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A Price Premium for the District Heating System: An Empirical Investigation on South Korean Residents

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Abstract: Representative heating methods in residential buildings in South Korea are the boiler-based individual heating system (IHS) and the district heating system (DHS). When constructing a large-scale new city or redeveloping an old one, the heating method must be determined in advance by reflecting consumers' preferences. This article intends to explore the price premium that South Korean residents are willing to pay for DHS over IHS. The price premium means the consumer's additional willingness to pay (AWTP). To obtain this, contingent valuation was employed and the data were gathered by conducting a nationwide survey of 1000 people. The one-and-one-half-bounded model was adopted as the method of inducing the AWTP. Comparison of the results from estimating the model with those from estimating other models revealed that there was no significant difference between the two. Moreover, the former held statistical significance. The price premium or AWTP was estimated as KRW 4353 (USD 3.88) per Gcal. This value corresponds to about 5.9% of the residential heat price, which was KRW 73,587 (USD 65.59) per Gcal in 2020. Heating prices are almost the same, with little difference between DHS and IHS. The results suggest that a large number of residents place a price premium on DHS over IHS.

Keywords: contingent valuation; district heating system; price premium; individual heating system

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1. Introduction

Currently, the representative type of housing for South Koreans are apartments. The prices of apartments are higher than those of other types of houses with similar conditions. The reason is that apartments are superior to other types of houses in terms of convenience, security, and low heating costs. Three main heating methods exist in South Korean apartments: the individual heating system (IHS), the district heating system (DHS), and the central heating system. The central heating system was mainly installed in the past and has recently been gradually replaced by IHS or DHS. When converting the central heating system in this way, the apartment residents must choose between either IHS or DHS. They do not differ much in terms of consumer price, but they have their own strengths and weaknesses. Thus, the residents have their preferences.

When a new city is developed by the government, either IHS or DHS should be decided on in advance. If the latter is chosen, the entire city is designated as a DHS zone based on the Integrated Energy Business Act. Since South Korea is an energy-deficient country that relies on imports for more than 96% of the energy consumed, energy efficiency is used as an important criterion in the decision-making. Residents' preferences are also an important criterion to consider. If one heating system is selected for a particular area, all apartments in the area are built with that heating system.

It is well known that DHS is more desirable than IHS from the perspective of environmental performance as well as energy efficiency [1–3]. Apart from these, in South Korea, DHS is generally preferred over IHS by residents for three reasons. First, since

DHS households do not need to have the individual boilers IHS households need, they can use the space occupied by the boiler for other purposes, such as storage of household items. Second, IHS households can suffer from supply disruptions to hot water and heat if individual boilers suddenly fail in winter, while DHS households do not suffer from such disruptions. Third, IHS households may experience inconvenience, such as incurring repair costs if an individual boiler fails, and albeit quite rarely, individual boilers can even explode, while DHS households do not suffer from these. The boiler required for the IHS should be managed under the responsibility of individual households, but DHS facilities are professionally managed by DHS operators or employees of apartment management offices.

A survey of people living in residential buildings can provide implications regarding the improvement of household heating systems [4,5]. The residents' preferences can be expressed as the price premium they are willing to pay for consuming DHS over IHS. In summary, the price premium needs to be quantitatively derived, and this study aims to empirically meet this need. This study can contribute to the literature in two aspects. First, since information on the updated price premium is urgently required in the situation of South Korea that is trying to continuously expand DHS, this study provides useful information to DHS policy makers in terms of policy. In particular, information on the up-to-date price premium can be used as important information to efficiently establish heating plans in housing sites under future housing site development plans.

Second, from a research perspective, this study can add one contribution to the relevant research field in that it is difficult to find a research case on the price premium of DHS in the literature. Of course, unlike the situation of South Korea where DHS and IHS compete, research on price premiums may be unnecessary in other countries. However, this study for South Korea, which is located in the northern hemisphere and requires heating from October to April of the following year and hot water throughout the year, will be useful information for other countries to refer to when establishing DHS policies.

Therefore, the prime purpose of this article was to collect data on the price premium through a survey of 1000 South Korean households, conducted during May 2021 and then explore the data. The contingent valuation (CV) was selected and applied in a way that met this purpose. The price premium refers to the amount of willingness to pay (WTP) additionally compared with the current IHS price to consume DHS instead of IHS. Thus, the price premium means the additional WTP (AWTP). The rest of this paper consists of Materials and Methods, Results, Discussions, and Conclusions.

