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Estimation of The Environmental Value of Recycled Wood Wastes: A
Conjoint Analysis Study

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ABSTRACT

The purpose of this paper is to estimate the environmental value of recycled wood wastes using conjoint analysis. A comparison of the pair-wise rating method and the choice experiment elicitation method is made. An empirical study of recycled water-cleaning filters made from wood wastes shows that recycling has significant value as estimated by both pair-wise rating and choice experiments. However, the estimated marginal willingness to pay for recycling differs somewhat between the two methods. It may be that profile design effects appear in our survey.

Keywords

conjoint analysis, recycling, wood wastes, environmental valuation

1. INTRODUCTION

In Japan, many people are interested in recycling. Public opinion polls show that 74% of respondents think that increasing consumption of resources is one factor contributing to global environmental problems, and 45% of respondents are trying to use recycled goods to conserve the environment (The Prime Minister's Office, 1995).

The purpose of this paper is to estimate the environmental value of recycled wood wastes using conjoint analysis. Conjoint analysis is one of many multi-attribute preference-elicitation techniques widely used in market research. Environmental economists have recently begun to employ conjoint analysis.

In section 2, the theoretical background of conjoint analysis is discussed. Conjoint analysis has many elicitation formats including pair-wise rating and choice experiments. Section 3 presents the economic model of the demand for recycled goods and methods of valuation. Section 4 presents the empirical results of the study of recycled water cleaner filters estimated by pair-wise rating and choice experiments. Finally, section 5 provides the conclusion.

2. CONJOINT ANALYSIS

Recycled goods have many attributes. For example, the attributes of paper products include its color, thickness, weight, price, materials, and so on. The environmental value of recycled paper is also one of the attributes of paper products. Though the market price of paper reflects the values of all its attributes, it is difficult to quantify the environmental value from the price of paper.

Table 1 shows an overview of stated preference elicitation methods. In the field of environmental economics, contingent valuation (CV) has traditionally been used to estimate the value of environmental resources (Carson et al., 1995). CV asks respondents' willingness to pay or willingness to accept compensation for the environmental change in question. CV evaluates both the use value and the non-use value (passive use value) of single-attribute environmental goods. However, the value of each attribute cannot be distinguished using CV in a multi-attribute environmental good. Therefore some economists have recently begun to pay attention to conjoint analysis as a new valuation technique that can identify the value of each attribute that makes up the multi-attribute environmental good.

TABLE 1. Stated Preference Approach and Conjoint Analysis

Conjoint analysis is a multi-attribute preference-elicitation technique widely used in marketing research, transportation, and psychometrics (Green and Srinivasan, 1978, 1990; Louviere, 1988 and 1994; Wittink and Cattin, 1989; Wittink, Vriens, and Burhenne, 1994; Green, Krieger and Schaffer, 1993; Carroll and Green, 1995). Conjoint analysis uses profiles which are bundles of attributes. For example, when evaluating preference for paper, respondents are given several profile cards, each of which shows a unique paper product composed of specific attributes, such as color, thickness, weight, price, materials, and so on. A rating-based conjoint asks respondents for their preference of profiles on a rating scale, whereas a choice experiment (sometimes called a choice-based-conjoint) asks respondents to choose their most preferred profile.

Previous conjoint analysis studies for environmental valuation include Viscusi et al. (1991, health risk; pair-comparison), Mackenzi (1993, hunting; pair-wise RBC), Opranch et al. (1993, hazardous waste; pair-wise RBC), Adamowicz et al. (1994, recreation; CE), Johnson and Desvousges (1997, electronic site; pair-wise RBC), Griner and Faber (1996a, b, water resource; pair-wise RBC), Boxall et al. (1996, hunting; CE), Roe et al. (1996, salmon-fishing; RBC), Adamowicz et al. (1997, hunting; CE), Kuriyama (1998, wetland ecosystem; CE) and Adamowicz et al. (1995; 1998, habitat protection; CE).

3. ECONOMIC MODEL

3.1 Rating-Based Conjoint (Pair-wise Rating)

Rating-based conjoint analysis asks respondents to indicate their preferences for profiles using a rating scale. Pair-wise rating, which shows a trade-off of two profile cards, is the most popular elicitation method among environmental economists. Pair-wise rating asks respondents which profile they prefer on a rating scale. For example, the rating scale may be from 1 to 9, where 1 means the respondent strongly prefers the left profile, 9 means they strongly prefer the right profile, and 5 means they are indifferent between the two profiles. Figure 1 shows an example of a pair-wise rating questionnaire.

