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Will South Korean Residential Consumers Accept the Renewable Heat Incentive Scheme? A Stated Preference Approach

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Received: 1 April 2019; Accepted: 10 May 2019; Published: 18 May 2019

Abstract: In South Korea, renewable energy policy is mainly focused on electricity and tends to neglect renewable heat (RH). However, for the purpose of reducing greenhouse gas emissions, the heating sector must sharply switch from its use of conventional fuels to renewable sources. The South Korean Government is considering an RH incentive (RHI) program with financial and policy support schemes and is thus demanding information about residential consumers' acceptance of the RHI program to expand the use of RH. Therefore, this study looked into residential consumers' acceptance of the introduction of the RHI program by applying contingent valuation (CV). For this purpose, a CV survey of 600 interviewees was conducted using a dichotomous choice question format that asked a respondent if she/he is willing to pay a given amount. Furthermore, among the various dichotomous choice question formats, the one-and-one-half-bounded format, which is considered desirable in terms of efficiency as well as consistency, was applied. One point to note in analyzing the CV responses was that not a few interviewees had zero willingness to pay (WTP). Thus, a spike model was employed to deal with the dichotomous choice CV data with a number of zero observations. The results revealed that the household mean WTP amounted to KRW 5753 (USD 5.35) per year. If we look at this value from a national perspective, it is worth KRW 113.63 billion (USD 105.61 million) per year. This value corresponds to the economic value or benefits that the introduction of an RHI program provides to the South Korean people each year and needs to be compared to the costs that the introduction of RHI will incur.

Keywords: renewable energy; renewable heat incentive; residential consumer; contingent valuation; acceptability; willingness to pay

1. Introduction

Heating, as the largest part of energy consumption by the end-user, greatly contributes to global greenhouse gas (GHG) emissions. Many countries that have high shares of renewables in heat supply have had active heat policies. In South Korea, renewable energy policy is mainly focused on electricity while neglecting renewable heat (RH). However, heat accounts for over 52% of final energy uses globally [1], and over 30% of total energy consumption is used for different types of heat energy in South Korea. Heating and water heating account for 72% of total annual home energy consumption in South Korea [2]. However, according to the South Korean national roadmap for reducing GHG emissions, South Korea should cut GHG emissions by 37%, from 850 million to 536 million tCO_2 by 2030. One of the key measures is to switch sources that provide heat from conventional fossil fuels to renewable sources.

The South Korean Government (hereinafter, the "Government") has established and implemented the so-called "Renewable Energy 3020 Implementation Plan", which aims to expand the portion of renewable energy generation to 20% by 2030, and just 2.2% in 2016. The main means of implementation are solar and wind power generation. On the other hand, it is still under discussion how much RH energy can be supplied and what specific means can achieve this. Therefore, there are growing calls to introduce an RH incentive (RHI) program as a specific means of implementation after setting a target for the supply of RH by 2040. In response, the Government is considering an RHI program with financial and policy support schemes and demanding information about residential consumers' acceptance of the RHI program in order to expand the use of RH. The program establishes a goal to increase the portion of RH from 1% to 20% by 2040.

Public acceptance of the RHI program plays an important role in determining the success or failure of the RH expansion policy. This is because the cost-bearing entity of the implementation of the RHI program is, in turn, the consumers of residential heat. If residential consumers prefer heat made from fossil fuels over RH, the RH expansion policy cannot succeed. In addition, public acceptability will eventually be expressed as an expenditure to be incurred in addition to the current residential heat price under the income constraint, and therefore, it is necessary to investigate and analyze the willingness to pay (WTP) for the implementation of the RHI program.

