An Analysis of Demand for New Devices in the Transition from Terrestrial Broadcasting to Digital The Case of Digital Televisions

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Summary

In this paper, we examine Japanese consumers' preferences towards the basic attributes of digital television (DTV) using the stated preference (SP) method and analyze how consumers with strong preferences for new information devices (hardware) and content (software) behave in choosing a DTV. We obtain the following results.

(1) Consumers are affected not only by hardware attributes but also by software factors in choosing a DTV. In other words, we observe evidence of an indirect network externality.

(2) Consumers with strong preferences for broadcast and telecommunication services in terms of both hardware and software show a significantly high probability of choosing a DTV.

(3) The direct benefits of digital broadcast services, such as high picture quality and the receipt of a digital signal, is not appear to be influenced by consumers' preference in new information devices and content.

Keywords: transition from terrestrial broadcasting to digital, stated preference method, discrete choice model, diffusion process, indirect network externality

(*JEL* Classifications: D40, L82, L86)

1. Introduction

The Japanese government has overseen the transition from terrestrial broadcasting to digital. Digital broadcasting started in October 2003 in three major metropolitan areas (Kanto, Kansai and Chukyo). By the end of 2006, in principle, Japanese consumers could enjoy digital broadcasts in most of the districts of all over Japan if they had a digital television. According to the "broadcast band use schedule" that is planned by the Ministry of Internal Affairs and Communications (MIC), digitalization of broadcasting is expected to be completed by July 2011. In addition, almost 100% diffusion of digital television throughout the country is also targeted before shutdown of the analog spectrum[1]. In order to achieve these goals, broadcasters (including cable carriers), television manufacturers, dealers, and the central government and local public authorities have made specific efforts.

This trend of digitalization can be observed in many advanced countries, especially the US and Europe[2]. Benefits to the consumer of broadcasting digitalization include the provision of a high-quality picture and voice service, improvement in data broadcasting and so on, but we must also consider the indirect additional effects. For example, because television has a 100% adoption rate and because most households possess more than one unit because of so-called "personalization," digital television can be advertised as a familiar and easy-to-use IT appliance, and this can partly eliminate the digital divide problem. In addition, because digital television is expected to promote enhanced services such as internet-related services or two-way services, it is possible to enhance linkages between telecommunications and broadcasting and to promote content digitalization or network distribution[3]. Furthermore, extra frequency bandwidth that is saved by broadcast digitalization can be effectively allocated to another promising service[4].

In the development of broadcast digitalization, however, different policies are adopted by each country, reflecting the institutional and ideological differences toward broadcast services. In Japan, for example, the government decided that more than 50% of programs should be provided in the HD (high definition) TV-based method, while some other countries primarily adopted the SD (standard definition) TV-based method[5].

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[1] According to the goal that is jointly planned by broadcasters and manufacturers, digital television ownership is expected to reach 36 million units (1.5 units per household) by the Beijing Olympics in 2008, and 100 million units (2.1 units per household) by the shutdown of the analog spectrum in 2011.

[2] In foreign countries, broadcast digitalization was first started in the UK and US (1998), followed by Sweden (1999), Singapore and Korea (2001), Canada (2003) and France (2005).

[3] From this viewpoint, the Japanese government advocates an extensive network and plans to revise the legislation by 2011.

[4] The expert committee of the Telecommunication Council decided that extra frequency bandwidth that is saved by broadcast digitalization should be preferentially allocated to mobile phone services as a promising service (Nihon Keizai Shimbun 2007/5/15).

[5] HDTV has many more scanning lines than traditional television, which improves picture quality. However, SDTV can receive a digital signal if a "set-top box" is attached to a traditional television. In other words, we can view the digital program with the same picture quality without high additional cost if we adopt the SDTV method. In the process of broadcast digitalization, the SDTV method has been adopted by the UK, France, Italy, Germany and other advanced nations. It is said that these countries have a tradition of "public broadcasting" and SDTV is adopted in order to achieve

In Japan, the government is also very interested in the market penetration rate of digital television[6] because the analog spectrum will be shut down after the completion of digitalization in July 2011[7].

In this paper we first analyze the direct consumer benefits of broadcast digitalization from a political viewpoint. More precisely, we select a current model digital television with high resolution and large screen, and estimate consumer utility by the stated preference (SP) method. Through this analysis, we obtain data for forecasting the future diffusion of digital television. Furthermore, from a more economic viewpoint, we analyze complementarity between hardware (digital television) and software or content (the number of available channels or commencing date of digital broadcasting), and obtain empirical evidence of an indirect network externality in the Japanese broadcasting market.

