

Communication

Evaluating Residential Consumers' Willingness to Pay to Avoid Power Outages in South Korea

Ju-Hee Kim, Kyung-Kyu Lim and Seung-Hoon Yoo * 

Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 01811, Korea; jhkim0508@seoultech.ac.kr (J.-H.K.); kklm@seoultech.ac.kr (K.-K.L.)

* Correspondence: shyoo@seoultech.ac.kr; Tel.: +82-2-970-6802

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Abstract: South Korea experienced a nationwide rolling blackout in 2011 due to a rapid increase in the power demand and a lack of power supply facilities. In particular, the residential sector suffered from considerable inconveniences due to power outages, such as the interruption of elevators' operation and the stopping of all electronic appliances. Since then, ensuring a stable supply of electricity has emerged as an important task. This note aims to analyze residential consumers' willingness to pay (WTP) to avoid power outages. For this purpose, 1000 households were surveyed, applying the contingent valuation (CV) method during May 2018. The respondents understood the CV question well and gave meaningful answers. The results show that the mean of households' monthly WTP amounts to KRW 1522 (USD 1.41). This value is statistically significant. Converting it into an annual value and then expanding the value to the country indicate that the annual national value amounts to KRW 360.7 billion (USD 335.3 million). Since a substantial amount of investments should be made by power suppliers to prevent power outages in the residential sector, this value may be accepted as the upper limit of the benefits ensuing from those investments.

Keywords: rolling blackout; power outage; willingness to pay; residential consumer; contingent valuation

1. Introduction

South Korea, currently a member of the OECD, was a developing country in the past but has now become one of the developed countries. The country's dramatic economic growth over a short period of time has been backed up by a stable energy supply, like electricity. However, in 2011, the country underwent national rolling blackouts because of an electricity supply shortage. In particular, the residential sector suffered major inconveniences due to power outages, such as the suspension of the use of elevators and electronic appliances. Since then, improving the reliability of the electricity supply has become quite an important task to undertake [1].

The South Korean government faces challenges in setting its energy policy to support economic growth. The rapid increase in the power demand raised the challenge of securing stability in the power supply. In particular, expansion to provide sufficient power supply facilities has appeared as one of the most important national tasks, as power peaks have risen in recent years due to colder winters and hotter summers following climate change [2–5]. The electricity prices are capped to control inflation, as well as to promote industry development. The intentionally lowered price has caused enterprises and households to consume more electricity instead of using other primary energy sources, such as oil, coal, and natural gas [6].

Thus, high electricity intensity leads to complications in the demand forecasting and a lack of supply facilities. Moreover, power suppliers are facing a serious deficit due to electricity tariff controls

by supplying electricity at controlled prices that are below the price paid to purchase the supplies. In many cases, this pricing policy has prevented full cost recovery and has made electricity providers reduce their investment in the electricity supply infrastructure. To secure the stability of the power supply, investment is needed.

Investment to secure the stability of the power supply is needed in the three sectors: generation, transmission, and distribution. First, in the power generation sector, the South Korean government continues to invest in the construction of additional power plants, with the goal of a reserve rate for power generation of 22% by 2030. Particularly, gas-fired power plants, pumping-up power generation, and energy storage systems should be expanded to overcome the intermittent and uncertain nature of the power generation from renewable energy, since renewable energy will increase in coming years. Second, in the power transmission sector, there are some cases where the power plants cannot be operated due to transmission constraints due to deterioration of residents' acceptability. In addition, the construction of new substation is occasionally confronted by public opposition because substations are considered as an unpleasant facility. Thus, power supply stability is deteriorating due to the conflict surrounding the power transmission sector. Third, in the power distribution sector, there may be a blackout due to traffic accidents involving telephone poles, and excavation works that cut off underground distribution lines. Furthermore, a blackout can occur due to a magpie building a nest on a telephone pole. In order to overcome these problems, undergroundization and double wiring of pipelines and removal of magpie nests are being carried out and should continue to be implemented in the future. Therefore, information on residential consumers' evaluation of the economic benefits of avoiding power outage is required for securing stability of power supply [7–10]. In the economics sense, the benefits of consuming a good or a service should be assessed as the willingness to pay (WTP) for the consumption.

More specifically, this article aims to analyze residential consumers' WTP to avoid power outages. For this purpose, 1000 households were surveyed, applying the contingent valuation (CV) method, during May 2018 [11]. Arrow et al. [12] provided several recommendations and explained that reliable estimates can be gained through the CV method if several conditions are met and the results can be the basis of decision making. Furthermore, they emphasized respondents' familiarity with the good to be evaluated and professional interviewing skills for the purpose of obtaining more precise results [13–16]. This study was carefully designed under these conditions. The remainder of this article comprises three components. The methodology employed in the article is explained in Section 2. Section 3 deals with the data and the empirical results and provides a discussion. The conclusions are presented in Section 4.

