JOINT RESEARCH CENTER FOR PANEL STUDIES
SELECTED DISCUSSION PAPER SERIES

SDP2012-003
March, 2013

Effect of Adding Web-Mode on Unit-Response in Sample Survey:Evaluating the Effect of Adding an Alternative When No Control Group Exists

Koji Yamamoto*
Michio Naoi**

【Abstract】
The first wave of Japan Household Panel Survey (JHPS) was designed to let participants respond to questionnaires via the Web rather than paper if they desired. In this study, we investigate whether introducing the Web option altered the response rate of the survey. We emphasize that eventual Web respondents would likely have responded even in the absence of this mode. In general, when gauging the effect of treatments, such as policy-related treatments, a control group is usually required, regardless of whether the design is experimental or quasi-experimental. However, in some cases, a control group cannot be assigned into or observed.We show that the effectof adding an alternative option can be estimated without a control group,under certain assumptions. We use this approach to estimate increase in unit-response due to adding the Web mode.The result shows that the options “Web response” and “paper response” were mutually easily substitutable, and, only few respondents would not have responded unless Web mode was available. In short, the *net* rise in unit-response introduced by Web mode was only limited. Inaddition, in this paper, we show the characteristics of those who had PC and Internet access, which enabled online responses, and those who actually responded via Web mode.

* JSPS Fellow, Chuo Univeristy
** Assistant Professor, Tokyo University of Marine Science and Technology

Joint Research Center for Panel Studies
Keio University

Effect of Adding Web-Mode on Unit-Response in Sample Survey: Evaluating the Effect of Adding an Alternative When No Control Group Exists [*]

Koji Yamamoto[†] and Michio Naoi[‡]

(Issued March 27, 2011)

Abstract

The first wave of Japan Household Panel Survey (JHPS) was designed to let participants respond to questionnaires via the Web rather than paper if they desired. In this study, we investigate whether introducing the Web option altered the response rate of the survey. We emphasize that eventual Web respondents would likely have responded even in the absence of this mode. In general, when gauging the effect of treatments, such as policy-related treatments, a control group is usually required, regardless of whether the design is experimental or quasi-experimental. However, in some cases, a control group cannot be assigned into or observed. We show that the effect of adding an alternative option can be estimated without a control group, under certain assumptions. We use this approach to estimate increase in unit-response due to adding the Web mode. The result shows that the options “Web response” and “paper response” were mutually easily substitutable, and, only few respondents would not have responded unless Web mode was available. In short, the *net* rise in unit-response introduced by Web mode was only limited. In addition, in this paper, we show the characteristics of those who had PC and Internet access, which enabled online responses, and those who actually responded via Web mode.

This English version was translated into by an external translation service supplier from the Japanese version issued on March 27, 2011. Note that information included in this paper is as of March 2011.

[*] The earlier versions of this paper were presented at the Workshop of the Joint Research Center for the Panel Studies at Keio University (November 18, 2009), Methods-and-Applications Workshop (November 20, 2009 and October 8, 2010), and Japanese Association for Mathematical Sociology (March 8, 2011). The authors are grateful to participants of these meetings for useful comments. In particular, the authors would like to offer a warm thanks to Tamaki Miyauchi for carefully guiding the first author, and to Hiroshi Ishida, Colin R. McKenzie, Satoshi Miwa, Hiroshi Taroumaru, and Takahiro Tsuchiya.

[†] Part-time Researcher, Joint Research Center for Panel Studies, Keio University

[‡] Assistant Professor, Faculty of Marine Technology, Tokyo University of Marine Science and Technology

1. Introduction

The type of sample surveys utilizing multiple data collection methods has become increasingly popular in recent years. In this paper, we evaluate the extent to which this type of design improves the response rate. In general, in order to measure the effect of treatments, for example policy-related ones, we usually need a control group, regardless of whether the design is experimental or quasi-experimental. In some cases, however, we cannot make assignment for, or observe, a control group. We propose a method to evaluate the effect of particular type of treatments, even in the absence of a control group.

In this study, we investigate the effect of mixed-mode survey design on participant response. In general, sample survey can employ a variety of survey methods, such as face-to-face interviewing, visitation and questionnaire retention, postal correspondence, and online survey. These different methods are called modes, and a survey involving multiple modes is called a mixed-mode survey. According to Groves et al. (2004: 163-165), mixed-mode survey enables participants to select the mode most convenient to them, thereby increasing the unit-response[1]. However, some scholars argue that adding Web mode in mixed-mode surveys has little effect on the response rate (Couper and Miller 2008: 834). Hence, we question the extent to which mixed-mode survey improves the response rate. From this perspective, we present a method for evaluating the effect of mixed-mode survey on response rate. Our analysis uses the data obtained by the method of visitation, retention, and self-administered answering, with Web-mode option.

The quality of a sample survey is not measured only by the response rate (Yamamoto and Ishida 2010); however, aiming to improve the response rate is extremely important. The quality of sample survey is improved by minimizing the errors (conditional on fixed cost). Improving the response rate reduces sampling error by increasing the sample size. Moreover, the improvement of response rate can reduce the non-response error, especially when the types of those with particularly low response rate are made more

[1] In Japan, although it was not a sample survey, in 2010 the National Census introduced postal mode and, partially, Web mode in addition to the existing method of visitation collection of paper questionnaires (Ministry of Internal Affairs and Communications 2010). Presumably, the purpose was to facilitate responses (although because the Census is a "population" survey, it was not stated that the aim was "the improvement of response rate").

likely to respond[2]. Hence, we have good reasons to seek methods that can improve the response rate, and, evaluate them.

The most powerful method for evaluating the impact of a survey mode on the response rate is to randomly assign the targeted sample into different survey modes and compare the response rates of the modes (for example, Israel 2009)[3]. However, in mixed-mode surveys, the impact of additional modes on the response rate should be assessed against a control group without those options. If we set a control group with a smaller number of response modes, we might be afraid that the response rate of that group may worsen and substantial information we obtain may be poorer. For this reason, such a method with assignment for a control group has shortcomings, unless we are willing to pay a lot of cost to investigate survey methodology itself.

Alternatively, the effect of adding modes in mixed-mode surveys may be evaluated by requesting non-respondents at the initial round to respond via the particular alternative mode. In this approach, an option is added after a time gap from the initial round and its effect is evaluated. Generally speaking, this approach is recommended, not merely in order to evaluate the effect of a mode, but also to improve the performance of the whole survey.[4] This type of approach was adopted by McCabe et al. (2006) and Dillman et al. (2009).

[2] We should be careful to discuss how we can reduce non-response error. When the response rate of types of people with particularly poor response rate does not improve, even when the response rate of the entire target sample improves, the non-response error is not necessarily reduced. Furthermore, adjustment techniques against non-response error may depend on the source of the non-response. Roughly speaking, we can argue like the followings. On one hand, suppose the individual's probability to respond is correlated only to the information that can be observed before the survey. This situation is equivalent to a situation referred to as missing at random (MAR) or selection-on-observables in missing data analysis, and we do have at hand some remedies for the non-response error. On the other hand, the situation in which the probability of response is related to factors that cannot be observed in advance (thus not observed for non-respondents) is equivalent to a status known as non-ignorable (NI) or selection-on-unobservables. In this situation we can only have remedies to adequately analyze data with even stronger assumptions than in the former situation, making it more difficult to analyze. For particular methods and issues on non-response in panel surveys, see Naoi (2009) for example. We should be aware that, even when an approach in sample survey improves response rate, if it strains the assumption of MAR, the approach may not be ideal for the purpose of reducing non-response error.

[3] Although not directly related to the evaluation of mixed-mode surveys, Kaplowitz et al. (2004) assigned target sample to postal and Web surveys, as well as to different methods of prior notification and follow-up, and compared the response rates among the groups.

[4] See Dillman (1999: 240-241).

However, this approach also has limitations. Adding the alternative option after a time gap lengthens the survey period and may reduce the validity of information we might be interested in. Therefore, surveys aimed at gaining substantial knowledge may not benefit from this type of approaches[5]. We also note that, in some sense, even this approach uses a control group for comparison, if we regard the target sample *before* adding the alternative and the sample *after* adding it, as a control group and a treatment group, respectively.

In this paper, we present an evaluation method that assesses the effect of a simultaneously presented alternative with no control group. More specifically, we analyze to reveal the *net* rise in the response rate when Web mode is added to the paper-based self-administered mode with visitation and retention. The analysis uses the data from the first wave of Japan Household Panel Survey conducted in 2009 (hereinafter abbreviated to "JHPS2009"). In JHPS2009, the Web-based option was introduced and available to individuals who desire to use it. Its primary aim was to improve the response rate among the sections of target individuals with previously poor response rate, and also to reduce the non-response error (Naoi, Yamamoto, and Miyauchi 2010: 35-36). Below we evaluate whether this type of setup indeed improves the response rate. Because a group without Web mode (which can be seen as a control group) was not set in this survey, in order to evaluate the effect of Web mode we construct a novel method. In doing this, we emphasize the fact that, the individuals who eventually made response via Web might have made response even via other mode, if Web mode had been unavailable.

