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5G Mobile Utility Function by Contractor and Income

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1 Introduction

This paper analyzes Japanese consumer preferences for mobile communication services including 5th generation mobile communication (5G). The analysis is presented after a questionnaire survey was given to 304 Japanese mobile communication subscribers in February 2023. The author found that user groups of different mobile communication contractors and user groups of different household income have different utility functions respectively through a discrete choice model analysis.

In the future, the diffusion and maturity of the mobile phone network services, which will include a public switched telephone network (PSTN), a data network, and fiber to the home (FTTH), may change the structure of the telecommunications industry, thus impacting existing telecommunications networks. Consequently, it is necessary to analyze which type of telecommunications industry will develop as a result of competition among telecommunication companies and regulations in Japan. Therefore, this paper will focus on the determinants of subscription and the utilization of Japanese mobile phone network contracts on the demand side.

The primary source of discreate choice response is two types of choice data; revealed preference (RP) and stated preference (SP). RP data refer to situations where the discrete choice is made in real market situations, and, in contrast, SP data refer to situations where a discrete choice is made by considering hypothetical situations. SP data are especially useful when considering the discrete choice among existing and new alternatives since the latter are not observed in RP data.

Firms in many markets supply differentiated services and compete in prices. Consumers might not possess all information about service attributes before they make their purchase decision. Accordingly, utilizing RP data, which requires the actual data of services, is difficult. For this reason, discrete choice model analysis as SP data is used in this paper.

2 Previous research

The purpose of this research is to estimate and measure Japanese consumer's preferences on mobile phone services through a questionnaire survey conducted in February 2023. Even though many analyses from the view of the supply side have been published since 1980's, the number of analyses from the view of the demand side have not been nearly enough because it is difficult for

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researchers to obtain enough pooled data. Since the mid-2000's, however, this situation has changed for the better because the Internet has enabled the use of web questionnaires and more research has been published. Nonetheless, most research was aimed at analyzing broadband telecommunications such as FTTH.

Using discrete choice model analysis in an Information and Communication Technology (ICT) market survey is a common method in foreign countries. Using discrete choice model analysis, Zubey et. al (2002) surveyed internet protocol (IP) telephone demand. In the Korean telecommunications market, Rhee and Park (2011) used discrete choice model analysis in terms of monthly charges and portability. Tripathi and Siddiqui (2009) published an empirical survey of the Indian mobile phone market from the aspects of connectivity, initial and monthly charges, and customer services.

In Japan, Nakamura (2015) conducted a discrete choice model analysis with SP to measure the marginal rate of substitution between 4G and FTTH and concluded that FTTH could be replaced by 4G with lower switching costs, if the compatibility of handset, contents and email addresses are available. Takano (2023a) and Takano (2023b) analyzed Japanese consumer preferences for mobile communication services including 5G as of February 2023 by utilizing original pool data and discrete choice model, and the estimated results revealed that a decline in the monthly data fee, an increase in transmission speed, a rise in the maximum data amount limit, a choice of iOS, and the discontinuation of contracts with the current telecommunication companies, all raise demand for 5G mobile networks. This article invocates the major findings in Takano (2023a) and Takano (2023b).

3 Discrete choice model analysis

Using discrete choice mode, it is possible to evaluate the value of property that constitutes targeted services or materials by repeatedly asking a consumer's preferences to plural alternative service sets. The respondents can easily interpret the hypothetical services, because they are stated as concrete service sets. It is easy for the respondents to compare the actual services that they prefer or use with the hypothetical services. In discrete choice model analysis, goods are deemed to consist of a variety of bundles of properties (profiles) and the value of every property can be calculated by presuming the statistical relationship between the profiles and answers. The conditional logit (CL) model, a discrete model, is used to estimate values from data. Because the log-likelihood function has to be maximized, particular statistical applications need to be handled, or a new program must be developed.

Instead of using a cross term in this paper, the author adopted attribution questions, for example, "What is your household income per year?". Consequently, the author was able to know the respondent's household income. This has been not stated in this paper until now *per se* because it is assumed that almost all respondents understand what a mobile phone is and therefore, a cross term was not necessary.

