}$$

$$Z_c^{ij} = \ln\left[\frac{2\exp\left(\boldsymbol{\theta}_{ic}^{ind}\cdot\mathbf{x}_{ic}^{ind}\right)}{\exp\left(\boldsymbol{\theta}_{ic}^{ij}\cdot\mathbf{x}_{ic}^{ij}\right)+\exp\left(\boldsymbol{\theta}_{jc}^{ij}\cdot\mathbf{x}_{jc}^{ij}\right)}\cdot\frac{c^{ij}}{c_i^{ind}}\right]\begin{cases}=\varepsilon_c^{ij}\left(t^{ij*}>0\right)\\ \geq\varepsilon_c^{ij}\left(t^{ij*}=0\right)\end{cases} \tag{23}$$

$$Z_t^{hwc} = \ln\left[\frac{\exp\left(\boldsymbol{\theta}_{ht}^{ind}\cdot\mathbf{x}_{ht}^{ind}\right)}{t_h^{ind}}+\frac{\exp\left(\boldsymbol{\theta}_{wt}^{ind}\cdot\mathbf{x}_{wt}^{ind}\right)}{t_w^{ind}}+\frac{\exp\left(\boldsymbol{\theta}_{ct}^{ind}\cdot\mathbf{x}_{ct}^{ind}\right)}{t_c^{ind}}\right]+\ln\left[\frac{t^{hwc}}{\exp\left(\boldsymbol{\theta}_{ht}^{ind}\cdot\mathbf{x}_{ht}^{ind}\right)+\exp\left(\boldsymbol{\theta}_{wt}^{ind}\cdot\mathbf{x}_{wt}^{ind}\right)+\exp\left(\boldsymbol{\theta}_{ct}^{ind}\cdot\mathbf{x}_{ct}^{ind}\right)}\right]\begin{cases}=\varepsilon_t^{hwc}\left(t^{hwc*}>0\right)\\ \geq\varepsilon_t^{hwc}\left(t^{hwc*}=0\right)\end{cases} \tag{24}$$

$$Z_c^{hwc} = \ln\left[\frac{3\exp\left(\boldsymbol{\theta}_{hc}^{ind}\cdot\mathbf{x}_{hc}^{ind}\right)}{\exp\left(\boldsymbol{\theta}_{hc}^{hwc}\cdot\mathbf{x}_{hc}^{hwc}\right)+\exp\left(\boldsymbol{\theta}_{wc}^{hwc}\cdot\mathbf{x}_{wc}^{hwc}\right)+\exp\left(\boldsymbol{\theta}_{cc}^{hwc}\cdot\mathbf{x}_{cc}^{hwc}\right)}\cdot\frac{c^{hwc}}{c_h^{ind}}\right]\begin{cases}=\varepsilon_c^{hwc}\left(t^{hwc*}>0\right)\\ \geq\varepsilon_c^{hwc}\left(t^{hwc*}=0\right)\end{cases} \tag{25}$$

where $i = h, w, c$ and $ij = hc, hw, wc$. For the derivation of the above equations, we assume that the error components in the individual utility function are common if the individuals share the time or expenditure consumed in the joint activity.

The elements of a household likelihood function are shown in Table 1 with the complementarity conditions of optimality. The complementarity conditions show the independence of the allocated time and expenditure among the activities. We can estimate the unknown parameters by the maximization of the total likelihood function of all the observed households. The model described above can be called a nonlinear Tobit model because it considers the inequality conditions for the likelihood maximization.

(Table 1 is inserted here.)

4.1 Survey

4.1.1 Activity Diary Survey

We survey the intra-household interaction using the same survey method in two different cities. We select Tokyo as one of the mega cities and Toyama as one of the typical local cities. Tokyo—the capital of Japan and one of the largest cities in the world—has a population of approximately 8.3 million with an area of 612 square km; the Tokyo Metropolitan Area, on the other hand, is populated by over 34 million people in an area of around 13 200 square km. Tokyo has a well-organized public transport network with a high modal share of public transport. Toyama—the capital of Toyama Prefecture located in the Hokuriku district—has a population of approximately 420 000 with an area of 1 240 square km. In most areas in Toyama, the modal share of private transportation is over 70%, although there is a public transport network of railways and buses.