2. Summary of Survey and Data

JHPS2009 is the first wave of the panel survey. The details of data collection methods and sample properties in this survey are given by Naoi and Yamamoto (2010) and Naoi, Yamamoto, and Miyauchi (2010). The following analyses use both of the main dataset and the survey confirmation form dataset. The main dataset are made from the responses of the target individuals (including the spouses of sampled individuals). This dataset comprises 4,022 valid cases. The survey confirmation form dataset is made from records of

[5] Moreover, in general, when an alternative A1 is presented initially and another alternative A2 is added after a time gap, if the decision makers are from the beginning aware that A2 will be added and they prefer A2, they may not choose A1 initially, willing to choose A2, but without hating to choose A1. When this occurs, those who chose the additional alternative A2 may have chosen alternative A1 in the absence of A2.

collection agents' visits to the target individuals' residences during the survey period. The collection agents recorded demographic data (such as housing type) of the entire target sample on the survey form (collection agents' survey confirmation form)[6]. This dataset contains 12,549 cases. Unlike the main dataset, which includes information only of the individuals who validly made response in the survey, the survey confirmation form dataset embraces information from the entire targeted sample, including those individuals who refused to partake in the survey.

JHPS2009 was conducted via visitation and retention method. To be precise, although part of the target sample was interviewed face-to-face, only a fraction of the items was surveyed in this manner, whereas other items were surveyed using self-administered paper questionnaires also for the interviewed group. The same items were surveyed in both groups, and individuals to be interviewed were randomly selected. No significant difference in the response rate was observed between the interviewed and non-interviewed groups (Naoi, Yamamoto, and Miyauchi 2010: 41).

In JHPS2009, the target sample was able to respond via Web instead of completing paper questionnaires. Participants freely selected whether to deliver their responses on paper or online[7]. Importantly, the Web option was not randomly assigned in the target sample by the administrator. If some target individuals were provided with Web mode and others were not, the effect of Web mode on the response rate could be analyzed by comparing the two groups. Because Web mode was in fact designed to be available to the entire target sample, we require a novel method to estimate its effect on the response rate. Hereafter, the responses returned via paper questionnaires shall be referred to as "paper response", whereas responses via Web shall be called "Web response", Invalid or null responses shall be referred to as "non-response". Furthermore, the cases where the collection agents had made contact with the target individuals or their family shall be called "contacted"[8]. "Contacted" comprises two subgroups: "cooperation", when valid answers were obtained, and "non-cooperation", when contacted participants failed to cooperate.

---

[6] For more information on this dataset, see also Naoi and Yamamoto (2010: 8).

[7] See Naoi and Yamamoto (2010: 11-12) and Naoi, Yamamoto, and Miyauchi (2010: 35-36).

[8] We consider the following cases as contacted: the cases recorded, in the survey confirmation form, as either "(the collection agent had) spoken through the intercom", "met with family members other than the target person or her/his spouse", "met the spouse", or "met with the target person". Individuals who refused cooperation in advance (e.g., via telephone) were excluded.

Of the 4,022 valid survey responses, 91 were returned online. The 4,022 participants were asked whether or not they use a PC at home, and whether they have home internet access. This information together with Web response status is summarized in Table 1. Table 1 is equivalent to Table 1–6 from Naoi and Yamamoto (2010: 12). Not surprisingly, most Web respondents use a PC at home and have home internet access.

[Table 1]

The analysis in Section 3 utilizes the abovementioned information regarding PC use and home internet access. As such, it uses the main dataset including 4,022 valid cases. On the other hand, the analysis in Section 6 requires explanatory variables even for the non-cooperation cases. In that section, the survey confirmation form dataset with 12,549 cases (including the entire target sample) is utilized. Also, we assume that, when a target individual was not contacted, she/he would never have an alternative to response via Web mode. Hence, the analysis in Section 6 was conducted on the 9,621 contacted individuals.

3. Characteristics of Web Respondents: PC Use and Internet Access

The effect of Web-mode addition and comparisons between the Web and paper respondents will be investigated in Section 6. Before them, in this section we put focus on the characteristics of Web respondents in JHPS2009, which have been studied by Naoi, Yamamoto, and Miyauchi (2010: 54-59). Naoi et al. compared the distribution of each variable between Web and paper respondents, and obtained the following results. Web respondents are more likely to be male, young, single, and university graduates. Also, this group comprised a larger proportion of those who are "mainly working". Moreover, Web respondents were more likely to be working full-time, largely in the clerical and information processing occupations. The income of Web respondents was relatively high.

Based on these results of Naoi et al. (2010), our questions here are twofold. First, although they showed the traits of the Web respondents by presenting distribution of each single variable, does a relationship exist between each variable and Web response when the variable used are mutually controlled? Second, when respondents with particular attributes tend to respond online, is it because they only tend to "use a home PC and have home internet access", or, are they likely to be online respondents even among those who use a home PC and have home internet access?

In considering these questions, two types of probit models were estimated using the main dataset of JHPS2009 [9]. The first model explains the case of "PC use and home internet access available". In this model, the dependent variable is, 1 when home PC is used and home internet is accessible, and 0 otherwise. The explanatory variables used are variables of respondents' attributions. The second model explains "Web response". This model limits the cases to those where a home PC is used and home internet access are available. The dependent variable is 1 when a Web response is made and 0 when response is provided via paper questionnaire. Also in this model, as in the former, the respondents' attributions are used as the explanatory variable. For both of two models, the explanatory variables are the respondent's sex, age, marital status, education level, occupation, and

[9] Two additional points should be made to the estimates provided in this section. First, selection bias may exist in the estimated results because the "Web response" model analyzes only the cases for which "PC use and internet access available" is true. Now suppose that, even if the respondents without "PC use and internet access" would have "PC use and internet access", other conditions being equal, then such respondents are unlikely to make Web response. In this case, the estimates of our model do not appropriately capture the Web response trend. However, there is no crucial need to consider the Web response trend of the individuals not in the state "PC use/internet access available". This is because we do not intend, for example, to measure the effect of policy where we provide PC and internet access with people and teach them to use PC and internet. In addition, it is extremely unlikely that the target individuals would "buy a PC and setup an internet access just in order to be able to respond via Web in the survey". Thus, the method here is appropriate to seek the type of individuals, among those with "PC use and internet access available", who are likely respond via Web. Note that the nature of the data here is different from that used in, for example, the analyses on factors determining wages, where "potential wages affect employment but only the wages of the employed can be observed". The second point relates to the analysis method of Section 6. In that section, we estimate nested logit model (details for which we will explain in later sections). Even in the analysis of this section, the choice between "Web response" and "paper response" depends largely on the state "PC use and internet access available". Thus, the choice structure is nested, and some might think nested logit model is an appropriate model such a structure. It is true that we can analyze the choice structure here by nested logit model. However, we have reasons not to do that. Nested logit model allows substitution patterns to be flexibly modelled by parameters, but such a flexible substitution patterns may not be applicable in the present analysis. Flexible substitution patterns mean that, for example, the tendency to be without "PC use and internet access" could possibly substitute with the tendency to make Web response. If none of the respondents "buys a PC and sets up internet just in order to respond via the Web in the survey", substitution between absence of "PC use and internet access present" with "Web response" has no basis in reality.

household income. By estimating these probit models, we are to answer to the aforementioned two questions.

The results are shown in Table 2. First, we discuss the result for the first model, explaining the case of "PC use and home internet access available". At 5% significance level, the probability of "PC use and home internet access available" is significantly high in males, young individuals, individuals with spouses, highly educated individuals, individuals in clerical and information processing occupations (compared with the unemployed), and those with high household income. Furthermore, compared with the unemployed respondents, the tendency of home PC and internet availability is significantly lower among workers in the agricultural, forestry, and fisheries industries. These effects exist even when other factors are controlled.

[Table 2]

The second model, explaining "Web response", yields apparently different results. Here, at 5% level, the attributes of sex, age, educational level, and household income do not have significant impact on Web response (in comparison with base categories for dummy variables)[10].

In other words, the factors explaining the tendency of "Web response" differ markedly from those explaining the tendency of "PC use and internet access available". With regard to sex, the probabilities of both Web response and "PC use and internet access available" are high in males. However, with regard to age, we cannot clearly say the probability of Web response is higher among the younger respondents and low among the

---

[10] We note that the sample size in this second model differs from that in the previous model. Thus, even for variables exerting the same effect, if the same significance level is used, the null hypothesis that no effect exists in the "Web response" model is harder to be rejected for a smaller sample size. For this reason, in order to better compare the results of two models, we also calculated the standard error and p value of each variable under the hypothetical condition that, for the subsample in the second model, the sample size is 3,349, and, the information it has is of the same nature as that in reality. More specifically, in this hypothetical scenario, the standard error is set as the square root of the square of the actually calculated standard error multiplied by 1,993/3,349. We omit the details of the results, but in this case, at 5% level, the dummy variables such as female, "30–39 year old", spouse present, and "Other Occupation" become significant. Even in this supplemental analysis, the factors explaining the tendency of "Web response" differ from those explaining the tendency of "PC use and internet access available" in multiple ways.

older respondents. Similarly, education level showed no significant effect on Web response, nor is Web response significantly more likely among clerical and information processing workers than among the unemployed. Furthermore, with regard to marital status, the probability of "PC use and internet access available" is high when the individual is married, whereas that of "Web response" is higher among those unmarried[11].

These results imply that, while Naoi, Yamamoto, and Miyauchi (2010: 54-59) identified some characteristics with which individuals are more likely to make Web response, namely "young", "single", "university graduate", "work in clerical or information processing", and "with higher income", these can explain who have home PC and internet access, but we cannot say these characteristics encourage Web response among respondents with access to home PC and the internet. In other words, these characteristics stipulate the environment in which Web response is possible, and do not necessarily explain inclination for Web response given such an environment.

In this section, we have examined what type of target individuals are likely to become Web respondents and why. We next consider whether, as pointed out by Naoi, Yamamoto, and Miyauchi (2010: 59), the Web respondents would have responded in the absence of Web mode; i.e., if no Web mode was available, would the Web respondents have responded via paper questionnaire? This issue is discussed below.