FIGURE 1. EXAMPLE OF A PAIR-WISE RATING QUESTIONNAIRE

Johnson and Desvousges (1997) propose an ordered probit model to analyze pair-wise rating data¹. Assume that the individual indirect utility function is represented by the following

¹ ACA, which is a typical program used in marketing research, uses OLS to estimate part-worth from pair-wise rating data. However, Roe et al. (1996) show that OLS dummy regression estimates of part-worth are not appropriate for calculating willingness to pay.

random utility model:

$$U_j = V_j(\mathbf{x}_j, q_j, p_j) + \varepsilon_j \quad (1)$$

where U_j is the total utility that the individual receives from profile j , \mathbf{x}_j is the vector of attributes of profile j , q_j is the environmental quality of the profile j , p_j is the price of profile j , V_j is the observable component of the total utility, and ε_j is the unobservable component. When asked, the pair-wise format is the trade-off between profile j and k , and the utility difference between the two profiles is

$$\begin{aligned} dU_{jk} &= U_j - U_k \\ &= V_j - V_k + \varepsilon_{jk} \end{aligned} \quad (2)$$

where $\varepsilon_{jk} = \varepsilon_j - \varepsilon_k$ is the difference in the unobservable components. When the indirect utility function is a linear function of attributes, the utility difference is

$$dU_{jk} = \beta(\mathbf{x}_j - \mathbf{x}_k) + \beta_q(q_j - q_k) + \beta_p(p_j - p_k) + \varepsilon_{jk} \quad (3)$$

where β is a vector of attribute parameters, β_q is the marginal utility of environmental quality, and β_p is the marginal utility of money.

Though we cannot observe the utility (U_{ik}) or utility difference (dU_{jk}) directly, we have discrete rating data related to the utility difference. Johnson and Desvousges (1997) use an ordered probit model which assumes the error term, ε_{jk} , in equation (3) is distributed as a standard normal distribution, $N(0,1)$. Figure 2 describes the ordered probit model. When the discrete rating category is between 1 and 9, there are 8 threshold parameters². Then the probability of observing response r_{jk} for the trade-off between profile j and k is

$$\Pr[r_{jk} = s] = \Phi(\alpha_s - dV_{jk}) - \Phi(\alpha_{s-1} - dV_{jk}) \quad s=1,2,\dots,9 \quad (4)$$

where Φ is the cumulative standard normal distribution function, α_s are threshold parameters. α_0 is normalized at $-\infty$ and α_9 at $+\infty$.

FIGURE 2. Ordered Probit

² Jonson and Desvousges recoded the original 9 category ratings into 5 categories.

3.2 Choice Experiment (Choice-Based Conjoint)

A choice experiment (choice-based-conjoint), developed by Louviere and Woodwarth (1983), asks respondents to choose their most preferred profile. Figure 3 shows an example of a choice experiment questionnaire.

FIGURE 3. EXAMPLE OF A CHOICE EXPERIMENT QUESTIONNAIRE

Assume that the utility function is the random utility model (1). Then the probability, $P(j;C)$, that the alternative, j , is chosen from choice set $C (=1,2,\dots,m)$ is

$$\begin{aligned}
 P_j &= \Pr(U_j > U_k, \forall k \in C) \\
 &= \Pr(V_j - V_k > \varepsilon_k - \varepsilon_j, \forall k \in C) \\
 &= \int_{-\infty}^{V_j - V_1} \int_{-\infty}^{V_j - V_2} \dots \int_{-\infty}^{V_j - V_m} f(\tilde{\varepsilon}_1, \tilde{\varepsilon}_2, \dots, \tilde{\varepsilon}_m, \Omega) d\tilde{\varepsilon}_m d\tilde{\varepsilon}_{m-1} \dots d\tilde{\varepsilon}_1
 \end{aligned} \tag{5}$$

where $\tilde{\varepsilon}_k = \varepsilon_k - \varepsilon_j$ is the error difference, Ω is the covariance matrix, and $f(\bullet)$ is the joint density of the error differences.

McFadden (1974) showed that if the error terms in equation (5) are independently and identically distributed with a type I extreme-value distribution (a Gumbel distribution), then the choice probability, P_j , has the following closed-form representation,

$$P_j = \frac{e^{\lambda V_j}}{\sum_k e^{\lambda V_k}} \tag{6}$$

where λ is the scale parameter, conventionally normalized to 1. McFadden's model is known as the conditional logit model.