CL is utilized in discrete choice model analysis. Discreate choice model is based on random utility theory (RUT) and it enables an analysis of various aspects of consumer behavior in choosing goods or services.

A decision maker, labeled n, faces J alternatives. The utility that the decision maker obtains from alternatives j is decomposed into (a) a part labeled V_{nj} that is known by the researcher up to some parameters, and (b) an unknown part ε_{nj} that is treated by the researcher as random: $U_{nj} = V_{nj} + \varepsilon_{nj}$. The logit model is obtained by assuming that each error term is an independently, identically distributed (IID) extreme value.

The density for each unobserved component of utility is

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}} \quad (1)$$

and the cumulative distribution is

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}} \quad (2)$$

The difference between two extreme value variable is distributed logistic. That is, if ε_{nj} and ε_{ni} are IID extreme value, then $\varepsilon^*_{nji} = \varepsilon_{nj} - \varepsilon_{ni}$ follows the logistics distribution

$$F(\varepsilon^*_{nji}) = \frac{e^{\varepsilon^*_{nji}}}{1 + e^{\varepsilon^*_{nji}}} \quad (3)$$

The choice probability of the conditional logit is shown by equation (4) below. The numerator represents consumer utility and the denominator represents the sum of the utility of alternatives (Train (2009): 34–36)

$$P_{ni} = \frac{e^{V_{ni}}}{\Sigma j e^{V_{nj}}} \quad (4)$$

4 Determining properties and levels

To begin discrete choice model analysis, properties that constitute an object or a service are determined. Each property has several levels. After the properties and their levels are determined, profiles of the combinations of properties and levels are made. Generally, an orthogonal table as a profile design is used.

Table 1 shows what properties and levels were determined in Japanese mobile phone services. The variables to each question are based on the following:

MONTHLY: Monthly data charge (unit: one thousand Japanese yen [1,000 JPY])
DATA: Monthly maximum data usage (unit: Gigabytes [GB])
OS: Operating System (OS) of smartphone (Dummy variable)
DISCOUNT: Discount of smartphone (unit: 1,000 JPY)
CARRIER: Whether the service provider is the same or not (Dummy variable)
SPEED: Maximum transmission speed (unit: Gigabit per second [Gbps])

Table 1　Properties and levels

	Level				
MONTHLY: Monthly data charge (1000 JPY)	0.7	2.7	4.5	5.15	6.65
DATA: Monthly max. data usage (GB)	1	5	20	100	1000
OS: OS of smartphone	iOS (0)			Android (1)	
DISCOUNT: Discount of smartphone (1000 JPY)	0	5	10	15	20
CARRIER: If the service provider is the same	No Change (0)			Change (1)	
SPEED: Max. transmission speed (Gbps)	0.5	1	2	3	4.9

MONTHLY has five levels ranging from JPY 700 (USD 5.4[(1)]) to 6,650 (USD 51.2) per month. MONTHLY was adopted from real monthly data charges in Japan as of February 2023. For example, OCN mobile ONE of NTT Communications Inc. including 1 GB per month data (packet) usage charge JPY 700 per month. Ahamo of NTT DOCOMO Inc. including 20 GB data usage charge JPY 2,700 (USD 20.8) per month and including 100 GB data usage charge JPY 4,500 (USD 34.6) per month. NTT DOCOMO's 5G Giga light including 5 GB data usage charge JPY 5,150 (USD 39.6) per month. Also, NTT DOCOMO's 5G Giga-ho premier including unlimited data usage charge JPY 6,650 (USD 51.1) per month.

DATA was adopted from real maximum data usage limit per month of each level of MONTHLY which varies from 1–1000 GB. Unlimited data usage in NTT DOCOMO's 5G Giga-ho premier was replaced by 1000 GB as possible data usage by one subscriber per month.

The maximum transmission speeds of Internet data access are 4.9 Gbps from theoretical maximum downstream speed of NTT DOCOMO'S 5G and 0.5–3 Gbps from actual data transmission speed of 5G in Japan as of February 2023.

