Joint Resource Allocation Model of Household Consisting of a Husband, a Wife and a Child for Non-work Activities: Comparative Analysis of Tokyo and Toyama, Japan

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Abstract

This paper investigates intra-household interactions with an activity-based model. The proposed model considers a child explicitly in addition to its parents. The model considers not only time allocation, but also monetary budget allocation of a household. We analyze a choice of activity duration as well as activity type. We compare the intra-household interactions between a week day and a weekend day and between two different cities. The data source used for the empirical analysis is obtained from an original survey which was designed and conducted by a study team of the University of Tokyo in 2003 at Tokyo and Toyama, Japan. With the sample datasets, we estimate four models: on a week day and on a weekend day in two cities. The estimation results show the common characteristics of two cities, for example: the more non-work days a husband has, the more marginal utility with respect to time he gains; and a housewife has higher marginal utility with respect to time allocated to her in-home leisure. On the other hand, the estimation results show the contrastive features between two cities such as, a younger child has higher marginal utility with respect to his/her individual out-of-home leisure in Tokyo whereas he/she has lower marginal utility in Toyama; a husband in his forties has higher marginal utility with respect to time allocated to his individual out-of-home leisure on a weekend day in Tokyo whereas he has lower marginal utility in Toyama.

Keywords

Joint resource allocation, intra-household interaction, comparative analysis

1. Introduction

Activity-based travel models typically have so far assumed an individual makes a decision on her/his activities. Although the assumption of individual decision-making is reasonable for some personal activities, it may not be suitable, for example, for some types of social activities in which more than one individual participate. A joint decision-making of household members is also important even from a viewpoint of transport planning. This is because a transport policy will impact an individual behaviour not only directly but also indirectly through a change of household behaviour. In addition, it is also meaningful to find out the social factors which affect the joint decision-making of household. For example, the intra-household interaction in an urban city with a high level of transport infrastructure may be different from in a rural city with a low level of transport infrastructure. A comparison of households' behaviour in different social backgrounds enables us to examine the intra-household interaction more vividly. This paper aims to investigate an intra-household interaction through a development of a household resource allocation model with the empirical activity diary data. This paper focuses on a non-obligatory activity. This is because the non-obligatory activities impose less constraint on the resource allocation than the obligatory activities. For example, in a case of labour, which is one of the typical obligatory activities, an employer may oblige an employee to work in a specific way such as a joint work with others. In this case, there is no choice for the employee about a way of work. On the contrary, in a case of leisure, an individual can choose the way of leisure activities as she/he likes. One individual may enjoy leisure time alone while the other shares leisure time with other members.

The proposed model has mainly four characteristics compared with similar types of models. First, we consider a child explicitly in the model. This is because we expect the existence of child influences the household resource allocation significantly. This paper covers a household with three members: a husband, a wife and a child. Second, the model considers not only time allocation, but also monetary budget allocation of a household. Third, we analyze the choice of activity duration as well as a choice of activity type. The types of activities cover both an independent activity and a joint activity with other members. Fourth, we compare the intra-household interactions between a week day and a weekend day and between two different cities.

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

2. Literature Review on Intra-household Interactions

Behavioural analysis of household decision-making or intra-house interaction has received substantial attention in some disciplines, such as marketing research[1] and economic research, although examples are still rare in transport research. However, as seen in a recent special issue of *Transportation Volume 32 Issue 5*, an activity-based travel model incorporating household decision mechanisms has gradually been explored by transport researchers. In this section, we review mainly researches in economics and in transport research. As a household behavioural model in transport research is much influenced by economic research, we first start a brief review of household time allocation models in economics and then review the recent transport researches on intra-household interaction.

2.1 Household Time Allocation Models in Economics

A household time allocation analysis originally started from a study by Becker (1965). He extended a traditional individual behavioural model to a household time allocation model by introducing the time into both a utility function and a household production function[2]. We call this type of model as a unitary model[3]. The unitary model treats a household as if it were an individual. A household has a household utility function which consists of the aggregated amounts of time and goods of the household, whereas it has a pooled time budget and a monetary budget. The model assumes a constrained maximization of the household utility function with respect to time and goods consumption. Although the unitary model is simple and clear, it has been criticized by a number of researchers who are mainly concerned with the

[1] Although we do not review marketing research in details, there are a number of studies on the intra-household interaction in marketing research, including Ferber and Lee(1974), Davis and Rigaux (1974), Munsinger, Weber and Hansen(1975), Davis (1976), Curry and Menasco (1979), Park (1982), Spiro (1983), Qualls (1987), Menasco and Curry (1989), Curry, Menasco and Van Ark (1991), Rossi and Allenby (1993), and Arora and Allenby (1999).

[2] Pollak and Wachter (1975) point out that an application of the household production function approach requires constant returns to scale and the absence of joint production. If these conditions are not satisfied, commodity prices depend on the household preferences and fail to serve the traditional role of prices in consumer theory (Pollak, 1977).

[3] This type of time allocation model has been referred to using several terms in the literatures, for example: traditional models, unified preference models, common-preference models and neo-classical models (Strauss and Beegle, 1996).

intra-household interaction. First, they claim the unitary model is unacceptable from a viewpoint of individualism which is the core of microeconomics (Chiappori, 1992). Second, they criticize the unitary model ignores an interaction of household members and deals with the joint decision-making process as a black box[4]. Third, the unitary model only considers allocations between households and disregards questions concerning intra-household inequalities, which may lead to wrong welfare implications (Haddad and Kanbur, 1990). For example, a tax reform may increase the welfare of household but it may not improve the inequity among household members (Apps and Rees, 1988). Fourth, although the demand functions in the unitary model must satisfy homogeneity, Walras law and Slutsky equations (or revealed preferences restriction) in the same way as an ordinary individual consumer model, they are not often supported by empirical analyses (e.g. Kooreman and Kapteyn, 1986).

In order to overcome the above problems of the unitary model, three approaches have been proposed so far. The first approach is to incorporate the difference of preference among household members into the unitary model. First, Samuelson (1956) proposes a household utility function which consists of household members' individual utility functions with an analogy of the social welfare function. Then he assumes the household utility function should be developed with a hypothetical consensus among household members. Second, Becker (1974a, b) proposes a "Rotten Kid Theorem" which assumes an 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."[5] Third, Becker (1981) proposes an introduction of altruism into the household decision-making. The altruism is defined with the direct dependence of one person's utility on another's[6].

[4] Especially, the unitary model assumes that individual nonlabour incomes of the household members are pooled in a single household nonlabour income. This "income pooling hypothesis" implies that the source of this exogenous income does not play any role in the household's allocation with regard to consumption. This restriction has been strongly rejected in numerous studies (e.g. Thomas, 1990; Browning *et al.*, 1994; Lundberg *et al.* 1997; Fortin and Lacroix, 1997).

[5] Bergstrom (1989) pointed out that this theorem does not hold without an assumption of transferable (cardinal) utility.

[6] Some people may regard altruism as an essential element in defining a family (e.g. Ben-Porath, 1982). It ties people together even if only one of them is altruistic. They then all care about their joint income and all try to maximize it, even the selfish beneficiaries.

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

The third approach is a model which requires only the Pareto efficiency. This model is named as the collective model (Chiappori, 1988, 1992; Bourguignon and Chiappori, 1992). The collective model has been proposed with a critic against the unitary model and with a generalization of the cooperative game model. In the collective model, no additional assumption to the Pareto efficiency is made about the decision-making process. This means no restriction is imposed a priori on which point of the Pareto frontier will be chosen[7]. 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) point out, gradually, the collective approach has found acceptance in recent microeconomic theory.

