CAPTURING DECLINE AND ITS FACTORS OF JAPANESE YOUNG PEOPLE'S CAR OWNERSHIP AND USAGE BEHAVIOR BASED ON NATIONAL SURVEY OF FAMILY INCOME AND EXPENDITURE IN JAPAN*

Junyi ZHANG [1†], Weiyan ZONG [2] and Shun YOSHIMOTO [3]

[1]Member of JSCE, Professor, Mobilities & Urban Policy Lab, Graduate School for International Development and Cooperation, Hiroshima University
(1-5-1 Kagamiyama, Higashi Hiroshima 739-8529, Japan)
E-mail: zjy@hiroshima-u.ac.jp

[2] Non-member of JSCE, Doctoral Candidate, Mobilities & Urban Policy Lab, Graduate School for International Development and Cooperation, Hiroshima University
(1-5-1 Kagamiyama, Higashi Hiroshima 739-8529, Japan)
E-mail: zongweiyan0509@163.com

[3] Non-member of JSCE, The Chugoku Electric Power Co. Inc.
(4-33 Komachi, Naka-ku, Hiroshima City, Hiroshima 730-8701, Japan)

1. Introduction

It is said that a declining trend of young people's car ownership and usage has been observed in Japan, similar to some other developed countries. However, the evidence is limited. This research presents additional evidence by using a household-level long-term and large-scale national survey data: i.e., National Survey of Family Income and Expenditure in Japan collected in 1984, 1989, 1994, 1999, 2004, and 2009. Every time, about 50,000 households participated in the survey. Different evidence, from existing studies, of young people's car ownership and usage has been revealed, especially in terms of engine displacement. Interactions between car-related expenditure and other expenditure have been empirically explored. Furthermore, a new type of multiple discrete-continuous choice model based on the concept of multilinear utility is built. The analysis focuses on the effects of socio-demographic attributes are focused on. The current manuscript presents detailed information of the modeling development. Modeling results will be reported at the time of the conference.

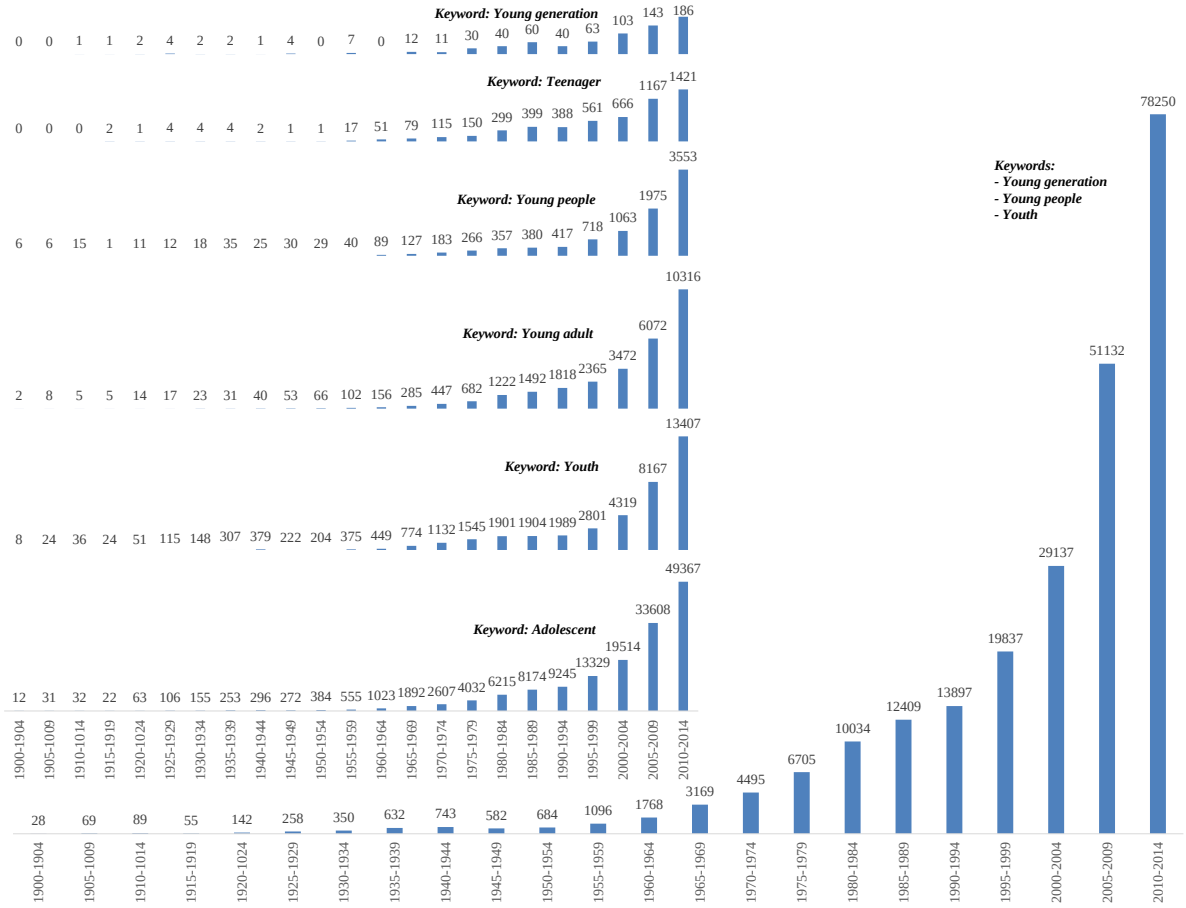
The remaining part of this paper is organized as follows. Section 2 summarizes existing research on young people and Section 3 presents existing evidence of young people's car ownership and usage all over the world, including Japan. Section 4 illustrates new evidence of young people's car ownership and usage in Japan based on the above-mentioned National Survey of Family Income and Expenditure. To explore factors affecting young people's car ownership and usage, Section 5 builds two types of multiple discrete-continuous choice models are introduced and compared: MDCEV model (Bhat, 2005 and 2008) and RAM-MLF model (Yu and Zhang, 2015), the latter model is an extension of the multilinear utility based time allocation model by Zhang et al. (2002, 2005). Finally, Section 6 summarizes the contents of this manuscript.

2. Research on Young People

Young people have been researched in many disciplines over years. The definition of *young people* is culturally and historically specific, varying through time and between different societies (Cieslik and Simpson, 2013: p.45). Similar terms include *young generation*, *young adults*, *youth*, *adolescent/adolescence*, and *teenager*s. Youth refers to the period between childhood and adulthood.

* This paper is made by combining the following two papers: Zhang et al. (2016), Yu and Zhang (2015), and adding some new contents. This paper is not submitted for being reviewed by the conference journal, but for sharing the academic information.
† Corresponding author

Several organizations of The United Nations treat '*youth*' and '*young people*' in the same meaning, but adopt different age ranges (e.g., UN Secretariat, UNESCO and ILO: 15 – 24 years old; UN Habitat: 15 – 32 years old; UNICEF: under 18 years old; The African Youth Charter: 15 – 35 years old) [1]. Differently, UNICEF, WHO, and UNFPA distinguish between *adolescent* (10 – 19), *young people* (10 – 24), and *youth* (15 – 24). In the USA, *youth* is same as *teenager* (10 – 19). *Young adults* refer to the population aged 15 – 34 in Japan [2] and 16 – 24 in the UK[3]. Searching these keywords from paper titles included in the *Web of Science* ™, we found 235,561 hits, as shown in Figure 1 (*adolescent/adolescence*: 151,187; *youth*: 40,281; *young adult*: 28,693; *young people*: 9,356; *teenager*: 5,332; *young generation*: 712) at the time of writing. Early studies started in the 1900s. Since 1960s, the number of studies has gradually increased and especially, a dramatic increase has been observed since the late 1990s. Studies in the late 2000s are 75% more than those in the early 2000s. The early 2010s observed about 50% more studies than the late 2000s.