Because smartphone price discounts vary from place to place and from channel to channel, the author adopted 0 (no discount), JPY 5,000 (USD 38.5), JPY 10,000 (USD 76.9), JPY 15,000 (USD 115.3), and JPY 20,000 (USD 153.8), which are considered generally adequate levels.

OS and CARRIER are dummy variables and they have two alternatives: iOS (0) and Android (1) or no change (0) and change (1).

5 Formulating profile design

Table 2 shows how the author formatted the profile design.

One respondent is asked 25 different questions. Each question contains four alternatives (profiles) and the respondent answers the alternative he/she most prefers. In concrete terms, the respondent was asked the following example question.

Question 1: Which mobile communication service do you most prefer? Please choose one.

Suppose you are purchasing and contracting a mobile phone service. A mobile phone shop will show you four (4) alternative plans and you must choose one from Plan A, Plan B, Plan C, and Plan D (Table 3).

Table 2 Profile design

	Attribution	Profile 1	Profile 2	Profile 3	Profile 4
1	MONTHLY	6.65	4.5	0.7	6.65
	DATA	1000	20	1000	20
	OS	1	1	0	0
	DISCOUNT	15	5	5	10
	CARRIER	0	0	0	1
	SPEED	2	4.9	3	3
2	MONTHLY	0.7	4.5	4.5	4.5
	DATA	5	5	1	100
	OS	1	0	0	1
	DISCOUNT	10	15	10	0
	CARRIER	1	1	0	0
	SPEED	4.9	0.5	2	3
3	MONTHLY	0.7	2.7	2.7	4.5
	DATA	5	1000	5	100
	OS	1	1	0	1
	DISCOUNT	10	10	20	0
	CARRIER	1	0	0	0
	SPEED	4.9	0.5	3	3
25	MONTHLY	5.15	2.7	2.7	4.5
	DATA	20	1	100	100
	OS	1	1	0	1
	DISCOUNT	20	5	15	0
	CARRIER	0	1	0	0
	SPEED	0.5	1	4.9	3

Table 3 Example of profile design

Attribution	Plan A	Plan B	Plan C	Plan D
Monthly data charge (1000 JPY)	0.7	6.65	0.7	2.7
Monthly max. data usage (GB)	1000	100	5	1
OS of smartphone	iOS	iOS	Android	Android
Discount of smartphone (1000 JPY)	5	5	10	5
If the service provider is the same	No change	Change	Change	Change
Max. transmission speed (Gbps)	3	0.5	4.9	1

By using an orthogonal table, a set of 25 questions was made and the 25 questions were randomized. The author asked potential respondents to answer the questions and 304 of them answered adequately. Consequently, the number of data is 25 × 304 = 7,600.

6 Estimated results by current mobile communication contractor

The correlation between the utility of a respondent and the current mobile communication contractor of a respondent is examined in this section. The respondents are classified into five current mobile communication contractor groups: NTT DOCOMO, KDDI (au), Softbank, Rakuten Mobile, and MVNO. MVNO in Japan includes OCN Mobile ONE, mineo, IIJmio, AEON Mobile, BIGOBE Mobile, and other mobile communication services operated by MVNO.

The estimated result of the coefficient by a current mobile communication contractor in Japan is shown in Figure 2. The coefficient of MONTHLY is much larger than others by approximately 2–6 times and it implies that the amount of the monthly data charge is the most important concern of possible smartphone subscribers. From this analysis, regardless of the current mobile communication contractor, the difference in each coefficient seems almost stable, except MONTHLY. In other words, the difference among coefficients by attribute is greater than the difference by current mobile communication contractors, which is overwhelmingly large.

