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Public Willingness to Pay for Increasing Photovoltaic Power Generation: The Case of Korea

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Abstract: Renewable energy receives particular attention in Korea because of concerns about climate change and scarce traditional energy resources. The government plans to enhance photovoltaic (PV) power's share of total power generation from 0.5% in 2014 to 10.1% in 2029. The present study tries to look into the public willingness to pay (WTP) for increasing PV power generation, applying the contingent valuation approach. A survey of 1000 interviewees was carried out in Korea. The observations of the WTP responses were gathered using a dichotomous choice question and analyzed employing the mixture model. The mean household WTP estimate is obtained as KRW 2183 (USD 1.9) per month, which possesses statistical significance. The total yearly WTP expanded to the population is worth KRW 476.9 billion (USD 423.1 million). These values can provide a useful basis for policy-making and decision-making about the economic feasibility of increasing PV power generation.

Keywords: public value; photovoltaic power generation; willingness to pay; contingent valuation; economic evaluation

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1. Introduction

Korea is an energy-deficit country with an energy self-sufficiency rate of only 4%, and the country's primary energy supply heavily relies on fossil fuels. For example, fossil fuels accounted for 83.0% of the total primary energy supply in Korea, including oil (38.1%), coal (29.7%), and natural gas (15.2%), in 2015 [1]. Generally, energy production from fossil fuels can lead to carbon dioxide (CO_2) emissions, which negatively affect climate change. It has been expected that renewable energy will play a major role in mitigating greenhouse gas emissions under the new climate regime [2]. Moreover, increased anxiety regarding nuclear power after the Fukuoka nuclear disaster has enlarged the demand for increasing power generation from renewable energy, one of the safe and sustainable energy sources. Thus, many countries have been fostering the diffusion of renewable energy sources [3].

Under such conditions, the Korean government [4] has been planning to increase the supply of renewable energy by utilizing the new energy business model through technology development, deregulation, and rentals. More specifically, the plan includes increasing the share of photovoltaic (PV) power in the total generation from 0.5% in 2014 to 10.1% by 2029. Lee and Huh [3] anticipated that PV will grow from 0.98 million MWh in 2012 to 18.04 million MWh in 2035 in terms of the electricity supply. Recently, the government made an ambitious plan to raise the ratio of PV and wind power generation to total generation from 0.9% in 2015 to about 16.0% by 2030. Therefore, PV power generation will increase drastically.

PV power generation is understood to be a sustainable energy system because it depends on the most abundant renewable energy sources, such as the sun. Generally, the PV power capacity can range from an ordinary residence to ten thousand houses, and its maintenance is relatively easy. For PV power generation increase, the government can implement three policy instruments: feed-in-tariff schemes for providing a premium tariff for renewable energy generation; capital subsidies for the research and development of innovative PV generation technologies; and the implementation of renewable portfolio standards (RPS), a regulatory mandate [5,6]. PV power generation increase can lead to CO_2 emission reduction, new job creation, an increase in the energy self-sufficiency rate, and the substitution of five nuclear power plants. Before implementing policy instruments, it is necessarily required to examine whether such government-driven instruments are financially feasible.

This leads to the need for an economic feasibility study into increasing PV power generation. To this end, many previous studies have carried out the economic evaluation of various PV systems [5–9]. Olivia et al. [5] estimated the marginal social value of residential PV in Australia. Rodrigues et al. [6] conducted an economic feasibility study on PV systems in 13 countries. Liu et al. [8] examined the economic benefits of PV systems. Moreover, Sandén [10] thoroughly explored the economic rationale of PV subsidies. They concluded that the current support program tends to create economic virtuous circles and institutional virtuous circles. Chaurey and Kandpal [11] gave an overview of the techno-economic viability of PV based decentralized rural electrification. Choi and Song [12] looked into PV systems in the mining industry.