(Source: Web of Science ™)

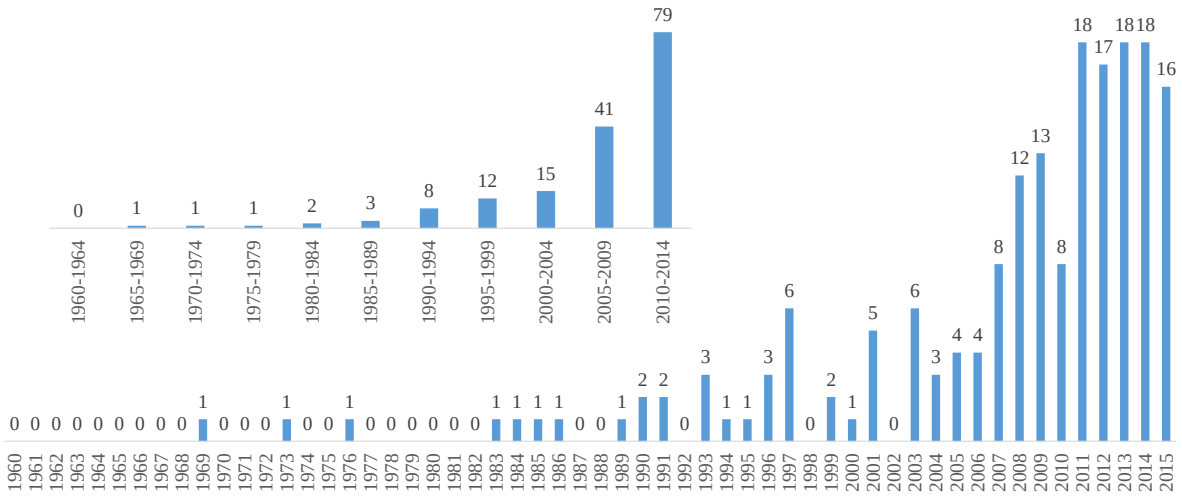
Figure 1. The number of papers dealing with young people and relevant keywords

One more relevant keyword is *millennial generation* (or *generation Y*: aged 26 – 40), which is included only in 204 papers, in total. In case of Japan, we searched relevant studies from the database of grants-in-aid for scientific research *KAKEN* and found 163 projects, most of which were conducted since the late 2000s (Figure 2).

Thus, more and more researchers in various disciplines (e.g., education, social science, psychology, health, medical science, law, culture, and history) have paid a remarkably increasing attention to young people. For example, as stated by Cieslik and Simpson (2013), in the social science, which is especially beneficial to travel behavior research, young people has been studied about their identities, cultural practices, and the life course transitions they make towards adulthood by situating

[1] http://www.un.org/esa/socdev/documents/youth/fact-sheets/youth-definition.pdf
[2] Statistics Bureau of Japan: http://www.stat.go.jp/english/data/nenkan/1431-02.htm.
[3] http://www.ukyouth.org/events/item/292-statistics-about-young-people-in-the-uk.html#.VmbxmbiLRD8

their lives in wider social and historical contexts. Research topics include education, job training, work and employment, leisure, social network, place, housing, poverty, homelessness, health, music, religion, new technologies, globalization, social movements, gender, inequality, crime, and wellbeing, etc. Related to travel behavior, the relationship between young people and place has also been explored widely. Place not only refers to physical space or location, but also indicates an order of priority, outcome, occupation or vocation as well as a mental or psychological construction imbued with meaning, symbolisms and emotions, which shape people's social identities and practices as they grow through life (Cieslik and Simpson, 2013: p.112). Different types of young people may understand place differently from older people, where the environmental characteristics of places (e.g., neighborhoods and communities) have different meanings for the young people that reside within them (Hopkins, 2010). Research on young people and the living environment has a long history in the social science as seen in the Chicago School whose social ecology of the city linked the physical characteristics of neighborhoods with the norms and values of its residents, and early studies focused on the social exclusion of young people (Thrasher, 1927). In recent studies targeting the North East of English, researchers showed how places affected socially excluded working-class young people's strong sense of attachment and belongings to place-based social networks, which however also limit the possibilities of their escaping the conditions of social exclusion (MacDonald et al., 2005). Even under the current globalization trend, local places are still influencing young people's life in complex ways (Robertson, 1992). Travel behavior research has been done for more than 40 years. Since the beginning, age has been often treated as an important variable to explain travel behavior. In this sense, we should say that studies on young people's travel behavior have a similar length of history of general travel behavior research. Then, after four decades, what we have learnt about young people's travel behavior? How different from other people's travel behavior? Why we have to focus on young people in travel behavior research from the perspectives of both behavioral studies and policy decisions?



(Source: *KAKEN*: https://kaken.nii.ac.jp/)

Figure 2. The number of scientific research projects about young people in Japan

Behavioral differences between young people and older people are mainly due to the age difference and the era within which people grow. Age is a symbol of life experience, which has various effects on and meanings for different life choices and daily activities. Human decisions are influenced by not only decisions made in the past (i.e., state dependence, which analysis is usually troubled with the issues of long-term vague memory, and forgetting), but also those in the future (i.e., future expectation, which is usually involved with various uncertainties). As shown in Figure 3, when comparing young people and older people, such time-related decision-making mechanisms cannot be ignored. Older people have a longer life trajectory than young people who have a longer life expectancy. If state dependence is a kind of reflection of accumulated experiences in the past, experiences may have a larger impact on the present behavior than future expectations in case of older people, while on the contrary, young people's behavior may receive more influence from future expectation than from experiences. Furthermore, existence of various future uncertainties makes the above decision-making

mechanisms more difficult to understand and represent. One more issue is that the same age (e.g., 20 years old) in the present and that in the past (e.g., 20 years ago) may have different meanings for and impacts on human decisions. In other words, the young people in the past and those in the present may behave very differently. Therefore, it is very important to compare young people and older people over time for understanding their behavioral differences.

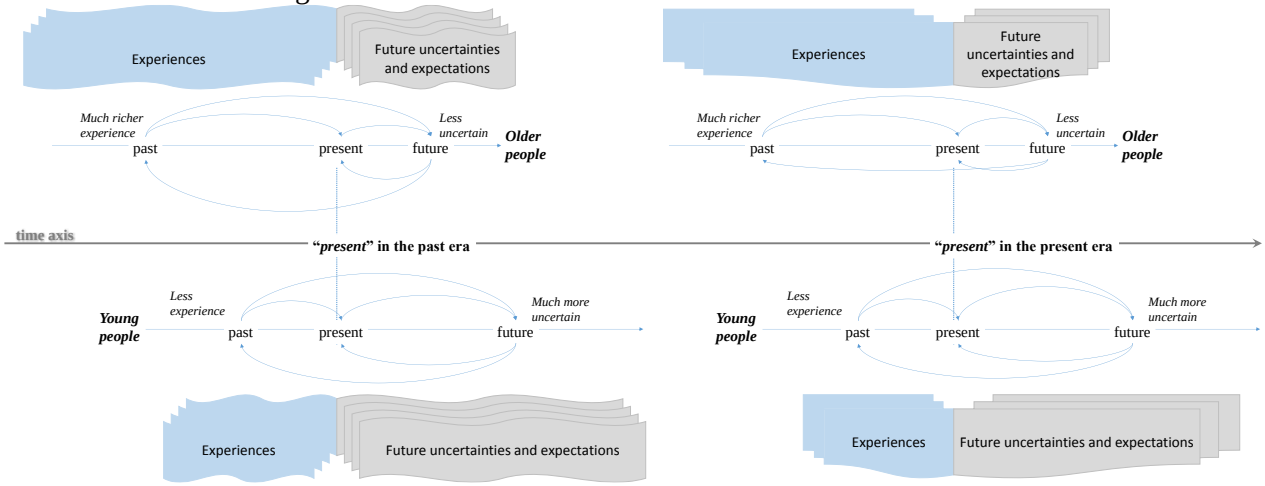


Figure 3. Differences of behavioral decisions between young people and elderly people

3. Young people's car ownership behavior

3.1 Evidence in general

The average travel time for daily activities is about 60~80 minutes (e.g., Metz, 2004; Van Wee et al., 2006; Vilhelmson, 2007; Zumkeller, 2009)[4]. Even if car users may have a longer travel time, they have to park their cars somewhere for most of the time of a day. In this sense, owning a car is costly and using it is inefficient, but car is surely a convenient means for accessing to goods and services. In recent years, some developed countries observe a decreasing trend of car ownership among young people (e.g., Metz, 2010; Davis et al., 2012; Goodwin and Van Dender, 2013; Kuhnimhof et al., 2012; Kuhnimhof et al., 2013). In the developing countries, generally speaking, car ownership is still growing. For example, in India, college students who find that car use improves their societal image and car ownership contributes to happiness have a higher propensity to own a car (Verma et al., 2015). This finding is understandable. A good news for sustainable transportation development in India is that college students who are satisfied with public bus systems are less likely to buy a car. Surprisingly, Verma et al. further revealed that male college students in India have a lower tendency to own a car in near future than female.

