Using choice experiment to value the external benefits of developing organic waste-to-energy technologies in Korea

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Ⅰ. Introduction

On 30 June 2015, South Korea submitted its INDC (Intended Nationally Determined Contributions) to the UNFCCC. Korea plans to reduce its greenhouse gas (GHG) emissions by 37% from the business-as-usual level by 2030 across all economic sectors. Policy-makers are currently addressing the potential effectiveness of regulations and other measures for reducing GHG emissions to avoid future climate change impacts and achieve the 2030 mitigation target. One such measure is to utilize organic waste-to-energy (OWtE) technologies. It is a one way for reducing its GHG emissions to using organic waste for conversion to energy. By adopting this approach, it is developing its organic waste technologies, and contributing to the climate change goals pursued by the Korean government. Therefore, the government discusses future plans to recycle and generate energy from organic waste by means of anaerobic digestion.

The purpose of this study is, therefore, to measure the external benefits from developing organic waste-to-energy technologies using the specific case study of Korea. To this end, the study applies a choice experiment (CE) with three attributes or types of benefits, such as improvements in energy security, the extension of landfill life expectancy, and job creation. This study is expected to be used in creating future OWtE policies and making a decision about our energy mix in Korea. The remainder of this paper is organized as follows: Section Ⅱ describes its methodological issues and statistical models to derive the willingness to pay (WTP). Section Ⅲ discusses the results. Concluding remarks are made in the final section.

Ⅱ. Methodology and model

1. CE approach

The CE approach can offer a promising opportunity to measure the various economic external benefits of OWtE technologies and has its theoretical underpinnings in the random utility model, which is consistent with economic theory. CE has been employed increasingly in the field of environmental economics to analyze user preferences for environmental resources and to estimate the value of non-market goods and services. We identified the three attributes of OWtE impacts, such as energy security, landfill life expectancy, and job creation.

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Table 1 shows these attributes, including the price attribute, and how each level of attributes was defined. To identify the important attributes of the effects of OWtE, we selected a preliminary set of attributes derived from extensive literature reviews.

<Table 1> Attributes and levels of the OWtE impacts

Attributes	Descriptions	Levels
Energy security	The percentage of increase in annual ratio of domestic energy to total energy consumption	Level 1: current level Level 2: 1%p Level 3: 3%p Level 4: 4%p
Landfill life expectancy	Extension of landfill life expectancy	Level 1: current level Level 2: doubled Level 3: quadrupled Level 4: septupled
Job creation	Increase in annual new persons per 350 of earning job from expanding OWtE facilities	Level 1: current level Level 2: 35 Level 3: 87 Level 4: 175
Price	Willingness to pay for expanding OWtE facilities through an increase in the yearly income tax (unit: Korean won)	Level 1: current level Level 2: 1,000 Level 3: 3,000 Level 4: 6,000 Level 5: 10,000

CE involves the use of statistical design theory to construct choice sets that yield coefficient estimates that are not confounded by other factors. In this study, we employed the ‘orthogonal main effects design’ which is effective in terms of isolating the effects of individual attributes on the choice.

In the CE questions, there were three alternatives two of which represented the OWtE featuring combinations of attribute levels and specific price levels. The third alternative represented the status quo. There were $4^2 \times 4^2 \times 4^2 \times 5^2$ possible combinations of attributes and levels to form the choice sets. Since it was impractical to ask respondents to choose from all combinations, we drew a subset of all choice sets to estimate coefficients and drew eight choice sets.

The final survey questionnaire consists of three parts. The first part aimed to familiarize respondents with the attributes of the OWtE being evaluated and to elicit information about their past experiences of these attributes. To enhance respondents’ understanding, a color photograph of a process of OWtE and policy expectations was inserted into this section. The second part contained CE analysis questions that were designed to elicit respondents’ WTP for expanding OWtE facilities by estimating trade-offs between price and other attributes. The final part elicited socioeconomic information concerning the respondents, such as income, age, and education.

2. Multi-nomial logit and nested logit models

The multi-nomial logit (MNL) model, widely used in dealing with the data from a CE survey, assumes the condition of independence from the irrelevant alternatives (IIA). However, the MNL model is mis-specified when the IIA assumption does not hold. In this case, a nested logit (NL) model can be employed as an alternative to the MNL model. Therefore, we will take three steps: i) estimating the MNL model; ii) testing for the IIA assumption; and iii) inferring necessary information from the NL model rather than the MNL model if the IIA assumption is not satisfied.