In a steam of the economic researches, our model proposed in this paper is considered as the Samuelson (1956)'s model, because the household utility function is defined as the Bergson-Samuelson-type social welfare function. This type of household utility function is also

[7] The collective model can be interpreted as an alternative process. This alternative process assumes a two-stage budgeting decision-making. Members first divide the total nonlabour income received by the household between them, according to some predetermined sharing rule. Once income has been allocated, all members face an individual budget constraint. Then they choose their consumption through constrained utility maximization. Chiappori (1988) proves the collective model and its alternative interpretation are equivalent: household decisions are efficient if and only if a sharing rule exists. Therefore, the "income pooling hypothesis" which is criticized in the unitary model can be accepted in the collective model, because the household income should be allocated under some sharing rule if the collective model is assumed.

considered as one of the special forms of the collective model as Chiappori (1992) points out[8]. Thus, not like the unitary model, our model explicitly takes account of the fact that multi-person households consist of several members who have different preferences.

2.2 Household Behavioural Models in Transport Research

The examples of group decision-making research are still rare in transport research. Although the importance of inter-personal dependencies is recognized widely, much 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 (Surinivasan and Bhat, 2004). Recently, some studies have explored the household activity analysis with an explicit consideration of intra-household interactions. They can be categorized into four types of approaches from a methodological viewpoint. First approach is based on the discrete choice model system. The studies of Vovsha *et al.* (2004), Bradley and Vovsha (2005), Scott and Kanaroglou (2002), Wen and Koppelman (1999, 2000), Srinivasan and Bhat (2005) and Srinivasan and Athuru (2005) are included in this approach. Gliebe and Koppelman (2002) using the proportional share model of time allocation may be also included in this approach. The second approach is based on the simultaneous equation system including Golob (1997, 1999), Golob and McNally (1997), Lu and Pas (1997), Fujii *et al.* (1999), Meka *et al.* (2002) and Simma and Axhausen (2002). The third approach is based on the computer simulation system. Meister *et al.* (2005) is included in this approach. Finally, the fourth approach is based on the time allocation model system. Zhang *et al.* (2004), Zhang and Fujiwara (2005) and Zhang *et al.* (2005) are included in this approach. The models in the above economics research and our proposed model are also included in the fourth approach.

Although a considerable number of researches in transport research have analyzed the joint decision-making of household, there still remain a number of issues that should be examined further more. First, most of the approaches were limited to household heads only and did not consider explicitly the other household members as active agents in the intra-household decision making. Some researches considered the other household members but they are limited to only couple, although the presence of a child affects significantly the household

[8] A model suggested by Samuelson (1956) includes the weight parameters given to each member's utility which are independent of prices and incomes, whereas a general collective model proposed by Chiappori (1988) contains the parameters dependent on prices and wage. Chiappori (1992) calls the Samuelson's model as a "collective neoclassical case".

joint activity (Jones *et al.*, 1983; Chandraskharan and Goulias, 1999). Second, as Meister *et al.* (2005) point out, the intra-household interactions and group dynamics in activity-travel scheduling and the utility derived from such interactions are inextricably linked to monetary expenditures, an aspect of activity-travel engagement that is often overlooked due to the absence of both data and a fundamental theory that links monetary expenditures to activity travel expenditures by household members. Third, as Zhang *et al.* (2005) pointed out, although the decision making process may differ between weekdays and weekend, it is rarely examined.

First, this paper covers a household with three members: a husband, a wife and a child. Second, we analyze the household joint allocations of both time and monetary expenditure. Third, we compare the household resource allocations to non-work activities on a week day with a weekend day. Fourth, we survey the intra-household interactions in two cities and compare them.

3. Model

3.1 Household Utility Function

Suppose a household consisting of two or more than two members with a household utility function which includes sub-utility functions of household members. Assume an individual has a selfish sub-utility function of her/his time and expenditure for activities. We consider the household members allocate their time and expenditure by maximizing the household utility function under the constraints of time and monetary budgets. Then a resource allocation of a household can be formulated as

$$\max_{\mathbf{t},\mathbf{c}} W_n = U_n\left(U_{n1}(\mathbf{t}_{n1},\mathbf{c}_{n1}), U_{n2}(\mathbf{t}_{n2},\mathbf{c}_{n2}), \cdots\right) \tag{1a}$$

$$\text{s.t.} \qquad \mathbf{T}_n(\mathbf{t}) \le 0\,,\ \ \mathbf{C}_n(\mathbf{c}) \le 0 \tag{1b}$$

where $U_n(\cdot)$ is a group utility function of a household n; $U_{ni}(\cdot)$ is a sub-utility function of a household member i in the household n; $\mathbf{t}_{ni}$ is a vector of time consumption of the household member i in the household n; $\mathbf{c}_{ni}$ is a vector of expenditure of the household member i in the household n; $\mathbf{T}_n(\mathbf{t})$ is a vector of constraint associated with the vector of time consumption $\mathbf{t}$ of the household n; and $\mathbf{T}_n(\mathbf{t})$ is a vector of constraint associated with the vector of expenditure $\mathbf{c}$ of the household n.

In order to analyze the model, we need to specify a functional form of the utility function. There have been a number of discussions on the types of group utility function or the social welfare function (e.g. Atkinson, 1970; Eliashberg and Lilien, 1993; Zhang *et al.*, 2004). First, one of the most basic types of group utility function is a non-weighted linear function of individual utility function as

$$U_n(U_{n1}, U_{n2}, \cdots) = \sum_{ni} U_{ni} \tag{2}$$

The second type of group utility function is a weighted linear function of individual utility functions as

$$U_n(U_{n1}, U_{n2}, \cdots) = \sum_{ni} w_{ni} U_{ni} \tag{3}$$

The third type is so-called a Rawls-type group utility function which equals to an individual utility function with the lowest utility level as

$$U_n(U_{n1}, U_{n2}, \cdots) = \min_{ni}\{U_{ni}\} \tag{4}$$

The fourth is so-called a Nash-type group utility function which is defined as a product of individual utility functions as

$$U_n(U_{n1}, U_{n2}, \cdots) = \prod_{ni} U_{ni} \tag{5}$$

The fifth type is a multi-linear group utility function defined as a combination of the weighted linear function and the Nash-type function as

$$U_n(U_{n1}, U_{n2}, \cdots) = \sum_{ni} w_{ni} U_{ni} + \sum_{ni} \sum_{nj=ni+1} w_{nij} U_{ni} U_{nj} + \sum_{ni} \sum_{nj=ni+1} \sum_{nk=nj+1} w_{nijk} U_{ni} U_{nj} U_{nk} + \cdots \tag{6}$$

As Zhang *et al.* (2004) point out, there has been no clear theory for selecting a specific group utility function. However, there is a theoretical minimum requirement for the group utility function. We should select a group utility function with which we can obtain a unique solution. This means the group utility function should be a concave function (Dorfman, 1975; Panzar and Willig, 1976). In addition to the above requirement, in order to select a specific functional form of the group utility function, we need to assume the decision-making process of group members. This paper assumes a household has the weighted linear group utility function based on the Utilitarian social welfare function. The theoretical background for this type of social welfare function is shown by Harsanyi (1953, 1955). He shows the social welfare function should be the weighted linear function of individual utility functions, if the individual decision-making and the social decision-making satisfy both the von Neumann-

Morgenstern axioms and Pareto Efficiency under an assumption of cardinal utility. Recent studies in labour economics often use the weighted linear group utility function (e.g. Browning and Chiappori, 1988) for the empirical analysis of household decision-making.