The above-mentioned inefficient and costly performance of a car might be one reason for keeping young people away from cars. Delbosc and Currie (2013) examined causes of youth licensing decline in 14 developed countries based on both cross-sectional and longitudinal studies, including changes in life stage and living arrangements, changes in motoring affordability, location and transport, graduated driver licensing schemes, attitudinal influences and the role of e-communication. They concluded that there would be multiple causes rather than any single influence, even though evidence is weak and preliminary. In their study, affordability is identified as a stronger influencing factor, together with life stage factors. In addition, changes in lifestyles might be another reason. Previously owning a car is a symbol of social status for many people. Nowadays, such symbolic meaning of a car seems less important for young people in some developed countries. These days, many young people spend a lot of time on the Internet via PC, smartphone, and tablets, etc. Driving a car reduces the opportunities to enjoy the Internet surfing, probably becoming one more reason why some young people do not like to own a car. At least, when using a train or a bus, they may enjoy multitasking (e.g., reading, listening to

[4] We found similar results about Japanese daily travel time between 1976 and 2006 by using data from the Survey on Time Use and Leisure Activities collected by the Ministry of General Affairs.

music, and surfing the Internet). Many of other reasons might be relevant to life choices in other domains. First, both car users and non-car users may take advantage of public transport, which is sufficiently high enough to satisfy their mobility needs (Metz, 2010; Kuhnimhof et al., 2012). Second, the structural relationship between income and car ownership and usage has probably changed. Goodwin and Van Dender (2013) noted that "although the classic 'economic' factors are still seen to be important, without doubt, the nature of their importance seems to have changed, with a reduction over time of the size of some elasticities with respect to price and income, and more important through the medium of differential responses by population category and location". Unfortunately, most empirical studies on estimating the elasticities have been made without the consideration of population category (e.g., Goodwin et al., 2004; Graham and Glaister, 2004), and need to wait further empirical results to get sound conclusions.

3.2 Evidence in Japan

There are some empirical studies on young people's car ownership and usage in Japan. Nishimura (2012) pointed out that, compared to the previous generation, the current young generation does not really enjoy driving. Car tends to be regarded as a tool for moving around rather than a status symbol. If this is the case, young people residing along the public transportation might be less likely to own and use a car in their life. Fujioka et al. (2012) analyzed young women's travel behavior in Tokyo, and found that married couples tend to reduce car use, while it does not change for households with children. They concluded that the current urban structure in Tokyo might allow married couples to fulfill their activity needs without cars, while some activities for/with children may be impossible with cars. Yotsumoto (2012) discussed the possible reasons why the percentage of young men who are interested in cars rapidly declines from 71% (in 2001) to 42% (in 2011) based on the psychological cognitive dissonance theory. He argued that young men might unconsciously repress their will to own a car mainly due to financial reasons. However, there is no clear evidence indicating that.

4. New evidence of young people's car ownership behavior in Japan based on new data

Here, we present some preliminary results based on National Survey of Family Income and Expenditure in Japan, in the years 1984, 1989, 1994, 1999, 2004, and 2009.

Figures 4 – 6 show changes of different population groups' car ownership by income over time. Figures 7 – 9 illustrate changes of different population groups' expenditure (including car usage costs) by income over time. Figures 10 and 11 shows the trend in terms of engine displacement. Findings from these figures are summarized as follows:

- Irrespective of income, car ownership of the middle-aged people (aged 36 – 64) and the elderly people (aged 65+) show a trend that is clearly increasing from 1984 to 2009. Especially, the increase from 1994 to 1999 is dramatic for the middle-aged people. An increasing trend can be observed with respect to the middle-income young people (aged 18 – 34), but the trend from 1994 to 2009 is not significant.
- The low- and high-income young people first increased their car ownership from 1984 to 1999. However, the ownership dropped from 1999 to 2004, which is dramatic (-7.8 points from 50.5% to 42.7% for the low-income group and -10.3 point from 75.2% to 64.9% for the high-income group), compared to the drops from 2004 to 2009.
- As for expenditure[5], the low-income young people's expenditure on car use decreased from 5.7% in 1994 to 3.9% in 2009, the middle-income group from 8.2% in 1994 to 6.4% in 2009, and the high-income group from 9.8% in 2004 to 5.2% in 2009. Particularly, the decrease in the rate of expenditure on car use is higher (-4.6 points) for the high-income group, and the drop started earlier for the low- and middle-income groups than the high-income group.
- Overall, the decrease of car ownership is higher than that of the car usage.

[5] Car purchase costs are excluded. This is because once a car was purchased in a year, such costs are not counted in the next year.

