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The External Benefits of Research and Development Investment in Waste-to-Energy Technology in Korea

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Abstract The Korean government considers expanding the WtE share of total energy from 1% to 5% by 2020 through research and development (R&D) in waste-to-energy (WtE) technologies. This study attempts to measure the external benefits of investing in R&D in these technologies. To this end, a contingent valuation (CV) is employed. More specifically, a 2016 national survey of randomly selected 1,000 households was carried out across the nation to gauge the willingness to pay (WTP) for the investment. One-and-one-half-bounded dichotomous choice question was used in the CV survey, and the spike model was applied to dealing with zero WTP responses. The mean yearly WTP is estimated to be KRW 4,175 (USD 3.57) per household, which is statistically significant at the 1% level. Expanding the value to the entire nation translates into an investment of about KRW 79.1 billion (USD 67.6 million), which can be interpreted as the annual external benefit of the R&D investment in WtE technology.

Keywords Waste-to-energy, external benefit, willingness to pay, contingent valuation, spike model

I. Introduction

Waste-to-energy (WtE) technologies consist of any waste treatment processes that create energy in the form of electricity, heat or transport fuels from a waste source (World Energy Council, 2013).

Korea's government invests in WtE technologies to gain energy from waste and reduce the amount of waste. Korea is seeking a solution to overcome the serious crisis, which comes from environmental standard. First, Korea is under domestic and international pressure to reduce greenhouse gases (GHGs). The government announced its commitment to reduce its GHG

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emissions by 37% from the business-as-usual level by 2030. Korea has to use a certain amount of renewable energy like WtE when generating power instead of relying on fossil fuel.

Second, Korea should dispose of food wastewater in land because London convention which is a ban on dumping it in the ocean comes into force. Korea promulgated the revised enforcement rule for the Marine Environment Management Act on 2011, with respect to banning the dumping of food wastewater into the ocean, effective from 2013 onwards. The aim of the London Convention, which at present counts 87 signatory states, is to prevent marine pollution caused by the dumping of waste and other matters into the ocean. The London Protocol, that updated the Convention, has been ratified by 42 parties, including Korea (International Maritime Organization, 2016).

Furthermore, the Korean government is committed to increase the WtE share of total energy from 1% to 5% by 2020. WtE technologies should be ready to support this expansion in advance. However, Korea's WtE technology level is 76.5% of that of developed countries in 2014 (Ministry of Science, ICT and Future Planning, 2015). Korea is highly dependent on foreign technology, as domestic technology levels are not enough to operate. However, there are problems regarding differences of waste properties among countries. Therefore, research and development (R&D) on domestic technology is strongly required.

Substantial investment should be made in order to develop WtE technology given that it takes a long time for these to be put to practical use. R&D in WtE technology has to be evaluated because a lot of public money has poured into these projects. Although information about the benefits is critical for an evaluation, it is not easy to estimate. Therefore, this paper attempts to measure the external benefits of the investment in R&D targeted to WtE technology. The paper is organized as follows. Section 2 describes methodological issues. Section 3 explains the model of WTP adopted. Section 4 presents and discusses the empirical results. The final section includes concluding remarks.

II. Methodology

1. The Object to be Valued

If WtE expands share of total energy from 1% to 5%, we could get benefits made if external benefit as well as internal benefit (private benefit). The purpose of this study is to evaluate the external benefits of the R&D investment in WtE technology in Korea. WtE waste is divided in combustible waste and organic waste. Combustible waste is made of household waste and is converted to solid-refuse fuel. Organic waste includes food, sewage sludge, whose dumping into the ocean is banned, as are landfilled biogas and solid fuel.

To increase the WtE share of total energy from 1% to 5% by 2020, the Korean government has plans to support advances in WtE technologies. The government is conducting WtE R&D projects to raise the domestic technological level in the WtE development to the 95% level, and nurture state-of-the-art solutions to fit Korea's situation. Economic benefits are composed of sum of internal and external benefit. It has no difficulty to gauge internal benefits including reduction of production cost, creation of value added, or reduction of damage cost. However, it is not easy to measure external benefit like non-use value. For instance, it derives four positive effects, such as the reduction of GHG emissions, improvements in energy security, job creation, and the extension of landfill life expectancy.