---

[11] The results relating to marital status are worthy of further mention. The high probability of "Web response" among singles contrasts with the high probability of "PC use and internet access available" among married individuals. About this, we can make the following interpretation. Home PC and internet resources may be shared in a household. Therefore, even if a married individual possesses no strong desire to use a PC or internet access, they may be encouraged to use these resources if their spouse uses them. In contrast, among individuals with "PC use and internet access present", Web responses may be harder for those with spouses. JHPS2009 was designed such that, when a spouse was present, both the target individual and his/her spouse completed the retained questionnaire. When the target individual used the paper survey form, even if the individual and his/her spouse were to complete it at different times, the paper survey form was passed on and completion requested. However, if Web response was selected, and the target individual and his/her spouse wished to respond at different times, both individuals were required to login to the response website. In this case, for example, if the target individual easily completed the login process while the spouse experienced difficulty, Web response completion might have been precluded. That is, when a spouse is present, unless the login process cost is low for both the target individual and the spouse, Web response is seen as difficult. This may explain why the probability of Web response is smaller than that for singles.

4. Illustrative Description of the Method

As mentioned above, in JHPS2009, the availability of Web mode was not assigned to only a part of target individuals, but given to all; hence, to estimate the effect of Web mode on the response rate requires a novel analysis method. In this section, we present a method for evaluating the effect on the response rate of mixed-mode surveys with no control group. In general, this method evaluates the effect of a type of treatments, where we add alternative(s), with no control group.

Of the 4,022 valid respondents to the JHPS, 91 responded via Web. Therefore, the number of additional valid responses gained by adding Web mode is at most 91. We should note that, part of these 91 respondents may have responded to the survey via paper, if Web response option was not available. Therefore, presumably, the *net* increase in number of respondents "generated" by Web mode is smaller than 91. To measure the increase in number of respondents generated purely by Web mode, we must determine whether the online responders would have responded in the absence of Web mode.

Even if Web mode could "generate" valid responses, it could not do that unless the target individual was notified that Web mode is available. Hence, the "non-contact" cases, in which no contact was made during the survey period, are excluded from the discussion and analysis.

For the purpose here, we need to identify, which alternative (paper response or non-cooperation) would be chosen by each individual, who in reality responded via Web, under the counterfactual situation that Web mode did not exist[12]. In other words, we must analyze the substitution pattern of the alternatives. To this end, we should adopt a multiple

[12] Here all "Web response", "paper response", and "non-cooperation" are treated as "alternatives to choose". Strictly speaking, "non-cooperation" includes cases in which the agents did not personally contact the target individual. Therefore, we cannot assume that all the target individuals consciously "chose the alternative of non-cooperation"; thus, the term like these may not be appropriate. To avoid misunderstanding, the terms "alternative" or "choice" might be better replaced with vocabulary such as "target individuals are 'classified' into one of the 'states': 'web response', 'paper response', and 'non-cooperation'". In this paper, however, we retain the terms "alternative" and "choice" for simplicity and consistency with existing literature.

choice model in which substitution patterns can be flexibly expressed. We note that, the type of multinominal logit model and conditional logit model, often used as multiple choice models, expresses only specific substitution patterns. Specifically, the substitution patterns in these models are fixed by the independence from irrelevant alternatives (IIA) assumption. This section introduces nested logit model in which substitution patterns are flexibly expressed. We will estimate the model, explaining the choice among the three alternative modes, “paper response”, “Web response”, and “non-cooperation”, and next, we will evaluate the number of valid responses “generated” by Web mode, based on the predictions using the estimates.

Below we explain the concept of the substitution pattern used to analyze “Web response” with a pattern diagram.

First, we assume a state in which “Web response” and “non-cooperation” reside within the same nest[13], and the two alternatives can be substituted extremely easily. Figure 1 shows the correspondence between the tendency for an individual to conduct a “Web response”[14], indicated by X-axis, and the probabilities of “paper response”, “web response”, and “non-cooperation”, indicated by Y-axis. The tendencies for choosing “paper response” and “non-cooperation” are assumed to be fixed. In the case of Figure 1, the probability of “non-cooperation” is small among the target individuals with strong “Web response” tendency compared with those with weak tendency. On the other hand, the probability of conducting “paper response” is similar in both groups. Thus, Figure 1 graphically represents the pattern where substitution occurs very easily between “Web response” and “non-cooperation”. The state of no Web mode can be regarded as a state in which the Web response tendency is extremely small (equal to negative infinity) among the entire target sample[15]. Therefore, given the substitution pattern in Figure 1 and provided that the target sample contains members with strong tendencies to conduct “Web response”, the existence of the “Web response” alternative reduces the probability of “non-cooperation”, i.e., improves the response rate.

[Figure 1]

[13] The nest structure in this case corresponds to “nest structure (a)” shown in Figure 4.
[14] Strictly, the tendency to make “Web response” discussed here refers only to the part expressible by observed variables.
[15] The condition for this proposition is given in Formula [18].

We now assume a different nest structure in which “Web response” and “paper response” reside in the same nest[16], and thus are easily substituted. The choice probabilities of this situation are shown in Figure 2. In this case, for the individuals strongly inclined to respond online, the probability of “non-cooperation” is similar to those less inclined, whereas the probability of “paper response” is small. This expresses the ease with which “Web response” and “paper response” are substituted. In the case of Figure 2, even if target individuals with strong “Web response” tendency exist in the population, the alternative “Web response” merely discourages the selection of “paper response” and does not signify an improvement in the response rate.

[Figure 2]

Figure 2 shows a state in which “Web response” and “paper response” can be extremely easily interchanged, whereas the substitution between “Web response” and “non-cooperation” almost never occurs. In reality, even if “Web response” and “paper response” reside in the same nest, the substitution pattern might be less extreme than that of Figure 2. Nested logit models can express substitution patterns flexibly by using parameters, as an example shown in Figure 3. In the case of this figure, “Web response” and “paper response” remain nested together, but non-negligible substitutions occur between “Web response” and “non-cooperation”.

[Figure 3]

According to the substitution pattern of Figure 3, target individuals with strong tendency for “Web response” have low probability of “paper response” compared with those with weak tendency. In addition, the high-tendency group has a low probability of “non-cooperation”. Consequently, when Web mode is added in this scenario, “Web response” replaces “paper response” and also “non-cooperation” to a certain extent. The extents to which “Web response” replaces “paper response” and “non-cooperation” are expressed by a parameter estimated in the nested logit model. Once these estimated results specify the substitution pattern, we can evaluate the contribution of Web mode to the response rate, by calculating the level of “Web response” replacing with “non-cooperation”.

A more specific description of our method is as follows. As described above, under

[16] The nest structure in this case corresponds to “nest structure (b)” shown in Figure 4.

certain assumptions, the state of no Web mode is equivalent to that of no tendency (or tendency indicated by the value "negative-infinite") for Web response among the whole population. Roughly speaking, when the tendency for "Web response" is extremely weak (corresponding to left-hand side endpoint in Figure 3), the probability of "Web response" is extremely small, and this state reflects a virtual situation where no Web mode exists. On the other hand, when the tendency for "Web response" is strong (corresponding to right-hand side endpoint in Figure 3), a significant probability of "Web response" exists. We can interpret, comparing with the left side of the figure, at the right side the "Web" probability comprises two parts, which replaced "paper response" and "non-cooperation", shown as γ and δ, respectively. Thus, in this pattern, δ reflects the extent to which the probability to make valid response is increased by letting the Web option available.

In the following analysis, first, the nested logit model is used to determine the choice structure (substitution pattern) and the effect of individual attributes on selection tendencies. Next, we simulate two states: Web mode available and Web mode absent. We determine each individual's probability of "non-cooperation" in each state, and obtain the expected value of the increase in the number of respondents generated by Web mode, by summing up the δ values across all target individuals. Thus the *net* effect of the optional Web mode is measured.

5. The Model

We adopt a nested logit model with two levels. In this section, we introduce the model formulation based on random utility maximization (RUM), and, demonstrate that the estimated probabilities in the case of no "Web response" can be calculated consistently with RUM. We owe a considerable portion of the following discussion to Heiss (2002) and Train (2003).

First, we present a general two-level nested logit model as follow. Consider a situation in which each individual i selects one option from J alternatives. The index for the alternatives is j (or k), and the alternative selected by individual i is y_i. Each alternative belongs to one of the M nests, expressed as B_m ($m = 1, \ldots, M$). The nest to which alternative j belongs is denoted by $B(j)$. Consistent with preceding research, the tendency for the individual i to select the alternative j is called "utility," denoted by U_{ij}.

The utility U_{ij} when individual i selects the option j can be separated into a component V_{ij} on the basis of the observed variables and an unobserved component (disturbance term) ε_{ij}. Typically, V_{ij} is expressed as a linear combination of observed variables and parameters.

[1] $$U_{ij} = V_{ij} + \varepsilon_{ij}$$

The disturbance term ε_{ij} is a random variable that distributes a standard Type I Extreme Value distribution whose variance is $\pi^2/6$. ε_{ij} is independent among individual decision makers. Among the alternatives, ε_{ij} is independent between the alternatives in different nests, but is correlated between the alternatives within the same nest. The correlation coefficient between the ε_{ij}'s in nest B_m is denoted by ρ_{Bm}.

[2] $$\varepsilon_{ij} \sim \text{Standard Type I Extreme Value},$$

and this means $\Pr(\varepsilon_{ij} < x) = \exp[-\exp(-x)]$.