Our paper has five sections. In Section 2, we survey related previous studies and describe the design and basic statistics of our questionnaire. In Section 3, we explain the conjoint analysis estimation model, then we interpret the estimation results in Section 4. Finally, in Section 5, we summarize our results and consider the implications for the future.

2. Previous Studies and Design of Questionnaire

2.1 Previous studies

With the digitalization of terrestrial broadcasting, economic analysis on the factors affecting the purchase of a DTV (digital television) or on the diffusion process of DTV has increased in foreign countries. In one of the earliest studies, Farrell et al. (1992) analyzed the decision process regarding technical standards for HDTV, such as digital signal or program format, based on a theoretical model. They conducted a case study about the past diffusion processes of similar electrical appliances such as the color television and VCR. In particular, they pointed out that it is necessary to solve the "chicken and egg problem" in order to succeed in the transition from terrestrial broadcasting to digital. They also showed three conditions for successful transition: (1) programs for HDTV are available, (2) each household can receive a HDTV signal and (3) each household owns a television capable of receiving a digital signal. They pointed out that it is possible that (2) and (3) are bottlenecks in the transition process.

In more recent studies in the US, Gupta et al. (2004) used a survey in Chicago on consumer preferences for DTV attributes on both hardware (picture quality, size of screen and retail price) and software (program availability for DTV), and examined

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minimization of audience burden (Matsuda (2005)). However, the HDTV method has been adopted by Japan, the US and Korea.

[6] Refer to Information and Communications Policy Bureau, MIC (2005, 06, 07).

[7] In the UK, government has adopted a more flexible transition policy. They set a certain criterion, "95% penetration rate of digital television," with the shutdown date of the analog spectrum being determined by the date at which the penetration rate exceeds this criterion. Korea has adopted a similar policy. In Japan, the government set a shutdown date of 2011 as part of the current transition policy, and examined policies similar to those of the UK and Korea in the process of discussion.

past forecasts for DTV diffusion based on their original forecasting models. They showed that speed of DTV diffusion seems to be slower than the general forecasts and a lack of TV programs for DTV is one of the reasons for the delay. In other words, complementarity between hardware and software (or an indirect network externality) is one of the most important factors for the diffusion of new electric devices. They finally concluded that current forecasts of DTV diffusion in the US are too optimistic.

However, in Europe, Adda and Ottaviani (2005) used a survey based on the stated preference method in the UK, and conducted a simulation on DTV diffusion. They found three factors capable of politically promoting DTV diffusion: (1) control of the quality of the digital signal and content offered by the public broadcast station (BBC), (2) intervention by subsidy and (3) announcement of definite diffusion conditions and a schedule of the transition. They also pointed out that the delay in the transition process may be because of consumers' strategic behavior or an expectation change if the government announces the shutdown date of the analog spectrum after completion of the transition by a certain percentage of households. In addition, Maier and Ottaviani (2006) examined the impact of political variables, such as a subsidy or a shutdown date of the analog spectrum, on economic welfare if the value consumers place on digital broadcasting is extremely varied. However, their analysis is based only on a theoretical model and did not indicate the best policy option.

In Japan, Yamashita (1999, 2000) analyzed the diffusion process of DTV from terrestrial broadcasting to digital. Referring to the past diffusion processes of similar electric devices such as the VCR or color television, she forecasted the penetration rate of DTV based on macrodata, using the Bass model, and concluded that it will take about 10 years for the diffusion rate to reach 100%. However, Kimura (2004) analyzed factors that promote DTV diffusion, based on microdata, after implementation in three metropolitan areas. He reported that the primary factors that determined the speed of DTV diffusion were price and after-sales service. About 60% of respondents desired a price below 100,000 yen, and about 10% of consumers would purchase a DTV regardless of product quality or the service provided, Kimura reported. With respect to DTV prices, he pointed out that it is quite difficult to reach 100% diffusion without a decrease in DTV prices to the same level as analog TVs, and that prices should be decreased to this level in order to attain a complete transition by 2011. However he could not predict precise time and diffusion rates[8].