2. Methodology

2.1. Literature Review on Power Outage Cost in the Residential Sector

There are two approaches to measuring power outage costs [9]. First, we can assess the economic damage that non-household consumers suffer in the event of power outages or shortage [9]. Non-household consumers include businesses, public entities, and non-governmental organizations. Information about the economic activities of non-household consumers and the decrease in value caused by power outages is required for assessing non-households' economic damage. Second, we can evaluate household consumers' WTP to avoid power outages. There are several studies which concentrated on power outage cost in the residential sector, and most of those studies used a second method. The choice experiment (CE) and CV method are utilized representatively to evaluate household consumers' WTP to avoid power outages as the second method. A summary of previous studies dealing with the household consumers' WTP for avoiding power outages is reported in Table 1.

Table 1. Summary of previous studies addressing household consumers' willingness to pay (WTP) to avoid power outages.

Countries	Sources	Methodologies ^a	Mean WTP
Australia	Hensher et al. [10]	CE	For avoiding a power spike/surge: USD 32 For avoiding a momentary outage: USD 23 For avoiding flicker: USD 8.83
England	Morrissey et al. [17]	CE	For avoiding power outages in peak periods: GBP 5.29 For having power outages during the week rather than the weekend or bank holiday: GBP 7.37 For avoiding power outages in winter: GBP 31.37 For reducing unplanned power outages of 4 hours: SEK 21.54
Sweden	Carlsson and Martinsson [18]	CE	For reducing unplanned power outages of 8 hours: SEK 60.60
Australia	Reichl et al. [9]	CV	The residents' average outage cost: EUR 1.4/hour
Hong Kong	Woo et al. [19]	CV	The residents' average outage cost: USD 45/hour
North Cyprus	Ozbaflı and Jenkins [20]	CV	For improving reliability of the electricity service: a 13.8% increase in a household' monthly electricity bill

Notes: ^a CV and CE imply contingent valuation and choice experiment, respectively.

The studies using CE focused on a method to assess complex trade-offs between attributes. For example, Hensher et al. [10] explored the household's WTP to avoid specific restrictions on service supply quality in residential electricity. Morrissey et al. [17] examined the households' WTP for avoiding a power outage depending on the length of the power outage. Carlsson and Martinsson [18] estimated the Swedish households' marginal WTP for reducing unplanned power outages.

In Table 1, the studies utilizing CV method concentrated on the valuation of increased reliability of electricity supply by preventing power outages. Reichl et al. [9] applied a proxy method which finds the lost value added for non-household consumers, while CV method was used to elicit households' WTP to avoid power cuts. Woo et al. [19] assessed residential preferences for the reliability of electricity. Ozbaflı and Jenkins [20] examined households' WTP for an improved electricity service.

2.2. Method: CV Approach

The CV approach can be applied to measure consumers' WTP to consume a good or service [21]. Similarly, consumers' WTP to avoid power outages can be elicited through the application of the CV method. The use of the CV technique is conceptually correct in the measurement of economic benefits [11,22–25]. The CV method directly asks respondents to determine their WTP contingent on a proposed situation. Arrow et al. [12] proposed several measures to ensure that a CV study is valid and accurate. First, for instance, the CV survey should be based on person-to-person interview, neither telephone nor postal interviews. In this study, a professional survey firm conducted the CV survey by person-to-person interview [13–16]. Second, it is desirable to measure WTP rather than WTA in the CV study. Thus, we estimated WTP in this study. Third, it is suggested that the dichotomous choice (DC) question should be used as a payment method, and the DC question was used in this study. Fourth, a detailed and persuasive explanation of the goods to be valued and its expected effect should be provided in the CV survey. We conveyed the details to the respondents by using newspaper articles, color pictures, and well-made presentation materials during the CV survey. Fifth, it should be recognized that respondents should reduce expenditure on other goods by the payment of WTP in the CV survey. A statement concerning payment is provided in the survey questionnaire. For example, the respondents are told: "Please consider that your household's income is limited, and it should be spent for multiple purposes." Sixth, there should be additional questions to ensure that the respondents understood the question correctly and answered it rationally in the CV survey. We have asked the respondents additional questions about the extent to which they thought the economic damage from the blackout and confirmed the adequacy of the overall survey responses through the additional questions.

For the purpose of conducting a CV study, the baseline state as a starting point, the target state as a destination, and the policy instruments to reach a destination from the starting point are needed. The baseline state indicates a situation in which power outages may occur for many reasons. In South Korea, the number of power outages has been gradually decreasing from 544 in 2015, 520 in 2016, and 509 in 2017, but so far, power outages continue to occur occasionally. The target state implies a situation in which power outages never happen. To this end, some policy instruments, which contain demand regulation through the adjustment of electricity rates, the construction of additional power supply facilities, and the improvement of residents' acceptance of the upgrading of the national grid's condition will be implemented as a means to achieve the goal of stable electricity supply. These were appropriately and sufficiently communicated to the respondents in the CV survey.

2.3. DC Question

The stated preference techniques based on survey require individuals to give economic value to the goods presented in a hypothetical scenario [26]. A DC question is widely used for deriving a WTP response. Generally, there are three types of DC question methods: the single-bounded, double-bounded, and one-and-one-half-bounded (OOHB) DC question methods. The first method requires the respondent to select "yes" or "no" only once. It is simple and convenient but not statistically efficient compared with the second method. The second method is made up of two single questions. The first question is similar to the first method, and the response to the first question determines the type of the second question. Thus, the second question provides the respondents with a higher bid than the first bid if they answer "yes." Otherwise, the second question asks whether they accept the lower bid. Whereas the estimates resulting from the second method can gain statistical efficiency, the second method may generate inconsistency due to the correlation between the first bid and the second bid [27–29] and can cause a compliance issue [30].