[3] $$\mathrm{Corr}(\varepsilon_{ij}, \varepsilon_{ik}) = \rho_{B(j)},$$ if $B(j) = B(k)$ and $j \neq k$

[4] $$\varepsilon_{ij} \perp \varepsilon_{ik}$$ if $B(j) \neq B(k)$

For a nest B_m, an inclusive value coefficient (or dissimilarity parameter) τ_{Bm} is defined as follows.

[5] $$\tau_{B_m} \equiv \sqrt{1 - \rho_{B_m}}.$$

Furthermore, for individual i, the inclusive value I_{iBm} of nest B_m is defined as follows:

[6] $$I_{iB_m} \equiv \ln\Big[\sum_{k \in B_m} \exp(V_{ik} / \tau_{B_m})\Big].$$

On the other hand, RUM assumes the following:

[7] $$\Pr(y_i = j) = \Pr(U_{ij} > U_{ik} \forall k \neq j)$$.

Under the above assumptions, the probability that individual i selects alternative j is expressed as below:

[8] $$\Pr(y_i = j) = \Pr[y_i \in B(j)] \cdot \Pr[y_i = j \mid y_i \in B(j)]$$

[9] $$\Pr[y_i \in B(j)] = \frac{\exp[\tau_{B(j)} I_{iB(j)}]}{\sum_{m=1}^{M} \exp[\tau_{B_m} I_{iB_m}]}$$

[10] $$\Pr[y_i = j \mid y_i \in B(j)] = \frac{\exp[V_{ij} / \tau_{B(j)}]}{\sum_{k \in B(j)} \exp[V_{ik} / \tau_{B(k)}]}.$$

We next consider the case in which specific alternatives are excluded from the model. Assuming $J > 2$, when the number of alternatives reduces by one (i.e., the number of alternatives is $J - 1$), with other assumptions unchanged, the choice probability of each alternative derived consistently with RUM takes a general form shown in Formulae [6], [8], [9], and [10].

In a lead-up to the next section, we specifically show the formulation of the situation where "Web response" option does not exist. As will become evident later, "Web response" and "paper response" are estimated to be included in the same nest, so we assume such a structure also here. We use the notations as follow: *web*, *paper*, *nocoop*, B_{coop}, and B_{nocoop}, which indicate, "Web response", "paper response", "non-cooperation", the nest comprising "Web response" and "paper response," and the nest comprising "non-cooperation" alone, respectively. Then the utility from selecting each option is as follows:

[11] $$U_{i,web} = V_{i,web} + \varepsilon_{i,web}\ ,\ U_{i,paper} = V_{i,paper} + \varepsilon_{i,paper}\ ,\ U_{i,nocoop} = V_{i,nocoop} + \varepsilon_{i,nocoop}$$

We note that, according to RUM, the selection probability depends only on the utility differences between selection modes. Because of it, and also because we only use individual-specific variables in estimation, $V_{i,nocoop}$ is constrained to be 0. Here $\varepsilon_{i,web}$, $\varepsilon_{i,paper}$, and $\varepsilon_{i,nocoop}$ each distributes the standard Type I Extreme Value, but because $\varepsilon_{i,web}$ and $\varepsilon_{i,paper}$

belong to the same nest B_{coop}, they can be correlated with correlation coefficient ρ_{Bcoop}. On the other hand, no correlation exists, between $\varepsilon_{i,web}$ and $\varepsilon_{i,nocoop}$, nor, between $\varepsilon_{i,paper}$ and $\varepsilon_{i,nocoop}$. Assuming RUM, the selection probability of "Web response" is derived as follows. Here $\tau_{Bnocoop}$ cannot be uniquely determined, thus we arbitrarily fixed it as 1.

[12] $$\tau_{B_{coop}} \equiv \sqrt{1-\rho_{B_{coop}}}$$

[13] $$I_{iB_{coop}} \equiv \ln[\exp(V_{i,web}/\tau_{B_{coop}}) + \exp(V_{i,paper}/\tau_{B_{coop}})]$$

[14] $$\Pr(y_i = web) = \Pr[y_i \in B_{coop}] \cdot \Pr[y_i = web \mid y_i \in B_{coop}]$$

[15] $$\Pr[y_i \in B_{coop}] = \frac{\exp[\tau_{B_{coop}} I_{iB_{coop}}]}{\exp[\tau_{B_{coop}} I_{iB_{coop}}] + \exp[\tau_{B_{nocoop}} I_{iB_{nocoop}}]} = \frac{\exp[\tau_{B_{coop}} I_{iB_{coop}}]}{\exp[\tau_{B_{coop}} I_{iB_{coop}}] + 1}$$

[16] $$\Pr[y_i = web \mid y_i \in B_{coop}] = \frac{\exp[V_{i,web}/\tau_{B_{coop}}]}{\exp[V_{i,web}/\tau_{B_{coop}}] + \exp[V_{i,paper}/\tau_{B_{coop}}]}$$

In this model, when V_{ij} is provided for each alternative, the selection probability can be estimated for each individual assuming a virtual state with no "Web response." In the absence of "Web response", the individual would make a selection from choice sets comprising two modes, "paper response" and "non-cooperation", but each of the disturbance terms for these modes ($\varepsilon_{i,paper}$ and $\varepsilon_{i,nocoop}$) has an *independent* Type I Extreme Value distribution. Hence, their difference distributes with the standard logistic distribution, and the selection probability between "paper response" and "non-cooperation" can be denoted by the binomial logit model. This conclusion is also derived from Formulae [6], [8], [9], and [10]. More specifically, under the constraint $V_{i,nocoop} \equiv 0$,

[17] $$\begin{aligned}
&\Pr[y_i = paper \mid \Pr(y_i = web) = 0] = \Pr(U_{i,paper} > U_{i,nocoop}) \\
&= \Pr(V_{i,paper} + \varepsilon_{i,paper} > V_{i,nocoop} + \varepsilon_{i,nocoop}) \\
&= \Pr(V_{i,paper} - V_{i,nocoop} > \varepsilon_{i,nocoop} - \varepsilon_{i,paper}) \\
&= \Pr(V_{i,paper} > \kappa_i) \\
&= F(V_{i,paper}) \\
&= \frac{\exp(V_{i,paper})}{1+\exp(V_{i,paper})}
\end{aligned}$$

Here κ_i is the random variable following the standard logistic distribution, and $F(\cdot)$ is the cumulative density function of the standard logistic distribution.

Even if the "Web response" alternative pre-existed, provided that the following Formula [18] is satisfied, as $V_{i,web}$ becomes small enough to be negative infinity, the probability that individual i selects "Web response" tends to 0. In this situation, this individual must select between "paper response" and "non-cooperation". This is the assumption of the formerly discussed proposition in terms of Figures 1–3, i.e., when the tendency for Web response is very small, the selection reduces to "paper response" or "non-cooperation".

[18] $\Pr(-\infty + \varepsilon_{i,web} < r) = 1$ for any real number r.

We now specify V_{ij}, i.e., the component of the utility, explained by the utility explanatory variable. Ideally, if we aim to estimate a multiple choice model directly consistent with a theory, we should use explanatory variables which represent what each alternative means to the individual. In other words, the explanatory variables should be alternative specific. In the current analysis, for example, we could use the alternative-specific variable such as the perceived cost of each alternative for each target individual. In this way, the general theory such as "the sense of cost sways the selection behavior" could be more directly modelled and tested. If we had the variable such as "the sense of cost relating to the input operation on the Web and PC operation", then we could use it as the alternative-specific variable for "Web response" consistently with the "cost" theory above. However, because we have no such a variable in the dataset, the present analysis uses only individual-specific variables.

To be more specific, letting the variable vector indicating the attributes of individual i represented by $\boldsymbol{x}_i$, the parameter vector applied to each variable when explaining the utility of alternative j be represented by $\boldsymbol{\beta}_j$ and the individual-specific constant of alternative j be represented by α_j, V_{ij} can be expressed as:

[19] $V_{i,paper} = \alpha_{paper} + \boldsymbol{\beta}'_{\boldsymbol{paper}}\boldsymbol{x}_{\boldsymbol{i}}$, $V_{i,web} = \alpha_{web} + \boldsymbol{\beta}'_{\boldsymbol{web}}\boldsymbol{x}_{\boldsymbol{i}}$, $V_{i,nocoop} \equiv 0$

In this model formulation, the estimated parameters express the differences in utility of the selection behavior, caused by the individual's attributes. This utility difference may arise from differences in, e.g., the value of payments received for survey cooperation, the psychological sense of satisfaction gained by survey cooperation, or the sense of cost incurred by survey cooperation. Because the survey method influences the sense of cost for survey cooperation, we use variables relating to the survey process in the following estimates.

To simplify the calculations, the parameters in the next section are not directly estimated from the aforementioned model but from the model formulated in Greene (2003: 725-727). Here because we do not use generic variables, i.e., variables whose coefficients are common across the nests, the model itself is still consistent with RUM (Heiss 2002). The estimated parameter vector and alternative-specific constant, denoted by $\tilde{\boldsymbol{\beta}}_j$ and $\tilde{\alpha}_j$, respectively, are related to the aforementioned parameters as follows:

$$[20] \qquad \tilde{\boldsymbol{\beta}}_j \equiv \frac{1}{\tau_{B(j)}} \boldsymbol{\beta}_j \ , \ \tilde{\alpha}_j \equiv \frac{1}{\tau_{B(j)}} \alpha_j$$

The coefficients we will show in the result table are not $\hat{\tilde{\boldsymbol{\beta}}}_j$ and $\hat{\tilde{\alpha}}_j$, which are estimated parameters themselves, but $\hat{\boldsymbol{\beta}}_j$ and $\hat{\alpha}_j$, which are obtained from transformation to let RUM-consistent interpretations, determined as follows:

$$[21] \qquad \hat{\boldsymbol{\beta}}_j \equiv \tau_{B(j)} \hat{\tilde{\boldsymbol{\beta}}}_j \ , \ \hat{\alpha}_j \equiv \tau_{B(j)} \hat{\tilde{\alpha}}_j$$

In addition, hypothesis testing is conducted on $\hat{\boldsymbol{\beta}}_j$ and $\hat{\alpha}_j$.