2. Background

As explained in the Introduction section, the price premium obtained in this study means the additional amount to be readily paid to consume good B instead of good A, namely AWTP. From an economics point of view, WTP is the area under the demand function for the object to be evaluated. In other words, in order to obtain a price premium, it is necessary to calculate the area after obtaining the demand function for the object or to obtain the area directly. If the object is freely traded on the market, it is not difficult to obtain the price premium. However, if the object is not traded on the market, a specially designed method should be applied.

In this case, CV is a representative method to easily obtain the area under the demand function for the object. Therefore, there are quite a number of applied CV studies in the literature [6]. The reason why there are so many applications of CV is that the adequacy of CV technique has not only been validated in many literatures, but also their application procedures are much standardized [7–9]. Of course, there are still research cases that maintain a critical perspective on CV, but CV application cases are steadily appearing in the literature. In short, the application of CV is useful and in some cases, it is inevitable in order to obtain the economic value or WTP for objects without transaction data in the market. The object dealt with in this study is such a case.

In particular, since the appropriateness of CV utilization and precautions in the application of CV have been outlined through various literature in recent years, researchers should fully refer to these literatures in applying CV. For example, studies by Johnston et al. [10], Mariel et al. [11], and Sajise et al. [12] presented methodological guidelines to be followed in applying CV, emphasizing the usefulness of CV. As will be described later, this study sought to follow these guidelines well in applying CV. Thus, the authors believe that this study is consistent with existing well-utilized CV application cases as well as CV-related methodological guidelines.

3. Materials and Methods

3.1. Method

An appropriate method that meets the primary objective of this research to measure the consumer's price premium for using DHS instead of IHS should be selected. In this regard, the most frequently used method in estimating the price premium or AWTP in the literature is CV. For instance, Yoon et al. [13], Kim et al. [14,15], and Lee et al. [16]. Thus, CV is also adopted in this study. In particular, according to Settumba et al. [17] and Humphreys et al. [18], the literature shows that the reliability as well as the validity of CV are satisfied to some extent.

CV can be explained through the utility maximization of consumer behavior theory presented in microeconomics [6,19,20]. Consumers can pay to consume DHS instead of IHS by as much as they can reduce spending on other goods and services to maximize their utility within a limited income. The AWTP of some consumers may be 0, while others may be positive. Consequently, in a CV survey, it is necessary to emphasize that interviewees' income has a constraint. Moreover, it is also stressed that their stated AWTP means a reduction in spending on other goods or services. This point was sufficiently reflected in the survey conducted in this study. The procedure of applying the CV in this study is explained in detail in the following section and its flowchart is presented in Figure 1.

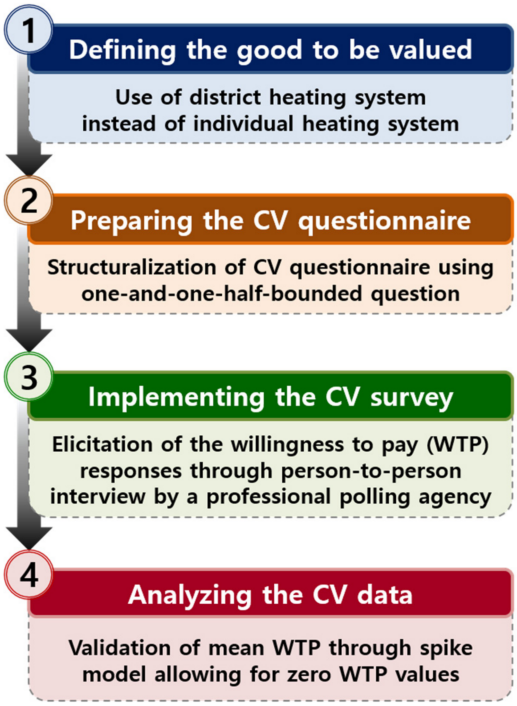

Figure 1. Process of applying the contingent valuation method in this study.

3.2. Procedure of Collecting the CV Data

The process of collecting the CV data largely consists of two steps [10]. In the first step, a CV questionnaire is prepared. In the second step, a field CV survey is implemented with

the prepared questionnaire. There are three key issues in fulfilling the first step. First, the valuation target must be defined. The valuation target in CV should be a change from the current state to the target state. Thus, clearly setting these two states is quite important in applied CV works. The current state is the consumption of one Gcal of heat from IHS. On the other hand, the target state is that of one Gcal of heat from DHS. In the CV questionnaire, it was clearly explained to the respondents that one Gcal means the amount of heat required when 230 apartment households are heated for an hour in winter. In addition, several advantages of DHS over IHS mentioned in the Introduction were described through photos and pictures.