When respondent i chooses alternative j in the choice set, we can specify the utility function, V_{ij}, as a linear function of the attributes, Z_{ij}. Assuming a vector of attributes, $(Z_{1,} Z_{2,} Z_{3,} Z_{4})$ = (Energy security, Landfill life expectancy, Job creation, and Price) and letting β's be the parameters to be estimated for each attribute that affects the utility, we obtain:

$$V_{ij}= ASC_i + \beta_1 Z_{1,ij} + \beta_2 Z_{2,ij} + \beta_3 Z_{3,ij} + \beta_4 Z_{4,ij}. \quad (1)$$

The marginal WTP (MWTP) is defined as WTP for one unit of increase in the status quo level of each attribute when all the other variables are not changed. Totally differentiating Eq. (1), using Roy's identity, and deleting i for simplicity, the MWTP for each attribute can be derived as:

$$\begin{aligned} MWTP_{Z_1} &= -(\partial V / \partial Z_1)/(\partial V / \partial Z_4) = -\beta_1 / \beta_4 \\ MWTP_{Z_2} &= -(\partial V / \partial Z_2)/(\partial V / \partial Z_4) = -\beta_2 / \beta_4 \\ MWTP_{Z_3} &= -(\partial V / \partial Z_3)/(\partial V / \partial Z_4) = -\beta_3 / \beta_4. \end{aligned} \quad (2)$$

1) Utility function and MWTP from the model with covariates

In order to explain preference heterogeneity and WTP variations among individuals, it is useful to use alternative model specifications where some individual-specific variables (socioeconomic, attitudinal, and past experience) are taken into account. Gordon et al. presented the idea of making the individual-specific variables interact with ASC terms in the utility function. We chose to interact the four individual-specific variables with ASC. This can be formulated using the following utility function:

$$\begin{aligned} V_{ij} = ASC_i &+ \beta_1 Z_{1,ij} + \beta_2 Z_{2,ij} + \beta_3 Z_{3,ij} + \beta_4 Z_{4,ij} + \beta_5 ASC_i \cdot Income_i \\ &+ \beta_6 ASC_i \cdot Age_i + \beta_7 ASC_i \cdot Education_i + \beta_8 ASC_i \cdot Gender_i. \end{aligned} \quad (9)$$

Ⅲ. Results and discussions

1. Estimation results of the models

A total of 1,300 person-to-person interviews were conducted in July, 2015. For this study, 1,000 were valid for further examination, resulting in a total of 4,000 (1,000×4) observations. The estimation results of both MNL and NL models are contained in Table 2. The coefficients for 'Energy security', 'Landfill life expectancy', and 'Job creation,' are all positive, which is consistent with our prior expectations. In addition, they are statistically significant at the 5% level. This indicates that the level of these attributes has a strongly positive relation to the utility. In contrast, the coefficient for the Price attribute is estimated to be negative. This implies that the price negatively contributes to the respondent's utility.

To test the IIA property holds, a likelihood ratio (LR) test and *t*-test were carried out. The former test statistic follows asymptotically a chi-square distribution with one degree of freedom under the null hypothesis. The later test statistic follows asymptotically student-t distribution with one degree of freedom under the null hypothesis that is zero. The LR- and *t*- statistic are 49.59 and -8.59, respectively. Both test statistics exceed the critical values at the 1% level. Thus, the null hypothesis can be rejected in two tests. This means that the NL model outperforms the MNL model in our data.

<Table 2> Estimation results of the model without covariates

Variables[a]	Multi-nomial logit coefficient estimates[c]		Nested logit coefficient estimates[c]	
ASC[b]	-0.6184**	(-8.11)	-0.6083**	(-10.06)
Energy security	0.0552**	(3.35)	0.0363**	(3.49)
Landfill life expectancy	0.0537**	(4.28)	0.0226*	(2.29)
Job creation	0.0004	(0.33)	0.0023**	(2.88)
Price	-0.2429**	(-26.21)	-0.1529**	(-10.15)
α			0.5193**	(9.25)
Number of observations	4,000		4,000	
Log-likelihood	-3,911.49		-3,886.69	
Wald statistic[d] (p-value)	733.46**	(0.000)	309.10**	(0.000)

Notes: [a]The variables are defined in Table 1.