There are several case studies to investigate the feasibility of renewable energy or PV in Korea [13–19]. Kim et al. [13] conducted a feasibility analysis of hybrid systems on Jeju Island in Korea. Kim et al. [15] evaluated the efficiency of the investment on renewable energy technologies. Baek et al. [16] attempted to indicate the suitable arrangement of renewable power generation in Busan, Korea. Using a real option framework, Kim et al. [18] calculated the net present value of a real-life building integrated PV project in Daejeon, Korea. Nematollahi and Kim [19] presented findings showing that the central and southern regions of Korea take higher quantities of horizontal radiation in the case of solar energy.

Several studies applied the contingent valuation (CV) method for empirically estimating the external benefit of renewable energy in the perspective of the public preference [20–30]. The goods to be valued in the studies found in the literature include green electricity, wind power, ocean energy, solid refuse fuel, bioethanol, hydrogen station, fuel cell, and PV. However, there have been a few studies of the CV approach to deal with the public WTP for increasing PV power generation. The implications of this article are useful in that the policy-makers need information on the public WTP for increasing PV power generation, to determine how much tax revenue to invest in the increase.

The public assessment of increasing PV power generation to achieve the mentioned benefits can be adopted as an appropriate guideline for decisions on establishing power transmission facilities. We can estimate public preference by assessing respondents' additional willingness to pay (WTP) for the increase. Moreover, WTP can be adopted as an indication of benefits of PV power generation. This study can contribute to raising applicability of the CV approach and laying the groundwork for evaluating policy instruments for renewable energy projects.

The current study aims to explore the public WTP for increasing PV power generation. The analysis particularly handles WTP responses of zero via the mixture model. The results will offer a reliable indication of the public value of the PV power generation increase program and help the Korean government formulate renewable energy policies. The rest of this paper is structured as follows. Section 2 explains the methodology. Section 3 provides the WTP model. The penultimate section presents the results. Section 5 deals with conclusions.

2. Methodology

2.1. Methods: CV

As addressed above, the object that this study investigates is the increase of PV power generation that can convert solar energy into electricity through semiconductors. This article tries to investigate people's WTP for increasing the PV power generation. From the literature review, we found that stated preference (SP) methods have usually been applied to carrying out such tasks. The SP methods usually ask people to state their WTP for consuming the goods or services concerned. Two representative approaches belonging to SP methods are the CV approach and choice experiment (CE) approach [20,21]. The former elicits the WTP response directly, but the latter derives the WTP responses indirectly. This study will employ the CV approach instead of the CE approach because the first is much simpler to apply than the second and the attributes required in using the CE approach are not well defined in this study.

Our research can be compared with the previous studies in four points. First, the studies that measured people's WTP for increasing the PV power generation remain scarce. Most related studies have dealt with renewable energy (e.g., [22–31]). In this regard, this study can contribute to the literature on the economic valuation of the external benefits of increasing PV power generation. In particular, there is no former study that has measured the external value of increasing PV power generation in Korea.

Second, our application of the CV technique coincides with the practice adopted in former studies dealing with this kind of research topic. Moreover, the CV technique is based on microeconomics and thus theoretically sound [32]. Since the observations obtained from this paper may be used for decision and policy making about increasing PV power generation, it is crucial to use a reasonable and sound methodology. The CV technique is not only practically useful but also theoretically robust.

Third, we tried to follow several guidelines recommended for applying the CV approach in the literature. They include the use of a dichotomous choice (DC) question, a minimum sample size of 1000, the adoption related to their actual expenditure as payment method, the declaration of the possible presence of substitutes for the goods to be investigated in the CV survey, and so on. More details will be presented in the next subsections.

Fourth, when eliciting the WTP responses, this study paid more attention to not only mitigating response bias but also augmenting the statistical efficiency. The respondents are asked just one question in the single-bounded (SB) DC method. Hence, it may suffer from low statistical efficiency. The double-bounded (DB) DC method, which requires two WTP questions, may suffer from response bias. As an alternative, the one-and-one-half-bounded (OOHB) DC method was contrived by Cooper et al. [33]. It is known to increase statistical efficiency relative to the SB DC method and reduces response bias compared to the DB DC method.