Previous studies of the acceptability of renewable energy have mainly concentrated on electric power. For example, there are several reports related to power generation using various renewable sources such as green prices for renewables, photovoltaic, and biomass [3–9] and renewable energy supply mandates [10–16]. Moreover, some studies have focused on analyzing the feasibility of RH [14] and devising policy means [15–17] or business models [18]. However, only two studies investigated preference for RH [19,20]. The most widely used methodology in the preceding studies of the acceptability of renewable energy is contingent valuation (CV), which is one of the most popular methods used by environmental and energy economists to value environmental and nonmarket goods [21–26]. Thus, it seems that applying the CV method to investigate the public acceptability of introducing the RHI program is a good strategy.

So far as the authors are aware, this article is the first study to analyze the consumer acceptability of introducing an RHI program using CV. For this reason, the implications of this paper will be even more useful. The rest of this article is made up of three sections. The methodology, model, and data used here are described in Section 2. Section 3 reports and discusses the empirical results. Section 4 is devoted to providing some conclusions.

2. Methodology

2.1. CV Method

Various techniques have been proposed in economics to obtain the demand function or the area under the demand function for a nonmarket good or service. The most widely used technique among them is CV. The demand function means the marginal WTP function from a microeconomics perspective, and the area under the demand function implies the WTP. The CV method can be applied to measure the WTP for a change from the current-level demand to a particular level of demand for a good or service [27,28]. In addition, CV is known to provide more accurate WTP estimates from a theoretical perspective than other techniques.

The CV method directly asks respondents to determine their WTP contingent on a given situation. Moreover, Arrow et al. [29] proposed several measures to ensure the validity and accuracy of a CV study. A CV study considers the current status as the starting point, the target status as the destination, and the policy measures that are necessary. The current status indicates a situation whereby consumed heat is produced from conventional fossil fuels. The target status implies a situation in which the share of RH is 20% until 2040 through the introduction of an RHI program. In applied CV studies, it is important to set up a payment vehicle well to overcome the hypothetical bias. In this study, annual income tax per household was set up as a payment vehicle.

2.2. Dichotomous Choice (DC) Question

A DC question is widely used for deriving a WTP response in applied CV works since it can reduce the protest responses and generate incentive-compatible responses. Among DC question methods, the one-and-one-half-bound (OOHB) question method provided by Cooper et al. [30] has merits such as decreased inefficiency and improved consistency. Thus, this study utilized the OOHB DC question method which used two bids, of which one was higher than the other. If a lower bid was presented to an interviewee first and the answer was "yes", a higher bid was additionally offered to the interviewee. If a lower bid was presented to an interviewee first and the answer was "no", no additional question was offered to the interviewee. On the contrary, when a higher bid was presented to an interviewee first and the answer was "no", a lower bid was additionally offered to the interviewee. If a higher bid was presented to an interviewee first and the answer was "yes", no additional question was offered to the interviewee.

Let s be sth respondent for $s = 1, \ldots, S$. If T_s^L is offered to the respondent first, then "yes-yes", "yes-no", and "no" are the possible responses. When T_s^H is provided to the respondent first, "yes", "no-yes", and "no-no" are the possible answers. Therefore, for the OOHB DC question format used, there was a total of six possible responses.

When a lower bid (T_s^L) is offered first,

(i) "no" implies WTP $< T_s^L$;
(ii) "yes-no" implies $T_s^L \leq$ WTP $< T_s^H$;
(iii) "yes-yes" implies $T_s^H \leq$ WTP.

When a higher bid (T_s^H) is offered first,

(iv) "no-no" implies WTP $< T_s^L$;
(v) "no-yes" implies $T_s^L \leq$ WTP $< T_s^H$;
(vi) "yes" implies $T_s^H \leq$ WTP.

2.3. WTP Model

According to the utility difference approach given in Hanemann [31], the utility difference function takes the following form:

$$\Delta V = V(Y, I - T; D) - V(N, I; D) \geq \lambda_N - \lambda_Y \tag{1}$$

where Y and N indicate the states in which the RHI program is introduced and not introduced, respectively, V is an indirect utility function, I is the household's income, D is the household's sociodemographic characteristics, and the λs are the error terms. If ΔV is positive, then the respondent may say "yes". Thus, the following relationship can be derived:

$$\Pr(\text{"yes"}) = \Pr(W \geq T) = 1 - F_W(T) \tag{2}$$

where W and $F_W(\cdot)$ are the respondent's WTP and the cumulative distribution function of W.