2. CV Method

There is currently a great deal of interest among economists on the issue of valuing non-market goods. Non-market goods provide outputs or services that are not bought and sold, such as recreation, wilderness, and clean air. In order to value non-market goods, many economists elicit responses from individuals about their stated preferences in relation to those goods. The stated preference literature has grown rapidly over the last few decades, and since the 1990s the CV method has become the main method to value non-market goods, especially within environmental economics. A CV technique that gauges an individual's maximum WTP for a given good has been widely applied in the literature for obtaining the WTP for non-market goods.

There is no restriction on the objects to be valued when using the CV method. In particular, it is especially useful because it can capture the non-use or existence value of a good that cannot be measured through market mechanisms. Non-market goods include some environmental goods or public goods like the WtE technology R&D project. Thus, as explained earlier, this study seeks to utilize the CV approach to assess the external benefits that will derived from the project. It asks randomly chosen consumers questions concerning the WTP for the conduct of the project using a well-structured survey (Kwak and Yoo, 2015).

The major objective of this study is to measure the external benefit of R&D investment in WtE technologies in Korea. The study aims to provide policy-makers with at least a preliminary evaluation of the decision related to expanding WtE. This objective is pursued through a survey approach called the CV method. The CV method is a standardized and widely used survey method for estimating WTP (Mitchell and Carson, 1989). The distinguished National Oceanic and Atmospheric Administration's (NOAA) Panel concluded that the CV method can produce estimates that are reliable enough to be the starting point for administrative and judicial determinations and the presentation of several recommendations (Arrow et al., 1993). Furthermore, the validity and accuracy of a CV study can be enhanced if people are familiar with the object to be valued. To achieve that, professional interviewers are used, and other conventions suggested by the NOAA Panel are followed. This study meets the conditions, which will be discussed below in detail.

3. Survey Design Issues

The data on households' mean yearly WTP for R&D investment in WtE technology are derived from a 2016 survey of the nation's households. To draw a random sample of this population, a professional polling company carried out sampling. The survey was conducted with the householder aged between 20 and 65. The survey yielded 1,000 reliable interviews.

Such a survey can be conducted either via face-to-face interviewing, telephone interviewing, or by mail. Of these methods, we chose to use face-to-face interviews for the CV survey for cultural and practical reasons (Yoo and Chae, 2001; Krinsky and Robb, 1986). First, we felt that randomly chosen Korean households would be even less familiar than Americans or Europeans with the idea of supplying unprompted values for proposed public goods if their answers were solicited through a telephone interview or a mail survey. However, face-to-face interviews with well-trained interviewers can offer the most scope for detailed questions and answers. We, therefore, selected the most experienced polling firm's experts to conduct the interviews and we briefed them thoroughly. Second, a telephone interview was the least preferred method because conveying information about the product or service being considered may be difficult over the telephone. Finally, mail surveys are rarely used because they suffer from non-response bias and extremely low response rates; thus it seemed especially risky to use this method in the Korean context.

4. Survey Instrument

The survey instrument (questionnaire) was pre-tested with 100 persons. In designing a CV survey, the scenario should provide the respondents with information on the characteristics of a specific product or service and the context in which the requirements of understandability, plausibility, and meaningfulness will be met to enhance the credibility of the survey and the likelihood of producing reliable results. The survey questionnaire consisted of a) introductory questions assessing respondents' perception after providing general background information on the WtE; b) the WTP question about R&D investment in WtE technology (contribution to expand WtE share of total energy from 1% to 5% until 2020); and c) household information.

5. Elicitation Method

The elicitation format employed in this study is a referendum or dichotomous choice (DC) question according to the 'blue-ribbon CV panel' of Arrow et al. (1993), which strongly endorses a referendum question rather than an open-ended question. The DC model has been favored since it was popularized by Hanemann (1984). Typically, a random sample of the population is asked a question with a 'yes' or 'no' answer regarding their willingness to contribute a specific amount of money toward the preservation of some environmental resource or the provision of a service for the public good. The question format employed in this study is usually called the single-bounded (SB) DC question because it asks a respondent only one close-ended question.