3.2 Formulation of Resource Allocation for Nuclear Family

We assume a nuclear family with a husband, a wife and a child as a household. Each household member chooses one of activities discretely while she/he allocates time and expenditure continuously for a chosen activity.

In general, an activity can be classified into two types: an obligatory activity and a non-obligatory activity (Yamamoto and Kitamura, 1999). The obligatory activity is defined as an activity which an individual should engage in within a given period, while the non-obligatory activity is defined as an activity which an individual can choose to engage in or not. In our analysis, we classify the above two activities further more into following four activities:

(a) Non-obligatory activity:

- Out-of-home leisure: an activity with a travel such as going shopping and going theatre.
- In-home leisure: an activity without a travel such as watching television at home and reading books at home.

(b) Obligatory activity:

- Required activity: a productive or a learning activity such as working at workplace, working at home and learning at school.
- Fundamental activity: a basic activity for human beings such as sleeping, taking a bath and having meal at home.

We assume both time and expenditure allocated to obligatory activities are given and fixed, although the time and the expenditure in the required activity may be adjusted in the long term, for example through a change of jobs. In this sense, we can say our model is a short-term model.

As for out-of-home leisure, we classify it further more into two: an independent activity and a joint activity. The independent activity is engaged in by an individual alone, while the joint activity is engaged in together with other members. We consider an individual will choose a type of out-of-home joint leisure by selecting members with whom she/he will engage the joint out-of-home leisure.

Next, we set six basic assumptions on the choice of activities of household members:

Assumption 1: all household members participate in their household joint decision-making process

It may be true that a too young child does not have an ability of choosing a type of activity. However, we assume even the young child can contribute to the joint decision-making through a discussion with her/his parents, if she or he is old enough to communicate with her/his parents. As our empirical analysis focuses on children who learn at primary school with an age of from six to twelve years old, we consider this assumption is satisfied.

Assumption 2: two or more than two types of activities are not engaged by an individual simultaneously.

We assume that an individual never engage two or more than two types of activities one at a time (monochromic time use). This is due to an independency of defined activities[9].

Assumption 3: all individuals who participate in a joint activity can gain the common utility from time and expenditure consumed in the joint activity

On the one hand, it is quite reasonable to consider the same amount of time is consumed by all members participating in the same activities. On the other hand, it may not seem reasonable to consider the same amount of expenditure is consumed by all members participating in the same activities. However, we set this assumption simply because we consider an individual consumes a kind of public goods in the joint activity. When the public goods is consumed, the amount of consumption should be the same for all members.

Assumption 4: member's income is pooled as a single monetary budget of a household

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[9] Kaufman *et al.* (1991) examine a polychronic time use such as eating while watching television. Although our model excludes the polychronic time use, exactly to say, it may be possible for an individual to engage in an individual activity with other members. For example, a husband and a child go together to a same playground and the child plays football while the husband watches it. In this case, the husband individually watches a football game but this activity does not make sense without the existence of his child in the playground. Extremely to say, any kind of activity can be considered as an individual activity. Thus, we define a joint activity as the one in which two or more than two members simply *go together to the same destination*. We do not care the detailed type of activities engaged in by each individual for the analytical simplification. The biases caused by this simplification will be discussed in the final section.

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) shows theoretically, if we use the "collective model", we do not need to care about the nonlabour income allocation among members. As mentioned earlier, our model is considered as one type of the collective models. Therefore, this assumption does not bias our model structure.

Assumption 5: an activity space constraint is not considered explicitly

The activity space availability may impact an individual activity pattern and it may be influenced by socio-demographic factors such as an available travel mode. However, for the simplification of the analysis, we ignore a dimension of activity space.

Assumption 6: an individual gains the utility not from the goods consumption but from the activity

We focus on the activity rather than the goods/service consumption in modelling the individual behaviour. This distinction makes our resource allocation analysis richer. For example, suppose an example that a household member A purchases a goods X on behalf of another member B. Although the goods X is the common between two members, the individual A gains the utility from an activity of purchasing X, while the individual B gains the utility from an activity of consuming X. As these two activities are completely different, they cannot be considered as a joint activity. We follow an activity-based approach where consumer's behaviour are analysed not with the goods consumption but with the activity as Pollak and Wachter (1975), Juster (1985) and Jara-Diaz (1998) suggest.

Then, we formulate the household joint decision-making as

$$\max U(U_h, U_w, U_c) = w_h \cdot U_h + w_w \cdot U_w + w_w \cdot U_c \tag{7a}$$

subject to

$$t_i^{ind} + t_i^{hwc} + t_i^{hc} + t_i^{wc} + t_i^{hw} + t_i^{\text{hom}\,e} = T_i \tag{7b}$$

$$\sum_i c_i^{ind} + c^{hwc} + c^{hc} + c^{wc} + c^{hw} = Y \tag{7c}$$

$$t^{hwc} = t_h^{hwc} = t_w^{hwc} = t_c^{hwc} \tag{7d}$$

$$t^{hc} = t_h^{hc} = t_c^{hc}, t^{wc} = t_w^{wc} = t_c^{wc}, t^{hw} = t_h^{hw} = t_w^{hw} \tag{7e}$$

$$t_i^{ind} \geq 0, t^{hwc} \geq 0, t^{hw} \geq 0, t^{hc} \geq 0, t^{wc} \geq 0, t_i^{\text{hom}\,e} \geq 0 \tag{7f}$$

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

$$c^{hc} = c_h^{hc} = c_c^{hc}\ , c^{wc} = c_w^{wc} = c_c^{wc}\ , c^{hw} = c_h^{hw} = c_w^{hw} \tag{7h}$$

$$c_i^{ind} \geq 0\ , c^{hwc} \geq 0\ , c^{hw} \geq 0\ , c^{hc} \geq 0\ , c^{wc} \geq 0 \tag{7i}$$

where t_i^{ind} and c_i^{ind} are the time and the expenditure for an independent out-of-home leisure for an individual i ; t_i^{hwc} and c_i^{hwc} are the time and the expenditure for a joint out-of-home leisure of all household members for an individual i ; t_i^{wc} and c_i^{wc} are the time and the expenditure for joint out-of-home leisure of a wife and a child for an individual i ; t_i^{hc} and c_i^{hc} are the time and the expenditure for a joint out-of-home leisure of a husband and a child for an individual i ; t_i^{hw} and c_i^{hw} are the time and the expenditure for a joint out-of-home leisure of a husband and a wife for an individual i ; t_i^{home} is the in-home leisure time for an individual i ; T_i is an available time in a day for an individual i ; Y is the available household income in a day. As for an individual i , h , w and c indicate a husband, a wife and a child, respectively.