A total of six responses can emerge from the OOHB DC CV question. Thus, six indicator variables, E_s^N, E_s^{YN}, E_s^{YY}, E_s^{NN}, E_s^{NY}, and E_s^Y, can be introduced, as follows:

$$\begin{cases} E_s^N = \mathbf{1}(s\text{th respondent's answer is "no"}) \\ E_s^{YN} = \mathbf{1}(s\text{th respondent's answer is "yes} - \text{no"}) \\ E_s^{YY} = \mathbf{1}(s\text{th respondent's answer is "yes} - \text{yes"}) \\ E_s^{NN} = \mathbf{1}(s\text{th respondent's answer is "no} - \text{no"}) \\ E_s^{NY} = \mathbf{1}(s\text{th respondent's answer is "no} - \text{yes"}) \\ E_s^{Y} = \mathbf{1}(s\text{th respondent's answer is "yes"}) \end{cases} \quad (3)$$

where $\mathbf{1}(\cdot)$ is an indicator function. It has a value of one if the proposition in the parentheses is true and a value of zero otherwise.

Interviewees who responded "no" to a lower suggested amount (T_s^L) or "no-no" to a higher suggested amount (T_s^H) would be divided into those whose WTP is zero and those whose WTP is greater than zero but smaller than the lower suggested amount. Therefore, these respondents were asked if they were willing to pay a little. If the response is "yes", then $0 < W_s < T_s^L$ comes into effect, and otherwise, $W_s = 0$. Additional indicator variables are considered, as follows:

$$\begin{cases} E_s^{TY} = \mathbf{1}(s\text{th respodent's answer to the additional question is "yes"}) \\ E_s^{TN} = \mathbf{1}(s\text{th respodent's answer to the additional question is "no"}) \end{cases}. \quad (4)$$

Thus, the log-likelihood function derived for the spike model is

$$\begin{aligned} \ln L = \sum_{s=1}^{S} \Big\{ & (E_s^{YY} + E_s^{Y}) \ln[1 - F_W(T_s^U; \phi_0, \phi_1)] \\ & + (E_s^{YN} + E_s^{NY}) \ln[F_W(T_s^U; \phi_0, \phi_1) - F_W(T_s^L; \phi_0, \phi_1)] \\ & + E_s^{TY}(E_s^N + E_s^{NN}) \ln[F_W(T_s^L; \phi_0, \phi_1) - F_W(0; \phi_0, \phi_1)] \\ & + E_s^{TN}(E_s^N + E_s^{NN}) \ln F_W(0; \phi_0, \phi_1) \Big\} \end{aligned}. \quad (5)$$

In the spike model, $F_W(T; \phi_0, \phi_1)$ is assumed as

$$F_W(T; \phi_0, \phi_1) = \begin{cases} [1 + \exp(\phi_0 - \phi_1 T)]^{-1} & \text{if } T > 0 \\ [1 + \exp(\phi_0)]^{-1} & \text{if } T = 0 \\ 0 & \text{if } T < 0 \end{cases}. \quad (6)$$

The probability of $W_s = 0$ is usually called the spike, which corresponds to $[1 + \exp(\phi_0)]^{-1}$ in Equation (4) [32]. Since our main concern was to measure the mean WTP, we needed to compute it from $F_W(T; \phi_0, \phi_1)$. If a well-known formula for the mean calculated from the cumulative distribution function were used, we obtain the mean WTP as $(1/\phi_1) \ln[1 + \exp(\phi_0)]$ [31,33]. If one needs to consider some covariates, ϕ_0 can be substituted with $\phi_0 + z'_s\theta$ in Equation (4), where θ is a vector of coefficients that corresponds to a vector of covariates, z_s.