The double-bounded (DB) question presents each respondent with a sequence of two bids and asks for a 'yes' or 'no' answer on whether the respondent's WTP equals or exceeds each bid. While the DBDC question format results in higher efficiency, we did not use this format for the following reasons. While there can be a dramatic increase in statistical efficiency, some bias can occur in moving from an SB to a DB format. This is because there is evidence that some of the responses to the second bid are inconsistent with the responses to the first bid. A number of studies have dealt with this issue and have concluded that the DB elicitation method is internally inconsistent in that the hypothesis (that the first and second responses in the DB DC experiment are drawn from the same distribution) can be rejected at the 1% level (e.g., Cameron and Quiggin, 1994; McFadden, 1994). Bateman et al. (2001) considered a variety of potential causes of such inconsistencies, tested both the effects caused by moving from SB to DB, and suggested that the responses to the second follow-up DB questions should not be used as the basis of valuation exercises.

The elicitation format employed in this study is a DC question, which is in accordance with Arrow et al. (1993). Generally, the DC question format is divided into the SBDC question and the DBDC question formats. The SBDC asks the respondent only one closed-ended question, and DBDC presents each respondent with a sequence of two bids and asks the question twice. Although each format has both merits and demerits, the SBDC has low statistical efficiency, and the DBDC may manifest a correlation between the responses to the two bids. McFadden (1994), Bateman et al. (2001), and Cooper et al. (2002) have explicitly dealt with this issue.

To solve this problem, we adopted the one-and-one-half-bound dichotomous choice (OOHB DC) question format, which is proposed by Cooper et al. (2002). In the OOHB DC format, the interviewer randomly chooses between lower and upper bids as an initial value at which to elicit the respondent's WTP. The lower and upper bids are determined by the result of a pre-test from a focus group. The sets of bids used in this study were (1,000; 3,000), (2,000; 4,000), (3,000; 6,000), (4,000; 8,000), (6,000; 10,000), (8,000; 12,000) and (10,000; 15,000) - the first element of each set is the lower bid and the second corresponds to the upper bid. (At the time of the survey, USD 1.0 was approximately equal to KRW 1,170.50).

The WTP question was: "Would your household be willing to pay an extra amount of tax provided that it is securely investing on R&D for WtE technology?" A provision point mechanism was used to define the costs that the households themselves were likely to bear. The respondents were told that: "The amount you indicate will tell us what this provision is really worth to your household. If the policy actually costs less than the amount you are willing to pay, your extra payment will be adjusted downward. If the policy turns out to require a greater investment than people are willing to pay, the policy will not be implemented."

III. Modeling of WTP Responses

1. The WTP Model

This section focuses on the theoretical aspects of DC CV surveys based on the utility difference model. The observed discrete choice response of each individual is assumed to reflect a utility maximization process. The indirect utility function, v, for each respondent depends on his or her income as well as individual characteristics and the quality of the objects to be valued. The respondent will pay the increased bid amount, A, to accept the proposed project if either

$$v(1, m - A; S) + \varepsilon_1 \geq v(0, m; S) + \varepsilon_0 \quad (1)$$

or

$$\Delta v(A) \equiv v(1, m - A; S) - v(0, m; S) \geq \varepsilon_0 - \varepsilon_1, \quad (2)$$

where state 0 represents no existence of the proposed program and state 1 represents the existence if the respondent pays the stated bid amount, A, and the income is m. Random elements that influence the respondent's indirect utility function are defined by ε_0 and ε_1, which are independent and identically distributed random variables with zero means. Other observable attributes that influence individual preferences are represented by S and also appear in the utility difference specification.