In contrast, Ishii (2004) discussed personal informatization from the viewpoint of the diffusion process. He examined the initial adopter of new information devices and reported that the initial adopter of PHS (Personal Handyphone System) has many similarities to those of other new information devices such as the internet or PC, whose functions are quite different from PHS. In short, he pointed out that common psychological factors such as greater affinity for new information devices affect early adoption for new devices.

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[8] In addition, some studies deal with broader topics and analyze the relationship between recent sophisticated televisions and available services. Madden et al. (2002) analyzed consumer demand for entertainment services, such as information and video services, which are distributed through pay TV in Australia. Andersson et al. (2004) examined the usage trends of both basic internet services and high-value-added interactive TV services (iTV) aimed at consumers in Norway. These topics are increasingly gaining researchers' attention.

In this paper, because there are few quantitative microdata-based analyses on the Japanese market situation of broadcast digitalization, we conduct an empirical analysis on the consumer benefit of digitalization using the SP method. In the next section we explain our data in detail.

2.2 Questionnaire design

Using conjoint analysis, we assumed a multiattribute utility function as the respondent's utility function. In other words, we assumed that the consumer obtains his/her utility from various attributes that constitute the good, not from the good itself[9]. When we designed and implemented this survey, we included six factors from two categories that affect consumer's DTV purchasing decision; one category included factors related to hardware, that is, "picture quality," "screen size," "screen type" and "price." The other category included factors related to software, that is, "the number of available channels" and "commencing date of the digital broadcast." Levels and attributes that were used in this survey are summarized in Table 1.

According to the Information and Communications Policy Bureau of the MIC (2007), 69.3% of consumers who own a DTV said that they are "satisfied" or "slightly satisfied" with digital broadcasts, and the reason for their satisfaction is "picture quality" (93.7%), so we adopted this as one of the most important factors. As a related attribute, we adopted "screen size," considering that some consumers prefer strong visuals. We also adopted "screen type" in order to investigate consumer's preference for flat-screen televisions, so we could obtain information on respondents' preference for the advantages and disadvantages of each screen type[10].

In the same survey, a question on the future purchase plan of DTV (multiple-choice answers) was included. Respondents answered that they will "purchase if current television in use breaks down" as the top response (39.2%), and they will "purchase if DTV prices become cheaper" as the second most common response (29.2%), so we found again that price is an important factor for DTV purchases and adopted it in our analysis. Furthermore, considering that the role of DTV is simply to receive broadcast signals and that consumers cannot increase their utility without corresponding content being provided, we used "the number of available channels" and "commencing date of the digital broadcast" as software factors in order to examine complementarity between hardware and software[11].

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[9] Refer to Zeng and Tsuge (2005) for details.

[10] Let us briefly compare characteristics of three screen types excluding CRT (cathode ray tube). With respect to LCD (liquid crystal display), it is possible to produce small screens, and it has the advantages of a relatively longer life span, and burn-in of the monitor (shadow caused by deterioration of fluorescent material) never occurs even when it displays a static picture for a long time. In contrast, PDP (plasma display panel) is limited to larger screen sizes and uses more electricity as the screen size becomes larger. However it has the advantage that the larger the screen size becomes, the lower is the manufacturing cost. Projectors are a display method primarily used for home theaters, and consumers can watch powerful visuals on a large screen at low cost. However, these characteristics were not clearly indicated on the survey sheet, so respondents had to judge these characteristics by themselves.

[11] Therefore, "the number of available channels" in this survey means the number of channels that corresponds to digital broadcast.

Table 1 Levels and attributes

Attributes	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Picture quality	SDTV	HDTV					
Screen size	14 inch	20 inch	29 inch	35 inch	42 inch		
Display type	CRT	LCD	PDP	Projector			
Price	¥50,000	¥100,000	¥150,000	¥200,000	¥250,000	¥300,000	¥400,000
# of available channels	5	10	15	20	30		
Commencement time	Not determined	3 years later	1 year later	Already started			

Combining the above levels and attributes, we created profiles for the survey. We first created profiles based on the levels and attributes in Table 1 using orthogonal design methods offered by statistical software, SPSS, then eliminated unrealistic profiles[12].

In our survey for conjoint analysis, we asked six questions per person and obtained 12,210 responses in total. After eliminating nonrespondents, the effective response rate was 89% (10,857 responses). We adopted a choice-type answer format. In short, choices 1–4, which were created by combinations of the levels and attributes in Table 1, were presented to the respondents and they chose one of the fictitious televisions (choices)[13]. An example of the actual questionnaire is shown in Table 2. Because digitalization of terrestrial broadcasting has been promoted as national policy and audiences in principle cannot watch digital programs with traditional TV sets after the shutdown of the analog spectrum, we eliminated the alternative, "continue to use current television" at this time[14].