2.2. Sample and Survey Instrument

In consideration of the research budget, we decided to set the sample size at 1000. The 1000 respondents were allocated to each city proportionally to the total number of households in each city given in Statistics Korea [34]. In this regard, our sampling method was stratified random sampling. Each city constitutes a stratum. Within each city, the allocated number of households were randomly selected. The entire process of sampling and carrying out the survey was administered by a professional survey firm during March 2017. The firm sought to make sure that the sample characteristics represent the population characteristics well. An experienced specialist at the firm ran the whole process.

A pretest using a focus group of thirty persons was implemented with an earlier version of the survey instrument to examine whether it is understandable and sufficiently clear for the interviewees to complete the survey questionnaire. The outcomes of in-depth interviews with the focus group have been utilized to fully correct the questionnaires for use in the main survey. The first part presents the background and objective of the survey. The second part includes several questions deriving the interviewees' opinions and judgment regarding PV generation increase. The third part deals with the questions about the WTP for increasing PV generation. Some questions about the respondents' characteristics are given in the final part.

2.3. How to Elicit WTP

As explained above, this article adopted an OOHB DC question for the purpose of eliciting the WTP responses. The DC question was originally recommended for use in the field CV survey by a number of studies. The main reason for the recommendation is that it can reduce the respondents' burden of answering the WTP question and derive an incentive-compatible response from interviewees [35]. The DC question is quite simple. The only work for a respondent to do is to state "yes" or "no" to a given bid amount. The respondent will report "yes" if her/his WTP for increasing PV generation is more than or equal to offered bid and "no" otherwise. On the other hand, an open-ended question of directly asking the WTP value is not preferred to the DC question in the literature because the former can induce a number of protest WTP responses [32,36,37]. The OOHB DC format has the merit of taking only the preferential features of the SB and DB DC formats.

One complication involved in applying the CV is that it puts people in a hypothetical situation and thus the respondents can have difficulties in stating their true WTP. An appropriate payment can help the respondents confronted with the hypothetical situation to report their WTP making them feel as if they were in the real world. Some examples of the payment vehicle include a tax such as income tax or property tax, a donation, a fund, a usage fee, and so on. The payment vehicle should be related to the funds used for enforcing the policy, should not be confined to routine expenditure, and should be familiar to people. We decided that the payment vehicle meeting these conditions is monthly electricity bills.

3. WTP Model

3.1. Mixture Model

To model WTP responses, the utility difference method indicates Hicksian compensated surplus [35]. On the other hand, the WTP function method stipulates such responses as a dependent variable [38]. However, given that the two methods have the same meaning in terms of economics, the selection between the two methods depends on researchers' tendency [39]. The utility difference method is employed here, since the former has been more frequently used in the literature than the latter.

Some people will pay attention to the increase of photovoltaic power generation, but others are thoroughly unconcerned with or attach no significance to such project. This situation may lead to high proportion of zero WTP responses. Researchers need to take note of addressing WTP responses of zero. Thus, we employ a mixture model which utilizes the mixture of the two distributions. The first is point mass at zero and the second is a distribution defined over positive real number.

Let the WTP, Z, be the random variable, and $k(Z;\omega)$ is the probability density function (pdf), where $K(0;\omega) = 0$. Moreover, σ is assumed to be the probability of zero WTP responses, and $f(Z;\omega)$ and $F(Z;\omega)$ are the pdf and cdf of Z. The pdf of the WTP takes the following:

$$f(Z;\omega) = \begin{cases} 0, & \text{if } Z < 0 \\ \sigma, & \text{if } Z = 0 \\ (1-\sigma)k(Z;\omega), & \text{if } Z > 0 \end{cases} \tag{1}$$

Moreover, $F(Z;\omega)$ is expressed as:

$$F(Z;\omega) = \sigma + (1-\sigma)K(Z;\omega), \quad Z \geq 0 \tag{2}$$

In Equation (2), the probability of a zero WTP means σ and the probability of a positive WTP comes from $K(Z;\omega)$ with $1-\sigma$. Given that σ must be placed from zero to one, we specify σ as logistic distribution:

$$\sigma = \frac{\exp(\lambda)}{1+\exp(\lambda)} \tag{3}$$

In accordance with previous studies, we specify the positive WTP as Weibull:

$$K(B;\omega) = K(B;\alpha,\beta) = 1 - \exp(-\beta B^{\alpha}) \quad (4)$$

where B is the suggested bid amount. Then, the mean WTP is calculated as:

$$\begin{aligned} E(Z) &= \int_0^{\infty} [1 - F(B;\sigma,\alpha,\beta)]dB - \int_{-\infty}^{0} F(B;\sigma,\alpha,\beta)dB \\ &= (1-\sigma)\left(\frac{1}{\beta}\right)^{1/\alpha}\Gamma\left(1+\frac{1}{\alpha}\right) \end{aligned} \quad (5)$$

where $\Gamma(\cdot)$ is a gamma distribution:

$$\Gamma(t) = \int_0^{\infty} y^{t-1}\exp(-y)dy \quad (6)$$

We can estimate the case with covariates. Firstly, λ in Equation (3) is replaced with $x'\theta$ where x and θ are covariates and parameters, respectively. Next, β in Equation (4) is changed with $u'\gamma$ where u and γ are covariates and parameters.

3.2. OOHB DC Model

Cooper et al. [33] suggested an approach to model the OOHB DC CV data. A_j is defined as a bid presented to respondent j. Before implementing the field CV survey, we need to determine several sets of two bids, A_j^L and A_j^U ($A_j^L < A_j^U$). A set is randomly selected from several sets and presented to each interviewee. Each set is composed of A_j^L and A_j^U. About half of the respondents in a group who receive the same set are asked to state "yes" or "no" to the payment of A_j^L. If the response is "yes," a further question about whether they are willing to pay A_j^U or not is asked. When the answer to the payment of A_j^L is "no," the additional question is needless. The other half of the respondents are presented with a question about the payment of A_j^U. If the response is "no," a follow-up question about whether they are willing to pay A_j^L or not is asked. If the answer to the payment of A_j^U is "yes," the succeeding question is not required.

Let Y_j be the interviewee's WTP. Three responses, "yes-yes" ($Y_j > A_j^U$), "yes-no" ($A_j^L < Y_j < A_j^U$), and "no" ($Y_j < A_j^L$) can emerge from the situation where A_j^L is offered first. One of three responses, "yes" ($Y_j > A_j^U$), "no-yes" ($A_j^L < Y_j < A_j^U$), and "no-no" ($Y_j < A_j^L$) can occur in the case that A_j^U is given first. Therefore, there can be six kinds of responses. Let I_j^{YY}, I_j^{YN}, I_j^{N}, I_j^{Y}, I_j^{NY}, and I_j^{NN} be binary variables which correspond to the six kinds of responses. For instance, I_j^{YY} is one if the jth interviewee says "yes-yes" and zero otherwise.

4. Results and Discussion

4.1. Data

The list of sets of A_j^L and A_j^U used in the CV survey is as follows: KRW 1000/3000, 2000/4000, 3000/6000, 4000/8000, 6000/10,000, 8000/12,000, and 10,000/15,000. USD 1.0 equaled KRW 1134 when the survey was performed. The list of bids was determined through the focus group interview of thirty individuals as follows: first, we asked the WTP for the increase and obtained a set of WTP values; second, we deleted zero WTP values and then sorted the remaining positive WTP values to look into empirical distribution; third, some bids were selected from the distribution. The WTP question presented to the respondents was "Is your household willing to pay a given additional bid each month for ten years in electricity bills for increasing PV power generation?" One of the seven sets of A_j^L and A_j^U was randomly offered to the interviewees.

Finally, 1000 useable observations were obtained from the CV survey. Table 1 summarizes the interviewees' responses to each set of bids. Overall, 34, 60, 135, and 271, 62, 49, 120, and 269 interviewees gave "yes-yes", "yes-no", "no-yes", "no-no", "yes", "no-yes", "no-no-yes", and "no-no-no" responses, respectively. Out of the 1,000 respondents, 540 said they had no intention of paying a penny ("no-no" and "no-no-no" responses).

Table 1. The number of the interviewees' responses to each set of bids.