The OOHB DC question method provided by Cooper et al. [28] is able to resolve problems such as the inefficiency of the first method and the inconsistency of the second method. The merits of the OOHB DC format have promoted its application in a substantial number of previous studies [31–36]. Consequently, this article utilizes the OOHB DC question method. Two bids, of which one is higher than the other, are used in the OOHB DC question. Let T^L and T^H be lower and higher bids. If a T^L is presented to an interviewee first and the answer is "yes," a T^H is additionally offered to the interviewee. If a T^L is presented to an interviewee first and the answer is "no," no additional question is offered to the interviewee. When a T^H is presented to an interviewee first and the answer is "no," a T^L is additionally offered to the interviewee. If a T^H is presented to an interviewee first and the answer is "yes," no additional question is offered to the interviewee. The OOHB DC format is described in Figure 1.

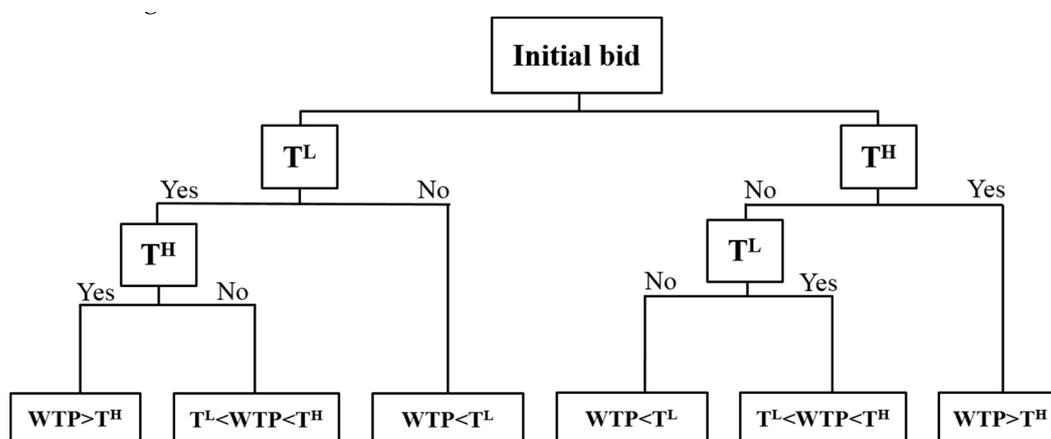


Figure 1. Flowchart of one-and-one-half-bounded dichotomous choice question for deriving a willingness to pay (WTP) response.

2.4. OOHB DC Spike Model

The following explanation is based on a utility difference approach [37]. An interviewee will say “yes” to a suggested bid, T , if the following condition meets [15,37]:

$$V(Y, I - T; D) + \lambda_Y \geq V(N, I; D) + \lambda_N \quad (1)$$

where N and Y indicate the states in which power outages may occur and never occur, respectively, V is an indirect utility function, I is the household’s income, D is the household’s socio-demographic characteristics, and the λ s are the error terms. The utility difference function takes the following form [15,37]:

$$\Delta V = V(Y, I - T; D) - V(N, I; D) \geq \lambda_N - \lambda_Y. \quad (2)$$

If ΔV is positive, the respondent may say “yes.” Thus, the following relationship can be derived [15,37]:

$$\Pr(\text{“yes”}) = \Pr(W \geq T) = 1 - F_W(T) \quad (3)$$

where W and $F_W(\cdot)$ are the interviewee’s WTP and the cumulative distribution function (cdf) of W .

There are R respondents. T presented to respondent s is expressed as T_s for $s = 1, \dots, R$. Let T_s^L and T_s^H be lower and higher bids. If T_s^L is offered to the respondent first, “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 [32]. Thus, a total of six indicator variables can emerge from the OOHB DC question format. Hence, E_s^{YY} , E_s^{YN} , E_s^N , E_s^Y , E_s^{NY} , and E_s^{NN} are introduced as follows [31–33]:

$$\begin{aligned} E_s^{YY} &= \mathbf{1}(\text{sth interviewee's answer is “yes-yes”}) \\ E_s^{YN} &= \mathbf{1}(\text{sth interviewee's answer is “yes-no”}) \\ E_s^N &= \mathbf{1}(\text{sth interviewee's answer is “no”}) \\ E_s^Y &= \mathbf{1}(\text{sth interviewee's answer is “yes”}) \\ E_s^{NY} &= \mathbf{1}(\text{sth interviewee's answer is “no-yes”}) \\ E_s^{NN} &= \mathbf{1}(\text{sth interviewee's answer is “no-no”}) \end{aligned} \quad (4)$$

where $\mathbf{1}(\cdot)$ is an indicator function [31]. It has a value of one if the proposition in the parentheses is true and a value of zero otherwise.