Table 2 Example questionnaire for conjoint analysis

What is your most favored alternative? (Choose only one)

Alternatives	1	2	3	4
Picture quality	HDTV	HDTV	SDTV	SDTV
Screen size	20 inch	20 inch	29 inch	29 inch
Display type	LCD	LCD	LCD	PDP
Price	¥200,000	¥100,000	¥400,000	¥150,000
# of available channels	30 CH	30 CH	15 CH	10 CH
Commencement time	1 year later	Already started	3 years later	1 year later

2.3 Summary of the questionnaire survey results

The questionnaire in Table 2 was used as a part of the questionnaire survey implemented by the Institute for Information and Communications Policy of the MIC (2005). The purpose of this questionnaire was to examine various information on media usage, especially TV-watching behavior, and to obtain basic information about future industrial policy. The questionnaire was completed by a representative person in the household (males and females from ages 15 to 79) in March 2004. Out of the 4500

[12] We finally settled on 30 alternatives from the available combinations (total 5600).

[13] The answer format, "choice format" was developed by Louviere and Woodworth (1983) and is used most frequently because this format better reflects the consumers' actual behavior in the market compared with other format such as the "ordering format" or "evaluation format," and has the advantage that respondents find it easier to answer.

[14] Therefore, our estimation results on choice probability show higher values compared with the alternative, "continue to use current television." Note that we grouped HDTV choices in left hand of four alternatives, considering for respondents' convenience.

households that were mailed the survey, 2035 households answered and returned their answer sheet (giving a collection rate of 45.2%)[15].

Let us summarize the important results. First, for "the number of TVs owned per household," the average number of TVs currently used at home is 2.7. Looking at it by region, the number is 3.0 in Chubu and Hokuriku, and is 2.6 (below average) in the west of Kinki district. However, by city size, below average ownership occurs in 14 large cities with a population of more than 50,000 and less than 150,000 (average ownership equals 2.4), while the number is above average in cities with a population of less than 50,000 (average ownership equals 3.0), in rural districts (average ownership equals 3.0), and in cities with a population of more than 150,000 (average ownership equals 2.8).

Next, with respect to "size of screen," the average screen size of TVs currently used at home is 21.8 inches and the most popular size is "25–29 inches" (27.6%). Looking at it by region, the smallest average is observed in the Kanto area (21.4 inches) and small screen sizes of less than 15 inches tend to be preferred in the North area. However, by city size, televisions with screen sizes less than 20 inches tend to be preferred in large cities, instead of rural districts. In addition, for "whether owned television is high definition or not," the percentage owning HDTVs is 12.1%, and the larger the city size is, the more households have a HDTV in general.

3. Estimation Model

In this paper, we estimate econometric models based on a random parameters logit model (or mixed logit model), because the evaluation of preferences for digitalization can vary between individuals.

Random parameters models assume that heterogeneity of respondents varies with the specified continuous distribution. Suppose that the random utility function of person k obtained from alternative i is specified as follows:

$$\begin{aligned} U_{ki} &= V_{ki}(\beta_k) + \varepsilon_{ki} \\ &= \beta_k' x_{ki} + \varepsilon_{ki} \end{aligned}, \tag{1}$$

where ε_{ki} is a random term that is an independent and identical extreme value, and β_k is the parameter of utility for person k, representing the person's specific preference. The choice probability, $P_{ki}(\beta_k)$, the probability that respondent k associated with β_k chooses alternative i, is expressed as the choice probability based on a conditional logit model as follows:

$$L_{ki}(\beta) = \frac{\exp(V_{ki}(\beta_k))}{\sum_j \exp(V_{kj}(\beta_k))}. \tag{2}$$

[15] Mailed households were drawn by a stratified two-step extraction method based on random sampling. The survey was conducted by Japan Research Center Inc.

However, parameter β_k is unobservable. The unconditional choice probability is therefore estimated as the integral of the conditional logit probabilities over all possible variables of β_k:

$$P_{ki}(\Omega) = \int L_{ki}(\beta) \cdot f(\beta|\Omega) d\beta$$
$$= \int \left(\frac{\exp(V_{ki}(\beta))}{\sum_j \exp(V_{kj}(\beta))} \right) \cdot f(\beta|\Omega)\, d\beta. \quad (3)$$

Note that equation (3) shows the mixed logit model. Here, $f(\beta|\Omega)$ is a density function with mean β and covariance Ω. In most applications, β has been specified to be normally distributed, that is, $\beta \sim N(b, W)$.