2.4. Data

As mentioned earlier, 600 households were sampled throughout South Korea to implement a CV survey. In order to represent the national population well, a stratified random sampling was adopted. There are 17 provinces. Of them, since Jeju Island Province is an island away from the Korean Peninsula, it is usually excluded from CV surveys, and because Sejong Province has a relatively small population, it is usually included in Chungnam Province for CV surveys. Thus, a total of 15 strata were used. Each stratum corresponded to each province in South Korea.

The distribution of responses to the bid amounts that were presented to the respondents is shown in Table 1. One of the finally determined bid amounts was randomly presented to each respondent. The sets of lower and higher bids in Korean won were the following: (1000, 3000), (2000, 4000), (3000, 6000), (4000, 8000), (6000, 10,000), (8,000, 12,000), and (10,000, 15,000). In the case of offering two bids (1000, 3000), "yes-no" from the lower bid given first and "no-yes" from the higher bid given first are symmetric; however, in practice, interviewees' WTP appeared between 1000 and 3000. If a lower bid (1000) was presented to an interviewee first and the answer was "yes", a higher bid (3000) was additionally offered to the interviewee and the answer was "no." On the contrary, when a higher bid (3000) was presented to an interviewee first and the answer was "no", a lower bid (1000) was additionally offered to the interviewee and the answer was "no."

Table 1. Distribution of the responses.

Bid Amount a		Lower Bid is Offered First (%) b				Higher Bid is Offered First (%) b				Sample Size b
		"Yes-Yes"	"Yes-No"	"No-Yes"	"No-No"	"Yes"	"No-Yes"	"No-No-Yes"	"No-No-No"	
1000	3000	10 (11.8)	6 (7.0)	0 (0.0)	27 (31.4)	15 (17.4)	3 (3.5)	1 (1.2)	24 (27.9)	86 (100.0)
2000	4000	9 (10.5)	11 (12.8)	0 (0.0)	23 (26.7)	15 (17.4)	1 (1.2)	2 (2.3)	25 (29.1)	86 (100.0)
3000	6000	11 (12.8)	5 (5.8)	2 (2.3)	25 (29.1)	15 (17.4)	4 (4.7)	3 (3.5)	21 (24.4)	86 (100.0)
4000	8000	5 (5.9)	4 (4.7)	2 (2.4)	31 (36.5)	11 (12.9)	4 (4.7)	2 (2.4)	26 (30.6)	85 (100.0)
6000	10,000	8 (9.3)	8 (9.3)	6 (7.0)	21 (24.4)	8 (9.3)	5 (5.8)	2 (2.3)	28 (32.6)	86 (100.0)
8000	12,000	6 (7.1)	8 (9.4)	8 (9.4)	21 (24.7)	12 (14.1)	2 (2.4)	4 (4.7)	24 (28.2)	85 (100.0)
10,000	15,000	9 (10.5)	6 (7.0)	7 (8.1)	21 (24.4)	12 (14.0)	2 (2.3)	7 (8.1)	22 (25.6)	86 (100.0)
Totals		58 (9.7)	48 (8.0)	25 (4.2)	169 (28.2)	88 (14.7)	21 (3.5)	21 (3.5)	170 (28.3)	600 (100.0)

Notes: [a] The unit is Korean won, and when the survey was implemented, USD 1.0 equaled KRW 1076. [b] The number in parentheses indicates the percentage of the sample size.

Half the interviewees were provided with a lower bid first. Interviewees who stated "yes" to a first bid, KRW 1000, were provided with a higher bid, KRW 3000. However, those who stated "no" to first bid were not provided with an additional question. The range of WTP depended on the interviewees' response. If an interviewee responded "yes-yes", the WTP was greater than KRW 3000. In the case of a "yes-no" response, KRW 1000 < WTP < KRW 3000 came into effect. If an interviewee responded "no", the WTP was less than KRW 1000.