An interviewee who responds “no-no” to T_s^H or “no” to T_s^L is given a follow-up question asking whether she/he has the intention to pay nothing [31]. If the response is “yes,” $0 < W_s < T_s^L$ comes into effect and otherwise $W_s = 0$. To reflect these points, additional indicator variables are considered as follows [31,38]:

$$\begin{aligned} E_s^{TY} &= \mathbf{1}(\text{sth interviewee's answer to the additional question is “yes”}) \\ E_s^{TN} &= \mathbf{1}(\text{sth interviewee's answer to the additional question is “no”}) \end{aligned} \quad (5)$$

Thus, the log-likelihood function derived for the OOHB DC spike model is [6,15,31,38,39]:

$$\begin{aligned} \ln L = & \sum_{s=1}^R \{ (E_s^{YY} + E_s^Y) \ln[1 - F_W(T_s^U; \varphi_0, \varphi_1)] \\ & + (E_s^{YN} + E_s^{NY}) \ln[F_W(T_s^U; \varphi_0, \varphi_1) - F_W(T_s^L; \varphi_0, \varphi_1)] \\ & + E_s^{TY} (E_s^N + E_s^{NN}) \ln[F_W(T_s^L; \varphi_0, \varphi_1) - F_W(0; \varphi_0, \varphi_1)] \\ & + E_s^{TN} (E_s^N + E_s^{NN}) \ln F_W(0; \varphi_0, \varphi_1) \} \end{aligned} \quad (6)$$

In the spike model, $F_W(T; \varphi_0, \varphi_1)$ is assumed as [31,38]:

$$F_W(T; \varphi_0, \varphi_1) = \begin{cases} [1 + \exp(\varphi_0 - \varphi_1 T)]^{-1} & \text{if } T > 0 \\ [1 + \exp(\varphi_0)]^{-1} & \text{if } T = 0 \\ 0 & \text{if } T < 0 \end{cases} \quad (7)$$

The probability of $W_s = 0$ is usually called the spike, which corresponds to $[1 + \exp(\varphi_0)]^{-1}$ in Equation (7) [39]. Since our main concern is to measure the mean WTP, we need to compute it from $F_W(T; \varphi_0, \varphi_1)$. If a well-known formula for the mean calculated from a cdf is used, we obtain the mean WTP as $(1/\varphi_1)\ln[1 + \exp(\varphi_0)]$ [31,37,38]. If one needs to consider some covariates, φ_0 can be substituted with $\varphi_0 + z_s'\theta$ in Equation (7), where θ is a vector of coefficients that correspond to a vector of covariates, z_s .

3. Results

3.1. Data

As mentioned above, a survey of 1000 interviewees was implemented to gather the data. A professional polling company managed the entire process of the nationwide survey during May 2018. For example, supervisors from the company trained interviewers and conducted stratified random sampling matching the characteristics of the population. Furthermore, following Arrow et al.'s [12] recommendation, the survey was implemented through person-to-person interviews.

The results of a focus group interview administered to 100 individuals enabled us to modify and supplement the early version of the CV survey instrument. The finalized survey instrument comprises three sections. The first section presents an explanation of the aim and scope of the survey to the interviewees and questions them about their perceptions related to the power supply. The second section deals with the collection of information about WTP in earnest, explaining the meaning and principle of additional payments and then asking whether they would be willing to pay the amounts presented. The third section relates to the collection of personal information about the respondents, asking questions about their age, income level, gender, education level, and so on. The payment vehicle of the WTP question is households' electricity bills.

A distribution for the WTP values collected through open-ended questions in a pre-test of the focus group was created and then the range and number of suggested bid amounts were determined using a trimmed distribution that cuts a percentage at each end of the WTP distribution. One of the finally determined bid amounts was randomly presented to each respondent. The sets of lower and higher bids in Korean won are the following: (1000, 3000), (2000, 4000), (3000, 6000), (4000, 8000), (6000, 10,000), (8000, 12,000), and (10,000, 15,000). When the survey was implemented, the exchange rate was USD 1 = KRW 1076. The distribution of responses to the bid amounts presented to the respondents is shown in Table 2. About 65.0% of all the respondents were found to have no intention of paying only 1 Korean won to avoid power outages. Therefore, it can be seen that applying the spike model is an appropriate strategy.

Table 2. Summary of the responses to willingness to pay questions.

Bid Amount ^a		Higher Bid Is Given First (%) ^b				Lower Bid Is Given First (%) ^b				Sample Size
		"Yes-Yes"	"Yes-No"	"No-Yes"	"No-No"	"Yes"	"No-Yes"	"No-No-Yes"	"No-No-No"	
1000	3000	8 (11.1)	19 (26.4)	7 (9.7)	38 (52.8)	9 (12.7)	17 (23.9)	4 (5.6)	41 (57.7)	143 (100.0)
2000	4000	5 (7.0)	13 (18.3)	8 (11.3)	45 (63.4)	8 (11.1)	7 (9.7)	6 (8.3)	51 (70.8)	143 (100.0)
3000	6000	3 (4.2)	10 (14.1)	8 (11.3)	50 (70.4)	3 (4.2)	8 (11.1)	18 (25.0)	43 (59.7)	143 (100.0)
4000	8000	2 (2.8)	11 (15.3)	15 (20.8)	44 (61.1)	7 (9.9)	3 (4.2)	15 (21.1)	46 (64.8)	143 (100.0)
6000	10,000	3 (4.2)	4 (5.6)	14 (19.7)	50 (70.4)	3 (4.2)	1 (1.4)	13 (18.3)	54 (76.1)	142 (100.0)
8000	12,000	1 (1.4)	5 (7.0)	22 (31.0)	43 (60.6)	5 (7.0)	2 (2.8)	18 (25.4)	46 (64.8)	142 (100.0)
10,000	15,000	0 (0.0)	1 (1.4)	19 (26.4)	52 (72.2)	6 (8.3)	3 (4.2)	16 (22.2)	47 (65.3)	144 (100.0)
Totals		22 (2.2)	63 (6.3)	93 (9.3)	322 (32.2)	41 (4.1)	41 (4.1)	90 (9.0)	328 (32.8)	1000 (100.0)