The activity diary survey used in this paper was designed and conducted by a study team from the University of Tokyo that we were part of. We designed a questionnaire sheet for a paper-based household survey on a daily activity episode using the socio-demographic data obtained. We prepared four types of questionnaire sheets per household: for the heads of households, husbands, wives, and children, respectively. The questionnaire sheet for the heads of households includes questions on basic information on the household such as the number of household members; structure of the household including gender, age, job, and status of the household members; and the location of residence. The other sheets for each member of the household request respondents to fill their activity episodes during a working (weekday) and a nonworking day (weekend day) along the time schedule. The survey days are given and fixed by the study team as the November 14th, 2003 (Friday) and November 16th, 2003 (Sunday). We obtained the support of two local primary schools in Tokyo and three local schools in Toyama for our survey. The details of the activity diary survey and data arrangement are provided in Kato and Matsumoto (2007). In total, we distributed 318 sheets in Tokyo and 1 114 sheets in Toyama. Finally, we obtained 89 respondents in Tokyo and 303 respondents in Toyama. The response rates were approximately 27% in both cities.

4.1.2 Socio-demographic Comparison of Both the Cities

Table 2 shows the distributions of the household members' ages in the responding households. The average ages of the husbands, wives, and children are 41.0, 38.5, and 9.29, respectively, in Tokyo and 41.5, 38.6, and 9.70, respectively, in Toyama.

(Tables 2, 3, and 4 are inserted here.)

Next, Table 3 shows the distributions of the number of children in the responding households. The average number of children in Tokyo is lower than in Toyama. Table 4 shows the types of jobs held by the parents in the responding households. The majority of the husbands in both the cities are employees of private companies. The share of public servants in the jobs held by husbands is higher in Toyama than in Tokyo, while that of the self-employed is higher in Tokyo than in Toyama. As regards the jobs held by wives, in-home workers account for the dominant share in both the cities.

4.1.3 Resource Allocation Pattern of Households

Table 5 presents the allocation of time and expenditure in the responding households. We can examine the common characteristics of both the cities. First, more than half the available time is allocated to in-home leisure in both a weekday and a weekend day. Second, the time and expenditure allocated to any type of activity on a weekend day are greater than on a weekday. The only exception is the time and expenditure allocated to the individual out-of-home leisure of wives; the allocation is greater on a weekday than on a weekend day. This seems reasonable because the majority of the observed wives are housewives who can allocate greater individual time on weekdays than on weekends. Third, households allocate the highest amount of expenditure to the joint out-of-home leisure of all household members.

(Table 5 is inserted here.)

Next, we can also observe the differences between the two cities. First, the time allocated to in-home leisure for all household members is greater in Tokyo than in Toyama on both a working and non-working day. This may reflect the difference in the accessibility to facilities for out-of-home leisure. Tokyo has a high density of and better accessibility to service facilities as compared to Toyama. Second, in Tokyo, the time allocated to the joint activities of wives and children on a working day is greater than that on a non-working day, whereas that allocated to the joint out-of-home leisure of wives and children is greater on a weekend day than on a weekday in Toyama. This may reflect the difference in the observed housewives between the cities. Housewives are expected to engage in additional joint activities with children on weekdays than on weekend days. The higher share of observed housewives in Tokyo than in Toyama may cause the different results. Third, the time allocated to the joint out-of-home leisure of husbands and wives is almost 10 times larger on a weekend day than on a weekday in Tokyo, whereas it is only 1.3 times larger in Toyama. Fourth, the husband's expenditure for his own individual leisure is approximately two times larger in Tokyo than in Toyama on both a working and non-working day.

5.1 Empirical Analysis

5.1.1 Parameter Estimation

We estimate the unknown parameters using the data of the respondents in our survey. For analytical simplification, we assume that all the responding households allocate their resources as though they have a single representative child. If a household has more than one child, we consider only the data of the child who goes to primary school as being representative of the children in the household. Further, if a household has two or more children going to primary school, we consider the data of the eldest child as being representative. This assumption may be reasonable if all children always behave alike. However, in reality, children who are not representative may influence their household resource allocation significantly. Thus, if we encounter a household that has a non-representative child who significantly impacts the household behavior, we eliminate the data of the household from the original data set. Travel time and travel cost are assumed to be included in the time and expenditure of the activities corresponding to travel. Further, we assume that the basic period of each household's joint resource allocation is one day, although the households could allocate their time across two or more days, for example, in the case of private journeys with overnight stay. Thus, we also eliminate the data of overnight stay for the parameter estimation.