[b]ASC refers to alternative-specific constant, which represents a dummy for the respondent choosing the status quo.

[c]* and ** indicate statistical significance at the 5% and 1% levels, respectively, and *t*-values are reported in parentheses beside the estimates.

[d]The null hypothesis is that all the parameters are zero and the corresponding *p*-values are reported in parentheses beside the statistics.

1) Estimation results of the model with covariates

One can estimate the model with covariates, such as socioeconomic variables. The definitions and sample statistics of the covariates used in this study are presented in Table 3. The mean monthly household income of the sample in this study was KRW 4.84 million (USD 4,132). The mean age of the sample was 46.48 years and the mean level of education in years was 13.79. The mean of gender was 0.49, which means 49% of the sample was male. The estimation results of the model with covariates are shown in Table 4. All the estimated coefficients for the covariates are statistically significant at the 5% level.

<Table 3> Definitions and sample statistics of variables in the model

Variables	Definitions	Mean	Standard deviation
Income	The household's monthly income (million Korean won)	4.84	3.07
Age	The respondent's age	46.48	10.36
Education	The respondent's education level in years	13.79	2.34
Gender	The respondent's gender (0=female; 1=male)	0.49	0.50

<Table 4> Estimation results of the nested logit model with covariates

Variables	Coefficient estimates[b]	
ASC[a]	−0.9136**	(−4.98)
Energy security	0.0360**	(3.65)
Landfill life expectancy	0.0217*	(2.33)
Job creation	0.002**	(2.91)
Price	−0.1536**	(−24.54)
Income	−0.0382**	(−3.29)
Age	−0.0133**	(3.96)
Education	−0.1736**	(−2.40)
Gender	−0.1444*	(−2.15)
Number of observations	4,000	
Log-likelihood	−3,862.23	

Notes: [a]ASC refers to alternative-specific constant, which represents a dummy for the respondent choosing the status quo.
[b]* and ** indicate statistical significance at the 5% and 1% levels, respectively, and t-values are reported in parentheses beside the estimates.

2. MWTP estimates of each attribute

The estimation results of the MWTP are contained in Table 5. In the model, the MWTP for Energy security is calculated to be KRW 237 (USD 0.2) per household. Next, the residents' MWTP for Landfill life expectancy is KRW 148 (USD 0.13) per household. The MWTP for Job creation and is KRW 15 (USD 0.01). The MWTPs for all the three attributes (Energy security, Landfill life expectancy, and Job creation) are statistically significant at the 5% level. Furthermore, we use the Monte Carlo simulation technique suggested by Krinsky and Robb to obtain the 95% confidence intervals for the MWTP estimate for each attribute, which are presented in Table 5. They allow for uncertainty involved in computing the point estimate.

<Table 5> Marginal willingness to pay (MWTP) estimates and their confidence intervals

Attributes	MWTP per month per household		
	Estimates	*t*-values	95% confidence intervals
Energy security (unit: 1%p)	KRW 237** (USD 0.20)	3.63	KRW 106 to 367 (USD 0.09. to 0.31)
Landfill life expectancy (unit: times)	KRW 148* (USD 0.13)	2.35	KRW 20 to 275 (USD 0.02 to 0.23)
Job creation (unit: person)	KRW 15** (USD 0.01)	2.84	KRW 5 to 26 (USD 0.004 to 0.02)

Note: * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Ⅳ. Concluding remarks

This study was motivated by the need for information to help policy-makers take appropriate actions to improve OWtE technologies in Korea. The study aimed to measure the external benefits of developing OWtE technologies by applying a CE to three attributes or types of benefits, such as the improvement of energy security, the extension of landfill life expectancy, and job creation. The results suggest that people are willing to pay a premium for income tax to acquire the external benefits of developing OWtE technologies. The MNL model widely employed in dealing with CE data requires a restrictive assumption of IIA. Thus, as an alternative to the MNL model, we utilized an NL model here. Two specification tests indicate that the NL model outperformed the MNL model. The estimation results for the NL model show that the MWTPs for a 1% increase in energy security, the doubling of landfill life expectancy, for a 1 person increase in job creation, and caused by expanding OWtE facilities were estimated to be KRW 237 (USD 0.2), 148 (0.13), 15 (0.01) per household per month. These findings can provide policy-makers with useful information for evaluating and planning OWtE policies and projects.

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