Notes: ^a The unit is Korean won. When the survey was implemented, the exchange rate was USD 1 = KRW 1076. ^b The percentage of the responses is given in parentheses next to the number of respondents.

3.2. Estimation Results

Table 3 reports the estimation results of the model given in equation (6). All the parameter estimates are statistically meaningful at the significance level of 1%. The estimated equation is

significant judging from the Wald statistic. In addition, the sign of the coefficient estimates meets the prior expectations. The household monthly WTP to avoid a power shortage is KRW 1522 (USD 1.37), which is statistically significant. The WTP to avoid a power shortage can be calculated as KRW 4.02 (USD 0.004) per kWh, given that the average electricity uses per household per month is 379kWh in 2017. This value amounts to 3.65% of the average price for electricity including costs for generation, distribution, and transmission, KRW 110.07 (USD 0.10) per kWh in 2017 [40].

Table 3. Estimation results of the spike model.

Variables	Coefficient Estimates (<i>t</i> -Values)
Constant	−0.635 (−9.65) #
Bid amount ^a	−0.279 (−17.40) #
Spike	0.654 (43.85) #
Mean WTP	KRW 1522 (USD 1.41)
<i>t</i> -value	15.03 #
95% confidence interval ^a	KRW 1327 to 1754 (USD 1.23 to 1.63)
99% confidence interval ^a	KRW 1269 to 1837 (USD 1.18 to 1.71)
Number of observations	1000
Log-likelihood	−988.33
Wald statistic (<i>p</i> -value) ^b	198.13 (0.000)

Notes: ^a The confidence intervals are computed using the method reported by Krinsky and Robb [41]. ^b The null hypothesis is that all the parameters are jointly 0. # denotes statistical meaningfulness at the 1% level.

As of 2017, the monthly residential electricity bill was KRW 41,000 (USD 38.10) per household per month on average. Thus, the mean WTP amounts to 3.7% of the monthly residential electricity bill. It would be preferable to provide a confidence interval (CI) rather than a point estimate to reflect explicitly the uncertainty associated with the mean WTP estimation process [6]. Applying the method reported by Krinsky and Robb [41] to the estimation results for both parameters, φ_0 and φ_1 , produces the CI for the mean WTP. Table 3 contains the 95% and 99% CIs.

As the next step, it is necessary to deal with a model including covariates that can address the effect of the covariates on the probability that the respondents will answer “yes” to the proposed bid amount. Moreover, the model can be used for deciding whether the results of applying the CV method involving the survey will ensure internal consistency or theoretical validity. For this purpose, this study employed six covariates, which are explained in Table 4. Table 5 shows the results of the model estimation.

Table 4. Description of the variables in the model.

Variables	Definitions	Mean	Standard Deviation
Damage awareness	Degree of the interviewee’s awareness of the damage caused by power outages (from 1 to 3)	1.56	0.60
Rate awareness	Degree of the interviewee’s awareness of the level of the current electricity rate (from 1 to 3)	2.42	0.63
Outage experience	Dummy for the interviewee’s having experienced power outages (0 = no; 1 = yes)	0.24	0.43
Income	Interviewee’s households’ income per month (unit: million Korean won)	4.14	2.07
House size	Dummy for the interviewee’s house size being bigger than 66 m ² (0 = no; 1 = yes)	0.84	0.37
Family size	Number of the interviewee’s family members	3.44	1.06

Of the six covariates, the estimated coefficients for the four covariates are statistically meaningful at the 5% level. The sign of an estimated coefficient for a particular variable is positive (negative), which means that the value of that variable has a positive (negative) relationship with the probability

of responding “yes” to the proposed bid amount. For instance, the degree of the interviewee’s awareness of the damage caused by power outages favorably affects her/his acceptance of the bid price. The degree of the respondent’s awareness of the level of the current electricity rate is negatively correlated with the likelihood of reporting “yes” to a given bid. The respondents who own a bigger house were reluctant to say “yes” to an offered bid than others. This is because they already pay a large electricity bill, given that a big house can contain more electronic equipment such as refrigerators, air conditioners, and televisions. In addition, rich respondents have a greater tendency to answer “yes” to a suggested bid than others.

Table 5. Estimation results of the spike model with covariates.