Bid Amount [a]		Lower Bid Given as the First Bid (%) [b]				Upper Bid Given as the First Bid (%) [b]				Sample Size
		"yes-yes"	"yes-no"	"no-yes"	"no-no"	"yes"	"no-yes"	"no-no-yes"	"no-no-no"	
1000	3000	10 (13.9)	24 (33.3)	10 (13.9)	28 (38.9)	19 (26.8)	12 (16.9)	7 (9.9)	33 (46.5)	143 (100.0)
2000	4000	9 (12.7)	6 (8.5)	16 (22.5)	40 (56.3)	10 (13.9)	7 (9.7)	22 (30.6)	33 (45.8)	143 (100.0)
3000	6000	4 (5.6)	10 (14.1)	15 (21.1)	42 (59.2)	10 (13.9)	13 (18.1)	14 (19.4)	35 (48.6)	143 (100.0)
4000	8000	1 (1.4)	7 (9.7)	23 (31.9)	41 (56.9)	6 (8.5)	8 (11.3)	13 (18.3)	44 (62.0)	143 (100.0)
6000	10,000	1 (1.4)	4 (5.6)	27 (38.0)	39 (54.9)	10 (14.1)	2 (2.8)	21 (29.6)	38 (53.5)	142 (100.0)
8000	12,000	5 (7.0)	5 (7.0)	21 (29.6)	40 (56.3)	5 (7.0)	3 (4.2)	18 (25.4)	45 (63.4)	142 (100.0)
10,000	15,000	4 (5.6)	4 (5.6)	23 (31.9)	41 (56.9)	2 (2.8)	4 (5.6)	25 (34.7)	41 (56.9)	144 (100.0)
Sample size		34 (6.8)	60 (12.0)	135 (27.0)	271 (54.2)	62 (12.4)	49 (9.8)	120 (24.0)	269 (53.8)	1000 (100.0)

Notes: [a] The unit is KRW (USD 1.0 = KRW 1134 at the time of the survey). [b] The percentage of sample size is given in parentheses beside the number of responses.

4.2. Estimation Results

Table 2 depicts the sample statistics of the socioeconomic variables of the respondents. Half of the respondents were male. The mean age and education levels were 45.5 years and 13.9 years, respectively. The average monthly household income was about KRW 4.16 million (USD 3668), which approximates the published average household income in Korea for 2017, KRW 4.59 million (USD 4048).

Table 2. Description of the variables.

Variables	Definitions	Mean	Standard Deviation
Gender	Gender of respondent (1 = male; 0 = female)	0.50	0.50
Age	Age of respondent	45.52	8.89
Education	Education level of the respondent in years	13.91	2.42
Income	Monthly household income before taxes (unit: KRW one million)	4.16	2.00

Table 3 shows the estimation results of the OOHB DC mixture model. All the parameter estimates have statistical meaningfulness at the 1% level. Particularly, the estimate for σ is 0.5400. This value is close to the fraction of zero WTP observations in Table 1 (54.0%). This implies that the mixture model used in this article fits the data well. The mean monthly WTP is obtained as KRW 2183 (USD 1.9) per household. To address the uncertainty related to the point estimate, in Table 3 we present its 95% confidence interval computed adopting the bootstrapping approach with 5000 iterations [40].

Moreover, the estimation results of the model with covariates are shown in Table 4. We have three models with covariates: Model A with $x'\theta$ instead of λ, Model B with $u'\gamma$ instead of β, and Model C with both $x'\theta$ and $u'\gamma$. Some variables such as gender, age, education, and income were included as covariates. There are two sections in Table 4: the first part describes coefficient estimates for the probability of reporting a positive WTP, and the second part presents coefficient estimates for the positive distribution of WTP [39]. Respondents with higher education level have a tendency for nonzero WTP and are likely to admit a suggested bid level. In addition, respondents with higher incomes tend to accommodate a bid level gradually. The parameter estimates of the covariate Age were found to statistically insignificant.

Table 3. Estimation results of the model.