5.1.2 Estimation Results

Tables 6 and 7 present the estimation results of the household resource allocation models in Tokyo and Toyama, respectively. These show that in both the cities, the fitness of the model on a weekday is better than that on a weekend day. The estimated parameters show the characteristics of the marginal utility with respect to time and expenditure, associated with the types of activities of each household member in each city. Table 8 summarizes the characteristics of the estimated parameters in the four models.

(Tables 7, 8, and 9 are inserted here.)

Table 8 reveals the following common characteristics between the two cities. First, the child's individual out-of-home leisure time on a weekday has a higher significance for household welfare if the child is a girl rather than a boy. This may reflect the household members' tendency to allow girls to enjoy individual out-of-home leisure independent from other family members. Second, the joint out-of-home leisure of all household members on a weekend day has a higher significance for household welfare as husbands have more non-working days in a week. This may be attributable to the fact that the household members request the husband to allocate his time to a joint leisure activity with the other household members on a weekend day by engaging in his maintenance activities on a non-working day. Third, the husbands' individual out-of-home leisure on both a weekday and weekend day has a higher significance for household welfare since the husband has more allowance on weekends. This is probably because the husband can afford to engage in more individual out-of-home leisure activities with a higher budget. Fourth, the husband's individual out-of-home leisure time on a weekend day has a higher significance for household welfare if he is self-employed. This may be because the household members allow self-employed husbands to be alone on weekends to enable them to refresh their minds since they work with family members on weekdays. Fifth, the wife's individual out-of-home leisure on a weekend day has a higher significance for household welfare if she is in her forties. This may reflect the fact that the household members allow her to engage in individual out-of-home activities since she is involved in childcare on weekdays. Sixth, children's individual out-of-home leisure on a weekend day has a higher significance for household welfare if the wife is a housewife. This may be because the household members allow the child to play outdoors independent from their mothers on weekends since the mothers remain with their children on weekdays.

Table 8 also presents the following different characteristics between the two cities. First, the greater the number of children in a household, the higher is the significance of husbands and wives' joint out-of-home leisure on a weekday for household welfare in Tokyo while the significance is lower in Toyama. This may reflect the couple's attitudes on the relationship between childcare and couple activities. For example, some couples may give up their out-of-home leisure due to excessive burden from childcare, whereas other couples may find out-of-home leisure more attractive since they wish to refresh their minds in the absence of their children. The former case may apply to couples in Toyama, and the latter case to those in Tokyo. Second, the greater the non-working days of the husband, the lower is the significance of their individual out-of-home leisure on a weekday for household welfare in

Tokyo, while the higher is the significance in Toyama. There are two hypothetical reasons for this result. One reason is the influence of the husband's involvement in work during his leisure time. For example, husbands with few non-working days may be too tired to enjoy their individual out-of-home leisure on a weekday, while those with few non-working days may engage in individual out-of-home leisure in order to relax from the pressure of work. While the former case may apply to husbands in Toyama, the latter case may apply to those in Tokyo. The other reason is the extent of individual out-of-home leisure service provided in the city. For example, there are a number of facilities catering to individual out-of-home leisure in Tokyo including pubs, restaurants, shops, and various amusement spots, whereas there are fewer such facilities in Toyama. Third, if the husband is in his forties, his expenditure toward his individual out-of-home leisure has a higher significance for household welfare in Tokyo, whereas his time allocated to the same has a lower significance for household welfare in Toyama.

6. Conclusions

This paper investigates the household joint resource allocation using the empirical data obtained through an activity diary survey considering both time and monetary expenditure. Using a joint time-allocation model, we empirically compare the intra-household interactions during a weekday and weekend day between two different cities. The results of the empirical analysis show the common characteristics between the two cities with respect to whether the child's gender, the weekly non-working days of the husband, the husband's allowance and job, and the wife's age and job significantly influence the household's welfare. On the contrary, the empirical analysis also reveals the different characteristics across households. First, the number of children makes couples' joint out-of-home leisure on a weekday less attractive to households in Toyama but more attractive to those in Tokyo. Second, the greater the non-working days of the husband, the lower is the significance of his individual out-of-home leisure on a weekday for household welfare in Tokyo while the higher is the significance for Toyama. These characteristics may reflect the households' attitudes in intra-household interaction.