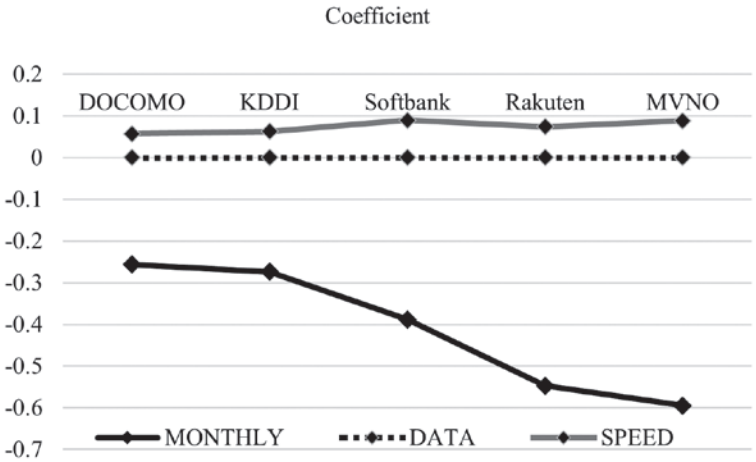

Fig. 1 Coefficient by current mobile communication contractor

The estimated utility for each attribute differs, depending on the current mobile communication contractor of the respondents, which is detailed below.

A decrease in the monthly data charge (MONTHLY) would be desirable for most smartphone subscribers. However, the estimated coefficient of MONTHLY differs depending on who is the current mobile communication contractor. Because the preference for a monthly data charge decline is usually inversely proportional to annual income, it implies that income distributions of customers differ with mobile communication contractors. The effect of price reduction could be

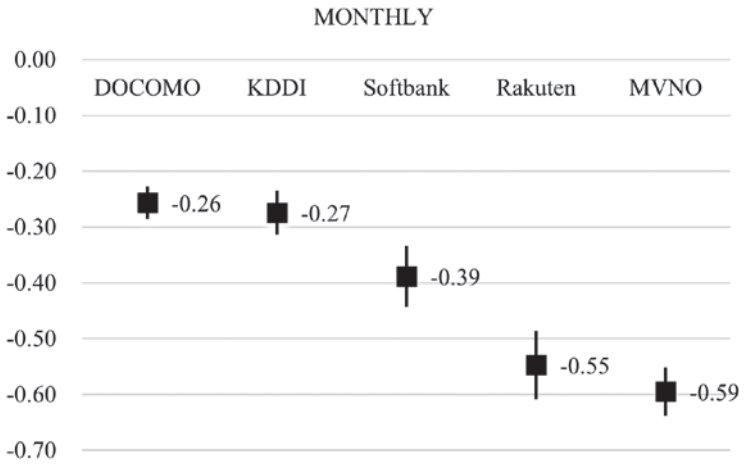

Fig. 2 Estimated coefficient of MOTHLY by current mobile communication contractor

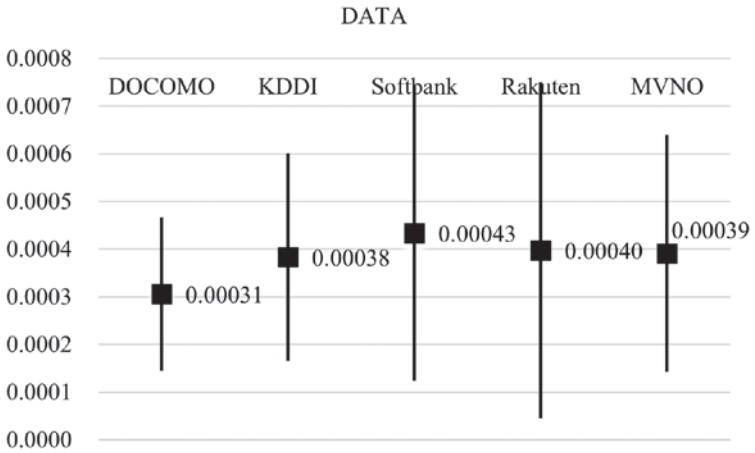

Fig. 3 Estimated coefficient of DATA by current mobile communication contractor

limited in NTT DOCOMO and KDDI(au), because it can be interpreted as a sign that mobile communications have become a necessity good for Japanese consumers. This matches the diffusion rate of mobile communication service in Japan, which is 159%.

The estimated coefficient of DATA shows little relationship to current mobile communication contractors, with the largest difference remaining constant at 0.0006. Therefore, the DATA has almost the same utility regardless of the current mobile communication contractor.