Parameters	Estimates [d]
α	0.8265 (13.13) **
β	0.3004 (7.66) **
λ	0.1603 (2.53) *
σ	0.5400 (34.26) **
Mean WTP	KRW 2183 (USD 1.9)
t-value [a]	13.16 **
95% confidence interval [b]	KRW 1947 to 2522
Sample size	1000
Log-likelihood	−1126.02
Wald statistic (*p*-value) [c]	2417.81 (0.00) **

Notes: [a] The numbers in parentheses beside the coefficients are the *t*-values. [b] It is derived by the use of Monte Carlo simulation approach with 5000 iterations. [c] It is computed under the null hypothesis of all the parameters' being jointly zero. The *p*-value is presented in the parentheses beside the statistic. [d] The values reported in parentheses beside the coefficient estimates are *t*-values. * and ** mean statistical significance at the 5% and 1% levels, respectively.

Table 4. Estimation results of the model with covariates.

Parameters	Model A	Model B	Model C
α	0.8265 (13.09) **	0.8293 (13.00) **	0.8293 (12.99) **
β	0.3005 (7.63) **		
Constant		0.5796 (3.04) **	0.5796 (3.04) **
Gender	-	−0.0188 (−0.55)	−0.0188 (−0.55)
Age	-	−0.0012 (−0.52)	−0.0012 (−0.52)
Education	-	−0.0161 (−2.01) *	−0.0161 (−2.00) *
Income	-	0.0026 (0.32)	0.0026 (0.32)
λ		0.1603 (2.53) *	
Constant	1.7830 (2.65) **		1.7829 (2.66) **
Gender	0.2965 (2.26) *	-	0.2965 (2.25) *
Age	−0.0096 (−1.15)	-	−0.0096 (−1.15)
Education	−0.0672 (−2.13) *	-	−0.0672 (−2.13) *
Income	−0.0951 (−2.68) **	-	−0.0951 (−2.67) **
σ	0.5410 (33.93) **	0.540 (34.26) **	0.541 (33.93) **
Mean WTP	KRW 2180	KRW 2137	KRW 2134
t-value[a]	13.11 **	13.30 **	13.27 **
Number of observations	1,000	1000	1000
Log-likelihood	−1115.34	−1123.58	−1112.90
Wald statistic (*p*-value) [b]	2433.02 (0.00) **	2470.05 (0.00) **	2498.62 (0.00) **

Notes: [a] The values reported in parentheses beside the coefficient estimates are *t*-values. [b] It is computed under the null hypothesis of all the parameters' being jointly zero. The *p*-value is presented in the parentheses beside the statistic. * and ** mean statistical meaningfulness at the 5% and 1% levels, respectively.

4.3. Discussion of the Results

It is necessary to expand the finding for the sample to that for the population. When the survey was conducted, Korea had 19,523,587 households [34]. However, the number of households observed here is just one thousand. Therefore, the representativeness of our sample should be examined. That is, whether our sample represents the population well or not is the key to obtaining information for the population. This study tries to address this issue in two aspects before the expansion is performed. First, random sampling in gathering the data is quite important to the expansion. As explained above, a professional survey company that has rich experience of field CV surveys conducted the entire process of the sampling, thereby guaranteeing that the sample maintains a representative nature. The sample size of 1000 is appropriate as it meets the criteria of sample size recommended by Arrow et al. [41].

Second, whether some variables for the sample are similar to those for the population or not should be examined. In this regard, the ratio of female respondents, and the monthly income of the household, are looked into here. The sample averages for the variables were 50.0%, KRW 4.16 million. The population averages were 50.0%, KRW 4.59 million when the survey was conducted [34]. Interestingly, it seems that there are no significant gaps between the two values for each variable. This finding makes the representativeness of our sample even stronger. Thus, the findings from the sample can be expanded to an inference of the population values.

The setting of the covariates may influence the mean WTP estimate when we apply the model with covariates. Therefore, the mean WTP found in the model without covariates is used. When the yearly value concerning the first and the total number of households in Korea are used, we can compute the total WTP, expanded to the relevant population. It was found that the population's WTP for increasing PV power generation in Korea is KRW 511.2 billion (USD 451.2 million) per annum.

The estimation results could be used for various indicators. We can integrate them into the computing of the overall economic benefits of consuming electricity generated from PV. Through electricity consumption, people will obtain private and external benefits. PV power can generate greater external benefits in respect to mitigating CO_2 emissions and assuring environmental protection than fossil fuels. We can readily measure private benefits elicited from electricity consumption. However, the estimation of external benefits may have a problem, given that they occur outside the market. Despite such a difficulty, the present study appraised the external benefits of increasing PV power generation.