3.3 Specification of Individual Utility Function

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

$$U_h = U_h^{ind}\left(t_h^{ind}, c_h^{ind}\right) + U_h^{hwc}\left(t_h^{hwc}, c_h^{hwc}\right) + U_h^{hw}\left(t_h^{hw}, c_h^{hw}\right) + U_h^{hc}\left(t_h^{hc}, c_h^{hc}\right) + U_h^{\mathrm{home}}\left(t_h^{\mathrm{home}}\right) \tag{8a}$$

$$U_w = U_w^{ind}\left(t_w^{ind}, c_w^{ind}\right) + U_w^{hwc}\left(t_w^{hwc}, c_w^{hwc}\right) + U_w^{hw}\left(t_w^{hw}, c_w^{hw}\right) + U_w^{wc}\left(t_w^{wc}, c_w^{wc}\right) + U_w^{\mathrm{home}}\left(t_w^{\mathrm{home}}\right) \tag{8b}$$

$$U_c = U_c^{ind}\left(t_c^{ind}, c_c^{ind}\right) + U_h^{hwc}\left(t_c^{hwc}, c_c^{hwc}\right) + U_c^{hc}\left(t_c^{hc}, c_c^{hc}\right) + U_c^{wc}\left(t_c^{wc}, c_c^{wc}\right) + U_c^{\mathrm{home}}\left(t_c^{\mathrm{home}}\right) \tag{8c}$$

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

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

$$U_i^a\left(t_i^a, c_i^a\right) = U_{it}^a\left(t_i^a\right) + U_{ic}^a\left(c_i^a\right) \tag{9a}$$

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 the marginal utility element with respect to time and expenditure is decreasing following the neoclassical microeconomic theory as

$$\frac{\partial U_{it}^{a}\left(t_{i}^{a}\right)}{\partial t_{i}^{a}}<0, \quad \frac{\partial U_{ic}^{a}\left(c_{i}^{a}\right)}{\partial c_{i}^{a}}<0 \qquad (9b).$$

Then, we specify the utility elements as a logarithmic function as

$$U_{it}^{a}\left(t_{i}^{a}\right)=\alpha_{it}^{a} \ln\left(t_{i}^{a}+1\right) \qquad (10a)$$

$$U_{ic}^{a}\left(c_{i}^{a}\right)=\alpha_{ic}^{a} \ln\left(c_{i}^{a}+1\right) \qquad (10b).$$

We add one to time and expenditure of the utility element functions. First, we add a positive constant value to the utility element function because it goes to $-\infty$ without adding 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[10]. As for the parameters of the utility elements functions in equations (10a) and (10b), we assume an individual has the heterogeneity in her/his preference with the positive marginal utility with respect to time and expenditure. We specify the parameters as

$$\alpha_{it}^{a}=\exp\left(\boldsymbol{\theta}_{it}^{a}\cdot\mathbf{x}_{it}^{a}\right) \quad \text{for } a=ind \qquad (11a)$$

$$\alpha_{ic}^{a}=\exp\left(\boldsymbol{\theta}_{ic}^{a}\cdot\mathbf{x}_{ic}^{a}\right) \quad \text{for } a=ind \qquad (11b)$$

$$\alpha_{it}^{a}=\exp\left(\boldsymbol{\theta}_{it}^{a}\cdot\mathbf{x}_{it}^{a}+\varepsilon_{it}^{a}\right) \quad \text{for } a\neq ind \qquad (11c)$$

$$\alpha_{ic}^{a}=\exp\left(\boldsymbol{\theta}_{ic}^{a}\cdot\mathbf{x}_{ic}^{a}+\varepsilon_{ic}^{a}\right) \quad \text{for } a\neq ind \qquad (11d)$$

where $\boldsymbol{\theta}$ is a vector of unknown parameters; $\mathbf{x}$ is a vector of individual attributes, ε_{it}^{a} and ε_{ic}^{a} are the independent error components which follow the normal distribution with mean zero and variances σ_{it} and σ_{ic}, respectively. These error components are introduced because the

[10] In this sense, there is no reason why the constant value should be one. However, we consider it is intuitively easy to understand a meaning of the cardinal utility if the utility level is zero when the allocated time and expenditure are zero.

heterogeneity in individual preference stems from not only the individual attributes $\mathbf{x}$, but also other unknown factors[11].

Although the original formulation of household utility function shown in equation (7a) has the individual weights w_i, these weight cannot be identified through the parameter estimation. This is because the individual weights can be incorporated into the parameter of the utility element functions of equation (10a) and (10b)[12]. Thus, we set the individual weight parameters as ones in the parameter estimation.

3.4 Parameter Estimation

We define a Lagrange function for the optimization problem of equation (7) with the specified functions in equations (8) to (11). Then we apply the Kuhn-Tucker theorem to them. The first order optimality conditions include

$$Z_{it}^{\mathrm{home}} = \ln\left(\frac{t_i^{\mathrm{home}}}{t_i^{ind}}\right) - \left(\boldsymbol{\theta}_{it}^{\mathrm{home}} \cdot \mathbf{x}_{it}^{\mathrm{home}} - \boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right) \begin{cases} = \varepsilon_{it}^{\mathrm{home}}\left(t_i^{\mathrm{home}*} > 0\right) \\ \geq \varepsilon_{it}^{\mathrm{home}}\left(t_i^{\mathrm{home}*} = 0\right) \end{cases} \tag{13a}$$

$$Z_t^{ij} = \ln\left[\frac{\exp\left(\boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right)}{t_i^{ind}} + \frac{\exp\left(\boldsymbol{\theta}_{jt}^{ind} \cdot \mathbf{x}_{jt}^{ind}\right)}{t_j^{ind}}\right] + \ln\left[\frac{t^{ij}}{\exp\left(\boldsymbol{\theta}_{it}^{ind} \cdot \mathbf{x}_{it}^{ind}\right) + \exp\left(\boldsymbol{\theta}_{jt}^{ind} \cdot \mathbf{x}_{jt}^{ind}\right)}\right] \begin{cases} = \varepsilon_t^{ij}\left(t^{ij*} > 0\right) \\ \geq \varepsilon_t^{ij}\left(t^{ij*} = 0\right) \end{cases} \tag{13b}$$

$$Z_c^{ij} = \ln\left[\frac{2\exp\left(\boldsymbol{\theta}_{ic}^{ind} \cdot \mathbf{x}_{ic}^{ind}\right)}{\exp\left(\boldsymbol{\theta}_{ic}^{ij} \cdot \mathbf{x}_{ic}^{ij}\right) + \exp\left(\boldsymbol{\theta}_{jc}^{ij} \cdot \mathbf{x}_{jc}^{ij}\right)} \cdot \frac{c^{ij}}{c_i^{ind}}\right] \begin{cases} = \varepsilon_c^{ij}\left(t^{ij*} > 0\right) \\ \geq \varepsilon_c^{ij}\left(t^{ij*} = 0\right) \end{cases} \tag{13c}$$

$$Z_t^{hwc} = \ln\left[\frac{\exp\left(\boldsymbol{\theta}_{ht}^{ind} \cdot \mathbf{x}_{ht}^{ind}\right)}{t_h^{ind}} + \frac{\exp\left(\boldsymbol{\theta}_{wt}^{ind} \cdot \mathbf{x}_{wt}^{ind}\right)}{t_w^{ind}} + \frac{\exp\left(\boldsymbol{\theta}_{ct}^{ind} \cdot \mathbf{x}_{ct}^{ind}\right)}{t_c^{ind}}\right] + \ln\left[\frac{t^{hwc}}{\exp\left(\boldsymbol{\theta}_{ht}^{ind} \cdot \mathbf{x}_{ht}^{ind}\right) + \exp\left(\boldsymbol{\theta}_{wt}^{ind} \cdot \mathbf{x}_{wt}^{ind}\right) + \exp\left(\boldsymbol{\theta}_{ct}^{ind} \cdot \mathbf{x}_{ct}^{ind}\right)}\right] \begin{cases} = \varepsilon_t^{hwc}\left(t^{hwc*} > 0\right) \\ \geq \varepsilon_t^{hwc}\left(t^{hwc*} = 0\right) \end{cases} \tag{13d}$$

$$Z_c^{hwc} = \ln\left[\frac{3\exp\left(\boldsymbol{\theta}_{hc}^{ind} \cdot \mathbf{x}_{hc}^{ind}\right)}{\exp\left(\boldsymbol{\theta}_{hc}^{hwc} \cdot \mathbf{x}_{hc}^{hwc}\right) + \exp\left(\boldsymbol{\theta}_{wc}^{hwc} \cdot \mathbf{x}_{wc}^{hwc}\right) + \exp\left(\boldsymbol{\theta}_{cc}^{hwc} \cdot \mathbf{x}_{cc}^{hwc}\right)} \cdot \frac{c^{hwc}}{c_h^{ind}}\right] \begin{cases} = \varepsilon_c^{hwc}\left(t^{hwc*} > 0\right) \\ \geq \varepsilon_c^{hwc}\left(t^{hwc*} = 0\right) \end{cases} \tag{13e}$$

[11] We do not introduce the error components into equations (11a) and (11b) because the random effects of the error terms of equations (11c) and (11d) influence them through the utility function.