Although we overcome some of the difficulties that have been pointed out in previous researches, there are still some issues that should be examined further. First, we assume a representative child in a household. However, if there are two or more children in a household, they are expected to behave differently and not alike, as per our assumption. The assumption of a representative child may bias the analysis due to this simplification. On the other hand, if we develop a joint household resource allocation model taking into consideration many children, we should use a more complicated model structure. We need to examine a trade-off between reality and complexity. Second, we do not investigate the allocation of the monetary budget among the household members. As Chiappori (1992) suggests, we may need to consider the allocation of income with another model in addition to the household resource allocation model. To develop this additional model, we should survey the income allocation rule among the household members, but this survey proves to be quite complex. Third, we consider the time and expenditure allocation for a day. However, an individual may allocate his/her resources over a week or more. If the resource allocation is done in a week as Axhausen et al. (2002) point out, we should use a weekly resource allocation model. Finally, we consider a child who is old enough to be able to contribute to the household decision-making. However, if a child is too young to judge his/her own resource allocation, we may need to focus on the resource allocation of parents, mainly a wife engaging in childcare, as is done in, for example, Gronau (1976), Ribar (1992, 1995) and Michalopoulos, et al. (1992).

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Table 1: Elements of likelihood functions by complementarity condition and activity

$t_i^{a*} > 0$	$L_{ht}^{home} = \frac{1}{\sigma_{ht}^{home*} \cdot t_h^{home*}} \cdot \phi\left[\frac{Z_{ht}^{home}}{\sigma_{ht}^{home}}\right]$ $L_{wt}^{home} = \frac{1}{\sigma_{wt}^{home*} \cdot t_w^{home*}} \cdot \phi\left[\frac{Z_{wt}^{home}}{\sigma_{wt}^{home}}\right]$ $L_{ct}^{home} = \frac{1}{\sigma_{ct}^{home*} \cdot t_c^{home*}} \cdot \phi\left[\frac{Z_{ct}^{home}}{\sigma_{ct}^{home}}\right]$ $L_t^{hc} = \frac{1}{\sigma_t^{hc} \cdot t^{hc*}} \cdot \phi\left[\frac{Z_t^{hc}}{\sigma_t^{hc}}\right]$ $L_t^{wc} = \frac{1}{\sigma_t^{wc} \cdot t^{wc*}} \cdot \phi\left[\frac{Z_t^{wc}}{\sigma_t^{wc}}\right]$ $L_t^{hw} = \frac{1}{\sigma_t^{hw} \cdot t^{hw*}} \cdot \phi\left[\frac{Z_t^{hw}}{\sigma_t^{hw}}\right]$ $L_t^{hwc} = \frac{1}{\sigma_t^{hwc} \cdot t^{hwc*}} \cdot \phi\left[\frac{Z_t^{hwc}}{\sigma_t^{hwc}}\right]$
$t_i^{a*} = 0$	$LL_{ht}^{home} = \Phi\left[\frac{Z_{ht}^{home}}{\sigma_{ht}^{home}}\right]$ $LL_{wt}^{home} = \Phi\left[\frac{Z_{wt}^{home}}{\sigma_{wt}^{home}}\right]$ $LL_{ct}^{home} = \Phi\left[\frac{Z_{ct}^{home}}{\sigma_{ct}^{home}}\right]$ $LL_t^{hc} = \Phi\left[\frac{Z_t^{hc}}{\sigma_t^{hc}}\right]$ $LL_t^{wc} = \Phi\left[\frac{Z_t^{wc}}{\sigma_t^{wc}}\right]$ $LL_t^{hw} = \Phi\left[\frac{Z_t^{hw}}{\sigma_t^{hw}}\right]$ $LL_t^{hwc} = \Phi\left[\frac{Z_t^{hwc}}{\sigma_t^{hwc}}\right]$
$c_i^{a*} > 0$	$L_c^{hc} = \frac{1}{\sigma_c^{hc} \cdot c^{hc*}} \cdot \phi\left[\frac{Z_c^{hc}}{\sigma_c^{hc}}\right]$ $L_c^{wc} = \frac{1}{\sigma_c^{wc} \cdot c^{wc*}} \cdot \phi\left[\frac{Z_c^{wc}}{\sigma_c^{wc}}\right]$ $L_c^{hw} = \frac{1}{\sigma_c^{hw} \cdot c^{hw*}} \cdot \phi\left[\frac{Z_c^{hw}}{\sigma_c^{hw}}\right]$ $L_c^{hwc} = \frac{1}{\sigma_c^{hwc} \cdot c^{hwc*}} \cdot \phi\left[\frac{Z_c^{hwc}}{\sigma_c^{hwc}}\right]$
$c_i^{a*} = 0$	$LL_c^{hc} = \Phi\left[\frac{Z_c^{hc}}{\sigma_c^{hc}}\right]$ $LL_c^{wc} = \Phi\left[\frac{Z_c^{wc}}{\sigma_c^{wc}}\right]$ $LL_c^{hw} = \Phi\left[\frac{Z_c^{hw}}{\sigma_c^{hw}}\right]$ $LL_c^{hwc} = \Phi\left[\frac{Z_c^{hwc}}{\sigma_c^{hwc}}\right]$