My findings show that estimated coefficient of SPEED has little relationship to the current mobile communication contractor, with the largest difference remaining constant at 0.14. Therefore, the SPEED has almost the same utility regardless of the current mobile communication contractor.

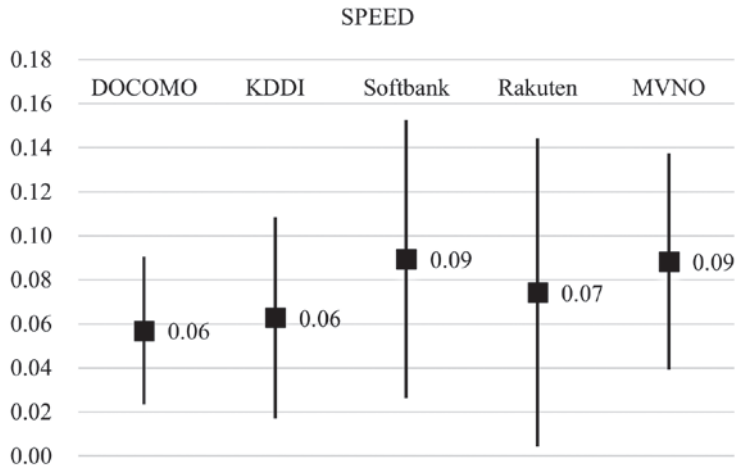

Fig. 4 Estimated coefficient of SPEED by current mobile communication contractor

7 Estimated results by annual household income

The correlation between the annual household income of a respondent and the utility of a respondent is examined in this section. The respondents are classified into three annual household income groups: JPY 0–4 million (USD 0–30,769), JPY 4–8 million (USD 30,769–61,538), and more than JPY 8 million (more than USD 61,538). The estimated result of a coefficient by annual household income in Japan is shown in Figure 1. The coefficient of MONTHLY is much larger than others by approximately 2–4 times and it implies that the amount of the monthly data charge is the most important concern of possible smartphone subscribers. From this analysis, regardless of the annual household income level, the difference in each coefficient seems almost stable. In other words, the difference among coefficients by attribute is greater than the difference by annual household income, which is overwhelmingly large.

The estimated utility for each attribute differs, depending on the annual household income of the respondents, which is detailed in Fig. 5.

A decrease in the monthly data charge (MONTHLY) would be desirable for most smartphone subscribers, usually inversely proportional to annual household income in Fig. 6. However, the estimated coefficient of MONTHLY is not proportional to annual household income. It implies that the effect of price reduction could be limited, because it can be interpreted as a sign that mobile phones have become a necessity good for Japanese consumers. That matches the diffusion rate of mobile phone service in Japan, which is 159%[(2)] as of December 2022.

The estimated coefficient of DATA shows little relationship to annual household income, with the largest difference remaining fairly constant at 0.0001 in Fig. 7. Therefore, the DATA has almost the same utility regardless of the annual household income.