The estimated mean WTP can be taken as the external benefit or premium of PV generation over traditional fossil fuel generation. If the additional PV generation cost arising compared with traditional fossil fuel generation is less than the premium, PV generation can be enforced easily. If not, an additional task is required to guarantee for executing the increase of PV generation. For instance, this might encompass allocating PV in the RPS and restoring the feed-in tariff. Moreover, diverse tax reductions or credits and other incentives, such as subsidies, could be made available to foster PV power generation. For example, sound incentives for the technology development for manufacturing PV economically and the enlargement of PV-producing equipment should be offered.

5. Conclusions

Recently, Korea, the seventh-largest CO_2 emitter in the world, announced its 2030 mitigation target of 37% from the business-as-usual level. Therefore, the Korean Government devised a plan to increasing the PV power generation share from 0.5% in 2014 to 10.10% by the year 2029 as part of their efforts to reduce CO_2 emissions. This article applied a CV technique to evaluating household WTP for increasing PV power generation. The estimate for the mean monthly WTP for the increase was KRW 2183 (USD 1.9) per household. It has statistical significance at the 1% level. Moreover, the sample reflected the population well. Expanding the value to the nation resulted in KRW 511.2 billion (USD 451.2 million) per annum.

The estimated results have overarching policy implications on the renewable energy such as PV power generation. The total PV generation amounted to 1800 GWh and the domestic wholesale market size of the PV generation was KRW 362.9 billion (USD 320.0 million) in 2016. The annual total WTP was calculated to be KRW 511.2 billion (USD 451.2 million). Thus, the total WTP for the increase is 1.5 times as big as the market size in 2016. It seems that the Korean people place relatively high value on increasing the PV generation.

Moreover, the analysis indicates an appropriate range of the uptake of the CV method for evaluating the renewable energy diffusion programs. Given that half of respondents stated zero WTP for increasing PV power generation, the Korean government should exert efforts to raise the people's understanding regarding the merits of PV. The research framework can provide the foundation for carrying out preliminary feasibility studies of renewable energy projects in Korea. The overall results can serve as a solid foundation of the benefits of the PV power generation increase. The findings can be applied to set priorities for investment projects, because the execution of projects with more benefits within limited budget is preferred. This study will activate future research in renewable energy field, which will help formulate policies on the renewable energy.

One point to note in interpreting the results is that the value measured in this study implies an intention rather than actual payment. There is no guarantee that the WTP amount will be actually paid as stated in the CV survey. Thus, the WTP value obtained in this study should be accepted as the upper bound of the public value arising from increasing the PV generation rather than achievable tax revenue gathered from Koreans. People's actual payment can be less than the total WTP value. The mean WTP estimate reported above was based on a parametric approach based on two assumptions: first, the form of the utility difference function is linear; second, the WTP value is specified as the mixture of the two distributions. The two assumptions may be too restrictive to be satisfied and thus relaxing or avoiding them may produce the mean WTP estimate that is significantly different from KRW 2183 (USD 1.9).

This article aimed to contribute to the current literature by deriving the household WTP for increasing the PV generation in Korea and evaluating the public value of the increase. The study provided empirical evidence that the CV approach theoretically grounded in microeconomics could be successfully utilized in measuring the national public value of the increase. The authors consider that the framework of the study can be extended in future studies in several ways. For example, it is necessary to examine how the value varies as time passes by conducting the CV survey every year for some years and analyzing the CV data. Identifying the socio-economic factors affecting the level of WTP and the degree of the affection can present a new point of view. It will be also interesting to compare the WTP estimate from Koreans with the WTP estimates from other countries. In addition, analyzing the WTP data and the determinants of the WTP amount can be done through a cross-country analysis. As mentioned above, this study applied parametric approach to obtaining the WTP estimate. However, semi-parametric or semi-nonparametric approach relaxing or avoiding the two parametric assumptions can provide more robust estimate of mean WTP.

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