In contrast, the remaining interviewees were given KRW 3000 first. If interviewees responded "no" to KRW 3000, they were additionally provided with a lower bid, KRW 1000. If interviewees responded "yes", they were not given an additional question. According to interviewees' response, the range of WTP was decided. If an interviewee responded "yes", the WTP was greater than KRW 3000. In the case of a "no-yes" response, KRW 1000 < WTP < KRW 3000 came into effect. If an interviewee responded "no-no", the WTP was less than KRW 1000.

When the survey was implemented, the exchange rate was USD 1 = KRW 1076. 56.5% of the respondents were found to have no intention of paying only KRW 1 for introducing the RHI program. That is, more than half of the respondents revealed a zero WTP. Therefore, it appears that employing the spike model explicitly reflecting zero WTP values was an appropriate strategy.

3. Results

3.1. Estimation Results of the Model

Table 2 reports the estimation results of the model given in Equation (5). All of the parameter estimates were statistically meaningful at the significance level of 1%. The estimated equation was significant judging from the Wald statistic. In addition, the sign of the coefficient estimates met the prior expectations. A household's yearly mean WTP for introducing the RHI program was KRW 5753 (USD 5.35). This value was statistically significant at the 1% level.

Table 2. Estimation results of the spike model.

Variables	Coefficient Estimates [c]
Constant	−0.2562 (−3.13) *
Bid amount [a]	−0.0996 (−11.65) *
Spike	0.5637 (27.98) *
Mean WTP per household per year	KRW 5753 (USD 5.35)
t-value	10.87 *
95% confidence interval [b]	KRW 4864–6946 (USD 4.52–6.46)
99% confidence interval [b]	KRW 4618–7367 (USD 4.29–6.85)
Sample size	600

[a] USD 1.0 = KRW 1076. [b] The confidence intervals were computed using Krinsky and Robb's [34] approach with 5000 replications. [c] The *t*-values are reported in parentheses beside the coefficient estimates. * denotes statistical meaningfulness at the 1% level.

It was necessary to implement a model including covariates that could address the effect of the covariates on the probability that the respondents would answer "yes" to the given bid amount. Moreover, the model could be used for deciding whether the results of applying the CV method that involved the survey would ensure internal consistency or theoretical validity. For this purpose, this study adopted three covariates, which are explained in Table 3. The results of estimating the spike model with covariates are reported in Table 4.

Table 3. Description of the variables in the model.

Variables	Definitions	Mean	Standard Deviation
Family	The interviewee's number of family members	3.39	1.06
Residence	Dummy for the interviewee's household residing in the Seoul Metropolitan Area (1 = yes; 0 = otherwise)	0.23	0.42
Income	The interviewee's household's monthly income (the unit is million Korean won)	4.03	1.99

Table 4. Estimation results of the spike model with covariates.

Variables [a]	Coefficient Estimates	*t*-Values
Constant	−1.0550	−3.77 *
Bid [b]	−0.1030	−11.78 *
Family	0.0571	0.73
Residence	0.5933	3.24 *
Income	0.1171	2.75 *
Spike	0.5633	27.53 *
Sample sieze	600	

Notes: [a] Table 3 defines the variables. [b] The unit is Korean won, and USD 1.0 = KRW 1076. * denotes statistical meaningfulness at the 1% level.

The sign of an estimated coefficient for a particular variable was positive, which explained that the value of that variable had a positive relationship with the probability of responding "yes" to the proposed bid amount. The estimated coefficients for Residence and Income variables were statistically meaningful at the 1% level. The respondents who lived in the Seoul Metropolitan Area showed a higher likelihood of saying "yes" to a given bid than others. Wealthy respondents had a greater tendency to answer "yes" to a suggested bid than others. Since the RHI program is a normal good and, thus, increased income will increase the consumption of RH, it was natural that the coefficient for the Income variable was positive. However, the coefficient estimate for the number of family members was not statistically significant.