Each respondent will maximize the utility by answering "yes" and agree to pay the bid amount if the difference in the indirect utility (Δv) from paying and having the continued existence of the R&D project of WtE technology is positive. Through Eq. (2), the utility difference model yields a single-equation binary-response model specification if the probability of a "yes" response is a random variable. The probability is as follows:

$$\Pr\{response\ is\ "yes"\} = \Pr\{\Delta v(A) \geq \eta\} = F_\eta[\Delta v(A)] \quad (3)$$

where $\eta = \varepsilon_0 - \varepsilon_1$ and $F_\eta(\cdot)$ is the cumulative distribution function of η. A "yes" response to the CV question is observed when $\Delta v \geq 0$, whereas a "no" response is observed when $\Delta v < 0$. The authors recognize that WTP (hereafter denoted as C) is a random variable with a cumulative distribution function defined here as $G_C(A)$. As an alternative to (3), the probability can be expressed as follows:

$$\Pr\{response\ is\ "yes"\} = \Pr\{C \geq A\} \equiv 1 - G_C(A) \quad (4)$$

Thus, the following is obtained:

$$1 - G_C(A) \equiv F_\eta[\Delta v(A)] \quad (5)$$

This result indicates that the fitting of the binary response model (3) can be interpreted as estimating the parameters of the distribution function $G_C(\cdot)$.

2. The OOHB DC Model

According to Cooper et al. (2002), the OOHB DC CV model can be described as follows. Let $i = 1,...,N$ be the index for each respondent in the sample and A be the bid amount presented to a respondent. Each respondent is presented with two prices, A_i^L and A_i^U, where $A_i^L < A_i^U$. If A_i^L is randomly drawn as the first price, then the possible responses are yes–yes, yes–no, and no.

If A_i^U is randomly drawn as the first bid, then the possible answers are yes, no–yes, and no–no. The binary-valued indicator variables of these six possible outcomes are I_i^{YY}, I_i^{YN}, I_i^{N}, I_i^{Y}, I_i^{NY}, and I_i^{NN}, respectively, such that:

$$\begin{aligned}
I_i^{YY} &= \mathbf{1}(i\text{th respondent's response is "yes-yes"}) \\
I_i^{YN} &= \mathbf{1}(i\text{th respondent's response is "yes-no"}) \\
I_i^{N} &= \mathbf{1}(i\text{th respondent's response is "no"}) \\
I_i^{Y} &= \mathbf{1}(i\text{th respondent's response is "yes"}) \\
I_i^{NY} &= \mathbf{1}(i\text{th respondent's response is "no-yes"}) \\
I_i^{NN} &= \mathbf{1}(i\text{th respondent's response is "no-no"})
\end{aligned} \tag{6}$$

where 1(.) is an indicator function, the value of which is one if the argument is true and zero otherwise. For example, I_i^{YY}=1(*i*th respondent's response is 'yes-yes') means that if the response of the *i*th respondent is "yes" to the first question and "yes" to the second question, the value of I_i^{YY} is one and zero otherwise.

WTP (hereafter denoted as C) is recognized as a random variable with a cumulative distribution function (cdf) defined here as $G_C(\cdot;\theta)$, where θ is a vector of parameters. Given the assumption of a utility-maximizing respondent, the log-likelihood function takes the form:

$$\begin{aligned} \ln L = \sum_{i=1}^{N} \{ & (I_i^{YY} + I_i^{Y}) \ln[1 - G_C(A_i^U;\theta)] \\ & + (I_i^{YN} + I_i^{NY}) \ln[G_C(A_i^U;\theta) - G_C(A_i^L;\theta)] \\ & + (I_i^{N} + I_i^{NN}) \ln G_C(A_i^L;\theta) \} \end{aligned} \tag{7}$$

Following the practice of previous studies, formulating $1 - G_C(\cdot)$ as a logistic cdf and combining this with $\theta = (a, b)$ yield $G_C(A;\theta) = [1 + \exp(a - bA)]^{-1}$. Let C^+ be the mean WTP when C can be positive or negative. Thus, the mean WTP can be computed as $C^+ = a/b$ (Hanemann, 1984).

3. Spike Model in the OOHB DC CV Setting

The respondents who report "no" and "no–no" are composed of two groups: those who really have a zero WTP and those who have a positive WTP that is less than the lower bid. For those respondents who gave a "no" response in the case that the lower bid was the starting price and a "no–no" response sequence in the case that the upper bid was the starting price, a third follow-up question was asked, i.e., whether or not they had a positive WTP. A considerable number of respondents refused to pay anything for R&D investment in the WtE technology in Korea.