[12] More exactly to say, if at least one of parameters associated with the individual heterogeneity of equations of (11) includes a constant variable, the weight parameters cannot be identified. As shown later in Table 3 and 4, in the parameter estimation, the constant dummy variables are introduced into the parameters of some types of activities.

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

where $i = h, w, c$ and $ij = hc, hw, wc$. For the derivation of the above equations, we assumed the error components in the individual utility function are common if the individuals share the time or the expenditure 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 allocated time and expenditure among activities. We can estimate the unknown parameters by a maximization of the total likelihood function of all observed households. The model shown above can be called as the non-linear Tobit model because it considers the inequality conditions for the likelihood maximization.

4. Survey

4.1 Activity Diary Survey

In general, it is expected that the intra-household interactions vary among different cities. For example, the accessibility to urban public service may be different in well-developed area from in poorly-developed area. This difference may influence the activity pattern. In order to see the difference of joint activity patterns under the different social environments, we survey the intra-household interaction with 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 is a capital city of Japan which is one of the largest international cities in the world. Tokyo city area includes about 8.3 million populations in 612 square km, while the Tokyo Metropolitan

Area includes more than 34 million people in about 13,200 square km. Tokyo has a well-organized public transport network with a high modal share of public transport. Toyama is a prefectural capital of Toyama Prefecture located in the Hokuriku district. Toyama city has about 420,000 populations in 1,240 square km. In most areas in Toyama city, the modal share of private car is over 70 % although there is a public transport network of railway and bus.

The activity diary survey was designed and conducted by a study team of the University of Tokyo including us. We design a questionnaire sheet for a paper-based household survey on a daily activity episode with the socio-demographic data. We prepare four types of questionnaire sheets per household: for a head of household, for a husband, for a wife and for children, respectively. The sheet for the head of household includes questions of basic information on the household such as the number of household members, a structure of the household including gender, age, job and status of household members, and the location of residence. The other sheets for each member of household request a respondent to fill her/his activity episodes of a work day and of a non-work day along the time schedule. The survey days are given and fixed by the study team as 14th November 2003 (Friday) and 16th November 2003 (Sunday). The activity episodes cover all types of activities from waking-up in the morning to going-to-bed at night. We request the respondents to answer the time and the expenditure allocated to each activity with the names of those who participate in the joint activity. In the survey sheet, the activities are classified into the obligatory activity, the out-of-home leisure and the in-home leisure. A respondent is requested to choose one of three sub-categories for the obligatory activity: out-of-home work, in-home work and learning at school. As for the sleep, a respondent will answer the times of waking-up and going-to-bed. The out-of-home leisure is categorized into five sub-categories: sight-seeing, shopping, playing sports, enjoying hobby or having meal at restaurant, and others. In addition to the type of activities, we request a respondent to answer the travel episode when they move from one place to another. The travel episode cover the travel mode, travel time and travel cost.

In order to distribute the questionnaire sheets to households with children, we obtained the support from the local primary schools. In Japan, the education at the primary school is obligatory and it covers children of six-year-old to twelve-year-old. We obtained the supports of two local primary schools in Tokyo whereas three local schools in Toyama. First, we requested the teachers to select the grades and the classes randomly in their schools. Then we also requested them to explain the survey purposes and the survey methods to the children, to distribute the survey sheets to the children and to collect them from the children. We communicate the supporting teachers very closely in order to train them and to share the information with them. All teachers supported our survey very positively and their devoted supports make our survey successful and smooth. In addition to the distribution of survey sheets through the primary schools, we distribute by ourselves the same survey sheets randomly through the postal mail. This is first because we expect the responding rate is too low to analyze the activity episode only with the data through the primary schools and second because we consider it is necessary to avoid the data bias due to the biased selection of primary schools. In total, we distributed 318 sheets in Tokyo and 1,114 sheets in Toyama. The reason for less sheets of distribution in Tokyo is that we could not obtain the support from school teachers in Tokyo compared with in Toyama. Finally, we obtained 89 respondents in Tokyo and 303 respondents in Toyama. The responding rates are about 27 % in both cities.

4.2 Socio-demographic comparisons of two cities

Figure 1 shows the distributions of ages of household heads and their spouses in the responding households. The average ages of the heads and their spouses are 41.0 and 38.5 in Tokyo whereas 41.5 and 38.6 in Toyama, respectively. These distributions and averages of couples seem quite reasonable. Figure 2 shows a distribution of children's ages in the responding households. We carefully designed the survey with a random distribution of questionnaire sheets in order not to collect the biased respondents with respect to children's

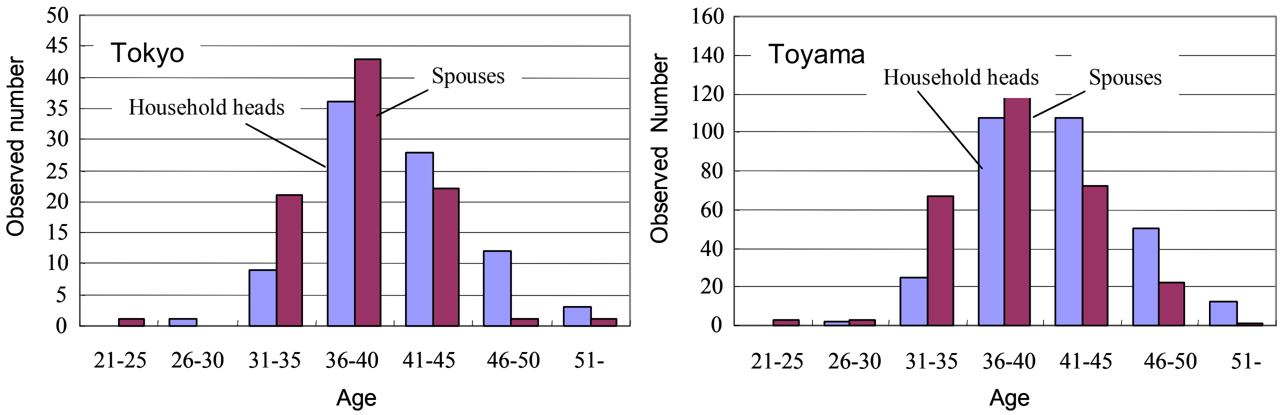

Figure 1: Age distributions of household heads and their spouses in the responding households