3.2. Discussion of the Results

In order to derive nationwide values using information derived from samples with 600 observations, it was necessary to examine the representativeness of our sample. In this study, we conducted CV surveys across the country, excluding Jeju Island, to ensure the representativeness of the sample in conducting the CV survey. Furthermore, we did not arbitrarily conduct sampling and the CV survey but spent a considerable amount of money to have a professional survey company administer the sampling and CV survey to ensure the representativeness of the sample. Therefore, it is judged that there is no problem in expanding the results of this study to the nation.

As of 2018, when the CV survey was implemented, there were 19,751,807 households in South Korea [35]. By multiplying this value by KRW 5753 (USD 5.35) per household, which was obtained in this study, we obtained a nationwide value of KRW 113.63 billion (USD 105.61 million) per year. This value corresponds to the economic value or benefits that the introduction of the RHI program provides to the South Korean people each year and needs to be compared to the costs that the introduction of the RHI program will incur. On the other hand, the costs associated with introducing the RHI program have not yet been measured and is uncertain. Thus, it is difficult to directly compare the costs and benefits of introducing the RHI program. If cost information is available later, it is necessary to compare which is larger. If the benefits outweigh the costs, the introduction of the RHI program is socially beneficial and should be implemented immediately; otherwise, it would be desirable not to do so.

4. Conclusions

The South Korean Government is considering the introduction of am RHI scheme, which establishes a goal to increase the share of RH from 1% to 20% by 2040 to expand the production of RH. This study investigated the residential consumers' acceptance of the introduction of the RHI program using a CV approach. The results revealed that the household mean WTP amounts to KRW 5753 (USD 5.35) per year. This value was statistically significantly distinguishable from zero at the 1% level.

The authors think that this research is relevant from both policy and research perspectives. First, from the policy perspective, it derived and presented a value for introducing an RHI program in South Korea, which is information that the Government desperately needs. The research found that the national value amounted to KRW 113.63 billion (USD 105.61 million) per year. This value is important information that the Government will use when developing mid- and long-term expansion plans for RH. Above all, it is clear that the level of investment needs to be increased to introduce an RHI scheme. The Government has decided to expand the use of renewables for energy transition and to introduce the use of excess heat and RH for national energy efficiency. These measures are consistent with the findings in the research.

Second, from the research perspective, this article contributes to the CV literature by applying the CV technique, an economic valuation technique, to calculate the public acceptance of the RHI program. In particular, the implications of the article will be especially beneficial, as it is the first study to be conducted in South Korea, which requires information on the consumer's acceptance of the RHI program. Of course, the framework of this article needs to be expanded further. For example, some topics, such as a comparison of our results with the consumers' acceptance derived for the other program, and the application of the framework of this study to other countries for comparison, will be fruitful. We can conclude that it seems that the South Korean residential consumers will accept the RHI program.

Meanwhile, the Government has already introduced a zero-energy mandate, including private or commercial buildings, that will be implemented starting in 2025. According to the mandate, such owners are required to use renewable energy for more than 20% of total heat consumption, and then an RH obligation for new or renovated building owners is granted. However, there is "price gap" between RH and heat from conventional fossil fuels. Thus, the important point of the RHI program is a "soft landing" in the energy market, so that a feed-in-tariff policy can contribute to a soft landing and lead to grid parity.

The paper concludes with suggestions for future research directions. Transforming electricity into heat from renewables presents lower efficiency than heating. This is an important property to consider when expending renewables. Moreover, we need to utilize several renewable energy sources, such as solar thermal, waste incineration, industrial surplus heat, and combined heat and power. In order to use RH, it is necessary to make an in-depth assessment of the effectiveness of policies using RH data. These implications can provide fundamental information for introducing an RHI program.

Author Contributions: Both authors played a significant role in writing the paper. The first author (S.-Y.L.) wrote most of the paper. The second author (S.-H.Y.) made the CV questionnaire, analyzed the CV data, and drew the implications of the results.

Funding: This research was financially supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20184030202230).

Conflicts of Interest: The authors declare no conflict of interests.

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