ϕ : probability density function of standard normal distribution

Φ : probability distribution function of standard normal distribution

Table 2: Age distributions in the responding households by household members

	Tokyo (N = 89)			Toyama (N = 303)		
Ages	Husband	Wife	Child	Husband	Wife	Child
21–25	0	1		0	3	
26–30	1	0		2	3	
31–35	9	21		25	67	
36–40	36	43		107	135	
41–45	28	22		107	72	
46–50	12	1		50	22	
51–	3	1		12	1	
6			10			11
7			7			33
8			16			35
9			11			50
10			17			60
11			15			55
12			13			59

Table 3: Number of children in the responding households

	Tokyo (N = 89)	Toyama (N = 303)
1	15	41
2	53	173
3	19	85
4	2	2
5	0	2

Table 4: Types of jobs held by husbands and wives in the responding households

	Tokyo (N = 89)		Toyama (N = 303)	
	Husband	Wife	Husband	Wife
Employee of private company	60	10	179	36
Executive of private company	2	0	18	2
Civil servant	7	2	58	25
Self-employer	15	4	31	25
Home worker	1	50	1	116
Staff of non-profit organization	3	2	7	1
Part-time employee	1	18	1	83
Others	0	3	8	15

Table 5: Average time and expenditure allocated to activities

			Tokyo (N = 89)		Toyama (N = 303)	
Variables	Definitions	unit	Week day	Weekend day	Week day	Weekend day
T-home(h)	Time for in-home leisure of husband	mins.	186.5	389.5	132.3	307.5
T-ind(h)	Time for individual out-of-home leisure of husband	mins.	81.4	125.5	60.1	104.5
T-home(w)	Time for in-home leisure of wife	mins.	342.7	374.4	176.8	266.2
T-ind(w)	Time for individual out-of-home leisure of wife	mins.	100.3	40.8	76.3	45.1
T-home(c)	Time for in-home leisure of child	mins.	327.0	470.2	266.1	439.4
T-ind(c)	Time for individual out-of-home leisure of child	mins.	31.6	52.9	37.0	61.3
T-hc	Time for joint out-of-home leisure of husband and child	mins.	1.0	22.2	4.2	31.1
T-wc	Time for joint out-of-home leisure of wife and child	mins.	63.4	29.9	51.5	88.1
T-hw	Time for joint out-of-home leisure of husband and wife	mins.	11.5	109.9	12.5	16.0
T-hwc	Time for joint out-of-home leisure of husband, wife and child	mins.	46.2	177.3	53.8	162.6
C-ind(h)	Expenditure for individual out-of-home leisure of husband	yen	2027.1	2136.1	1019.3	1135.7
C-ind(w)	Expenditure for individual out-of-home leisure of wife	yen	2076.1	980.6	2095.5	1150.2
C-hc	Expenditure for joint out-of-home leisure of husband and child	yen	0.0	370.8	16.2	426.1
C-wc	Expenditure for joint out-of-home leisure of wife and child	yen	741.7	962.3	784.1	1455.4
C-hw	Expenditure for joint out-of-home leisure of husband and wife	yen	174.2	307.9	56.1	364.1
C-hwc	Expenditure for joint out-of-home leisure of husband, wife and child	yen	130.3	3614.4	278.1	3258.1