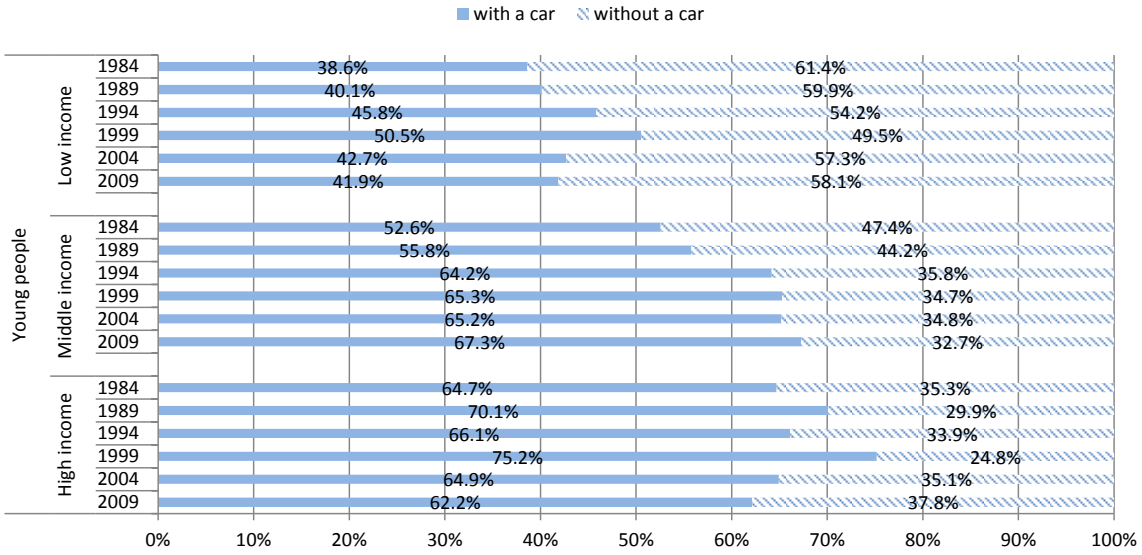


Figure 4. Changes of young people' car ownership over time by income

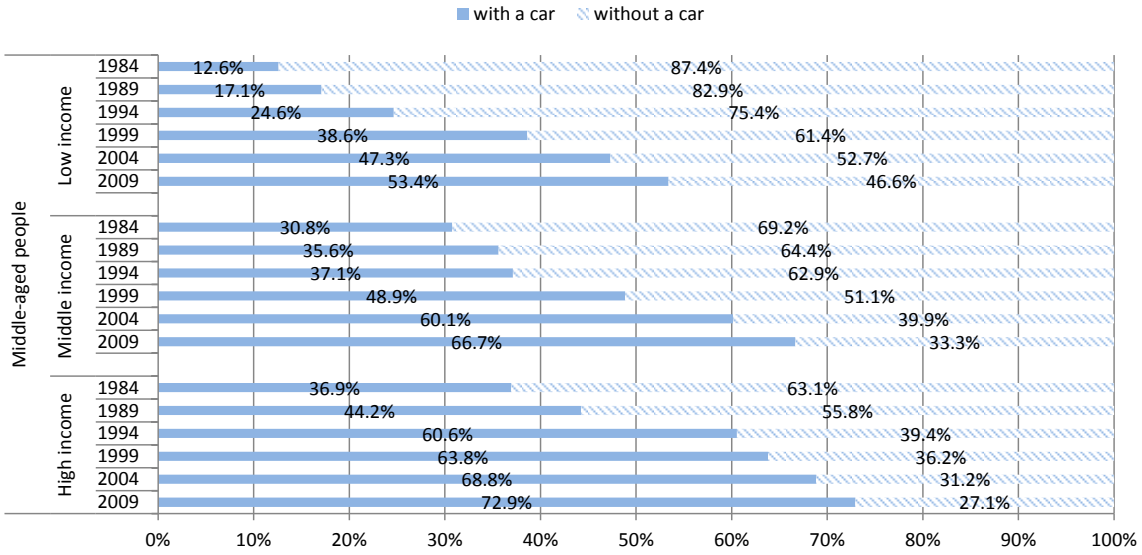


Figure 5. Changes of middle-aged people' car ownership over time by income

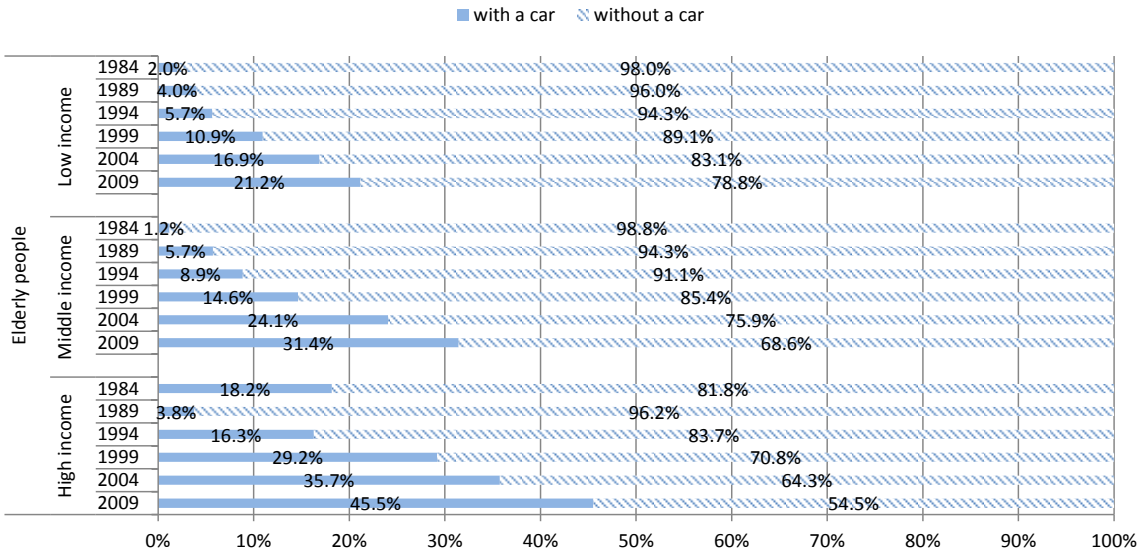


Figure 6. Changes of elderly people' car ownership over time by income

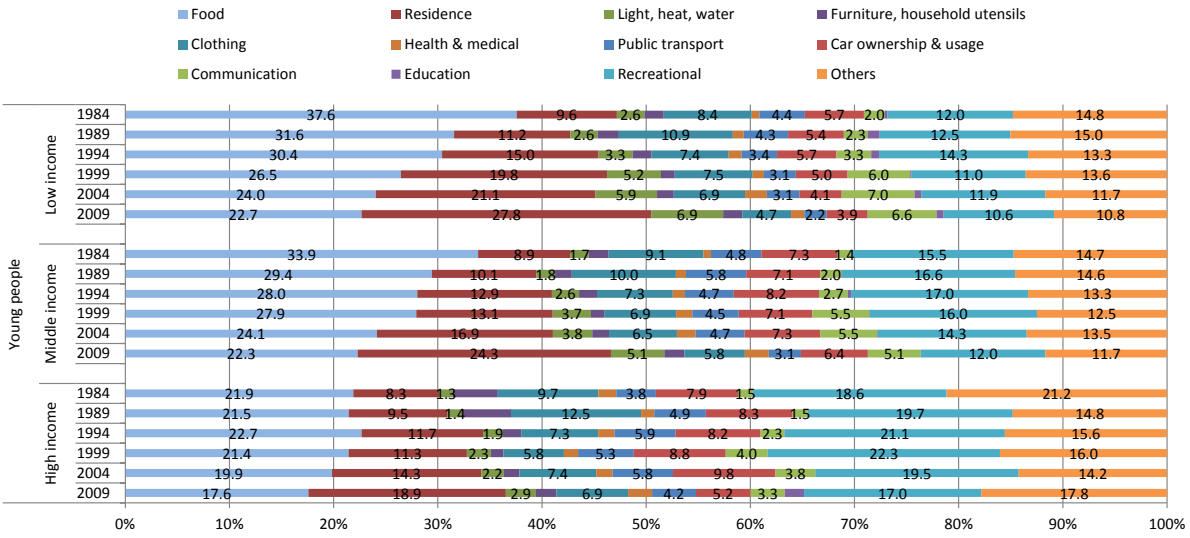


Figure 7. Changes of young people' expenditure over time by income

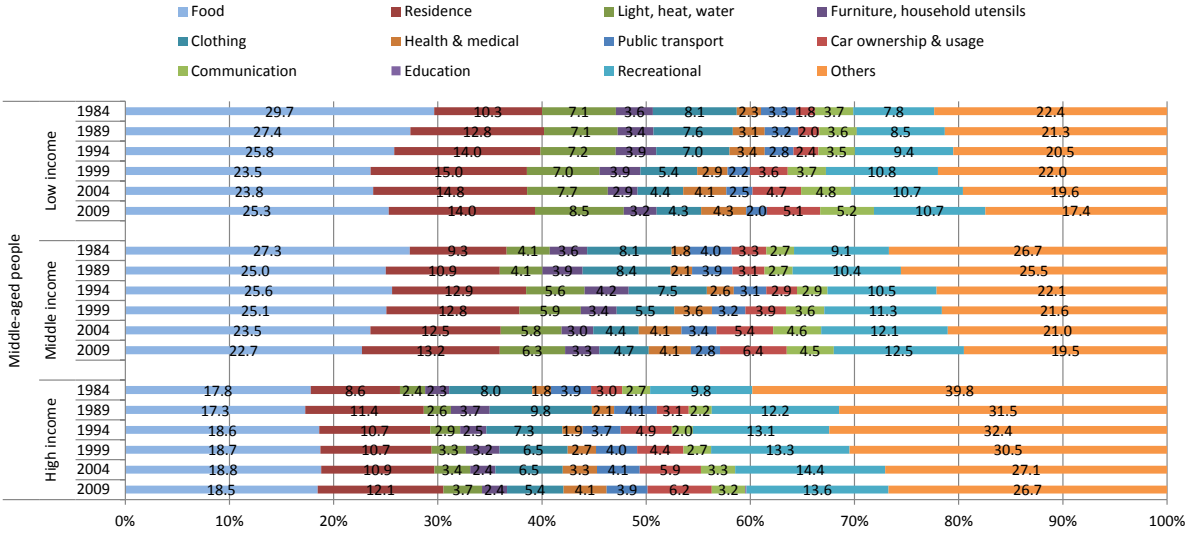


Figure 8. Changes of middle-aged people' expenditure over time by income

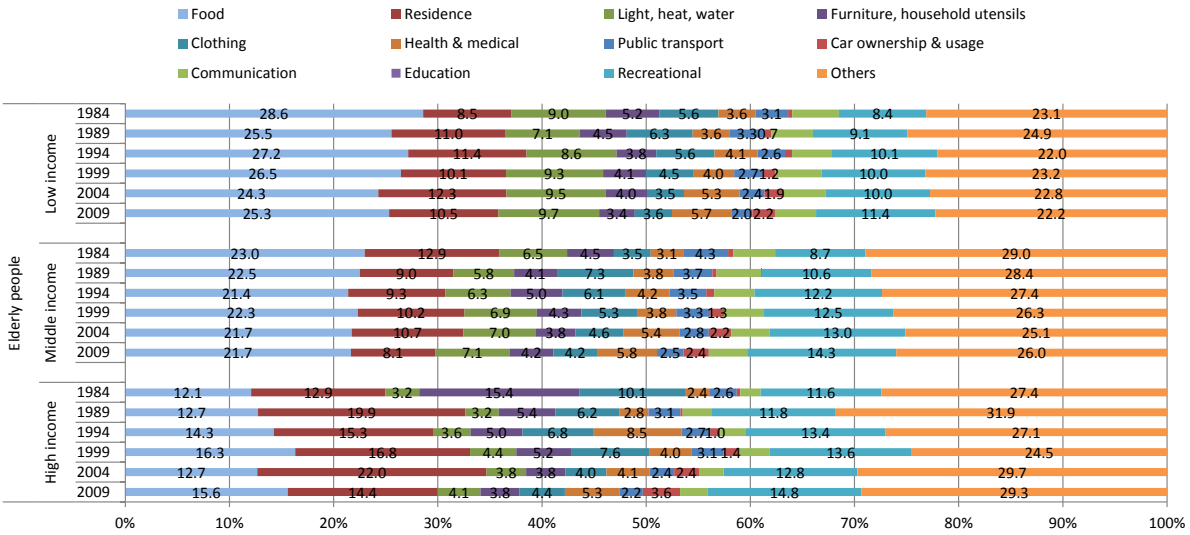


Figure 9. Changes of elderly people' expenditure over time by income

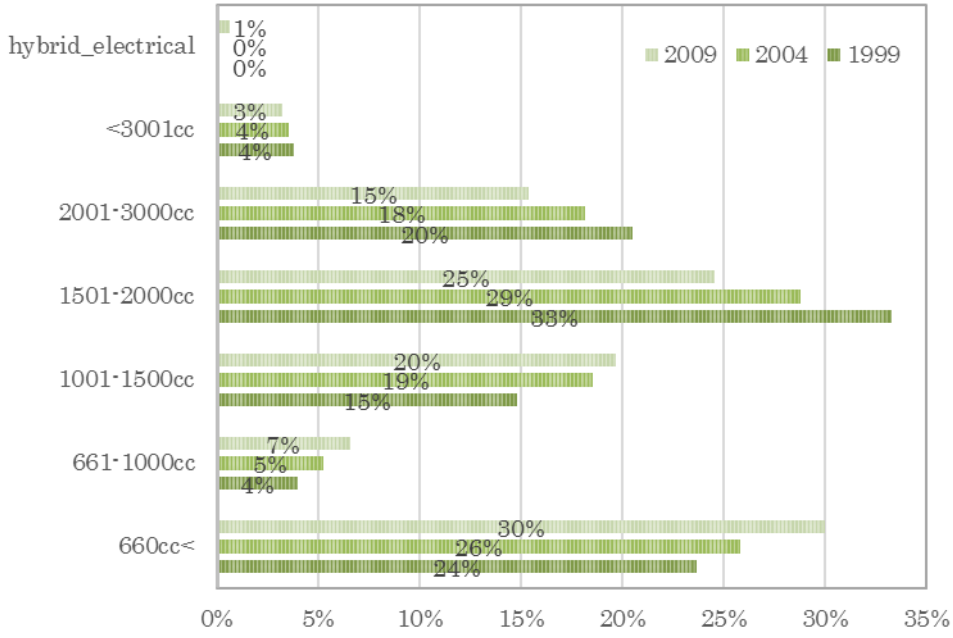
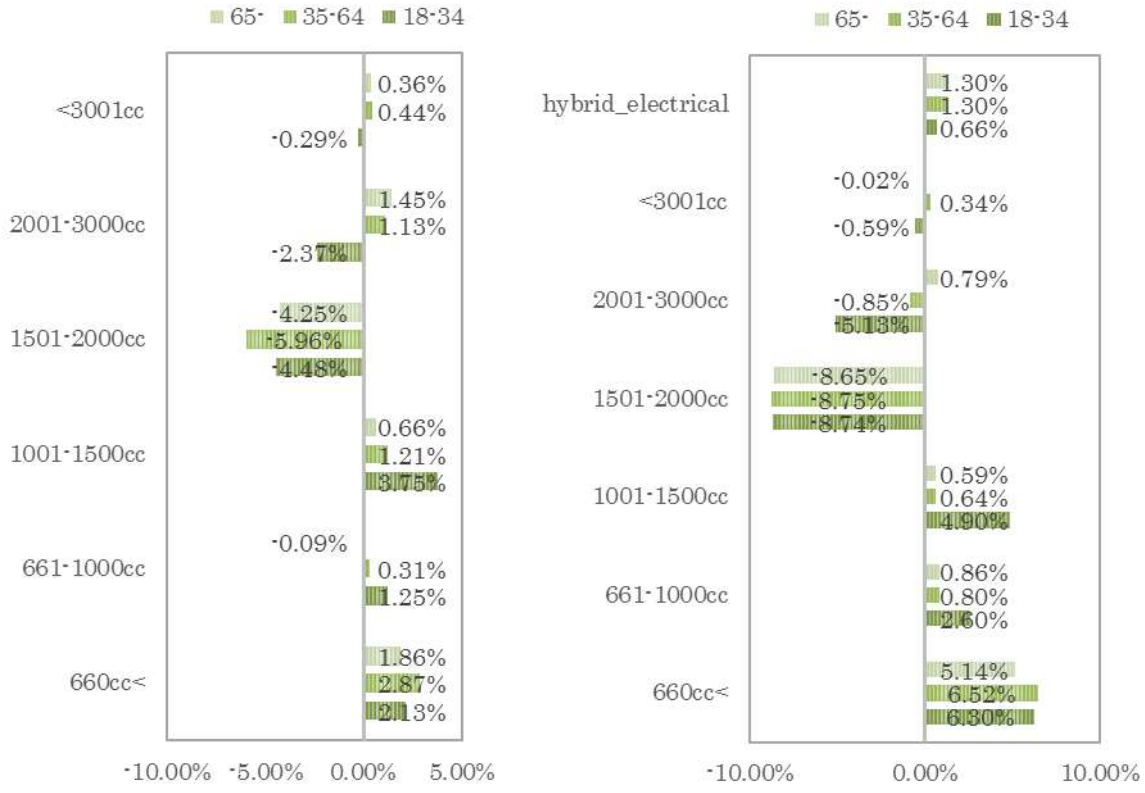


Figure 10. Car ownership by engine displacement from 1999 to 2009 (Young people)



(a) from 1999 to 2004 (b) from 2004 to 2009

Figure 11. Changes of car ownership by engine displacement for different age groups

- Differently, the middle-aged people and the elderly people still show increasing trends even in case of car usage.
- How about expenditure on public transport? For young people, the low-income group shows a continuous decrease from 4.4% in 1984 to 2.2% in 2009, while the middle-income group's expenditure started to decrease from 1989 when its share in the total expenditure was 5.8% and it

decreased to 3.1% in 2009. The high-income group reduced its expenditure on public transport from 2004. The middle-aged people with low- and middle-income and the elderly people showed similar decrease in trends as of the young people. However, the decrease is not as significant as the young people's are. On the other hand, the ratio of expenditure of the middle-aged people with high income keeps almost the same.

- The low-income young people's expenditure on transportation (both car and public transport) continuously decreased from 10.1% in 1984 to 6.1% in 2009 (-4.0 points), the middle-income young people decreased their expenditure on transportation from 12.1% in 1984 to 9.5% in 2009 (-2.6 points), and the high-income young people from 11.7% in 1984 to 9.4% in 2009 (-2.3 points).
- The above changes in transport expenditure occurred jointly with changes in other expenditure. For example, young people's expenditure trends for clothing and recreational activities are decreasing similarly to the trend of their expenditure on transport. Especially, the young people's expenditure on food decreased remarkably. What increased are expenditure on light, heat and water, and communication. In particular, the residence expenditure had continuously increased since 1984, especially the increase from 2004 to 2009 was significant. Similar to the young people, the increase in expenditure on light, heat and water, and communication can be observed from the middle-aged people as well.