Having estimated the nested logit model as described above, we evaluate the number of additional responses generated by the Web mode, using the estimates. The increase in respondent number due to the Web mode is the difference between the number choosing "non-cooperation" in the absence and presence of Web mode. We can calculate the expected value of it using the estimates of the model. Denoting the expected increase in respondents generated by the Web mode as D, and the expected number of "non-cooperation" responses in the absence and presence of Web mode by $NC(T = 0)$ and $NC(T = 1)$, respectively, we obtain the following:

$$[22] \qquad D = NC(T = 0) - NC(T = 1) \, .$$

We intend (T = 1) shall indicate the state of Web mode availability. Here the expected number of choosers of each alternative is the sum of the selection probabilities of each individual. Therefore, if the number of individuals is n, the following is obtained from Formulae [17], [19], and [20]:

[23]
$$\begin{aligned} NC(T=0) &= \sum_{i=1}^{n} \Pr(U_{i,paper} < U_{i,nocoop}) \\ &= \sum_{i=1}^{n} \frac{1}{1+\exp(V_{i,paper})} \\ &= \sum_{i=1}^{n} \frac{1}{1+\exp(\tau_{B_{coop}} \tilde{\alpha}_{paper} + \tau_{B_{coop}} \tilde{\boldsymbol{\beta}}'_{\boldsymbol{paper}} \boldsymbol{x_i})} \end{aligned},$$

whereas Formulae [13], [15], [19], and [20] yield

[24]
$$\begin{aligned} NC(T=1) &= \sum_{i=1}^{n} \Pr(y_i = nocoop) \\ &= \sum_{i=1}^{n} [1 - \Pr(y_i \in B_{coop})] \\ &= \sum_{i=1}^{n} \frac{\exp(\tau_{B_{nocoop}} I_{iB_{nocoop}})}{\exp(\tau_{B_{coop}} I_{iB_{coop}}) + \exp(\tau_{B_{nocoop}} I_{iB_{nocoop}})} \\ &= \sum_{i=1}^{n} \frac{1}{1+\exp[\tau_{B_{coop}} \ln\{\exp(\tilde{\alpha}_{paper} + \tilde{\boldsymbol{\beta}}'_{\boldsymbol{paper}} \boldsymbol{x_i}) + \exp(\tilde{\alpha}_{web} + \tilde{\boldsymbol{\beta}}'_{\boldsymbol{web}} \boldsymbol{x_i})\}]} \end{aligned}.$$

D can be expressed as the sum of δ values (see Figure 3):

[25]
$$D = \sum_{i=1}^{n} \delta_i ,$$

where $\delta_i = \Pr(U_{i,paper} < U_{i,nocoop}) - \Pr(y_i = nocoop)$

D can be obtained from Formulae [22], [23], and [24] by using the estimated parameters of nested logit model. Because it is based on the estimates of a statistical model, it contains an error, whose magnitude is assessed using the delta method. The calculation of this error is discussed in Appendix.

6. Results

(1) Estimated Results of the Statistical Model

In this subsection, we apply the model to the survey confirmation form dataset, and report estimated results[17].

Prior to estimating the nested logit model, the nest structure must be specified. Here we do not determine the nest structure a priori, and we let data determine whether "paper response" or "non-cooperation" is more easily substituted by "Web response". The nest structures formed from the three alternatives, "paper response", "Web response", and "non-cooperation", are shown in Figure 4. Nest structure (c) is not an essential target of this research because it assumes that "Web response" and "paper response" are substituted to the same extent as "Web response" and "non-cooperation," and thus, the effect of Web-mode addition cannot be evaluated with this structure. Hereafter, this nest structure shall be examined just for supplemental information.

[Figure 4]

Table 3 shows the inclusive value coefficients τ, resulting from the estimation of the nested logit model, with nest structures constructed in Figure 4. All explanatory variables listed in Table 4 are included as individual-specific variables.

[Table 3]

---

[17] The analysis in the previous section implies that the presence or absence of PC use and internet access strongly stipulates the Web responses. Therefore, if none of the target individuals would purchase PCs and setup internet access just in order to enable online response, we can say that, among the target individuals with no PC use or internet access, "Web response" is never likely to replace "non-cooperation". In this sense, the analysis in this section might be more appropriate using the dataset with only those who use PCs and have internet access. However, we cannot obtain information on PC and internet access of non-respondents. Consequently, in the following analysis, the sample cannot be limited by the presence of PC use and internet access.

The inclusive value coefficient represents the degree to which the alternatives collated in a nest are dissimilar. The coefficients below 0 or greater than 1 are incompatible with RUM[18]. In fact, Formula [5] indicates that, when the correlation coefficient between two disturbance terms lies in [0,1], the inclusive value coefficient also lies in [0,1]. From Table 3, we observe that the estimated inclusive value coefficient exceeds 1 in nest structure (a), suggesting that dissimilar alternatives are collated within a nest. In contrast, nest structure (b) yields an inclusive value coefficient estimate within [0,1]. Therefore, nest structure (b) is adopted throughout the remaining analysis, though we should note that the 95% confidence interval around the inclusive value coefficient includes the region below 0. We can think it natural that the target individuals decide to respond online after deciding to cooperate in the survey. If it is true, nested structure (b) is a valid construct.

Nest structure (b) suggests that the alternatives "paper response" and "Web response" are similar and easily interchanged. As shown in the two rightmost columns of Table 3, the null hypothesis that the inclusive value coefficient is 1 in nest structure (b) can be rejected at the 0.1% level by Wald test. This means that, in our analysis, the substitution pattern is not the one implied by IIA, i.e., the one assumed in the multinominal and conditional logit models. This result also confirms the appropriateness of our use of nested logit model.

If the aim is not to evaluate the effect of Web-mode addition, nest structure (c) can also be possibly adopted, because the estimated inclusive value coefficients fall within [0,1]. However, we should note that, as shown by the 95% confidence intervals in Table 3 and Wald test results, the null hypothesis that the inclusive value coefficient of nest structure (c) is 1 cannot be rejected.

The full estimated results based on nest structure (b) are shown in Table 4. The explanatory variables are sex, age, housing status, inhabited area block, the scale of city, and method of survey. The survey method variables are fourfold, as follow: (i) whether the target individual partakes only in the retained survey or partakes also in the interview survey; (ii) whether the target individual was a part of the initial target group or backup; and (iii) the completion reward for the collection agent surveying the target individual (whether a premium was earned by completing the initial target group), and the interaction

---

[18] More strictly, Formulae [6], [10] etc. suggest that, even when the inclusive value coefficient is 0, the probability cannot be calculated correctly.

between (ii) and (iii)[19]. Because this analysis mainly aims to acquire the estimates for predictions, a substantive interpretation of Table 4 is not conducted.

[Table 4]

(2) Evaluating the Effect of Web-Mode Addition

In this subsection, the effect of Web-mode addition is evaluated from the estimated results of the above statistical model.

The predicted numbers of selectors for each alternative, based on the estimates listed in Table 4, are shown in Table 5. The leftmost column of Table 5 lists the actual number of selectors of each alternative and their percentages in the real dataset. Similarly to the previous subsection, the result is based on the dataset including only those were contacted in the survey; i.e., among the total targeted sample 2,928 individuals who could not be contacted are excluded from this table.

[Table 5]

The column in the middle of Table 5 displays the expected number of individuals selecting each alternative, calculated by summing the estimated choice probabilities for each alternative for all target individuals in the dataset, assuming that Web mode exists. The expected number of individuals selecting “Web response” is 91.9, close to the actual number of Web selectors. The expected number of “non-cooperation” individuals is 5,598.8, and it is equivalent to $NC(T = 1)$.

The expected numbers of selectors in the absence of Web mode are shown in the second-right column of Table 5. Naturally, this state contains no Web respondents. The expected number of “non-cooperation” individuals is 5,602.6, and it is equivalent to $NC(T = 0)$. The rightmost column of Table 5 displays the difference in the expected number of selectors when Web mode is present and absent. The expected difference in the number of “non-cooperation” selectors, D, is 3.8.

This result indicates that 88.1 of the 91.9 Web respondents with internet access would have selected paper response if Web response was not available, whereas the

[19] For details of the survey method, see Naoi, Yamamoto, and Miyauchi (2010).

remaining 3.8 would not cooperate; i.e., among the online responders, approximately 3.8 would not have responded unless the Web option was available. Therefore, the number of responses gained by adding Web alternative was approximately 3.8.

In Table 6, we show the estimated errors, for the *D* estimated above, and also, for the increases in response rate and cooperation rate calculated based on it. The increase in respondents (cooperators) generated by Web mode is estimated as 3.8, and the standard error is 10.2. If a 95% confidence interval is setup around 3.8, the upper limit is 23.9. Even if this confidence interval indicates an acceptable range of the standard error, it is implausible that we expect adding Web mode generated more than 24 responses. This 95% confidence interval also covers negative values, suggesting that negative inclusive value coefficients are permitted by the error margins. However, as mentioned earlier, negative inclusive value coefficients are inconsistent with the model assumptions. Hence, this interpretation of confidence intervals requires careful consideration[20].