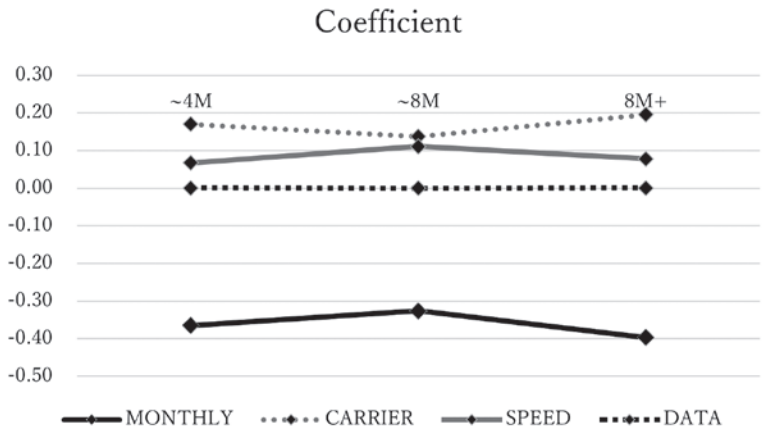

Fig. 5　Coefficient by annual household income

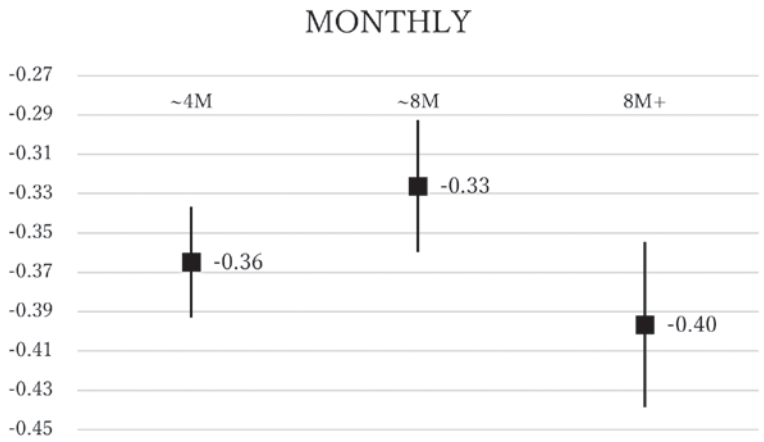

Fig. 6　Estimated coefficient of MOTHLY by annual household income

The attribute of CARRIER means that if suppliers of mobile phone networks is the same in Fig. 8. Choice 0 means no change and choice 1 means a change. The coefficient is positive so that most of current mobile phone subscribers may prefer to change its mobile phone carrier when he/she choose new mobile phone services. As a possible interpretation, because respondents of middle-income household communicate most frequently for both work and private and the change of carrier may bring the decrease of utility because of switching cost such as extra charge for new smartphone, phycological anxiety for new contract, wasted time to migrate personal data, or a training to use.

The estimated coefficient of SPEED increases with annual household income and decreases in higher income household like an arc in Fig. 9. As a possible interpretation, because respondents of middle-income household communicate most frequently for both work and private and SPEED may raise their utility of smartphone.