- Cars with smaller engine displacement have become more and more popular, especially among young people. Furthermore, a steady increasing trend of under-1500cc cars can be observed. The under-600cc cars, mainly light cars, occupy 30% of cars owned by young people in 2009, compared with 24% in 1999 and 26% in 2004. The proportions of both 661-1000cc and 1001-1500cc cars have an obvious augment from 4% to 7% and 15% to 20%, respectively. On the other hand, the shares of over-1501cc cars, composed of 1501-2000cc, 2001-3000cc and over-3001cc cars, have fallen all the way since 1999. Among all proportional changes, the largest absolute values are the increases in 1001-1500cc from 1999 to 2004 and under-600cc from 2004 to 2009, and the reductions in 1501-2000cc from 1999 to 2004 and from 2004 to 2009. Besides that, an additional choice is provided in the 2009 survey with the emergence of new-energy vehicles — hybrid vehicle and electric vehicle, and less than one percent of young people have adopted this new model. When compared with other age groups, young people's preference for low-emission cars seems to increase more intensively. In terms of the augments in the proportions of under-1500cc and the reductions in the proportions of over-1500cc, young people are well ahead of middle-aged people and elderly people. However, young people's adaptation rate of hybrid and electric vehicles is a bit behind other two groups.

5. Modeling issues

Practically, many consumer decisions are under the situation that multiple alternatives are simultaneously chosen and consumed. One example is the time use across varied activities within a given time period (e.g., a day, a week). Individuals always choose to participate in several types of activities and meanwhile allocate certain time on them. Another example could be the expenditure on several life domains. Under the constraint of the total available money, individuals/households decide to allocate budgets on a set of life domains and spend some amount of money on them so as to support their daily demand. Of course, in addition to these two cases, there are still many other decisions, which are related to multiple choices, such as the vehicle ownership and usage, brand choice and purchase quantity, and tourism destination group choice and the time/money allocated in each selected destination. In these contexts, traditional discrete-continuous models that usually deal with choice situations in which a household can choose only one alternative from a range of mutually exclusive alternatives in a choice set might be inappropriate. Instead, the multiple discrete-continuous models, which explicitly incorporate the limited resource (e.g., time and money), should be utilized from the behavioral perspective.