[Table 6]

In assessing performances of surveys with regard to responses, response rate and cooperation rate are frequently used[21]. So, we also calculated the percentage increases in the cooperation and response rates generated by Web mode, shown in the second and third rows of Table 6, respectively. The cooperation rate rises by 0.0397% points, whereas the response rate increases by 0.0304% points. The 95% confidence interval for the increase in the response rate is [−0.1294, 0.1902]. In other words, even if the 95% confidence interval constitutes a usual error range, even considering errors, increase in the response rate due to Web mode is not likely to exceed 0.1902% points. Note that, to show increases in response rates and cooperation rates, we are not using a proportion whose upper limit is 1, but using % points whose upper limit is 100.

---

[20] To avoid such inconsistencies, one can think of a method whereby, after specifying the nested structure, τ is not estimated directly but equals (for example) $1/[1 + \exp(-g)]$. The formula is rearranged to obtain g. Although, we might think negative inclusive value coefficients reflect the reality, in the following sense. Negative inclusive value coefficients may suggest that adding Web mode reduces the response rate. Israel (2009) found that, in the case of a postal survey method, adding Web mode caused lower response rate. Like Israel's case, possibility of negative inclusive value coefficients in our analysis might imply, even in the visitation survey method, Web-mode addition could reduce response rate.

[21] For indices on performance of surveys on responses, see Yamamoto and Ishida (2010).

7. Conclusion

In this study, we showed, taking Web-mode addition for example, how we can evaluate the effect of additional options without a control group. The data from JHPS2009 were used in the analysis. The results are summarized below.

First, given the choice of answering via paper or online, the Web responders tended to be young, university graduates, employed in the clerical and information processing sectors, and in household with high incomes. However, these characteristics are largely correlated with the availability of PC use and internet access.

Second, we evaluated the effect on the response rate when Web mode is added to the retained paper-based survey. By adopting a multiple-choice model in which substitution patterns are expressed flexibly, the increase in the response rate was shown to be no more than 0.0304% points. The analyses assumed that individuals' choice behavior can be expressed by explanatory variables consistent with RUM, and that the disturbances in utilities follow specified distributions.

The contribution we directly made is stated as follow. Ideally, sampling surveys should produce minimum error at a fixed cost, and, improvements in the response rates can contribute to minimizing errors, under certain assumptions. The effect of survey methods on the response rate is best evaluated by randomly assigning the target sample to different survey methods. However, this design may incur large cost and high risks. If the entire target sample is exposed to the same survey method, the effect of a specific method can be evaluated by a novel technique in analysis. Specifically, via flexible substitution patterns, the effect of mixed-mode survey methods on the response rate can be assessed. Such a technique is what we showed in this paper.

Finally, we discuss future research topics. In the present mixed-mode survey with paper and Web options, Web mode was regarded as the additional mode. With equal validity, one could analyze the contribution made by paper responses to the response rate. Thus, one could analyze the extent to which the response rate is reduced, assuming that the entire target sample has access to the Web and that paper response mode is absent. Such information would interest survey organizers who aspire to minimize the error at a fixed cost, provided that Web survey costs are low. Moreover, this method can assess not only the effect of Web-mode addition on the obtained sample's characteristics such as sample bias, but also (in theory at least) its impact on sample characteristics in the virtual case of lowered Web-mode response cost and increased Web response rate[22].

Furthermore, the proposed method can be used to verify the effects of other combinations of mixed-mode surveys. For example, the method should be applicable to scenarios in which Web mode competes with postal method or visitation method competes with postal method. The emerging substitution patterns would reveal how the alternative options sway the response rates. Through thorough investigation of survey methods, the errors in sampling survey can be minimized, and as a corollary to this, it is hoped that further meaningful and accurate scientific knowledge can be accumulated.

In general, the proposed method can evaluate alternative-addition treatments in the absence of a control group. For example, if a public secondary education school of new type was established in the vicinity of a private high school, the method could evaluate the effect of the new school on the private high school applicants, without bias caused by time trends. Another example relates to marriages among the highly educated women. By considering a virtual society in which highly educated women are extremely refused marriage, one could determine the extent to which the proportion of married people is increased by existence of marriages of women with men of lower education. Furthermore, people would be interested in the degree to which "regular" work and unemployment are substituted by "non-regular" work[23]. Though the flexible expression of substitution patterns in multiple-choice models is a classic tool, it is a very useful tool that yields knowledge of great importance.

Appendix. Evaluation of Error Relating to the Estimated Effect

Below we show the details of the method to evaluate the error in the estimated

[22] This virtual situation can be resulted from, for example, the conditions that procedures for Web response are made further simplified and skills needed to answer via Web become more widely spread. Such a virtual situation could be simulated by calculating the estimated probability while increasing the alternative-specific constant for the alternative and observing the resulted sample characteristics.

[23] We should note the following. If we analyze on this topic as a matter of labor market, so long as we take a simple approach, we could be neglecting the factors on demand side in labor market.

increase in the number of respondents generated by Web mode (see Section 6). The error is evaluated by the delta method in the following steps. To simplify the formulae, the symbol ^ ("hat" indicating estimated values) is omitted.

The parameter vector $\boldsymbol{\theta}$ is defined as follows:

[A1] $$\boldsymbol{\theta} \equiv (\tilde{\alpha}_{paper} \quad \tilde{\boldsymbol{\beta}}'_{\boldsymbol{paper}} \quad \tilde{\alpha}_{web} \quad \tilde{\boldsymbol{\beta}}'_{\boldsymbol{web}} \quad \tau_{B_{coop}})'.$$

The variance of D is calculated by below formulae:

[A2] $$\mathrm{Var}(D) = \left(\frac{\partial D}{\partial \boldsymbol{\theta}}\right)' \mathrm{Var}(\boldsymbol{\theta}) \left(\frac{\partial D}{\partial \boldsymbol{\theta}}\right)$$

[A3] $$\frac{\partial D}{\partial \boldsymbol{\theta}} = \frac{\partial NC(T=0)}{\partial \boldsymbol{\theta}} - \frac{\partial NC(T=1)}{\partial \boldsymbol{\theta}}.$$

The elements of $\frac{\partial NC(T=0)}{\partial \boldsymbol{\theta}}$ are calculated as shown below. The following substitution is used: $\tilde{V}_{i,paper} \equiv \tilde{\alpha}_{paper} + \tilde{\boldsymbol{\beta}}'_{\boldsymbol{paper}} \boldsymbol{x_i}$, $\tilde{V}_{i,web} \equiv \tilde{\alpha}_{web} + \tilde{\boldsymbol{\beta}}'_{\boldsymbol{web}} \boldsymbol{x_i}$.

[A4] $$\frac{\partial NC(T=0)}{\partial \tilde{\alpha}_{paper}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})}{\{1+\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})\}^2} \right]$$

[A5] $$\frac{\partial NC(T=0)}{\partial \tilde{\boldsymbol{\beta}}_{\boldsymbol{paper}}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})}{\{1+\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})\}^2} \cdot \boldsymbol{x_i} \right]$$

[A6] $$\frac{\partial NC(T=0)}{\partial \tilde{\alpha}_{web}} = 0$$

[A7] $$\frac{\partial NC(T=0)}{\partial \tilde{\boldsymbol{\beta}}_{\boldsymbol{web}}} = \boldsymbol{0}$$

[A8] $$\frac{\partial NC(T=0)}{\partial \tau_{B_{coop}}} = -\sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})}{\{1+\exp(\tau_{B_{coop}} \tilde{V}_{i,paper})\}^2} \cdot \tilde{V}_{i,paper} \right].$$

The elements of $\frac{\partial NC(T=1)}{\partial \boldsymbol{\theta}}$ are calculated as shown below. From Formula [13], we have the following:

$$I_{iB_{coop}} \equiv \ln[\exp(V_{i,web}/\tau_{B_{coop}}) + \exp(V_{i,paper}/\tau_{B_{coop}})] = \ln[\exp(\tilde{V}_{i,web}) + \exp(\tilde{V}_{i,paper})]\,.$$

[A9] $$\frac{\partial NC(T=1)}{\partial \tilde{\alpha}_{paper}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} I_{iB_{coop}})}{\{1+\exp(\tau_{B_{coop}} I_{iB_{coop}})\}^2} \cdot \frac{\exp(\tilde{V}_{i,paper})}{\exp(\tilde{V}_{i,paper}) + \exp(\tilde{V}_{i,web})} \right]$$

[A10] $$\frac{\partial NC(T=1)}{\partial \tilde{\boldsymbol{\beta}}_{\boldsymbol{paper}}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} I_{iB_{coop}})}{\{1+\exp(\tau_{B_{coop}} I_{iB_{coop}})\}^2} \cdot \frac{\exp(\tilde{V}_{i,paper})}{\exp(\tilde{V}_{i,paper}) + \exp(\tilde{V}_{i,web})} \cdot \boldsymbol{x}_i \right]$$

[A11] $$\frac{\partial NC(T=1)}{\partial \tilde{\alpha}_{web}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} I_{iB_{coop}})}{\{1+\exp(\tau_{B_{coop}} I_{iB_{coop}})\}^2} \cdot \frac{\exp(\tilde{V}_{i,web})}{\exp(\tilde{V}_{i,paper}) + \exp(\tilde{V}_{i,web})} \right]$$

[A12] $$\frac{\partial NC(T=1)}{\partial \tilde{\boldsymbol{\beta}}_{\boldsymbol{web}}} = -\tau_{B_{coop}} \sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} I_{iB_{coop}})}{\{1+\exp(\tau_{B_{coop}} I_{iB_{coop}})\}^2} \cdot \frac{\exp(\tilde{V}_{i,web})}{\exp(\tilde{V}_{i,paper}) + \exp(\tilde{V}_{i,web})} \cdot \boldsymbol{x}_i \right]$$

[A13] $$\frac{\partial NC(T=1)}{\partial \tau_{B_{coop}}} = -\sum_{i=1}^{n} \left[\frac{\exp(\tau_{B_{coop}} I_{iB_{coop}})}{\{1+\exp(\tau_{B_{coop}} I_{iB_{coop}})\}^2} \cdot I_{iB_{coop}} \right]$$

Inserting the estimated parameter and the variance-covariance matrix Var($\boldsymbol{\theta}$), the variance of *D* is obtained.