Table 6: Estimation results of the household joint resource allocation model in Tokyo

Variables	Weekday			Weekend day		
	Parameters associated with variables	Coeffcients	t-value	Parameters associated with variables	Coeffcients	t-value
Number of children	C-hw(h), C-hw(w)	1.56	2.9	C-wc(w), C-wc(c)	–0.47	–1.1
Child's gender (1: girl, 0: boy)	T-ind(c)	3.10	1.9	T-ind(w)	4.11	2.8
Child's age	T-ind(c)	–0.11	–1.5	T-ind(c)	–0.45	–1.4
Weekly ratio of non-working days of husband	T-ind(h)	–5.01	–1.8	C-hwc(h), C-hwc(w), C-hwc(c)	14.61	4.2
Husband's allowance for a non-working day	C-ind(h)	0.18	3.9	C-ind(h)	0.06	2.5
Dummy variable of husband's age (1 if in his 40s and 0 otherwise)	C-ind(h)	–4.94	–4.0	C-ind(h)	2.92	3.1
Dummy variable of husband's job (1 if employee and 0 otherwise)	T-ind(w)	–1.69	–1.5	C-hw(h), C-hw(w), C-hc(h)	–1.62	–1.4
Dummy variable of husband's job (1 if self-employed and 0 otherwise)	T-ind(h)	1.54	1.0	C-ind(h)	3.05	2.0
Constant for expenditure of husband's individual out-of-home leisure	C-ind(h)	13.08	8.8	C-ind(h)	4.09	4.0
Weekly ratio of non-working days of wife	T-ind(c)	4.89	1.6	C-wc(w)	3.63	2.0
Wife's allowance for a weekday	C-hwc(w)	0.23	4.5			
Wife's allowance for a weekend day				C-ind(w)	0.08	1.4
Dummy variable of wife's age (1 if in her 30s and 0 otherwise)	T-ind(w)	–0.88	–1.3	C-ind(w)	5.34	4.2
Dummy variable of wife's job (1 if housewife and 0 otherwise)	T-ind(w)	–1.65	–1.5	T-ind(c)	3.55	2.3
Dummy variable of wife's job (1 if part-time employee and 0 otherwise)	C-wc(w), C-wc(c)	–5.77	–2.9	C-ind(w), C-hw(w), C-hwc(w)	3.79	3.4
Constant for expenditure of wife's individual out-of-home leisure	C-ind(w)	3.88	6.1			
Constant for child's individual out-of-home leisure time				T-ind(c)	3.16	1.0
Variance w.r.t. husband's individual out-of-home leisure time	T-ind(h)	7.15	7.5	T-ind(h)	7.39	7.6
Variance w.r.t. wife's individual out-of-home leisure time	T-ind(w)	5.58	9.5	T-ind(w)	7.39	6.4
Variance w.r.t. child's individual out-of-home leisure time	T-ind(c)	7.37	6.0	T-ind(c)	7.90	6.2
Variance w.r.t. joint out-of-home leisure time of husband and child	T-hc(h), T-hc(c)	6.78	11.0	T-hc(h), T-hc(c)	6.97	11.2
Variance w.r.t. joint out-of-home leisure time of wife and child	T-wc(w), T-wc(c)	5.3	11.4	T-wc(w), T-wc(c)	6.49	11.2
Variance w.r.t. joint out-of-home leisure time of husband and wife	T-hw(h), T-hw(w)	5.85	11.1	T-hw(h), T-hw(w)	5.79	11.5
Variance w.r.t. joint out-of-home leisure time of all household members	T-hwc(h), T-hwc(w), T-hwc(c)	5.87	11.2	T-hwc(h), T-hwc(w), T-hwc(c)	4.39	11.7
Variance w.r.t. joint out-of-home leisure expenditure of husband and child, and wife and child	C-hc(h), C-hc(c), C-wc(w), C-wc(c)	4.4	17.7	C-hc(h), C-hc(c), C-wc(w), C-wc(c)	4.77	17.7
Variance w.r.t. joint out-of-home leisure expenditure of husband and wife	C-hw(h), C-hw(w)	2.26	11.3	C-hw(h), C-hw(w)	3.07	12.1
Variance w.r.t. joint out-of-home leisure expenditure of all household members	C-hwc(h), C-hwc(w), C-hwc(c)	2.75	11.0	C-hwc(h), C-hwc(w), C-hwc(c)	7.24	11.9
Number of observations	89 (267)			89 (267)		
Initial log-likelihood	–4146.7			–4352.5		
Final log-likelihood	–3517.8			–4135.3		
Likelihood ratio	0.152			0.050		