The mixed logit model can capture the diversity of individual-specific preferences by the way that the parameter varies by individual. The ratio of choice probabilities in the mixed logit model, P_{ki}/P_{kj}, depends on all the alternatives other than i or j. It is different from the conditional logit model because the denominator of the logit formula is inside the integrals and therefore is not canceled. This implies that the mixed logit model relaxes completely the constraint on independence from irrelevant alternatives and the restrictive substitution patterns of the conditional logit model.

In a simple linear model where each parameter in a utility expression is associated with marginal utility, the ratio of two utility parameters is considered to be an estimate of the marginal willingness to pay (MWTP), assuming all other potential influences are constant. For example, the MWTP of a unit increase in an attribute x_1 is calculated as the ratio of the parameter of x_1, β_1, to the parameter of the price p, β_p:

$$MWTP_{x_1} = \frac{dp}{dx_1} = -\frac{dV/dx_1}{dV/dp} = -\frac{\beta_1}{\beta_p}. \quad (4)$$

4. Estimation Results

4.1 Estimation method

In the estimation, in addition to the variables listed in Table 2, we included cross terms between the attributes of devices and respondents. In other words, we estimated equations considering the heterogeneity of respondents. We used variables that are classified in three categories: (1) personal attributes (watching time, the number of family members), (2) hardware characteristics (possession of new peripheral equipment and speed of internet connection), (3) software characteristics (payment for pay TV, payment for mobile phone). Note that we included two variables related to broadcasting and telecommunication services in categories (2) and (3).

However, there are too many variables in the estimation equation. Therefore we implemented a preliminary examination and excluded some variables. As a result, we excluded two variables in category (1) because individual attributes seem not to affect the choice probability. We also excluded the "speed of internet connection" variable in category (2) because those who possess new peripheral equipment also have a high-speed internet connection, as there is a high correlation between them[16].

The deterministic term in utility function V was assumed to be linear, and all subscripts indicating that person k chooses the ith alternative were omitted in order to make the utility expression succinct. The utility function in our estimation equation is expressed as equation (5) (please refer to Table 3 for a detailed explanation of each variable):

$$\begin{aligned} V = {} & (\beta_{Q6pq} \times Q6 + \beta_{n\_PQ})PQ + (\beta_{Q6size} \times Q6 + \beta_{n\_SIZE})SIZE + (\beta_{Q6LC1} \times Q6 + \beta_{n\_LC1})LC1 \\ & + (\beta_{Q6LC2} \times Q6 + \beta_{n\_LC2})LC2 + (\beta_{Q6LC3} \times Q6 + \beta_{n\_LC3})LC3 + \beta_{PRICE}PRICE \\ & + (\beta_{Q2CH} \times Q2 + \beta_{Q10CH} \times Q10 + \beta_{n\_CH})CH \\ & + (\beta_{Q2START} \times Q2 + \beta_{Q10START} \times Q10 + \beta_{n\_START})START. \end{aligned} \tag{5}$$

Table 3 List of variables used in estimation

Explanatory variable	Definition
[Attributes of devices]	
PQ	Dummy variable for picture quality (= 1 if HDTV, = 0 if SDTV).
SIZE	Screen size (inches)
LC1–LC3	Dummy variable on display type [LCD (LC1), PDP (LC2), Projector (LC3)]
PRICE	TV price (10,000 yen)
CH	Number of available channels
START	Dummy variable on availability of digital broadcasting service (= 1 if already available, = 0 otherwise)
[Attributes of respondents] (Hardware)	
Q6	Dummy variable for possession of new peripheral equipment (= 1 if household has DVD player or DVD/HDD or computer with TV recording function, = 0 otherwise)
(Software)	
Q2	Payment of pay TV (cable & CS) (yen, last month)
Q10	Dummy for mobile phone payment (= 1 if for household use, = 0 otherwise)

[16] We obtained almost the same estimation result if we use the "speed of internet connection" variable instead of the "possession of new peripheral equipment" variable.