Therefore, in order to allow for the zero WTP responses, a spike model suggested by Kriström (1997) is applied. As the spike model is based on the single-bound DC model, this study tries to modify the spike model for the OOHB DC model following the procedures proposed by Yoo and Kwak (2002) that adjusted it for the double-bound DC model. For people who were asked the additional follow-up question, the two binary-valued indicator variables can be defined as:

$$\begin{aligned} I_i^{NNY} &= \mathbf{1}(i\text{th respondent's response to the additional question is "yes"}) \\ I_i^{NNN} &= \mathbf{1}(i\text{th respondent's response to the additional question is "no"}) \end{aligned} \tag{8}$$

To estimate the parameters for the distribution of WTP, WTP is assumed to be distributed as a logistic on the positive axis. The log-likelihood function for the OOHB spike model is given by:

$$\begin{aligned}\ln L = \sum_{i=1}^{N} \{ & (I_i^{YY} + I_i^{Y}) \ln[1 - G_C(A_i^U;\theta)] \\ & + (I_i^{YN} + I_i^{NY}) \ln[G_C(A_i^U;\theta) - G_C(A_i^L;\theta)] \\ & + I_i^{NNY}(I_i^N + I_i^{NN}) \ln[G_C(A_i^L;\theta) - G_C(0;\theta)] \\ & + I_i^{NNN}(I_i^N + I_i^{NN}) \ln G_C(0;\theta) \}\end{aligned} \tag{9}$$

where:

$$G_C(A;\theta) = \begin{cases} [1+\exp(a-bA)]^{-1} & \text{if } A > 0 \\ [1+\exp(a)]^{-1} & \text{if } A = 0 \\ 0 & \text{if } A < 0 \end{cases} \tag{10}$$

Thus, the spike is defined by $[1+\exp(a)]^{-1}$. Using Eq. (10), the mean WTP in the spike model can be calculated as $C^+ = (1/b)\ln[1+\exp(a)]$. In CV studies, it is common to test for the internal consistency and theoretical validity of the model by estimating the model with covariates. To estimate the model with covariates, in the above equations, a is simply replaced with $a + x_i'\beta$, where x_i is a vector of explanatory variables, including the bid, and β is a vector of the parameters to be estimated.

IV. Results

1. WTP Responses

To measure the value to the public, a CV is applied using a national survey of randomly selected 1,000 households. OOHB DC question was used to elicit the WTP responses from the sample and the CV survey was administered via face-to-face interviews. Overall, the respondents accepted the contingent market and revealed a significant WTP for R&D investment in WtE. Based on interviewers' comments, the WTP elicitation procedures were well within the respondents' abilities. Table 1 presents the distribution of responses to the valuation question, indicating the total number of respondents who stated that they would be willing to pay for the R&D investment in WtE technology at each bid level ranging from KRW 1,000 to 15,000 per year. Note that the percentage of 'yes' responses to the bid amount roughly falls as the bid increases. For example, in the case of "from lower bid to upper bid" 11 (7.7%) favored investing in R&D for WtE technology at an annual income tax of KRW 1,000, whereas only 8 (5.6%) approved of it at a level of KRW 10,000.

Table 1 Distribution of responses by each bid amount

Bid amount [a]		Lower bid is presented as a first bid (%)[b]				Upper bid is presented as a first bid (%) [b]				Sample size [b]
Lower bid	Upper bid	yes-yes	yes-no	no-yes	no-no	yes	no-yes	no-no-no	no-no-yes	
1,000	3,000	11 (7.7)	18 (12.6)	2 (1.4)	41 (28.7)	22 (15.4)	7 (4.9)	5 (3.5)	37 (25.9)	143 (100.0)
2,000	4,000	15 (10.5)	14 (9.8)	6 (4.2)	36 (25.2)	25 (17.5)	6 (4.2)	4 (2.8)	37 (25.9)	143 (100.0)
3,000	6,000	12 (8.4)	15 (10.5)	7 (4.9)	37 (25.9)	19 (13.3)	5 (3.5)	3 (2.1)	45 (31.5)	143 (100.0)
4,000	8,000	10 (7.0)	15 (10.5)	7 (4.9)	40 (28.0)	14 (9.8)	12 (8.4)	3 (2.1)	42 (29.4)	143 (100.0)
6,000	10,000	11 (7.7)	4 (2.8)	8 (5.6)	48 (33.8)	18 (12.7)	4 (2.8)	7 (4.9)	42 (29.6)	142 (100.0)
8,000	12,000	8 (5.6)	9 (6.3)	7 (49)	47 (33.1)	13 (9.2)	2 (1.4)	10 (7.0)	46 (32.4)	142 (100.0)
10,000	15,000	8 (5.6)	14 (9.7)	10 (6.9)	40 (27.8)	8 (5.6)	7 (4.9)	6 (4.2)	51 (29.2)	144 (100.0)
Totals		75 (7.5)	89 (8.9)	47 (4.7)	289 (28.9)	119 (11.9)	43 (4.3)	38 (3.8)	300 (30.0)	1,000 (100.0)