Variables ^a	Coefficient Estimates	t-Values
Constant	0.538	1.39
Damage awareness	0.241	2.13 #
Rate awareness	−0.660	−6.24 #
Outage experience	−0.173	−1.09
Income	0.074	2.12 #
House size	−0.392	−2.10 #
Family size	0.038	0.55
Bid amount	−0.290	−17.60 #
Number of observations	1000	
Log-likelihood	−960.88	
Wald statistic (p-value) ^b	196.41 (0.000)	

Notes: ^a Table 4 defines the variables. ^b The null hypothesis is that all the parameters are jointly zero. # denotes statistical meaningfulness at the 5% level.

3.3. Discussion of the Results

In a CV study, computing the national population’s economic benefits is usually a main concern. As noted earlier, in this study, experienced and well-trained interviewers conducted the CV surveys with 1000 households nationwide. The authors therefore believe that this sample represents the population well. To confirm this, the ratio of female respondents, the household’s monthly income, and the size of the household are looked into here. The sample average for the variables were 48.4%, KRW 4.15 million, and 3.44 persons. The population averages were 49.9%, KRW 4.75 million, 3.07 persons when the survey was conducted [2]. It seems that there are no significant gaps between the two values for each variable. This finding makes the representativeness of our sample much stronger. Moreover, the authors do not think that there is any particular problem with extrapolating information from the sample to the population.

It is estimated that South Korea has a total of 19,751,807 households in 2018 [2]. If we multiply the number of households by the monthly mean WTP per household obtained previously and by 12 months, we can compute the yearly total national value of WTP as KRW 360.7 billion (USD 335.3 million), which implies the annual economic benefits of avoiding power outages in the residential sector. If the amount of investment in the residential sector is less than this value, this investment is socially desirable and reasonable, because the benefits of the investment exceed the costs of the investment and thus the investment passes the cost-benefit analysis.

In 2017, the Korea electric power corporation (KEPCO) compensated KRW 83.0 (USD 0.08) per kWh for the investment and operation of power generation facilities. Total power generation of South Korea was 553,530 GWh in 2017, so the investment amount in the power generation sector is calculated as KRW 45,943 billion (USD 42,698 million). Of the total cost of KRW 55,041 billion (USD 51,153 million) used by KEPCO for power supply in 2017, 84.23% was the cost of purchasing electricity from the power generation company, and 15.77% (KRW 8680 billion = USD 8067 million) was used for power transmission and distribution. Therefore, in 2017, KEPCO invested a total of approximately KRW 54,623 billion (USD 50,765 million) to supply stable electricity. However, to increase the stability of

power supply to a level where no power outage occurs, more investment is required than before, and the results of this study can be used to judge the appropriate level of additional investment.

It is clear that the respondents are willing to accept some economic strain to avoid power outages. Thus, investments made to avoid power outages can be socially profitable if they cost less than the economic benefit. As addressed above, the government planned to build enough new power plants and invest heavily in power transmission and distribution facilities to prevent an insufficient electricity supply. Thus, these implications can provide fundamental information justifying the enhancement of the electricity supply's reliability to avoid power outages.

It is difficult to compare directly the observations emerging from this study and those from related previous case works, because the objects to be assessed are different. However, the results of this study do not appear to differ much from those of preceding studies. For example, Abdullah and Mariel [7] showed that the additional monthly WTP to improve the electricity supply service in Kenya was USD 0.77 to 1.35. Baarsma and Hop [8] suggested that households' WTP to prevent power outages in the Netherlands would be EUR 10.4 to 20.8 per year. Reichl et al. [9] indicated that the mean WTP for the prevention of a 24-hour electricity outage amounts to EUR 17.3 in the household sector. Hensher et al. [10] estimated the mean WTP of households in the United States to avoid an 8-hour blackout that could occur once a year as USD 60. Woo et al. [19] analyzed that the average WTP for Hong Kong residents to avoid an hour electricity outage was USD 45 per month. Ozbaflı and Jenkins [20] found that additional WTP of households in North Cyprus to improve the reliability of electricity service was 13.8% of the monthly electricity bill.

4. Conclusions

This study aimed to examine the economic benefits of avoiding power outages in the South Korea residential sector. For this purpose, basic information about households' WTP for the avoidance was collected through a nationwide survey of 1000 households applying the OOHBCV technique, and statistical analysis using the spike model was performed to derive information on the mean WTP per household to avoid power outages. The results showed that the annual economic benefits amounted to KRW 360.7 billion (USD 335.3 million).

We think that this research is relevant from both the policy and the research perspective. From the policy perspective, it derived and presented a value for the economic benefits of avoiding power outages in the residential sector, which is information that the government excessively needs. The government will use this value as important information when developing its power supply plans. Above all, it is clear that the level of investment needs to be increased to avoid power outages in the residential sector. The government has decided to increase the number of natural gas-fired power plants and renewable energy facilities to expand the power supply and to enlarge the energy storage systems and pumping-up power generation facilities, to respond to the intermittent and variable supply of renewable power caused by the expansion of renewable energy. These measures are consistent with the findings in this study.