Recently, more and more attention is turned to model the multiple discreteness issues. This study aims to compare two types of multiple discrete-continuous models, deriving from random utility maximization, which are currently very popular in the literature: one is the multiple discrete–continuous extreme value (MDCEV) model proposed by Bhat (2005) and extended in Bhat (2008), the other is the resource allocation model based on the multi-linear function (RAM-MLF) developed by Zhang et al.

(2002, 2005). In the MDCEV model, the continuous part (e.g., the duration of the activities or the expenditure on the life domains) is a choice variable in the upper level and the discrete part (e.g., the participation in each activity or the budget allocation for each life domain) is captured by a multinomial logit component in the lower level (Fang, 2008). By embedding the upper level into the lower level, the MDCEV model is formulated. As for the RAM-MLF, although Zhang et al. (2002, 2005) treated the zero-expenditure which should be a result of the discrete choice as one part of continuous values, this problem actually can be easily figured out by using some estimators (e.g., Kuhn-Tucker conditions, and Amemiya (1974) estimator) which endogenously carry out the integration of the discrete and continuous components (similar with the Tobit model). In the empirical application, these two types of models have their own strengths and weaknesses. Specifically, apart from the simple manipulation of the MDCEV model, the flexible description of the utility which assumes diminishing marginal utility as the expenditure of any particular alternative increases (not only the logarithmic utility form), makes it being widely adopted recently. However, the additive-type utility function results in that increasing or disposing any alternative in the choice set will not influence the continuous decision for other alternatives, in other words, the inter-alternative interaction is not properly included in the model (similar with the IIA issue). Although the MDCEV model can be expanded to the mixed structure, which is, able to represent the correlation derived from the unobserved factors (i.e., error terms) between alternatives, it is only the statistical interaction without any behavioral rationality. In contrast, the RAM-MLF can incorporate diverse behavioral interactions by formulating the multi-linear group utility function. In addition, the relative importance of each alternative to the subject (e.g., individual, household, and other entities) can be also reflected in the model. However, the utility function is only defined as the log form and the interactions due to the unobserved factors are always ignored given the complex error terms after the transformation of the model structure.

By considering the unique characteristics of the MDCEV model and the RAM-MLF, this study first extends the RAM-MLF to incorporate the discrete choice behavior, after that the comparative analysis on the performance of these two types of models is conducted based on an empirical context of the household expenditure allocation behavior. It is easy to understand that households choose to allocate budgets on a set of life domains and spend some money on them. Meanwhile, expenditures for different life domains might be correlated with each other probably due to the income rebound effects, and/or the self-selection effects derived from the household social-demographics, and/or the function substitution or complementation between life domains. In this sense, the multiple discrete-continuous models, which can incorporate such interaction, might be more appropriate than the traditional models. Therefore, the MDCEV model and the RAM-MLF are developed to describe the above issue, respectively. These two models are estimated and compared by using the data collected in the national survey of family income and expenditure conducted in Japan every five years from 1984 to 2009.

5.1 MDCEV model

The MDCEV model is proposed by Bhat (2005, 2008). It assumes that there are *I* different life domains that a household can potentially allocate its income to. Let e_{ni} index the monetary expenditure on life domain *i* (*i = 2,3,…I*) for household *n*. Considering households will always spend their income on the food expenditure, which is labelled as the first life domain (i.e., i = 1), the model structure with an outside goods which is always consumed is adopted here (Bhat, 2008). The sum of the utilities derived from spending money on life domains u_{ni} is used to explain the overall utility u_n that household *n* obtains from life domain expenditure, see equation (1).

$$u_n = \sum_{i=1}^{I} u_{ni} = \frac{1}{a_1}\phi_{n1} e_{n1}^{a_1} + \sum_{i=2}^{I} \frac{\gamma_i}{a_i}\phi_{ni}\left\{\left(\frac{e_{ni}}{\gamma_i}+1\right)^{a_i} - 1\right\}, \quad \alpha_i \in (-\infty,\infty), \gamma_i > 0 \tag{1}$$

With the above utility specification, household *n* is assumed to maximize its utility subject to its monetary budget constraint E_n, that is $\sum_{i=1}^{I} e_{ni} = E_n$. As a result, the trade-offs between life domains

are accommodated in the model structure. φ_{ni}, the baseline utility for spending money on life domain *i*, is for controlling the discrete choice decision (i.e., whether to spend money on life domains) and continuous choice decision (i.e., money spent on life domain) with regard to life domain *i* for household *n*. a_i is a satiation parameter, which depicts the characteristic of the diminishing marginal utility with increasing expenditure for life domain *i*. Different values of a_i form various types of non-linear relationships between life domains. Specifically, when $a_i = 1$ (*i=1,2,…,I)*, the satiation effect is absent, suggesting a constant marginal utility and a linear competitive relation between life domain *i* and other life domains. With the decline of a_i from the value of 1, the satiation effect for alternative *i* amplifies. When a_i moves close to zero, the utility function for life domain *i* comes down to $u_n = (1/a_1)\varphi_{n1}e_{n1}^{a_1} + \sum_{i=2}^{I}\gamma_i\varphi_{ni}\ln(e_{ni}/\gamma_i + 1)$, indicating log-linear relationship between life domains. A negative value is also possible for a_i and, $a_i \to -\infty$ means immediate and full satiation, in other words, infinite decrease in the marginal utility. γ_i ($g_i > 0$), a translation parameter, serves to represent corner solutions (zero expenditure) for life domain *i*. Additionally, it also works as a satiation parameter, with γ_i closer to zero implying higher rate of diminishing marginal utility (or less expenditure) for a given level of the baseline preference. It is worth mentioning that since the outside goods is always consumed (non-zero expenditure), thus, the first life domain (i.e., food domain) does not have this translation parameter γ_1. After accommodating a_i and γ_i in the model structure, the description of the utility which assumes diminishing marginal utility with the increasing expenditure of any particular life domain becomes much more flexible compared with the widely adopted log-utility form. Mathematically, it is difficult to simultaneously estimate a_i and γ_i for the non-outside goods *i* (*i=2,3,…I*). Alternatively, we can estimate one of the three utility forms below and select the most appropriate form that fits the data best following the statistical considerations.

$$a\text{-profile } (\gamma_i = 1): \quad u_n = \frac{1}{a_1}\varphi_{n1}e_{n1}^{a_1} + \sum_{i=2}^{I}\frac{1}{a_i}\varphi_{ni}((e_{ni}+1)^{a_i} - 1) \tag{2-a}$$

$$\gamma\text{-profile } (a_i \to 0): u_n = \frac{1}{a_1}\varphi_{n1}e_{n1}^{a_1} + \sum_{i=2}^{I}\gamma_i\varphi_{ni}\ln(\frac{e_{ni}}{\gamma_i}+1) \tag{2-b}$$

$$\text{Constant } a: u_n = \frac{1}{a}\varphi_{n1}e_{n1}^{a} + \sum_{i=2}^{I}\frac{\gamma_i}{a}\varphi_{ni}\left\{\left(\frac{e_{ni}}{\gamma_i}+1\right)^{a} - 1\right\} \tag{2-c}$$

The baseline preference φ_{ni} is formed by a random utility specification:

$$\varphi_{ni}(z_{ni}, \varepsilon_{ni}) = \exp(\beta z_{ni} + \eta_{ni}) \tag{3}$$

where, z_{ni} is a set of explanatory attributes characterizing life domain *i* and household *n*, and η_{ni} is an error term for capturing the effect of unobserved factors on the baseline utility φ_{ni}.