In the estimation, we used the statistical software NLOGIT 3.0. In the mixed logit model, because we could not anticipate which parameters should be treated as random in advance, at first we estimated under the assumption that all parameters are randomly distributed except for "TV price." If the standard deviation of the estimated coefficient was not statistically significant, this parameter was treated as fixed. Then the estimation was undertaken again and the final model was identified[17]. We implemented 300 repeated Halton draws in order to estimate the random parameters by simulation and obtain their maximum likelihood value. Furthermore, because the respondent answered six questions for the conjoint analysis, we examined the estimation result assuming that the coefficient of certain respondents had the same value (in other words, each coefficient was not independent). All estimation results were shown in Table 4 with the results based on the conditional logit model included for comparison[18].

[17] Refer to Kuriyama and Syoji (2005) for details.

[18] We omit the result including the fixed number term for choice because it was not statistically significant.

Table 4 Estimates of conditional and mixed logit models

	"Conditional Logit Model"		"Mixed Logit Model"		"Mixed Logit Model" (s.t. coefficients are dependent)	
Explanatory Variable	Coefficient	t-statistics	Coefficient	t-statistics	Coefficient	t-statistics
Picture Quality (*PQ*)	0.516***	8.462	0.670***	6.991	0.663***	6.866
			(1.250)***	(5.214)	(1.079)***	(21.234)
Q6PQ	0.037	0.550	0.044	0.463	0.035	0.328
Size of screen (*SIZE*)	0.009***	2.404	0.013***	2.751	0.009*	1.703
			(0)		(0.039)***	(11.991)
Q6SIZE	0.018***	4.227	0.022***	4.060	0.023***	4.220
Display type						
Projector (*LC3*)	−0.301**	-2.183	−1.792***	-3.182	−0.270*	-1.862
			(2.7076)***	(4.561)	(0.426)*	(1.662)
Q6PRJ	0.284*	1.893	0.499*	1.848	0.302*	1.908
PDP (*LC2*)	0.738***	7.379	0.659***	4.348	0.807***	6.554
			(1.3973)***	(5.415)	(0.798)***	(9.630)
Q6PLA	0.060	0.547	0.089	0.590	0.022	0.165
LDC (*LC1*)	0.547***	7.212	0.728***	6.563	0.688***	6.651
			(1.495)***	(8.197)	(0.918)***	(15.458)
Q6CL	0.193**	2.310	0.236**	2.009	0.221*	1.942
TV price (*PRICE*)	−0.048***	-32.311	−0.060***	-22.600	−0.054***	-31.385
			(0)		(0)	
(*CH*)	0.018***	8.669	0.021***	7.630	0.020***	7.968
			(0)***		(0.023)***	(5.842)
Q2CH	0.000012**	2.003			0.000014*	1.837
Q10CH	0.008***	2.794	0.011***	2.725	0.011***	2.902
Commencing time of digital broadcasting (START)	0.350***	8.987	0.517***	8.758	0.383***	8.010
			(0)		(0.223)***	(11.754)
Q2ST	−0.000074	−0.610	−0.000089	−0.545	−0.000093	−0.631
Q10ST	−0.047	−0.826	−0.052950	−0.698	−0.050	−0.721
Number of Observations	36144		36144		36144	
Log Likelihood	−10203.82		−10147.45		−9932.32	
Likelifood ratio index	0.1183		0.1232		0.1418	

Note: 1) ***, **, * represent p-values in the case of statistical significance of < 0.01, < 0.05, < 0.1 respectively.

2) Parameters in brackets are the estimated standard deviations of the error terms from the mixed logit model, and corresponding t-values. An entry of 0 indicates that the parameters are not random but fixed.

According to Table 4, the likelihood ratio index of the mixed logit model, assuming that the coefficient of certain respondents shows the same value, has the highest value. Therefore our results are based on the third model.

Coefficients of the attributes on new information devices in equation (5) show significant positive signs except for projector and price, and this is consistent with our expectations. The coefficient of the attributes of hardware (Q6) also shows a significant positive sign for screen size and display type. In particular, with respect to projector, consumers who are sensitive to up-to-date information devices seem to choose it while the coefficient for choice probability of a DTV is negative. This result is consistent with the result reported in Ishii (2003). Coefficients of attributes on software (Q2, Q6) also show significant positive signs for the number of available channels, and this seems to indicate a strong preference on content. However, with respect to the typical benefits of digital broadcasting such as picture quality or availability of digital broadcasting services, the dummy variables are not significant. Considering the results of Information and Communications Policy Bureau of the MIC (2007)[19], consumers seem to value positively picture quality or availability of digital broadcasting services regardless of the respondents' attributes when they purchase a DTV. We reconfirm this point in next section.