3.3 Estimation of Marginal Willingness to Pay

Consider the following utility function, which contains only main effects:

$$V(\mathbf{x}, q, p) = \sum_i \beta_i x_i + \beta_q q + \beta_p p \tag{7}$$

where β is the set of parameters estimated by the ordered probit model for pair-wise rating and by the conditional logit model for the choice experiment. The total differential of the utility function, V , is as follows:

$$\sum_i \frac{\partial V}{\partial x_i} dx_i + \frac{\partial V}{\partial q} dq + \frac{\partial V}{\partial p} dp = dV \quad (8)$$

Assume that all attributes except for environmental quality are unchanged ($dx_i=0$) and utility is assumed to be held constant ($dV=0$). Then, the marginal willingness to pay (MWTP), which is the monetary measure for 1 unit change in environmental quality, is as follows:

$$MWTP = \left. \frac{dp}{dq} \right|_{dx_i=0, dV=0} = - \frac{\partial V}{\partial q} / \frac{\partial V}{\partial p} = - \frac{\beta_q}{\beta_p} \quad (9)$$

4. EMPIRICAL STUDY

4.1 Survey Design of Recycled Water Cleaners

This empirical study estimates the value of recycled water cleaners using pair-wise rating and choice experiments. Water cleaners have many attributes, including their cleaning performance, replacement time, materials, size, color, and price. Existing water-cleaning filters use propylene or polyethylene, which are made from petroleum resources. These filters become waste after being replaced. Another type of water-cleaning filter is being developed, known as a “recycled filter”, which is made from construction industry wood wastes and logs from thinning. This recycled filter can subsequently be dissolved by bacteria.

Table 2. Attributes List

Table 2 shows the attributes considered in our survey. Cleaning performance, replacement time, and price are data from existing water-cleaning filters. The associated questionnaire is composed of four parts: (1) an explanation of the difference between normal water-cleaning filters and recycled filters, (2) a question concerning the importance of the attributes, (3) 10 pair-wise rating questions, and (4) 10 choice experiment questions. We used both pair-wise rating and choice experiments. Figure 4 and 5, respectively, show an example of pair-wise rating and choice experiments in the questionnaire for water-cleaning filters.

Figure 4. Pair-wise Rating Question for Water-cleaning Filters

Figure 5 Choice Experiment Question for Water-cleaning Filters

After two pilot surveys using a small sample, we made a final survey of the general public in Sapporo, Japan on October 1997. The survey was conducted as an in-person interview. A sample of people randomly selected from the telephone directory was interviewed. 200 agreed to participate in this survey, and 163 respondents answered the elicited questions. The average interview time was 15 minutes.

After an explanation of the attributes, respondents were asked to rate the importance of each attribute on a 1-9 gray-scale rating, namely, where 1 was extremely important and 9 was not important at all. Table 3 shows the ratio of respondents who chose 1 or 2. While the most important attribute of water-cleaning filters is their ability to clean trihalomethane, recycling isn't important in comparison with other attributes.

Table 3. Importance of Each Attribute

4.2 Estimation Results

Table 4 shows the pair-wise rating results estimated by the ordered probit model. Parameters γ_1 to γ_8 are constant thresholds of discrete choice. All variables except for 'smells of mold' are statistically significant at the 1% level. McFadden's pseudo R^2 is 0.150. Table 5 shows the choice experiment results estimated by the conditional logit model. All variables except for 'smells of chlorine' are statistically significant at the 1% level. McFadden's pseudo R^2 is 0.220, which means the fit of the conditional logit model for the choice experiment data is better than the fit of the ordered probit model for the pair-wise rating data.

Table 4. The Results of the Ordered Probit Model

Table 5. The Results of the Conditional Logit Model

Table 6. Marginal Willingness to Pay

Table 6 shows the marginal willingness to pay (MWTP) for each attribute calculated by (9). $MWTP_{PW}$ is the marginal willingness to pay from pair-wise rating data, and $MWTP_{CE}$ is the marginal willingness to pay from choice experiment data. The 95% confidence intervals of MWTPs are calculated by Krinsky and Robb (1986) in a procedure that utilizes 4,000 repeated random draws of the coefficient vectors from the covariance matrix. Removing trihalomethane has the highest value in both pair-wise rating and choice experiments, but for removing trihalomethane the $MWTP_{PW}$ is two times higher than the $MWTP_{CE}$. The value of recycling as estimated by pair-wise rating ($MWTP_{PW}$) is 5,244 yen, and by choice experiments ($MWTP_{CE}$) is 997 yen.

From the data on respondents' stated importance of the attributes in Table 3, the

importance ratio of trihalomethane is highest and the importance of recycling is lowest. The $MWTP_{PW}$ and the $MWTP_{CE}$ of trihalomethane are consistent with stated importance. However, the $MWTP_{PW}$ of recycled filters, which has the second highest value (5,244 yen), is not consistent, so it may be overestimated.