Table 7: Estimation results of the household joint resource allocation model in Toyama

Variables	Weekday			Weekend day		
	Parameters associated with variables	Coeffcients	t-value	Parameters associated with variables	Coeffcients	t-value
Number of children	C-hw(h), C-hw(w)	–0.63	–2.6	C-wc(w), C-wc(c)	–0.01	–0.3
Child's gender (1: girl, 0: boy)	T-ind(c)	3.48	3.8	T-ind(w)	–0.31	–0.5
Child's age	T-ind(c)	–0.14	–3.7	T-ind(c)	–0.15	–0.3
Weekly ratio of non-working days of husband	T-ind(h)	8.91	3.8	C-hwc(h), C-hwc(w), C-hwc(c)	19.48	7.6
Husband's allowance for a non-working day	C-ind(h)	0.02	1.9	C-ind(h)	0.02	2.1
Dummy variable of husband's age (1 if in his 40s and 0 otherwise)	C-ind(h)	0.15	0.3	T-ind(h)	–0.71	–1.7
Dummy variable of husband's job (1 if employee and 0 otherwise)	T-ind(w)	–2.04	–3.7	C-hw(h), C-hw(w), C-hc(h)	–0.90	–1.3
Dummy variable of husband's job (1 if self-employed and 0 otherwise)	T-ind(h)	–1.23	–1.4	C-ind(h)	2.12	2.5
Constant for expenditure of husband's individual out-of-home leisure	C-ind(h)	8.19	18.8	C-ind(h)	5.88	11.7
Weekly ratio of non-working days of wife	T-ind(c)	–2.91	–1.4	C-ind(w)	10.18	4.7
Wife's allowance for a weekday	C-hwc(w)	0.02	0.4			
Wife's allowance for a weekend day				C-ind(w)	–0.015	–0.6
Dummy variable of wife's age (1 if in her 30s and 0 otherwise)	T-ind(w)	–0.14	–0.6	C-ind(w)	1.86	2.6
Dummy variable of wife's job (1 if housewife and 0 otherwise)	T-ind(w)	–3.48	–5.4	T-ind(c)	4.15	3.2
Dummy variable of wife's job (1 if part-time employee and 0 otherwise)	C-wc(w), C-wc(c)	–1.16	–1.1	C-ind(w), C-hw(w), C-hwc(w)	–0.087	–0.2
Constant for expenditure of wife's individual out-of-home leisure	C-ind(w)	8.00	12.8			
Constant for child's individual out-of-home leisure time				T-ind(c)	0.62	0.1
Variance w.r.t. husband's individual out-of-home leisure time	T-ind(h)	7.79	13.3	T-ind(h)	6.83	14.7
Variance w.r.t. wife's individual out-of-home leisure time	T-ind(w)	5.66	16.9	T-ind(w)	8.76	12.1
Variance w.r.t. child's individual out-of-home leisure time	T-ind(c)	7.10	12.1	T-ind(c)	9.54	10.8
Variance w.r.t. joint out-of-home leisure time of husband and child	T-hc(h), T-hc(c)	5.79	20.5	T-hc(h), T-hc(c)	6.17	20.7
Variance w.r.t. joint out-of-home leisure time of wife and child	T-wc(w), T-wc(c)	4.61	21.4	T-wc(w), T-wc(c)	5.11	21.4
Variance w.r.t. joint out-of-home leisure time of husband and wife	T-hw(h), T-hw(w)	4.56	20.9	T-hw(h), T-hw(w)	5.81	20.8
Variance w.r.t. joint out-of-home leisure time of all household members	T-hwc(h), T-hwc(w), T-hwc(c)	4.49	21.2	T-hwc(h), T-hwc(w), T-hwc(c)	4.74	21.6
Variance w.r.t. joint out-of-home leisure expenditure of husband and child	C-hc(h), C-hc(c)	2.11	22.0	C-hc(h), C-hc(c)	4.72	23.8
Variance w.r.t. joint out-of-home leisure expenditure of wife and child	C-wc(w), C-wc(c)	6.30	22.0	C-wc(w), C-wc(c)	6.36	22.0
Variance w.r.t. joint out-of-home leisure expenditure of husband and wife	C-hw(h), C-hw(w)	2.11	21.2	C-hw(h), C-hw(w)	3.63	23.4
Variance w.r.t. joint out-of-home leisure expenditure of all household members	C-hwc(h), C-hwc(w), C-hwc(c)	3.95	23.9	C-hwc(h), C-hwc(w), C-hwc(c)	7.13	22.3
Number of observations	303 (909)			303 (909)		
Initial log-likelihood	–13561.8			–15042.1		
Final log-likelihood	–11572.7			–14548.0		
Likelihood ratio	0.147			0.033		