Supplementary Note

The JHPS2009 datasets used in this analysis were provided in August 2009 by the Joint Research Center for Panel Studies at Keio University.

References

[In English]

Couper, Mick P., and Peter V. Miller. "Web Survey Methods: Introduction." *Public Opinion*

Quarterly 72 (5): 831-835.

Dillman, Don A. 1999. *Mail and Internet Surveys: The Tailored Design Method (Second Edition)*. New York: Wiley.

Dillman, Don A., Glenn Phelps, Robert Tortora, Karen Swift, Julie Kohrell, Jodi Berck, and Benjamin L. Messer. 2009. "Response Rate and Measurement Differences in Mixed-Mode Surveys Using Mail, Telephone, Interactive Voice Response (IVR) and the Internet." *Social Science Research* 38: 1-18.

Greene, William H. 2003. *Econometric Analysis (Fifth Edition)*. Upper Saddle River, N.J.: Prentice-Hall.

Groves, Robert M., Floyd J. Fowler Jr., Mick P. Couper, James M. Lepkowski, Eleanor Singer, and Roger Tourangeau. 2004. *Survey Methodology*. Wiley.

Heiss, Florian. 2002. "Structural Choice Analysis with Nested Logit Models." *Stata Journal* 2 (3): 227-252.

Israel, Glenn D. 2009. "Obtaining Responsed by Mail or Web: Response Rates and Data Consequences." Paper Presented at the 64th Annual Conference of AAPOR.

Kaplowitz, Michael D., Timothy D. Hadlock, and Ralph Levine. 2004. "A Comparison of Web and Mail Survey Response Rate." *Public Opinion Quarterly* 68 (1): 94-101.

McCabe, Sean Esteban, Alison Diez, Carol J. Boyd, Toben F. Nelson, and Elissa R. Weitzman. 2006. "Comparing Web and Mail Responses in a Mixed Mode Survey in College Alcohol Use Research." *Addictive Behavior* 31: 1619-1627.

Naoi, Michio. 2009. "Attrition Bias in Longitudinal Survey: A Validation Study with Interviwer's Record of Respondent Mobility." Joint Research Center for Panel Studies Discussion Paper Series DP2009-003.

Train, Kenneth E. 2003. *Discrete Choice Methods with Simulation*. Cambridge: Cambridge University Press.

[In Japanese]

Ministry of Internal Affairs and Communications. 2010. "2010 National Census Execution Plan." http://www.stat.go.jp/data/kokusei/2010/keikaku/pdf/sy02.pdf (Accessed March 24, 2011).

Naoi, Michio, and Koji Yamamoto. 2010. "Sample Design and Representativeness of Japan Household Panel Survey." Yoshio Higuchi, Tamaki Miyauchi, and C. R. McKenzie, eds. *Dynamism of Poverty*. Keio University Press: 3-27.

Naoi, Michio, Koji Yamamoto, and Tamaki Miyauchi. 2010. "Assessing the Performance of Alternative Survey Methods on Unit-Response and Item-Response in JHPS." Yoshio Higuchi, Tamaki Miyauchi, and C. R. McKenzie, eds. *Dynamism of Poverty*. Keio

University Press: 29-63.
Yamamoto, Koji, and Hiroshi Ishida. 2010. "Final Disposition Codes and Survey Outcome Rates for Japanese Life Course Panel Survey (JLPS): Measuring Cooperation of "Targeted" Respondents and Success of Collection Agents." The University of Tokyo Institute of Social Science Panel Survey Project Discussion Paper Series, No. 34.

Figures and Tables

Table 1. PC Use and Internet Access and Web Response

Home PC Use and Internet Environment	Response via Web		Total
	Yes	No	
Uses Home PC; Has Internet Access	89	2,240	2,329
Uses Home PC; No Internet Access	0	204	204
Uses Home PC; Internet Access Unknown	0	1	1
No PC Use at Home	2	1,464	1,466
Unknown PC Use at Home	0	22	22
Total	91	3,931	4,022

Source: Table 1–6 from Naoi and Yamamoto (2010: 12)

Table 2. Probit Analysis of Internet Environment and Web Response

	PC Use + Internet Access [b]			Web Response[c]		
	Coef.	S.E.	p	Coef.	S.E.	p
Sex (Reference: Male)						
Female	-0.139 *	0.055	0.011	-0.228 +	0.128	0.075
Age (Reference:19–29 years old)						
30–39	0.091	0.093	0.329	0.316 +	0.174	0.070
40–49	0.079	0.097	0.414	0.223	0.190	0.242
50–59	-0.336 **	0.095	0.000	-0.061	0.229	0.791
60+	-0.725 **	0.089	0.000	0.158	0.208	0.449
Marital Status (Reference: Single)						
Married	0.142 *	0.064	0.025	-0.473 **	0.133	0.000
Education Level (Reference: Junior High/Senior School)						
Junior College/Technical College	0.467 **	0.078	0.000	0.189	0.179	0.290
University	0.677 **	0.065	0.000	0.176	0.140	0.208
Graduate school	1.409 **	0.293	0.000	0.174	0.308	0.573
Other	0.469 **	0.108	0.000	0.190	0.218	0.385
Occupation (Reference: Unemployed)						
Agriculture, forestry, and fisheries	-0.502 **	0.185	0.007	---[d]		
Sales/Service	0.051	0.070	0.463	-0.207	0.189	0.273
Management/Professional	0.138	0.088	0.117	-0.062	0.192	0.745
Clerical/Information Processing	0.425 **	0.090	0.000	0.185	0.174	0.288
Transport/Manufacture/Security	-0.157 +	0.081	0.054	-0.120	0.212	0.572
Other	0.478 +	0.256	0.062	0.782 *	0.321	0.015
Household Income (Log)[a]	0.355 **	0.039	0.000	-0.011	0.083	0.899
Constant	-2.026 **	0.245	0.000	-1.585 **	0.540	0.003
n	3349			1993		
Log-Likelihood	-1811.818			-292.840		

Note: **: $p < 0.01$; *: $p < 0.05$; +: $p < 0.10$

[a] "Household Income (Log)" is the logarithm of (household income (Unit: 10,000 Yen) + 1). This operation was implemented because some households claimed 0 income.

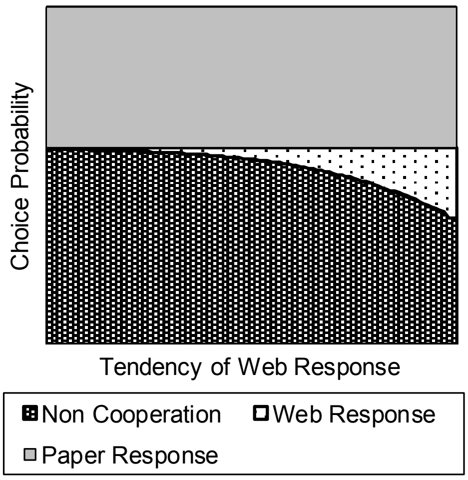
[b] Dependent variable was set to 1 when both of home PC and internet access were available and 0 otherwise. When no response was given regarding home PC use or internet access, these cases were excluded from the analysis.

[c] Dependent variable was set to 1 when the participant responded online and 0 otherwise. The subsample for this model consists of only those with home PC and internet access.

[d] When this variable is 1, the dependent variable is always 0; i.e., this variable is a perfect predictor. Consequently, this attribute is excluded from analysis. Thus, the 21 cases where this variable is 1 were excluded.

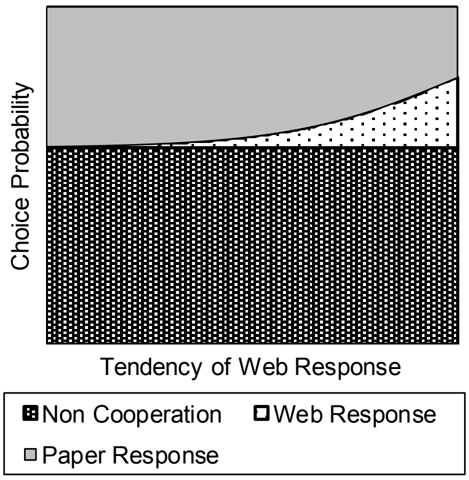
Source: JHPS2009

Figure 1. Hypothetical Substitution Pattern (a)



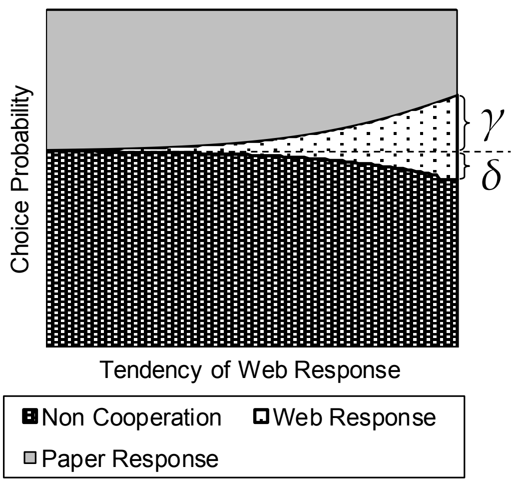
Note: Assuming "Web response" and "non-cooperation" belong to the same nest B in a nested logit model, with $V_{i,paper}$ = –0.331, $V_{i,nocoop}$ = 0, and τ_B = 0.01, the choice probability in the range where $V_{i,web}$ is [–0.05, –0.006] is shown.