Notes: [a] The unit is Korean won and the unit is Korean won and USD 1.0 was approximately equal to KRW 1,170.50 at the survey time.
[b] The numbers in parentheses below the number of responses are the percentage of sample size.

2. Estimation Results of the Model

The spike model in Eq. (4) was estimated by the maximum likelihood estimation (ML) method. Table 2 describes the estimation results of the model without covariates. All the parameters in the spike model are statistically significant at the 1% level. Using the Wald statistics, the estimated equation is significantly statistically different from zero at the 1% level. The mean yearly WTP is estimated to be KRW 4,175 (USD 3.57), which is statistically significant at the 1% level given that its t-value is computed to be 14.42. On the whole, respondents accepted the contingent market and were willing to contribute a significant amount, on average, per household.

Table 2 Estimation results of the spike model without covariates

Variables	Estimates [d]
Constant	-0.3592 (-5.61)#
Bid amount [a]	-0.1269 (-15.97) #
Spike	0.5889 (37.97) #
Mean additional WTP *t*-value 95% confidence interval [b] 99% confidence interval [b]	KRW 4,175 (USD 3.57) 14.42 # 3,667 to 4,797 (USD 3.13 to 4.09) 3,507 to 5,024 (USD 3.00 to 4.29)
Number of observations Log-likelihood Wald statistics (*p*-value) [c]	1,000 -1,136.43 355.20 (0.000)

Notes: [a] The unit is Korean won (KRW) and USD1.0 was approximately equal to KRW 1,170.50 at the time of the survey.

[b] The confidence intervals are calculated by the use of the Monte Carlo simulation technique of Krinsky and Robb (1986) with 5,000 replications.

[c] The null hypothesis is that all the parameters are jointly zero and the corresponding *p*-value is reported in the parentheses beside the statistic.

[d] The numbers in parentheses beside the coefficient estimates are *t*-values, computed from the analytic second derivatives of the log-likelihood.

# indicates statistical significance at the 1% level.

We adopt a strategy to construct confidence intervals for the point estimate of mean yearly WTP in order to allow for uncertainty, rather than report the point estimate only. To this end, we used the Monte Carlo simulation technique of Krinsky and Robb (1986). This involved simulating the multi-variate normal distribution of θ , using the ML estimates of the coefficients and the variance-covariance matrix, and calculating mean yearly WTP for each replicate of θ , thereby generating an empirical distribution function for mean WTP. The confidence intervals for the point estimates of the additional mean are reported in the middle panel of Table 2. They were obtained by including 5,000 replications and omitting 2.5% and 0.5% of the observations from both tails, respectively. The ML estimates of the variance-covariance of θ are computed from the analytic second derivatives of the log-likelihood. The method quantifies and models the uncertainty, and coincides with one objective of modern policy makers, who prefer to be presented with a range of values rather than one best value.

3. Estimation Results of the Model with Covariates

One can examine how the characteristics of the respondents or their households affect the likelihood that they will say "yes" to a given bid. It is also common to test for internal consistency (theoretical validity) in CV studies by estimating the model with covariates. Definitions and sample statistics of variables used in this study are presented in Table 3. Table 4 shows the estimation results of the model that includes covariates, or variables other than the Bid amount and Gender, that might be expected to affect the likelihood of voting 'yes'.