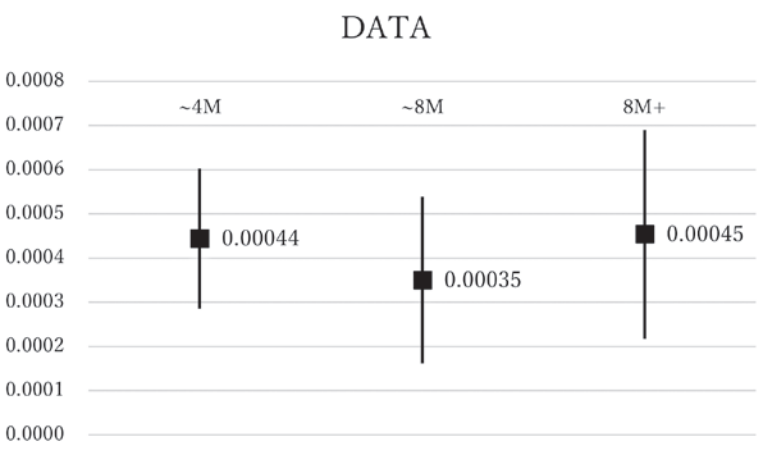

Fig. 7 Estimated coefficient of DATA by annual household income

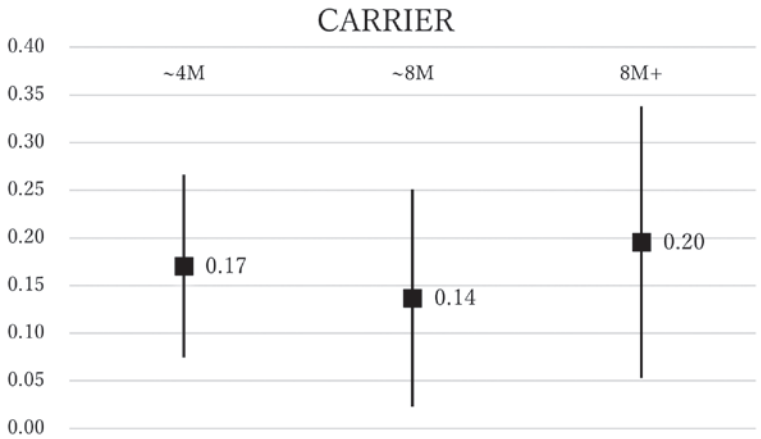

Fig. 8 Estimated coefficient of CARRIER by annual household income

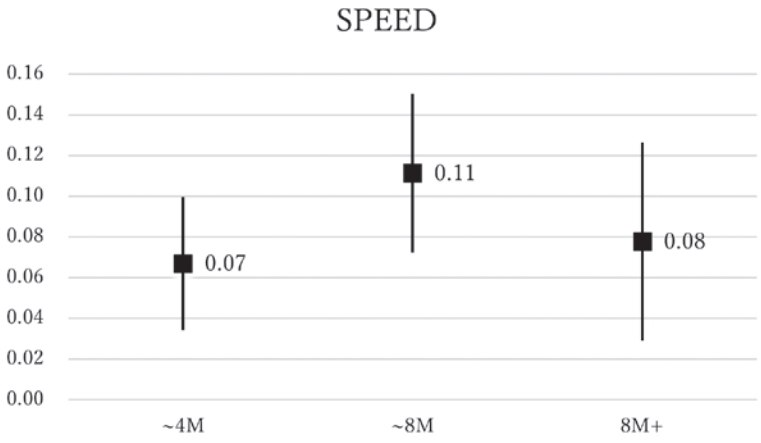

Fig. 9 Estimated coefficient of SPEED by annual household income

8 Conclusion

The author used a theoretical interpretation for demand analysis in the Japanese mobile communication services as a conclusion.

1. A group with a current mobile communication contractor of NTT DOCOMO, au(KDDI), Softbank, Rakuten mobile, and MVNO have different coefficients for Japanese mobile communication services.
2. A group with a household income of JPY 0-4 million, 4-8 million, and more than 8 million have different and independent coefficients for Japanese mobile phone services.
3. A mobile communication operator may be able to provide more attractive mobile communication services to potential customers by adjusting the properties of current mobile services. For example, if the targeted potential customers of a mobile communication operator, including MVNO, are more sensitive in estimated utilities about the monthly data fee than the theoretical maximum transmission speed, the mobile communication operator may design and could launch a less expensive and slower maximum speed billing package for potential customers.

The implications for the entire society and the economy are that the Japanese mobile phone market has been an artificial oligopoly by the Japanese government, but new entrants such as the mobile virtual network operator (MVNO) may change this situation because of inexpensive tariffs and new services which do not exist in the four major mobile operators in Japan. If a significant portion of Japanese mobile phone subscribers shift to MVNO, the market will be changed dramatically and social welfare will be allocated differently.

Appendix

The data in this research was obtained by outsourcing a Web survey to a Japanese research company. The outline of the Web survey is as follows.

- Research area: Japan (47 prefectures)
- Research period: February 6-8, 2023
- Respondents: Randomly sampled by 216 segments classified by gender, 12 age groups[(3)] separated by 5 years (older than 15 years old only), region by 9[(4)] ($216 = 2 \times 12 \times 9$), according to the result of the national census conducted by the Ministry of Internal Affairs and Communications in 2020.
- The number of samples: 7,600 = 304 respondents × 25 questions

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(1) "Japanese Yen (JPY) 130 = US Dollar (USD) 1" is the exchange rate in this paper.
(2) December 2022, Ministry of Internal Affairs and Communications
(3) Age group of (1) 15–19 years old, (2) 20–24, (3) 25–29, (4) 30–34, (5) 35–39, (6) 40–44, (7) 45–49, (8) 50–54, (9) 55–59, (10) 60–64, (11) 65–69, (12) 70–99.
(4) Region of (1) Hokkaido, (2) Tohoku, (3) Kanto, (4) Tokyo, (5) Chubu, (6) Kinki, (7) Chugoku, (8) Shikoku, (9) Kyushu.