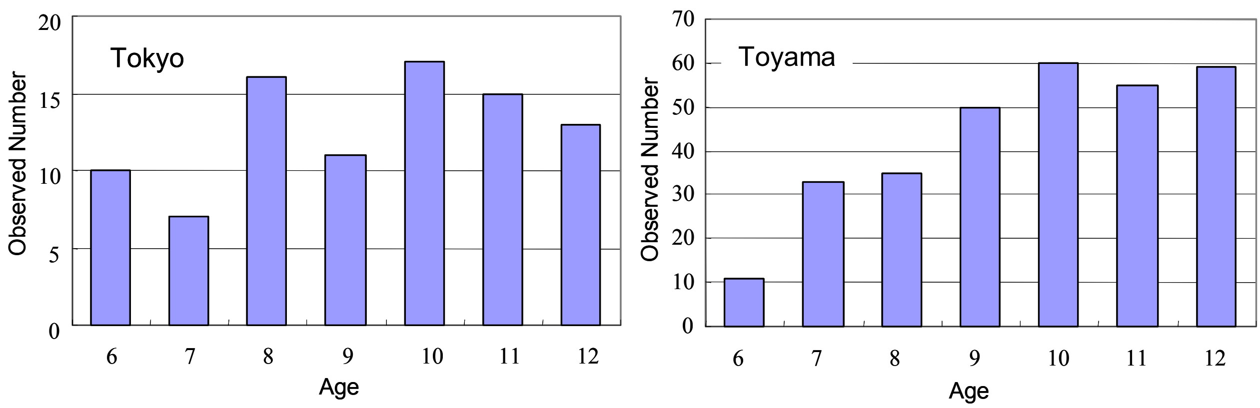

Figure 2: Age distributions of children in the responding households

age. However, the share of the children seems in proportion to their age in Toyama whereas it seems neutral in Tokyo. This may be because the children's ability of response and the feasibility of parents' support bias the distribution of children's age. The teachers requested the parents not to support the children's response for a household to which the survey sheets were distributed through their school. On the contrary, we could not request the parents directly for a household to which the survey sheets were distributed through postal mail, although we request the parents not to do so in the survey sheet. The respondents who received the survey sheets through postal mail are less than the respondents who received them through school teachers in Toyama, while those through postal mail are more than those through school teachers in Tokyo. The responses in Toyama may reflect the children's ability directly whereas the response in Tokyo may not.

Next, Figure 3 shows distributions of number of children in the responding households. The average number of children in Tokyo is smaller than in Toyama. Figure 4 shows the types of

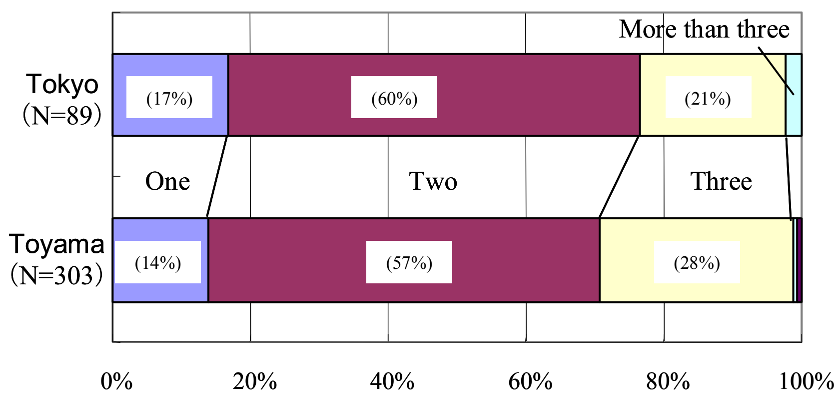

Figure 3: Numbers of child(ren) in the responding households

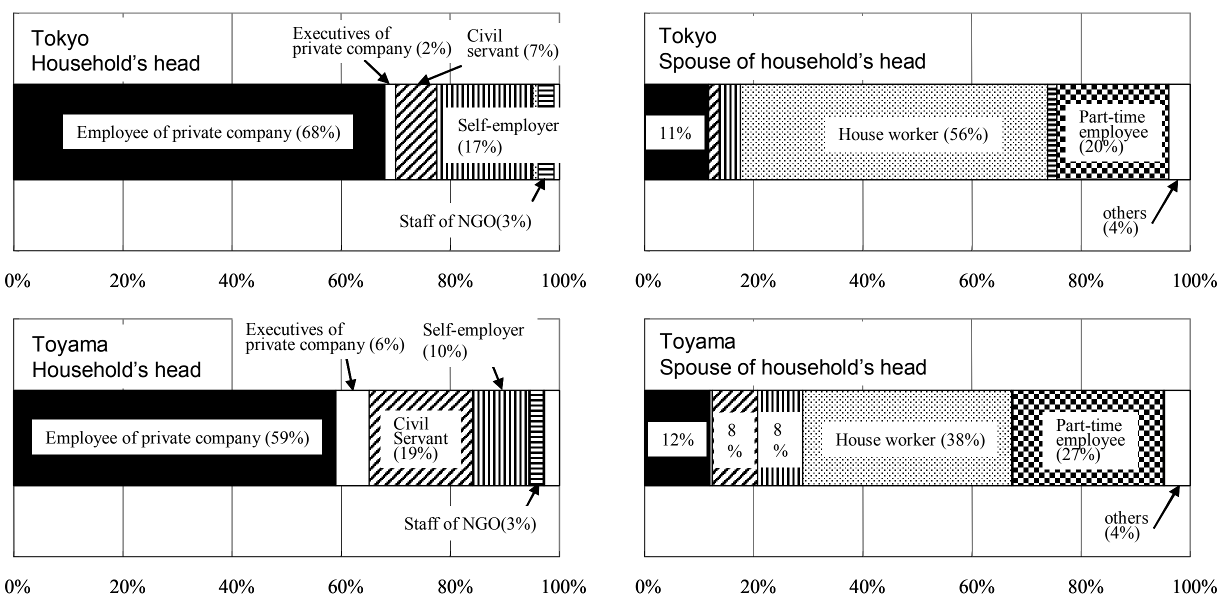

Figure 4: Jobs of household's heads and their spouses in the responding households

jobs of parents in the responding households. The majority of household heads are the employees of private companies in both cities. The share of public servants as a job of household head is higher in Toyama than in Tokyo, while the share of self-employer as a job of household head is higher in Tokyo than in Toyama. As for a job of a spouse of household head, the share of in-home-worker is dominant in both cities. As our survey shows that all husbands are a legally registered household's head and all wives are their spouses, we will regard a household's head as a husband while a spouse of the household's head as a wife.

4.3 Resource Allocation Pattern of Households

Table 2 shows the allocations of time and expenditure of the responding households. We can examine the common characteristics of both cities. First, more than half of available time is allocated to in-home leisure in both a week day and a weekend day. Second, the time and expenditure allocated to any type of activity are larger on a weekend day than on a week day. Only one exception is the time and expenditure allocated to individual out-of-home leisure of wife, which is larger on a week day than on a weekend day. This seems reasonable because majority of the observed wives are the housewives who can allocate more individual time on a week day than on a weekend day. Third, the households allocate highest amount of expenditure to the joint out-of-home leisure of all household members.

Next, we can also see the differences between two cities. First, the time allocated to in-home leisure is longer in Tokyo than in Toyama on both a work day and a non-work day and for all household members. This may reflect the difference of accessibility to facilities for out-of-home leisure. Tokyo has higher density of service facilities with higher accessibility to them than Toyama. Second, the time allocated to a joint activity of wife and child on a work day is longer than on a non-work day in Tokyo, whereas the time allocated to a joint out-of-home leisure of wife and child is longer on a weekend day than on a week day in Toyama. This may reflect the difference of share of observed housewives between cities. A housewife is expected to engage in more joint activity with her child on a week day than on a weekend day. As the share of observed housewives in Tokyo is higher than in Toyama, this may cause the different results. Third, the time allocated to the joint out-of-home leisure of husband and wife is almost ten times larger on a weekend day than on a week day in Tokyo, whereas it is only 1.3 times larger in Toyama. Fourth, the husband's expenditures for his own individual leisure are about twice larger in Tokyo than in Toyama on both a work day and a non-work day.