4.2 Calculation of consumers' values

Based on the estimation results shown in Table 4 based on the mixed logit model assuming that the coefficient of certain respondent has the same value, willingness to pay (WTP), calculated as the ratio of estimated coefficients of each attribute to "TV price," is shown in Table 5.

Generally speaking, the same tendency that was pointed out in the previous section is found. For example, projector has a negative WTP because it is not recognized as a standard DTV[20], however consumers who are sensitive to up-to-date information devices seem to give a positive evaluation. Therefore total WTP with respect to projector has a positive value. In addition, WTP for picture quality or availability of digital broadcasting services have relatively high values. Based on this fact, we can say there is an indirect network effect between hardware and software. However, with respect to software, WTP for both broadcasting and telecommunication services show positive values. This is also consistent with our expectations.

[19] In February 2007, actual users of digital terrestrial broadcast services were asked their degree of satisfaction. Of all users, 69.3% answered "satisfied" or "slightly satisfied," and 93.7% of satisfied users point out "picture quality" as the reason.

[20] For projector, it is well known that its picture quality is not as clear, although it provides a large screen size at low cost.

Table 5 WTP for attributes (yen)

Attributes and dummy variables	MWTP (Mixed logit)
"Picture quality"	122529
"Screen size"	1590
"Possession of new peripheral equipment (Q6)"	4338
"Display type"	
"Projector "	－49921
"Possession of new peripheral equipment (Q6)"	55760
"PDP"	149150
"LCD"	127137
"Possession of new peripheral equipment (Q6)"	40784
"# of available CH"	3697
"Amount of payment of pay-TV (Q2)"	3
"Amount of payment of mobile phone contents (Q10)"	1959
"Commencing date"	70712

5. Concluding Remarks

In this paper, with regard to broadcast digitalization, we examined Japanese consumer preferences toward basic attributes of DTV using the SP method and analyze how consumers with strong preferences for new information devices (hardware) and content (software) behave in choosing a DTV. Our results in this paper are summarized as follows.

(1) Consumers are affected not only by hardware attributes such as picture quality, screen size and display type but also by software factors such as the number of available channels and commencement time of the digital broadcast service in choosing a DTV. In other words, we observe evidence of an indirect network externality.

(2) Consumers with strong preferences for broadcast and telecommunication services in terms both of hardware and software show a significantly high probability of choosing a DTV.

(3) The direct benefits of digital broadcast services, such as high picture quality and the receipt of a digital signal, is not appear to be influenced by consumers' preference in new information devices and content.

Based on above result, let us consider the implications for the future diffusion path of DTV in Japan.

From result (1), the diffusion rate will accelerate to some extent because digital broadcasting has been available across the country in principle since the end of 2006. However, from result (2), the diffusion rate will slow if most information and communication technology heavy users have already purchased a DTV. However, from result (3), finally, diffusion will be promoted because the WTP of the direct benefit of digital broadcasting is high for everyone.

Although some people say that a government subsidy for DTV promotion is an important tool, based on the analysis in this paper, we should also focus on indirect network effects between hardware and software. Because consumers who place a high value on the number of available channels or availability of other broadcast/communication services also tend to purchase a DTV, enhancement of available services on DTVs will be one of the key factors affecting diffusion. Furthermore, regulation revision on broadcasting/telecommunication around 2011 can also affect DTV diffusion. New policies examined by the MIC, such as promotion of content distribution through networks or relaxation of copy restrictions for DTV programs, may promote DTV diffusion indirectly.

In the US, although digitalization of terrestrial broadcasting started earlier than in Japan, diffusion of DTV was slower than the initial prediction and the shutdown timing of the analog spectrum was extended to 2009. In Japan, the success of transition from analogue to digital in 2011 also depends largely on DTV diffusion. If the diffusion pace is slower than the initial prediction, complete transition will be extended and both the consumer and social benefits will be reduced. In this sense, we must carefully monitor the transition process of broadcast digitalization.

Acknowledgments

We are very grateful for useful comments from the seminar participants of the Japan Economic Policy Association. One of authors (Kasuga) is very grateful for financial support for overseas travel expense from the Telecommunication Advancement Foundation.

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