Table 3 Definitions and sample statistics of variables

Variables	Definitions	Mean	Standard deviation
Gender	The respondent's gender (0 = female, 1 = male)	0.52	0.50
Education	The respondent's education level (unit : years)	14.15	2.31
Income	Monthly household per capita income before tax deduction (unit: million Korean won=USD 854.34)	4.45	2.75
Background	Dummy for prior recognition of information about London Dumping Convention (0 = don't know, 1 = know well)	0.20	0.40

Table 4 Estimation results of the model with covariates

Variables [a]	Estimates	*t*-value
Constant	-1.5165	-3.89#
Bid amount [b]	-0.1319	16.10#
Gender	-0.2264	-0.18
Education	0.5194	1.84*
Income	0.0708	3.40#
Background	0.5943	3.91#
Number of observations	1,000	
Log-likelihood	-1,117.45	
Wald statistic [c] (*p*-value)	367.40 (0.000)	

Notes: [a] The variables are defined in Table 3.
[b] The unit is Korean won (KRW) and USD 1.0 was approximately equal to KRW 1,170.50 at the time of the survey.
[c] The null hypothesis is that all the parameters are jointly zero and the corresponding *p*-value is reported in the parentheses beside the statistics.
* and # indicate statistical significance at the 10% and 5% levels, respectively.

As in the model with covariates, the coefficient for the bid amount is significantly different from zero at the 1% level. The estimated coefficients for Income and Background (already known about London Dumping Convention) are also statistically significant at the 5% level. The estimated coefficient for Education is statistically significant at the 10% level, however, estimate coefficient for Gender is not. The respondents with a higher income have a tendency to answer "yes" to an offered amount than others.

Individuals, who are already known about London Dumping Convention, are more likely to say "yes" to the WTP question. The respondents' background knowledge of London Convention has a considerable effect on their WTP. It is expected that people who are aware of the background about project are more likely to respond "yes" to the WTP question. Therefore, promoting the necessity of R&D investment in WtE technology to the public could increase residents' support of WtE technology. The education level of the respondent has a positive relationship with the likeliness of saying "yes" to a given bid.

4. Discussion of the Results

The external benefit of the R&D investment in WtE technology is estimated to be KRW 4,175 (USD 3.57) per household. The value can be incorporated into the total economic benefit, therefore an individual gains benefits that are made up of private and external benefits. The economic benefit is essential for making economically sound investment decisions about whether to implement the project (Kaiser and Pulsipher, 2003) and would be applied to a comparison with the costs of the project to determine whether the project is economically undesirable.

In order to get an estimate of the total external benefits, we need to use the mean WTP estimate obtained from the investigation of the sample observations and information on population size. In the course of this estimation, the most important issue is whether or not the sample is representative of the population. As addressed above, the sampling was conducted by a professional firm so as to ensure the randomness of the sampling and its consistency with the characteristics of the population. Another important issue is the response rate in the CV survey. Our CV survey was implemented using face-to-face interviews, and thus the response rate was almost one hundred percent. Thus, we cannot deny that our sample is representative of the population.

We use the mean WTP estimate from the model with no covariates, since the setting of the covariates may influence the mean WTP value if we use the mean WTP value from the model with covariates. According to Statistics

Korea (http://kosis.kr), the number of households in Korea is 18,948,342 in 2016. Using this information, expanding the value to the national population gives us KRW 79.1 billion (USD 67.6 million) per year.

The corresponding 95% and 99% confidence intervals for the total external benefits are KRW 69.5 to 90.9 billion (USD 59.4 to 77.7 million) and KRW 65.5 to 95.2 billion (USD 56.8 to 81.3 million), respectively. To examine the economic feasibility of the project, we can compare this value with the cost involved in R&D investment in WtE technology. Overall, we can judge that Korean households are ready to bear a share of the financial burden of R&D investment in WtE technology.