Elrod, Louviere, and Davey (1992) and Oliphant et al. (1992) compared results of rating based conjoint and choice experiments and they showed that both led to estimated results that were comparatively similar in value. Our results, however, show that there is a significant difference between pair-wise rating and choice experiments, and the value of recycling estimated by pair-wise rating may be overestimated. One reason for the difference between the two elicitation methods has to do with sequential effects. Some CV studies have shown that the order of questions affects how respondents evaluate willingness to pay, known as a sequential effect (Boyle et al., 1993). In our survey, respondents were asked questions related to choice experiments after pair-wise rating, and this order of questions may be the cause of the differences in the results obtained from the two techniques.

Another reason for the difference between the two techniques may result from the effects of the profile design. Conjoint analysis uses multi-attributed profiles, and profile design may affect the estimated willingness to pay for attributes. There are large numbers of total possible combinations of attributes, so many researchers have proposed efficient profile designs that reduce this number without affecting estimation (for example, Huber and Zwerina, 1996). Table 7 shows the effects of profile design in our survey. Our survey used 10 profiles for each of the pair-wise rating and choice experiments respectively. FULL means the estimated WTP using all 10 profiles, and #1 means using 9 profiles removing profile #1. When removing #4, #5, or #7 profiles of pair-wise rating, the estimated parameters were not significant. The standard deviation of WTPs in pair-wise rating is larger than in choice experiments. This means that the effects of profile design on pair-wise rating are stronger than on choice experiments in our study.

Table 7 Profile Design Effects

5. DISCUSSION

Our results show that recycling goods has significant value, as estimated by both pair-wise rating and by choice experiments. However, the estimated marginal willingness to pay for recycling differs somewhat between pair-wise rating and choice experiments. In our study, the value of recycling as estimated by pair-wise rating is not consistent with the stated importance of recycling, and it might be overestimated. It may be, however, that a sequential effect and a

profile design effect appeared in our survey.

Conjoint analysis can estimate the value of multi-attribute goods, so conjoint analysis is suitable for evaluating recycled goods that have many attributes. However, conjoint analysis, like contingent valuation, uses stated preference data. Thus, the problems of bias that are already recognized in contingent valuation may also appear in estimates of values using conjoint analysis. Furthermore, profile design may affect the estimated willingness to pay. A future study will check the effects of biases and test the reliability of the willingness to pay as estimated by conjoint analysis.

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Table 1. Stated Preference Approach and Conjoint Analysis

stated preference approach	
contingent valuation (CV) single-attribute preference-elicitation	Asks respondents their willingness to pay or willingness to accept compensation
conjoint analysis (CA) multi-attribute preference-elicitation	
rating-based conjoint (RBC)	Asks respondents their preference on a rating scale (say, 1-9)
choice experiment (CE) or choice-based-conjoint (CBC)	Asks respondents for their most preferred alternative
contingent ranking (CR)	Asks respondents to rank alternatives in order of preference

Table 2. Attributes List

Attributes	Level
cleaning performance	smells of mold smells of chlorine reddish brown trihalomethane
replacement time	3 months 6 months 24 months
filter type	normal filter recycled filter
price	2000-6500 yen

Table 3. Importance of Each Attribute

smells of mold	68%
smells of chlorine	70%
reddish brown	74%
trihalomethane	80%
replacement time	64%
recycle	57%
price of filter	75%

NOTE: The ratio of respondents who chose 1 or 2 from the 1-9 gray scale.

Table 4. The Results of the Ordered Probit Model

Variable	Coefficient	t stat.	p value
α_1	-1.301	-22.30	0.000
α_2	-0.951	-16.76	0.000
α_3	-0.664	-11.89	0.000
α_4	-0.512	-9.14	0.000
α_5	0.228	4.14	0.000
α_6	0.459	8.22	0.000
α_7	0.804	14.30	0.000
α_8	1.101	19.44	0.000
smells of mold	0.062	0.38	0.702
smells of chlorine	0.574	5.68	0.000
reddish brown	0.406	3.33	0.001
trihalomethane	1.007	15.78	0.000
3 months	0.341	6.48	0.000
6 months	-1.080	-9.62	0.000
recycle filter	0.764	6.37	0.000
price	-0.0001457	-5.64	0.000
n	1625		
Log likelihood	-3035.492		
Pseudo R2	0.150		

Table 5. The Results of the Conditional Logit Model

Variable	Coefficient	t stat.	p value
smells of mold	1.318	5.435	0.000
smells of chlorine	-0.412	-1.723	0.085
reddish brown	0.450	5.44	0.000
trihalomethane	2.312	20.66	0.000
6 months	0.886	6.666	0.000
24 months	1.548	8.498	0.000
recycle filter	0.750	6.843	0.000
price	-0.0007524	-14.017	0.000
n	1,559		
Log likelihood	-1685.20		
Pseudo R2	0.220		