In addition, the results can be adopted as a basis for securing justification for the investment required to avoid the power outages in the residential sector. Large investments are needed to implement a project of improving the power supply stability. The funds required for the investments will eventually be borne by the people, and the project is just one of many projects the government will have to perform. Therefore, the economic feasibility of the project should be assessed, rather than putting public funds into it unconditionally. That is, only when the benefits ensuing from an investment are greater than the costs involved in the investment can this investment be socially justified. If the costs are greater than the benefits, it is preferable not to carry out the project. Whereas costs can usually be measured relatively easily, it is not easy to evaluate the benefits of an investment. However, the results of this study can be used to estimate the economic benefits of a project that improves the power supply stability.

One can think that the quantitative information extracted from the analysis may be used in generation capacity planning. For example, the information may be utilized in deciding when new generation facilities should be constructed in long-term horizon in order to avoid electricity outage events. If the total WTP for avoiding power outages is greater than the cost invested in increasing power generation facilities to prevent the power outages, this investment is socially desirable. In addition, as the power supply stability increases, the difference between the former and the latter becomes smaller, and the investments to improve the power supply stability are justifiable to the extent that the former is greater than the latter. In fact, the South Korean government has applied this logic to establishing a basic national plan for long-term power supply and demand and granted new power plant construction permits. Of course, power outages do not only occur when power generation facilities are insufficient but also when there are problems with transmission and/or distribution facilities. Thus, a similar reasoning can be applied to investments in transmission and/or distribution facilities.

From the research perspective, this study contributes to the CV literature by applying the CV technique, one of the economic valuation techniques, to calculate the economic benefits of avoiding power outages in the residential sector. In particular, the implications of this study will be especially beneficial as it is the first study to be conducted in South Korea, which requires information on the economic benefits of avoiding residential power outages. Of course, the framework of this study needs to be expanded further. For example, some topics, such as a comparison of our results with the economic benefits derived for the industrial or commercial sectors, the application of the framework of this study to other countries for comparison, and the derivation of regionally separated economic benefits of avoiding power outages in South Korea, will be fruitful. In particular, these follow-up tasks will contribute to preparing customized plans for power supply stabilization by helping to estimate the economic benefits of avoiding power outages more accurately.

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References

1. Lim, K.M.; Lim, S.Y.; Yoo, S.H. Estimating the economic value of residential electricity use in the Republic of Korea using contingent valuation. *Energy* **2014**, *64*, 601–606. [CrossRef]
2. Statistics Korea. Korea Statistical Information Service. Available online: <http://kosis.kr> (accessed on 5 October 2018). (In Korean)
3. Korea Electric Power Corporation. *Statistics of Electric Power in Korea*; Korea Electric Power Corporation: Seoul, Korea, 2013. (In Korean)
4. Korea Energy Economics Institute. *Yearbook of Energy Statistics*; Korea Energy Economics Institute: Sejong, Korea, 2013. (In Korean)
5. International Energy Agency. *Energy Balances of OECD Countries*; International Energy Agency: Paris, France, 2013.
6. Energy Information Administration, Country Analysis Brief of Overview. Available online: <http://www.eia.gov> (accessed on 5 October 2018).
7. Abdullah, S.; Mariel, P. Choice experiment study on the willingness to pay to improve electricity services. *Energy Policy* **2010**, *38*, 4570–4581. [CrossRef]
8. Baarsma, B.E.; Hop, J.P. Pricing power outages in the Netherlands. *Energy* **2009**, *34*, 1378–1386. [CrossRef]