Figure 2. Hypothetical Substitution Pattern (b-1)



Note: Assuming "Web response" and "paper response" belong to the same nest B in a nested logit model, with $V_{i,paper}$ = –0.331, $V_{i,nocoop}$ = 0, and τ_B = 0.01, the choice probability in the range where $V_{i,web}$ is [–0.380, –0.331] is shown.

Figure 3. Hypothetical Substitution Pattern (b-2)



Note: Assuming "Web response" and "paper response" belong to the same nest B in a nested logit model, with $V_{i,paper}$ = –0.331, $V_{i,nocoop}$ = 0, and τ_B = 0.5, the choice probability in the range where $V_{i,web}$ is [–2.6, –0.331] is shown.

Figure 4. Nest Structures of Paper Response, Web Response, and Non-Cooperation

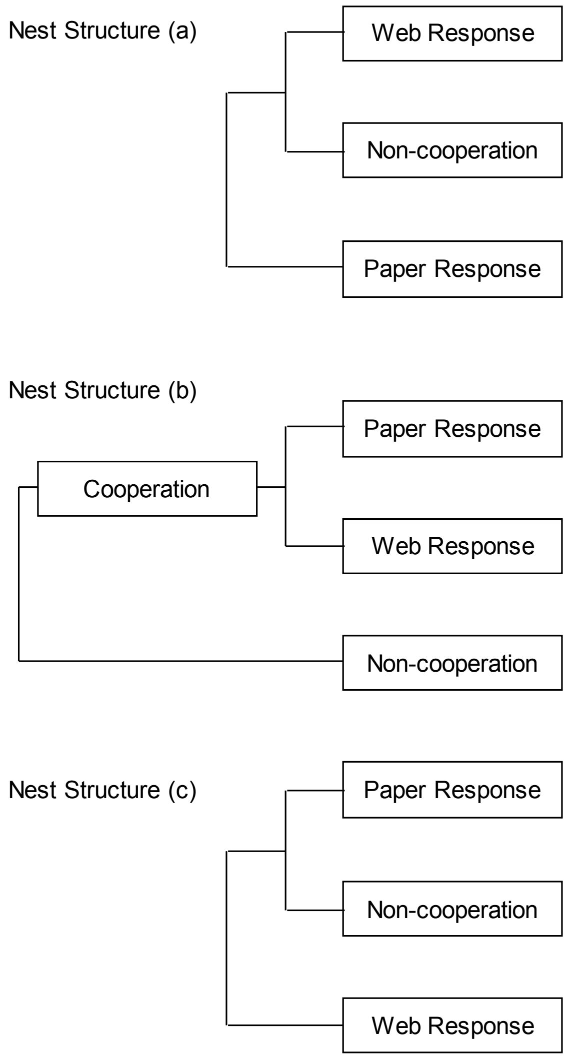


Table 3. Inclusive Value Coefficient for Each Nest Structure

	Inclusive Value Coefficient (τ) for Nest including 2 Alternatives							
	Estimate	S.E.	95% C.I.		Wald Test (H_0: τ = 0)		Wald Test (H_0: τ = 1)	
			Lower	Upper	χ^2	p-value	χ^2	p-value
Nest Structure (a)	9.523	5.776	-1.798	20.844	2.720	0.099	2.180	0.140
Nest Structure (b)	0.070	0.188	-0.298	0.439	0.140	0.709	24.470	0.000
Nest Structure (c)[a]	0.640	0.698	-0.728	2.008	0.840	0.359	0.270	0.606

Note: The Estimate of the inclusive value coefficient τ in each model corresponding to each nest structure in Figure 4 are shown. The estimations were conducted only for those cases with which contact was made during the survey period. The formulation of the model is as per Greene (2003: 725-727). The estimation algorithm is Newton–Raphson method. The explanatory variables used are the variables shown in Table 4. For this estimation, no convergence condition relating to the first-order partial derivative of the likelihood function was setup.

[a] In the vicinity of the initially estimated parameters satisfying the convergence condition, the likelihood function was not deemed to be a concave function, and hence, re-estimation was performed from the initially obained set of parameters.

Source: JHPS2009

Table 4. Results of Nested Logit Model on Choice from Non-Cooperation/Paper Response/Web Response [a]

	Base: Non-Cooperation					
	Paper Response			Web Response		
	Coef. [b]		p-value	Coef. [b]		p-value
Sex (Reference: Males)						
Female	0.028		0.498	-0.023		0.871
Age (Reference: 19–29 years old)						
30–39	0.153	*	0.034	0.150	*	0.046
40–49	0.226	**	0.003	0.204	*	0.034
50–59	0.208	**	0.005	0.139		0.480
60+	0.136	*	0.035	0.053		0.820
Housing Status (Reference: Detached and Wooden + N.A.)						
Detached and Concrete	0.203	*	0.043	0.211	+	0.050
Multiple Dwelling and Wooden	0.363	**	0.000	0.344	**	0.003
Multiple Dwelling and Concrete	0.133	*	0.029	0.158	+	0.084
Area Block (Reference: Hokkaido)						
Tohoku	-0.843	**	0.000	-0.940	**	0.005
Kanto	-0.968	**	0.000	-0.908	**	0.000
Chubu	-0.059		0.626	-0.004		0.984
Kinki	-0.429	**	0.000	-0.353		0.135
Chugoku	-0.757	**	0.000	-0.729	**	0.001
Shikoku	-0.717	**	0.001	-0.760	**	0.003
Kyushu	-0.057		0.645	-0.040		0.782
Scale of City/Town/Village (Reference: Large City)						
Other City	-0.009		0.854	0.019		0.837
Town/Village	0.086		0.292	0.141		0.402
Survey Method (Reference: Retention only)						
Interview also Conducted	-0.031		0.462	-0.024		0.616
Initial Target/Back-up Target (Reference: Back-up Target)						
Initial Target	-0.143	*	0.029	-0.145	*	0.038
Initial-Target Premium (Reference: No Premium)						
Premium for Initial Target Exists	0.521	**	0.000	0.490	**	0.003
Interactions between "Initial Target" and "Initial Target Premium"						
Initial Target × Initial Target Premium	0.210	*	0.019	0.293		0.218
Alternative-Specific Constant	-0.238	+	0.066	-0.526		0.506
Inclusive Value Coefficient for "Cooperation" Nest [c]	0.070					
Inclusive Value Coefficient for "Non-Cooperation" Nest [d]	1.000					
n	9621					
Log-Likelihood	-6873.731					

Note: **: $p < 0.01$; *: $p < 0.05$; +: $p < 0.10$

[a] Estimates of the model with nest structure (b) from Figure 4 are shown. The dataset used contain only the cases to which contact was made during the survey period. The model formulation is as per Greene (2003: 725-727). The estimation algorithm is Newton–Raphson method. For this estimation, no convergence condition relating to the first-order partial derivative of the likelihood function was setup.

[b] Coefficients shown are not the parameters in Greene's formulation itself, but they are the values of the parameters from Greene's formulation multiplied by the inclusive value coefficient. These values can be interpreted consistently with RUM and are equivalent to β and α in formulae in the present paper. The standard errors for these modified coefficients were estimated using the delta method, and p-values shown were also based on them.

[c] For the standard error and result of Wald test on this parameter, see Table 3.

[d] The inclusive value coefficient for the "non-cooperation" nest was constrained to 1 in estimation.

Source: JHPS2009

Table 5. Estimate of the Effect of Adding Web-Mode based on a Nested Logit Model

	Actual Selectors		With Web Mode	Without Web Mode	
	n	(%)	Expected Number of Selectors	Expected Number of Selectors	Difference
Cooperation					
Paper Response	3,931	(40.86)	3,930.3	4,018.4	88.1
Web Reponse	91	(0.95)	91.9	—	—
Non-cooperation	5,599	(58.20)	5,598.8	5,602.6	3.8
Total	9,621	(100.00)	9,621.0	9,621.0	91.9

Note: Shown are: the expected number of selectors (sum of estimated probabilities to select the alternative for all cases in the dataset) when there exists Web mode, the expected number of selectors when there is no Web mode, and the differences between them, all calculated based on the estimates of the nested logit model in Table 4.
Source: JHPS2009

Table 6. Error Evaluation for Effect of Web-Mode Addition

Benchmark for the Effect of Web-Mode Addition	Estimate	S.E.	95% C.I.	
			Lower	Upper
Increase in Number of Respondents (Cooperators)	3.816	10.233	-16.242	23.873
Increase in Cooperation Rate (% points)	0.0397	0.1064	-0.1688	0.2481
Increase in Response Rate (% points)	0.0304	0.0815	-0.1294	0.1902

Note: Effect of Web-mode addition is shown for each index, based on the estimate of the nested logit model in Table 4, and their errors are assessed. The errors are assessed by the delta method. The cooperation rate is defined as the ratio of the number cooperating in the survey to the number contacted in the survey. The response rate is defined as the ratio of the number cooperating in the survey to the number targeted by the survey. For JHPS2009, the number contacted in the survey is 9,621 and the number targeted is 12,549.

Source: JHPS2009