Table 8: Comparison of the estimated characteristics of the household time allocation model across cases

			Tokyo						Toyama					
			Weekday			Weekend day			Weekday			Weekend day		
Variables	Activity type		Husband	Wife	Child	Husband	Wife	Child	Husband	Wife	Child	Husband	Wife	Child
Number of children	Joint out-of-home leisure of wife and child	wc					-(?)	-(?)					-(?)	-(?)
	Joint out-of-home leisure of husband and wife	hw	+ + +	+ + +					- - -	- - -				
Child's gender (1:girl, 0:boy)	Wife's individual out-of-home leisure	ind(w)					+ + +						-(?)	
	Child's individual out-of-home leisure	ind(c)			+						+ + +			
	Joint out-of-home leisure of husband and child	hc												
Child's age	Child's individual out-of-home leisure	ind(c)			-(?)			-(?)			- - -			-(?)
Weekly ratio of non-work days of husband	Husband's individual out-of-home leisure	ind(h)	-						+ + +					
	Joint out-of-home leisure of all household members	hwc				+ + +	+ + +	+ + +				+ + +	+ + +	+ + +
Husband's allowance for a work day	Husband's individual out-of-home leisure	ind(h)	+ + +			+			+			+ +		
Dummy variable of husband's age (1 if in his 40s and 0 otherwise)	Husband's individual out-of-home leisure	ind(h)	- - -			+ + +			+(?)			-		
Dummy variable of husband's job (1 if employee and 0 otherwise)	Wife's individual out-of-home leisure	ind(w)		-(?)						- - -				
	Joint out-of-home leisure of husband and child	hc				-(?)						-(?)		
	Joint out-of-home leisure of husband and wife	hw				-(?)	-(?)					-(?)	-(?)	
Dummy variable of husband's job (1 if self-employed and 0 otherwise)	Husband's individual out-of-home leisure	ind(h)	+(?)			+ +			-(?)			+ +		
Weekly ratio of non-work days of wife	Wife's individual out-of-home leisure	ind(w)											+ + +	
	Child's individual out-of-home leisure	ind(c)			+(?)						-(?)			
	Joint out-of-home leisure of wife and child	wc					+ +							
Wife's allowance for a week day	Wife's individual out-of-home leisure	ind(w)											-	
	Joint out-of-home leisure of all household members	hwc		+ + +						+(?)				
Wife's allowance for a weekend day	Wife's individual out-of-home leisure	ind(w)					+(?)						-(?)	
Dummy variable of wife's age (1 if in her 30s and 0 otherwise)	Wife's individual out-of-home leisure	ind(w)		-(?)			+ + +			-(?)			+ + +	
Dummy variable of wife's job (1 if housewife and 0 otherwise)	Wife's individual out-of-home leisure	ind(w)		-(?)						- - -				
	Child's individual out-of-home leisure	ind(c)						+ +						+ + +
Dummy variable of wife's job (1 if part-time employee and 0 otherwise)	Wife's individual out-of-home leisure	ind(w)					+ + +						-(?)	
	Joint out-of-home leisure of wife and child	wc		- - -	- - -					-(?)	-(?)			
	Joint out-of-home leisure of husband and wife	hw					+ + +						-(?)	
	Joint out-of-home leisure of all household members	hwc					+ + +						-(?)	