Table 2: Average allocated time and expenditure to activities

Variables	Definitions	unit	Tokyo(N=89) Week day	Tokyo(N=89) Weekend day	Toyama(N=303) Week day	Toyama(N=303) 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

Finally, we examine a correlation between the time and expenditure for all types of activities on both days in both cities. However, we cannot find any strong correlation between them. This is probably because we do not categorize the type of activities into details. However in reality, the detailed types of activities vary very much. The variation in types of activities requires different proportion of time and expenditure and this may result in the weak correlation between them.

5. Empirical Analysis

5.1 Parameter estimation

We estimate the unknown parameters with the data of respondents of our survey. For the analytical simplification, we assume all responding households allocate their resources as if they would have a single representative child. If a household has more than one child, we use the data of a child who goes to the primary school as a representative of children in the household. And if there are two or more than two children who learn at the primary school, we use the data of the eldest child as the representative child. This assumption may be reasonable if all children always behave together. However, in reality, the children who are not a representative child may influence their household resource allocation significantly. Thus, if we find a household which have a non-representative child who impact significantly the household behaviour, we eliminate the data of the household from the original dataset. We also assume the variances of error components in the utility elements are common among individuals and among types of activities, whereas the variance associated with activity time is different from the variance associated with activity expenditure. Travel time and travel cost are assumed to be included in the time and expenditure of activities corresponding to the travel. We also assume the basic period of household joint resource allocation is a day although the households may allocate their time within two days or more, for example in the private journey with the overnight stay. We also eliminate the data of overnight stay for the parameter estimation.

5.2 Estimation results

Table 3 and 4 show the estimation results of the household resource allocation models of a work day and a non-work day in Tokyo and in Toyama, respectively. The estimated parameters show the characteristics on the marginal utility with respect to time and expenditure associated with types of activities of each household member in each city.

First, Table 3 shows the characteristics of household resource allocation on a weekday in Tokyo as,

- The more the number of children in the household is, the larger both a husband's and a wife's marginal utility with respect to expenditure allocated to their joint activity on a weekday is.
- The child's marginal utility with respect to time allocated to the child's in-home leisure on a weekday is higher if the child is a girl than if the child is a boy.
- The older the child's age is, the lower the child's marginal utility with respect to time allocated to the child's individual out-of-home leisure on a weekday is.
- A self-employed husband not in his forties with his high allowance for a non-work day has higher marginal utility with respect to expenditure for his own individual out-of-home leisure on a weekday.

- A housewife whose husband is an employee of a private company has higher marginal utility with respect to time allocated to her in-home leisure on a weekday.

- A wife who is a part-time worker has lower marginal utility with respect to expenditure allocated to the joint activity of the wife and her child on a weekday.

- A wife in her thirties has lower marginal utility with respect to time allocated to her individual out-of-home leisure on a weekday.

Second, Table 3 also shows the characteristics of resource allocation on a weekend day in Tokyo as,

- The more the number of children in the household is, the lower both the wife's and her child's marginal utility with respect to expenditure allocated to their joint activity on a weekend day is.

- The wife's marginal utility with respect to time allocated to her in-home leisure on a weekend day is lower if her child is a girl than if her child is a boy.

Table 3: Estimation results of household joint resource allocation model in Tokyo

	Week day			Weekend day		
Variables	Parameters associated with variables	Coeffcients	t value	Parameters associated with variables	Coeffcients	t value
Variance w.r.t. time	-	6.09	26.3	-	6.29	25.7
Variance w.r.t. expenditure	-	3.63	24.0	-	5.13	24.0
Number of children	C-hw(h), C-hw(w)	1.24	1.8	C-wc(w), C-wc(c)	-0.58	-1.2
Child's sex (1:girl, 0:boy)	T-home(c)	-3.12	-2.3	T-home(w)	-4.02	-3.2
Child's age	T-ind(c)	-0.11	-1.6	T-ind(c)	-0.42	-1.5
Weekly ratio of non-work days of husband	T-home(h)	3.64	1.7	C-hwc(h), C-hwc(w), C-hwc(c)	19.89	6.8
Husband's allowance for a non-work day	C-ind(h)	0.19	2.8	C-ind(h)	0.04	1.8
Dummy variable of husband's age (1 if in his 40s and 0 else)	C-ind(h)	-4.54	-2.8	C-ind(h)	3.29	3.5
Dummy variable of husband's job (1 if employee and 0 else)	T-home(w)	1.92	1.7	C-hw(h), C-hw(w), C-hc(h)	-3.49	-2.2
Dummy variable of husband's job (1 if self-employed and 0 else)	T-ind(h), T-home(h)	1.57	1.0	C-ind(h)	2.28	1.7
Constant for expenditure of husband's individual out-of-home leisure	C-ind(h)	13.95	8.0	C-ind(h)	5.02	4.7
Weekly ratio of non-work days of wife	T-home(c)	-4.99	-2.0	C-wc(w)	3.53	1.8
Wife's allowance for a week day	C-hwc(w)	0.24	3.4			
Wife's allowance for a weekend day				C-ind(w)	0.08	1.3
Dummy variable of wife's age (1 if in her 30s and 0 else)	T-ind(w)	-0.87	-1.3	C-ind(w)	5.58	4.1
Dummy variable of wife's job (1 if housewife and 0 else)	T-home(w)	1.85	1.5	T-home(c)	-3.27	-2.6
Dummy variable of wife's job (1 if part-time employee and 0 else)	C-wc(w), C-wc(c)	-5.24	-3.2	C-ind(w), C-hw(w), C-hwc(w)	3.01	2.7
Constant for expenditure of wife's individual out-of-home leisure	C-ind(w)	3.38	6.7			
Constant for expenditure of child's individual out-of-home leisure				T-ind(c)	3.40	1.3
Number of observation	89(267)			89(267)		
Initial log-likelihood	-13153.7			-14060.5		
Final log-likelihood	-3544.6			-4172.5		
Likelihood ratio	0.731			0.703		

- The older the child's age is, the lower the child's marginal utility with respect to time allocated to the child's individual out-of-home leisure on a weekend day is.

- The more the husband's non-work days in a week are, the higher all household members' marginal utility with respect to the expenditure allocated to the joint activity of all household members on a weekend day is.

- A self-employed husband in his forties with his high allowance for a non-work day has higher marginal utility with respect to expenditure for his own individual out-of-home leisure on a weekend day.

- The more the wife's non-work days in a week are, the higher the wife's marginal utility with respect to expenditure allocated to the joint activity with her child on a weekend day is.

- A wife in her thirties with her high allowance for a non-work day has higher marginal utility with respect to expenditure allocated to her individual out-of-home leisure on a weekend day.

- A child whose mother is a housewife has lower marginal utility with respect to time allocated to the child's in-home leisure on a weekend day.

Third, Table 4 shows the characteristics of household resource allocation on a weekday in Toyama as,

- The more the number of children in the household is, the lower the wife's marginal utility with respect to time allocated to her individual out-of-home leisure on a weekday is.

- Both the husband's and the child's marginal utility with respect to time allocated to their joint activity on a weekday is higher if the child is a boy than if the child is a girl.