Table 6. Marginal Willingness to Pay

	MWTP _{PW} (Pair-wise conjoint)	MWTP _{CE} (Choice experiment)
smells of mold	426 [-2,070 - 2,494]	1,752 [1,161 - 2,321]
smells of chlorine	3,940 [2,171 - 6,938]	-548 [-1,172 - 84]
reddish brown	2,787 [1,316 - 4,339]	599 [396 - 798]
trihalomethane	6,916 [5,366 - 9,993]	3,073 [2,783 - 3,424]
3 months	2,339 [1,750 - 3,216]	
6 months	-7,413 [-11,019 - -5,377]	1,177 [866 - 1,482]
24 months		2,058 [1,636 - 2,510]
recycle filter	5,244 [3,972 - 7,013]	997 [758 - 1,242]

The numbers in the brackets are 95% confidential intervals which are obtained by the method of Krinsky and Robb (1986), and based on 4000 random draws.

Table 7 Profile Design Effects

Pair-wise Rating

	Removing Profile											
	FULL ¹	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Std. Dev. ³
smells of mold	426	52	4,041	1,029			436		-24	411	-757	1,553
smells of chlorine	3,940	4,475	1,515	4,200			3,177		4,818	-316	3,297	1,837
reddish brown	2,787	3,016	1,663	2,180			1,625		2,942	5,190	2,834	1,213
trihalomethane	6,916	7,441	5,325	7,189	Not Sig ²	Not Sig	4,233	Not Sig	7,832	4,298	5,500	1,504
3 moths	2,339	2,411	1,063	2,355			2,774		2,577	2,785	1,854	615
6 months	-7,413	-7,765	-5,022	-7,501			-4,145		-8,804	-4,219	-7,148	1,878
recycle filter	5,244	5,367	2,622	5,280			5,265		5,665	5,291	5,248	1,042

Choice Experiment

	Removing Profile											
	FULL	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	Std. Dev.
smells of mold	1,751	1,733	1,518	1,944	1,836	1,815	1,916	240	1,718	1,583	1,762	498
smells of chlorine	-548	-473	-503	-744	-578	-545	-568	894	-321	-902	-539	490
reddish brown	599	641	884	159	518	510	677	1,127	495	593	609	254
trihalomethane	3,073	3,054	3,606	3,026	3,056	2,989	2,754	2,629	3,403	3,174	3,054	281
6 months	1,177	1,108	929	1,343	1,286	1,226	1,330	665	861	1,372	1,178	238
24 months	2,058	1,978	1,773	2,324	2,173	2,033	1,804	1,767	1,841	2,375	2,224	233
recycle filter	997	917	989	1,038	885	1,109	638	1,490	1,281	1,083	1,031	229

Note: 1 this WTP estimated by using all profiles
 2 this means estimated parameters are not significant
 3 standard deviation

Figure 1. Example of Pair-wise Rating Questionnaire

Which would you prefer? Choose a number to show your preference

	Profile A	Profile B
Attributes	x_A	x_B
Environmental Quality	q_A	q_B
Price	p_A	p_B
	STRONGLY PREFER LEFT	STRONGLY PREFER RIGHT
	1 2 3 4 5 6 7 8 9	

Figure 2. Example of a Choice Experiment Questionnaire

Which would you prefer? Choose only one alternative.

No	1	2	3	4
Attributes	x_1	x_2	x_3	NONE I wouldn't accept any of them
environmental quality	q_1	q_2	q_3	
price	p_1	p_2	p_3	

Figure 3. Pair-wise Rating Question for Water-cleaning Filters

Which would you prefer? Choose one number.

	filter A smells of mold smells of chlorine reddish brown normal filter 3,000 yen	filter B smells of mold trihalomethane recycled filter 4,000 yen							
cleaning performance filter type price of filter									
	Strongly Prefer Left	indifferent	Strongly Prefer Right						
	1	2	3	4	5	6	7	8	9

Figure 4. Choice Experiment Question for Water-cleaning Filters

Which water-cleaning filter would you prefer? Choose only one number.

No	1	2	3	4
cleaning performance	smells of mold smells of chlorine reddish brown	smells of mold smells of chlorine reddish brown trihalomethane	smells of mold smells of chlorine	NONE I wouldn't accept any of them
filter type	normal filter	recycled filter	recycled filter	
replacement time	3 months	6 months	24 months	
price of filter	3,000 yen	5,000 yen	6,000 yen	