By forming the Lagrangian and adopting the Kuhn-Tucker (KT) conditions, the above optimization issue can be solved. The Lagrangian is:

$$L = \sum_{i=1}^{I}\frac{\gamma_i}{a_i}\varphi_{ni}\left\{\left(\frac{e_{ni}}{\gamma_i}+1\right)^{a_i} - 1\right\} - \pi\left[\sum_{i=1}^{I}e_{ni} - E_n\right], \tag{4}$$

where π is the Lagrangian multiplier related to the expenditure constraint. Then the KT first-order conditions are obtained (Bhat, 2008).

$$\begin{aligned} &\exp(\beta z_{ni}+\eta_i)\left(\frac{e_{ni}}{\gamma_i}+1\right)^{a_i-1}-\pi=0, \quad \text{if } e_{ni}>0, \ \ i=1,2,...,I, \\ &\exp(\beta z_{ni}+\eta_i)\left(\frac{e_{ni}}{\gamma_i}+1\right)^{a_i-1}-\pi<0, \quad \text{if } e_{ni}=0, \ \ i=1,2,...,I. \end{aligned} \tag{5}$$

$e_{ni}>0$ only when household *n* chooses to spend money on life domain *I*, otherwise, $e_{ni}=0$, by which such discrete choice is embedded in the model. Because of the existence of the outside goods, the KT condition can be written as:

$$\begin{aligned} &V_{ni}+\eta_i=V_{n1}+\eta_1 \quad \text{if } e_{ni}>0 \ \ (i=2,3,...,I) \\ &V_{ni}+\eta_i<V_{n1}+\eta_1 \quad \text{if } e_{ni}=0 \ \ (i=2,3,...,I) \end{aligned}$$

where

$$V_{ni}=\beta z_{ni}+(a_i-1)\ln\left(\frac{e_{ni}}{\gamma_i}+1\right). \tag{6}$$

The probability that household *n* allocates expenditures on the first M_n alternatives from *I* life domains ($M_n \le I$) is subsequently derived from the above Kuhn-Tucker conditions (Bhat, 2005, 2008):

$$P(e_{n1},e_{n2},e_{n3},\ldots,e_{nM_n},\underbrace{0,0,\ldots,0}_{I-M_n})=\left[\prod_{i=1}^{M_n}f_{ni}\right]\left[\sum_{i=1}^{M_n}\frac{1}{f_{ni}}\right]\left[\frac{\prod_{i=1}^{M_n}e^{V_{ni}}}{\left(\sum_{i'=1}^{I}e^{V_{ni'}}\right)^{M_n}}\right](M_n-1)! \tag{7}$$

where, $f_{ni}=\left(\frac{1-a_i}{e_{ni}+\gamma_i}\right)$, and the expressions for the term *V* are given below for the three utility forms in equation (2), respectively.

$$a\text{-profile } (\gamma_i=1): \begin{cases} i=1: V_{n1}=(a_1-1)\ln(e_{n1}) \\ i\ge 2: V_{ni}=\beta z_{ni}+(a_i-1)\ln(e_{ni}+1) \end{cases} \tag{8-a}$$

$$\gamma\text{-profile } (a_i\to 0): \begin{cases} i=1: V_{n1}=(a_1-1)\ln(e_{n1}) \\ i\ge 2: V_{ni}=\beta z_{ni}-\ln(\frac{e_{ni}}{\gamma_i}+1) \end{cases} \tag{8-b}$$

$$\text{Constant } a: \begin{cases} i=1: V_{n1}=(a-1)\ln(e_{n1}) \\ i\ge 2: V_{ni}=\beta z_{ni}+(a-1)\ln(\frac{e_{ni}}{\gamma_i}+1) \end{cases} \tag{8-c}$$

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5.2 Resource Allocation Model based on Multi-linear Function

In the multi-linear function based resource allocation model, as with the MDCEV model, household *n* is assumed to allocate its available money E_n to several life domains (*i*) so as to maximize total utility

U_n. Differently, the utility U_n is specified by a multi-linear function with a non-additive structure (i.e., a multiplicative form) (Zhang et al., 2002, 2005). By using such multi-linear utility function, it is much easier and more straightforward to represent the interaction between life domains than the additive-type utility function (e.g., MDCEV model) (see the second term on the right hand side of equation (9) for the difference). We only model the binary interactions here for the ease of discussion, however, it can be easily extended to a multinomial form.

$$\text{Maximize} \qquad U_n = \sum_i \omega_i u_{ni} + \sum_i \sum_{j>i} \lambda \omega_i u_{ni} \omega_j u_{nj} \tag{9}$$

$$\text{Subject to} \qquad \sum_i e_{ni} = E_n \tag{10}$$

where,

$$\sum_i w_i = 1,\ w_i \geq 0 \tag{11}$$

$$u_{ni} = \rho_{ni} In(e_{ni} + 1) \tag{12}$$

$$\rho_{ni} = \exp(\theta_i x_{ni} + \varepsilon_i) \tag{13}$$

u_{ni} indexes the utility obtained from the service produced by life domain *i* . Additionally, it is specified as a logarithmic function so as to depict the diminishing marginal utility as the increasing expenditure of life domain *i*. w_i is a weight parameter of life domain *i* which indicates the relative importance (or interest) of the service generated by life domain *i*, and for understanding, it is generally assumed the sum of w_i to be 1. λ plays the main role to describe the direct interaction between different life domains which may be caused by the rebound effect, self-selection effect, function substitution or complementation, and/or others. If $\lambda = 0,$ the non-additive model will turn to the additive-type model, implying that except the interaction associated with the total constraint, there is no other interaction exist. e_{ni} denotes the monetary expenditure for life domain *i*. ρ_{ni} signifies the baseline preference (or baseline demand) for the service produced by life domain *i* and it is defined as a function of household attributes (e.g., income, household size, housing tenure, number of under-18 or over-65 members, car number etc.), householder attributes (e.g., gender, employment status, job type etc.) and living region specific characteristics (e.g., regional level, metropolitan area etc.), which are both included in x_{ni}. θ_i is the corresponding coefficient of x_{ni}, and ε_i is an error term showing the influence of unobserved factors on ρ_{ni}.

The phenomenon that households only allocate budgets on the life domains they need suggests that the expenditure on life domains might be censored. However, Zhang et al.(2002, 2005)'s papers did not address the discrete choice behavior and they treated zero-expenditure as one part of continuous values. Consequently, the Kuhn-Tucker conditions (Ransom, 1987; Wales and Woodland, 1983) are adopted to deal with the zero-observation problem in the process of deducing the likelihood function.

First, the Lagrangian is formed and then Kuhn–Tucker (KT) conditions are applied. Specifically, the Lagrangian function is given by:

$$L = \sum_i \omega_i u_{ni} + \sum_i \sum_{j>i} \lambda \omega_i u_{ni} \omega_j u_{nj} + \Gamma\left(E_n - \sum_i e_{ni}\right) \tag{14}$$

where, Γ is the Lagrangian multiplier associated with the expenditure constraint (that is, it can be viewed as the marginal utility of total money budget). The Kuhn-Tucker first order conditions for the optimal expenditure allocations are denoted as:

$$\frac{\partial L}{\partial e_{ni}} = \frac{\partial U_n}{\partial e_{ni}} - \Gamma = \omega_i (1 + \lambda \sum_{j \neq i} \omega_j u_{nj}) \frac{\partial u_{ni}}{\partial e_{ni}} - \Gamma \begin{cases} = 0 & if\ e_{ni} > 0 \\ \leq 0 & if\ e_{ni} = 0 \end{cases}. \tag{15}$$

Because the outside goods (i.e., food expenditure which is the first alternative in the choice set) is always consumed in this study, its Kuhn-Tucker condition can then be written as:

$$\Gamma = \omega_1 (1 + \lambda \sum_{j \neq 1} \omega_j \exp(\theta_j x_{nj} + \varepsilon_j) In(e_{nj} + 1)) \frac{\exp(\varepsilon_1)}{e_{n1} + 1}. \tag{16}$$

Substituting Γ in equation (15) by using equation (16), an alternative KT first-order condition can be derived subsequently:

$$\ln\left[\frac{\omega_1 (1 + \lambda \sum_{j \neq 1} \omega_j u_{nj})}{\omega_i (1 + \lambda \sum_{j \neq i} \omega_j u_{nj})}\right] - \ln\left[\frac{e_{n1} + 1}{e_{ni} + 1}\right] - \theta_i x_{ni} \begin{cases} = \hat{\varepsilon}_{ni} - \hat{\varepsilon}_{n1} = \Delta\hat{\varepsilon}_{ni} & if\ e_{ni} > 0 \\ \geq \hat{\varepsilon}_{ni} - \hat{\varepsilon}_{n1} = \Delta\hat{\varepsilon}_{ni} & if\ e_{ni} = 0 \end{cases}. \tag{17}$$

The utility terms u_{nj} in equations (17) are the relevant ones whose error terms have been extracted out. The error terms $\Delta\hat{\varepsilon}_{ni}$ in equation (17) are the derivates which have blended the error terms in the initial utility components together. Though the structure of these error terms becomes very complicated and is difficult to explain after doing in this way, mathematically it is always operable. In addition, because the interaction between error terms that represents the influence of unobserved factors is not the interest in this analysis, we will leave the clarification of the error terms as a future research issue.