- The older the child's age is, the lower the child's marginal utility with respect to time allocated to the child's individual out-of-home leisure on a weekday.

- A husband with many non-work days in a week with his high allowance for a work day has higher marginal utility with respect to expenditure allocated to his individual out-of-home leisure on a weekday.

- An employed husband in his forties has higher marginal utility with respect to time allocated to his individual out-of-home leisure on a weekday.

- A housewife whose husband is employed has higher marginal utility with respect to time allocated to her individual out-of-home leisure on a weekday.

- All household members' marginal utility with respect to expenditure allocated to the joint activities of all members on a weekday is higher if the husband is self-employed.

- A wife not in her thirties with many non-work days in a week with her high allowance for a non-work day has higher marginal utility with respect to expenditure allocated to her individual out-of-home leisure on a weekday.

- A wife who is a part-time worker has higher marginal utility with respect to expenditure allocated to the joint activity with her child.

Fourth, Table 4 also shows the characteristics of household resource allocation on a weekend day in Toyama as,

- The more the number of children in the household is, the higher the wife's marginal utility with respect to time allocated to her individual out-of-home leisure on a weekend day is.

Table 4: Estimation results of household joint resource allocation model in Toyama

	Week day			Weekend day		
Variables	Parameters associated with variables	Coeffcients	t value	Parameters associated with variables	Coeffcients	t value
Variance w.r.t. time	-	5.47	48.9	-	6.08	47.2
Variance w.r.t. expenditure	-	3.81	44.3	-	5.70	43.8
Number of children	T-ind(w)	-0.14	-1.3	T-ind(w)	0.44	2.9
Child's sex (1:girl, 0:boy)	C-hc(h), C-hc(c)	-4.26	-3.2	C-hc(h), C-hc(c)	-1.83	-2.3
Child's age	T-ind(c)	-0.04	-1.7	T-ind(c)	0.10	3.1
Weekly ratio of non-work days of husband	C-ind(h)	12.46	3.4	T-ind(h)	3.92	2.7
Husband's allowance for a work day	C-ind(h)	0.12	5.1			
Husband's allowance for a non-work day				C-ind(h)	0.02	1.9
Dummy variable of husband's age (1 if in his 40s and 0 else)	T-home(h)	0.68	1.4	T-home(h)	2.22	3.8
Dummy variable of husband's job (1 if employee and 0 else)	T-home(h), T-home(w)	1.13	2.9	C-hw(h), C-hw(w)	-5.18	-5.8
Dummy variable of husband's job (1 if self-employed and 0 else)	C-hwc(h), C-hwc(w), C-hwc(c)	2.20	1.8	C-ind(h)	2.52	2.9
Constant for expenditure of husband's individual out-of-home leisure	C-ind(h)	5.14	5.5	C-ind(h)	4.56	9.9
Weekly ratio of non-work days of wife	C-ind(w)	12.31	6.5	C-ind(w)	7.88	3.7
Wife's allowance for a week day				C-ind(w)	-0.08	-1.9
Wife's allowance for a weekend day	C-ind(w)	0.03	1.2			
Dummy variable of wife's age (1 if in her 30s and 0 else)	C-ind(w)	-0.97	-1.6	C-ind(w)	0.93	1.2
Dummy variable of wife's job (1 if housewife and 0 else)	T-home(w)	3.55	6.0	C-hwc(h), C-hwc(w), C-hwc(c)	5.05	7.4
Dummy variable of wife's job (1 if part-time employee and 0 else)	C-wc(w)	1.10	1.2	T-home(w)	1.29	1.5
Constant for expenditure of wife's individual out-of-home leisure	C-ind(w)	4.22	7.0	C-ind(w)	1.06	1.3
Number of observation	303(909)			303(909)		
Initial log-likelihood	-37856.0			-46059.2		
Final log-likelihood	-11799.7			-14711.3		
Likelihood ratio	0.688			0.681		

- Both the husband's and the child's marginal utility with respect to expenditure allocated to their joint activity on a weekend day is lower if the child is a girl than if the child is a boy.

- The older the child's age is, the higher the child's marginal utility with respect to time allocated to the child's individual out-of-home leisure on a weekday.

- A husband with many non-work days in a week has higher marginal utility with respect to time allocated to his individual out-of-home leisure on a weekend day.

- A self-employed husband with his high allowance for a non-work day has higher marginal utility with respect to expenditure allocated to his individual out-of-home leisure on a weekend day.

- A husband in his forties has higher marginal utility with respect to time allocated to his in-home leisure on a weekend day.

- A wife in her thirties with many non-work days in a week with her high allowance for a non-work day has higher marginal utility with respect to expenditure allocated to her individual out-of-home leisure on a weekend day.

- If a wife is a housewife, all household members have higher marginal utility with respect to their expenditure allocated to the joint activity of all members on a weekend day.

- A wife who is a part-time employee has higher marginal utility with respect to time and expenditure allocated to her in-home leisure on a weekend day.

Fifth, Table 3 and 4 show the common characteristics of two cities as,

- A husband with more non-work days in a week has higher marginal utility

- A husband with higher amount of allowance has higher marginal utility

- A wife in her thirties has lower marginal utility with respect to time of her individual out-of-home leisure

- A housewife has higher marginal utility with respect to time of her in-home leisure on a weekday.

Finally, we can find the contrastive characteristics between two cities. For example as far as the activities of a husband in his forties on a weekend day is concerned, his marginal utility with respect to expenditure of his individual out-of-home leisure is higher in Tokyo, whereas his marginal utility with respect to time of his in-home leisure is higher in Toyama. This may reflect that the average expenditure of husband's individual out-of-home leisure is about twice higher in Tokyo than in Toyama. We guess that a husband in his forties in Tokyo tend to go somewhere alone such as going golf whereas a husband in Toyama may not. As far as the child's activity on a weekend day is concerned, the older a child is, the lower the marginal utility with respect to time allocated to individual out-of-home leisure in Tokyo is, whereas the older a child is, the higher the marginal utility with respect to time allocated to individual out-of-home leisure in Toyama. We can point out some reasons for this. For example, one is that a family tend to enjoy the joint leisure together on a non-work day and the other is that there is less leisure facilities such as a park for children to play out on a non-work day.

6. Conclusions

This paper investigates the household joint resource allocation with the empirical data of activity diary survey including both time and monetary expenditure. The proposed model considers a child explicitly in addition to its parents. The model considers not only time allocation, but also monetary budget allocation of household. We analyze a choice of activity duration as well as activity type. We compare the intra-household interactions between a week day and a weekend day and between two different cities. The results of empirical analysis show that the intra-household interactions may vary between different cities.

Although we overcome some difficulties which have been pointed out in previous researches, we still have issues which should be examined further more. First, we assume a representative child in a household. However, if there are two or more than two children in a household, they are expected to behave in different ways. The assumption of a representative child may bias the analysis due to this simplification. On the other hand, if we will develop a joint household resource allocation model with a consideration of many children, we should use more complicated model structure. We need to examine a trade-off between reality and complexity. Second, we do not investigate an allocation of monetary budget among household members. As Chiappori (1992) suggests, we may need to consider the allocation of income with an additional model 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 should be quite difficult. Third, we consider the time and expenditure allocation on a day. However, an individual may allocate her/his resources in 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 such as Kato *et al.* (2006). 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 own resource allocation, we may need to focus on the resource allocation of parents, mainly a wife with a child-care such as Gronau (1976), Ribar (1992, 1995) and Michalopoulos *et al.* (1992).

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