V. Conclusion

WtE is renewable energy and, thus, a substitute fossil fuel. It helps to achieve the goal of reducing GHG emissions by 37% from the business-as-usual level by 2030. Moreover, WtE, which is an alternative to the ban on ocean dumping, makes possible the landfilled disposal of food wastewater. Therefore, Korean government would expand WtE share of total energy form 1% to 5% by 2020. To this end, WtE technologies should be developed with delay. WtE technologies are able to convert the energy content of different types of waste into various forms of valuable energy (World Energy Council, 2013). However, Korea is highly dependent on foreign technology, and the level of domestic technology is not enough to satisfy these requirements. Therefore, the government should support domestic WtE technology R&D projects.

Since R&D investment in WtE technology a substantial contribution from public funds, R&D projects have to be evaluated. It is not easy to measure external benefits of R&D investment in WtE technology. This study attempts to measure the external benefits of this investment using the CV method. The WTP elicitation procedure was within the respondents' ability. Overall, the survey was relatively successful in eliciting the additional WTP values, and the mean estimate of additional WTP from the spike model was significantly different from zero at the 1% level. The mean yearly WTP is estimated to be KRW 4,175 (USD 3.57) per household, which is statistically significant at the 1% level.

Results show that the R&D investment in WtE technology brings external benefits. This investment will create favorable external benefits as follow; a) a reduction of GHG emissions; b) improvements in energy security; c) job creation, and d) the extension of landfill life expectancy. More specifically, increasing the value to the all nation generate about KRW 79.1 billion (USD

67.6 million) per year, which can be interpreted as annual external benefits of the R&D investment in WtE technology. This value is external benefit which is composed of total economic benefit with internal benefit. This information can provide some insights into the R&D investment in WtE technology for both policy-makers and researchers. These collected data can be used to consider R&D investment and utilize them to conduct an economic feasibility study for a new project related to WtE technology.

References

Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R. and Schuman, H. (1993) Report of the NOAA panel on contingent valuation, Federal Register, 58, 4601-4614.

Bateman, I.J., Langford, I.H., Jones, A.P. and Kerr, G.N. (2001) Bound and path effects in double and triple bounded dichotomous choice contingent valuation, Resource and Energy Economics, 23, 191-213.

Cameron, T.A. and Quiggin, J. (1994) Estimation using contingent valuation data from a 'dichotomous choice with follow-up' questionnaire, Journal of Environmental Economics and Management, 27, 218-234.

Cooper, J.C., Hanemann, M. and Signorello, G. (2002) One-and-one-half-bound dichotomous choice contingent valuation, Review of Economics and Statistics, 84, 742-750.

Eurostat (2013) http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/introduction/

Hanemann, W.M. (1984) Welfare evaluations in contingent valuation experiments with discrete responses, American Journal of Agricultural Economics, 66, 332-341.

International Maritime Organization (accessed at: 2016. June) http://www.imo.org

Kaiser, M.J. and Pulsipher, A.G. (2003) A generalized modeling framework for public benefit fund program valuation, Energy, 28, 519-538.

Krinsky, I. and Robb, A.L. (1986) On approximating the statistical properties of elasticities, Review of Economics and Statistics, 68, 715-719.

Kriström, B. (1997) Spike models in contingent valuation, American Journal of Agricultural Economics, 79, 1013-1023.

Kwak, S.-Y. and Yoo, S.-H. (2015) The public's value for developing ocean energy technology in the Republic of Korea: a contingent valuation study, Renewable & Sustainable Energy Reviews, 43, 432-439.

McFadden D. (1994) Contingent valuation and social choice, American Journal of Agricultural Economics, 76, 689-708.

Ministry of Science, ICT and Future Planning (2015) 2014 Technology Level Evaluation, Korea Institute of S&T Evaluation and Planning.

Mitchell, R.C. and Carson, R.T. (1989) Using Surveys to Value Public Goods: The Contingent Valuation Method, Washington, D.C: Resources for the Future.

World Energy Council. (2013) World Energy Resources 2013 Survey, London.

Yoo, S.-H. and Chae, K.-S. (2001) Measuring the economic benefits of the ozone pollution control policy in Seoul: results of a contingent valuation survey, Urban Studies, 38, 49-60.

Yoo, S.-H. and Kwak, S.-J. (2002) Using a spike model to deal with zero response data from double bounded dichotomous contingent valuation survey, Applied Economics Letters, 9, 929-932.