9. Reichl, J.; Schmidthaler, M.; Schneider, F. The value of supply security: The costs of power outages to Austrian households, firms and the public sector. *Energy Econ.* **2013**, *36*, 256–261. [[CrossRef](#)]
10. Hensher, D.A.; Shore, N.; Train, K. Willingness to pay for residential electricity supply quality and reliability. *Appl. Energy* **2014**, *115*, 280–292. [[CrossRef](#)]
11. Mitchell, R.C.; Carson, R.T. *Using Surveys to Value Public Goods: The Contingent Valuation Method. Resources for the Future*; RFF Press: Washington, DC, USA, 1989.
12. Arrow, K.; Solow, R.; Portney, P.R.; Leamer, E.E.; Radner, R.; Schuman, H. Report of the NOAA panel on contingent valuation. *Fed. Regist.* **1993**, *58*, 4601–4614.
13. Fisher, A. The conceptual underpinnings of the contingent valuation method. In *The Contingent Valuation of Environmental Resources*; Bjornstad, D.J., Kahn, J.R., Eds.; Edward Elgar: Cheltenham, UK, 1996; pp. 19–37.
14. Vehkatalam, L. The contingent valuation method: A review. *Environ. Impact Assess. Rev.* **2004**, *24*, 89–124. [[CrossRef](#)]
15. Yoo, S.H.; Kwak, S.J. Willingness to pay for green electricity in Korea: A contingent valuation study. *Energy Policy* **2009**, *37*, 5408–5416. [[CrossRef](#)]
16. Park, S.Y.; Lim, S.Y.; Yoo, S.H. The economic value of the national meteorological service in the Korean household sector: A contingent valuation study. *Sustainability* **2016**, *8*, 834. [[CrossRef](#)]
17. Morrissey, K.; Plater, A.; Dean, M. The cost of electric power outages in the residential sector: A willingness to pay approach. *Appl. Energy* **2018**, *212*, 141–150. [[CrossRef](#)]
18. Carlsson, F.; Martinsson, P. Does it matter when a power outage occurs?—A choice experiment study on the willingness to pay to avoid power outages. *Energy Econ.* **2008**, *30*, 1232–1245. [[CrossRef](#)]
19. Woo, C.K.; Ho, T.; Shiu, A.; Cheng, Y.S.; Horowitz, I.; Wang, J. Residential outage cost estimation: Hong Kong. *Energy Policy* **2014**, *72*, 204–210. [[CrossRef](#)]
20. Ozbafli, A.; Jenkins, G.P. The willingness to pay by households for improved reliability of electricity service in North Cyprus. *Energy Policy* **2015**, *87*, 359–369. [[CrossRef](#)]
21. Brent, R.J. *Applied Cost-Benefit Analysis*, 2nd ed.; Edward Elgar: Cheltenham, UK, 2006.
22. Just, R.E.; Hueth, D.L.; Schmitz, A. *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*; Edward Elgar: Cheltenham, UK, 2004.
23. Carson, R.T.; Hanemann, W.M. Contingent valuation. In *Handbook of Environmental Economics: Valuing Environmental Changes*; Mäler, K.G., Vincent, J.R., Eds.; Elsevier: Amsterdam, The Netherlands, 2005; Volume 2, pp. 821–936.
24. Kim, H.J.; Jin, S.J.; Yoo, S.H. Public assessment of releasing a captive indo-pacific bottlenose dolphin into the wild in South Korea. *Sustainability* **2018**, *10*, 3199. [[CrossRef](#)]
25. Kim, J.H.; Kim, H.J.; Yoo, S.H. The public value of reducing the PM_{2.5} concentration in South Korean urban areas. *Sustainability* **2018**, *10*, 1144. [[CrossRef](#)]
26. Alberini, A.; Kahn, J. *Handbook on Contingent Valuation*; Edward Elgar: Cheltenham, UK, 2006.
27. Bateman, I.J.; Langford, I.H.; Jones, A.P.; Kerr, G.N. Bound and path effects in double and triple bounded dichotomous choice contingent valuation. *Resour. Energy Econ.* **2001**, *23*, 191–213. [[CrossRef](#)]
28. Cooper, J.C.; Hanemann, M.; Signorello, G. One and one-half bound dichotomous choice contingent valuation. *Rev. Econ. Stat.* **2002**, *84*, 742–750. [[CrossRef](#)]
29. McFadden, D. Contingent valuation and social choice. *Am. J. Agric. Econ.* **1994**, *76*, 689–708. [[CrossRef](#)]
30. Cameron, T.A.; Quiggin, J. Estimation using contingent valuation data from a “dichotomous choice with follow-up” questionnaire. *J. Environ. Econ. Manag.* **1994**, *27*, 218–234. [[CrossRef](#)]
31. Jang, J.; Lee, J.; Yoo, S.H. The public’s willingness to pay for securing a reliable natural gas supply in Korea. *Energy Policy* **2014**, *69*, 3–13. [[CrossRef](#)]
32. Kwak, S.Y.; Yoo, S.H.; Kim, C.S. Measuring the willingness to pay for tap water quality improvements: Results of a contingent valuation survey in Pusan. *Water* **2013**, *5*, 1638–1652. [[CrossRef](#)]
33. Lee, J.S.; Yoo, S.H. Willingness to pay for GMO labeling policies: The case of Korea. *J. Food Saf.* **2011**, *31*, 160–168. [[CrossRef](#)]
34. Nayga, R.M.; Woodward, R.; Aiew, W. Willingness to pay for reduced risk of food borne illness: A non hypothetical field experiment. *Can. J. Agric. Econ.* **2006**, *54*, 461–475. [[CrossRef](#)]
35. Ponce, R.D.; Vásquez, F.; Stehr, A.; Debels, P.; Orihuela, C. Estimating the economic value of landscape losses due to flooding by hydropower plants in the Chilean Patagonia. *Water Resour. Manag.* **2011**, *25*, 2449–2466. [[CrossRef](#)]

36. Wattage, P.; Mardle, S. Total economic value of wetland conservation in Sri Lanka identifying use and non-use values. *Wetl. Ecol. Manag.* **2008**, *16*, 359–369. [[CrossRef](#)]
37. Hanemann, W.M. Welfare evaluations in contingent valuation experiments with discrete responses. *Am. J. Agric. Econ.* **1984**, *66*, 332–341. [[CrossRef](#)]
38. Yoo, S.H.; Kwak, S.J. Using a spike model to deal with zero response data from double bounded dichotomous contingent valuation survey. *Appl. Econ. Lett.* **2002**, *9*, 929–932. [[CrossRef](#)]
39. Kriström, B. Spike models in contingent valuation. *Am. J. Agric. Econ.* **1997**, *79*, 1013–1023. [[CrossRef](#)]
40. Korea Electric Power Corporation. Electricity Cost Information. Available online: <http://home.kepco.co.kr> (accessed on 5 February 2019). (In Korean)
41. Krinsky, I.; Robb, A.L. On approximating the statistical properties of elasticities. *Rev. Econ. Stat.* **1986**, *68*, 715–719. [[CrossRef](#)]



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