By assuming $\Delta\hat{\varepsilon}_{ni}$ independent with each other and normally distributed with mean zero and variances $(\sigma_i)^2$, the probability of spending expenditure to the first *M* of the *I* life domains can be written as:

$$P(e_{n2}, e_{n3}, \Lambda\ , e_{nM_n}, \underbrace{0, 0, \Lambda, 0}_{I-M_n}) = \left[\prod_{i=2}^{M_n} \frac{1}{\sigma_i} \cdot \phi\left(\frac{\Omega_{ni}}{\sigma_i}\right)\right]\left[\prod_{i=M_n+1}^{I} \Phi\left(\frac{\Omega_{ni}}{\sigma_i}\right)\right] \tag{18}$$

where, ϕ and Φ denote the probability density function and cumulative density function of standard normal distribution, respectively. The unknown parameters in equation (18) are estimated to maximize the total likelihood of the whole sample. It is not difficult to see that the total likelihood is decided jointly by the probability of allocating non-zero continuous amount of expenditure to each life domain, as well as the probability of zero expenditure, which implies a discrete choice that implies whether to assign a budget on the life domain.

5.3 Comparison of model structures

After the elaboration of these two models, it can be found that there are many similarities and differences between them (Table 1). Concerning the similarities, both of MDCEV model and RAM-MLF describe the discrete choice and the continuous decision by using the same group of parameters. Besides, their model structures and the deduction of the likelihood function share some common points. Essentially, RAM-MLF could be described as the non-additive form of the MDCEV model with the logarithmic utility structure (i.e., $a_i \to 0$ and $\gamma_i = 1$). When the interaction term equals to 0 and the weights equal to 1, the resource allocation model turns to be a member of MDCEV model family. However, just because of the interaction term and the relative importance terms, the RAM-MLF under study seems

more rational than the MDCEV model since its marginal utility is not independent with other alternatives. However, the flexible utility structure of the MDCEV model is exactly the thing lacked in the RAM-MLF. Accordingly, it is obvious to summarize the difference between these two models as the decision-making mechanism included in the model and the utility structure used to describe the diminishing marginal utility with the increasing expenditure.

Table 1 Summary of the comparative results of MDCEV model and RAM-MLF

	MDCEV model	**RAM-MLF**
Utility form	Additive $u_n = \sum_{i=1}^{I} \frac{\gamma_i}{a_i} \phi_{ni} \left\{ \left(\frac{e_{ni}}{\gamma_i} + 1 \right)^{a_i} - 1 \right\}$	Non-additive $u_n = \sum_i \omega_i \rho_{ni} In(e_{ni} + 1)$ $+ \sum_i \sum_{j>i} \lambda \omega_i \rho_{ni} In(e_{ni} + 1) \omega_j \rho_{nj} In(e_{nj} + 1)$
Marginal utility	$\frac{\partial u_n}{\partial e_{ni}} = \phi_{ni} \left(\frac{e_{ni}}{\gamma_i} + 1 \right)^{a_i - 1}$	$\frac{\partial u_n}{\partial e_{ni}} = \omega_i (1 + \lambda \sum_{j \neq i} \omega_j \rho_{nj} In(e_{nj} + 1)) \frac{\rho_{ni}}{e_{ni} + 1}$
Discrete & continuous choice	Represented simultaneously by using the same group of parameters. Similar to Tobit model.	
Diminishing marginal utility	a – profile: exponentiate e_{ni} γ – profile: translate e_{ni} Log-form: $\ln(e_{ni})$	Log-form: $\ln(e_{ni})$
Behavioral mechanism		Interaction term λ Relative importance of alternatives
Deduction of the likelihood	Lagrangian and KT conditions	Lagrangian and KT conditions

5.4 Comparison of model structures

The above two types of multiple discrete-continuous choice models will be estimated with respect to different population groups in different years, separately. First, socio-demographics will be focused on, for clarifying the differences between the two models. Second, public policy variables are further introduced for examining the effects of various public policies (including transportation infrastructure development) on young people's car ownership and usage. Detailed analysis results will be reported at the time of the conference.

6. Conclusion

The expenditure patterns of the Japanese people derived from this study should be interpreted in a more careful way. Clearly, income seems to be an influential factor, but it is not the only decisive factor. Changes in lifestyles, reflected in expenditure patterns (or consumption patterns), should be examined in a more systematic way. In other words, what's more important is not the income itself, but how the income is consumed. Expenditure is a part of consumption in life (or life choices). One common goal of transport policy and other public policies is the improvement of people's QOL (e.g., life satisfaction and happiness). Various life choices (or consumption in life) affect QOL. QOL has been investigated with respect to various life domains, such as residence, neighborhood, health, education, work, family life, leisure and recreation, finance, and travel behavior. Using data collected from 2,178 respondents residing in various cities across Japan in 2010, which included 77 consumption variables, 13 happiness indicators and eight income-related variables, Zhang and Xiong (2015) found that income only influences whole-of-life happiness, however it is not the most influential factor. Saving is most important to enhancing people's whole-of-life happiness. One's current work-life balance does not matter for happiness. Education-related consumption variables are only associated with negative

affective experiences and, surprisingly, they are unrelated to whole-of-life happiness. The effects on happiness of expenditure- and residence-related consumption variables and of consumption choices to maintain an active lifestyle are mixed. Unfortunately, none of the residence-related variables influences whole-of-life happiness. Communication with neighbors is important to positive affective experiences.

As stated by Veenhoven (2015), people who have a car tend to be happier than people without, even though luxury cars do not add more to happiness than a thrifty car. If this is also the case for the young people, the decrease of the young people's car ownership should be regarded as a serious social issue. The availability of transport access to various facilities and locations is essential to people's life. Car users and other types of trip makers have different action spaces. In line with such considerations, it might also be important to investigate young people's car ownership behavior from the perspective of social exclusion (e.g., Stanley and Vella-Brodrick, 2009; Stanley et al., 2011). On the other hand, decrease of car ownership is good for environmental sustainability. For the environmental sustainability, policy makers are required to provide people with more attractive life-enjoying environments and opportunities supported by public transportation. One critical question is, however, whether, how, and how many car users may adapt their lives to the changing mobility and living environments, especially in relation to the realization of sustainable lifestyles. Related to this, it is worth exploring how the qualities of the mobility environments supported by cars and public transportation differentially affect people's QOL via various life choices.

However, decrease of car ownership is not a good news for automobile industry. In fact, in recent years, many automobile makers have invested a huge amount of money to improve functions and design of cars by explicitly reflecting young people's liking in order to encourage them to continue the tradition of car ownership, as before. If cars for some people are not an indispensable means, use of public transportation systems, cycling or walk may become more frequent, which is expected to be beneficial to people's health, too. When people have to travel by car, these days, more and more car-sharing services are available. Burkhardt and Millard-Ball (2006) found that in North America, the highest percentage of car-sharing users are between 25 and 35 years old. Using data collected in Beijing and Shanghai, Shaheen and Martin (2010) found that younger and more educated residents are more interested in car-sharing. Interestingly, a C2C (customer to customer) car-sharing business has been started in USA (e.g., RelayRides, Getaround), Japan (e.g., Anyca), China (e.g., Atzuche.com), and Singapore (iCarsclub) to assist car owners to rent their private cars to other drivers[6]. In the C2C service, the rental rate (including driving insurance) is lower than conventional rental car service, car owners can decide the rate and they receive a much larger percentage of the rate than the company does. Recent research revealed that the utility of trip making could be either positive or negative. Positive utility derived from travel may result from three sources: travel liking, multitasking during travel, and expectation of activity participation after travel. Recently, studies of subjective well-being in the context of trip making have been attracting ever-increasing attention from travel behavior researchers. It might be worth examining popular use of car-sharing by young people from the perspective of subjective well-being. In particular, considering that the ideal travel time of many people is not zero (e.g., Redmond and Mokhtarian, 2001)[7], the preferred distance from home to each type of daily facility has been under-researched. More studies are required, especially for specifying the proper size of a city and further realizing the transformation to sustainable urban forms from the viewpoint of young people as well as other population groups.

Because people have to spend a large amount of money to own a car, their decisions on ownership and resulting usage are more or less associated with decisions on other household expenditures. There are various studies of relationships between residential behavior and vehicle ownership and usage. Unfortunately, research on the influence of other life choices are very limited. For example, if a person's workplace is located in a place that is only accessible by car, he/she could not commute without a car. In this case, the workplace location influences the ownership and usage of the

[6] http://jp.techcrunch.com/2015/09/09/dena-lanched-anyca-c2c-car-sharing-service/ (in Japanese; Accessed December 13, 2015)

[7] The ideal commuting time of 1,300 commuters in the San Francisco Bay Area in 1998 was about 16 minutes on average. Related to this, I conducted a web-based questionnaire survey with respect to 547 commuters by public transportation in Hiroshima of Japan in 2008 (Zhang, 2009a) and found that the average ideal commuting time was about 30 minutes.

car. In the presence of younger children, a household may need a car to deliver and pick up their children, while such habitual use of the car may influence the children's future travel behavior and activity participation as well as health behavior. These influences should be properly incorporated into the implementation of mobility management and the research of residential and activity-travel behavior.

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