Second, an appropriate method of inducing AWTP should be determined between the open- and closed-questioning methods. Since the latter is mainly recommended in the literature, the latter was applied in this study [7,21]. There are several types of closed-ended questioning methods, among which the one-and-one-half-bounded (1.5B) model was adopted. This model was most recently suggested in the literature [22]. Third, the payment vehicle was determined as an increase in the price of one Gcal of heat provided through IHS. In the questionnaire, the price was presented as KRW 73,587 (USD 65.59). Therefore, the question presented in the questionnaire says, "Regardless of what heating type you are currently using, assume that your household is currently using an individual heating system at KRW 73,587 per 1 Gcal. Would you accept an additional payment of X Korean won per 1 Gcal to use a district heating system rather than the individual heating system"?

There are also three key issues in conducting the second step of collecting the data. First, as the sample size increases, the error may decrease. However, the larger sample size entails an increase in the survey cost. Therefore, the proper size of a sample must be determined. This study determined the sample size as 1000 by accepting the recommendation of Arrow et al. [8]. In addition, it was also considered that the use of 1000 was supported by the Korea Development Institute [23].

Second, the survey method should be determined, selecting from one of the following: postal survey, telephone survey, Internet survey, or person-to-person survey. Therefore, accepting the recommendation of Arrow et al. [8], a person-to-person survey was adopted in this research. Interestingly, the Korea Development Institute [23] also presented a person-to-person survey as a guideline. Finally, determining the unit of the survey is an issue. Since heating rates are charged per household, the unit of the survey was determined for households, not individuals. Thus, the person filling out the questionnaire was chosen as the household head or the spouse of the household head.

3.3. Procedure of Analyzing the CV Data

Applying the aforementioned 1.5B model gives us one or two discrete choice responses for each respondent. Let S denote the respondent's AWTP. In the 1.5B discrete choice question, two predetermined bids, T^L and T^H ($T^L < T^H$), are assigned to each interviewee. About 50% of all interviewees are presented with T^H first. If "yes" is answered to the payment of T^H, $T^H < S$ is obtained. If "no" is answered to the payment of T^H, T^L is additionally presented. When "yes" is responded, $T^L < S < T^H$ is obtained, and if "no" is responded, $S < T^L$ is observed. Respondents with $S < T^L$ are further divided into $S = 0$ and $0 < \mathrm{S} < T^L$ through an additional question.

Eventually, each respondent will provide one of four responses: "yes", "no-yes", "no-no-yes", and "no-no-no". Four indicator variables concerning the responses may be defined as I^Y, I^{NY}, I^{NNY}, and I^{NNN}. These responses or indicator variables correspond to $T^H < S$, $T^L < S < T^H$, $0 < \mathrm{S} < T^L$, and $S = 0$, respectively. At this time, $S < 0$, negative WTP, is not considered. This is because negative AWTP means that it should be compensated, but the compensation cannot happen and is not reasonable.

The other half of all the respondents are presented with T^L first. As in the previous case where half of all the respondents are provided with T^H first, each respondent's answer will be one of four: $T^H < S$, $T^L < S < T^H$, $0 < \mathrm{S} < T^L$, and $S = 0$. The indicator variables corresponding to each are defined as J^{YY}, J^{YN}, J^{NY}, and J^{NN}, respectively. In modeling the

responses, it should be reflected that the last response is point data with a value of zero and the other three are interval data. One of the models suitable for dealing with positive interval data as well as zero observations at the same time is the spike model given in Kriström [24]. A modified version of the model to suit the 1.5B CV data can be applied in this study [25].

Let T_k and $F_S(\cdot)$ be the bid offered to respondent k ($k = 1, \ldots, K$) and the distribution function of S. The log-likelihood function covered in this study is:

$$\begin{aligned} \ln L = \; & \sum_{k=1}^{K} \{ \left(I_k^Y + J_k^{YY}\right) \ln\left[1 - F_S\left(T_k^H; m_0, m_1\right)\right] + \left(I_k^{NY} + J_k^{YN}\right) \ln\left[F_S\left(T_k^H; m_0, m_1\right)\right. \\ & \left. - F_S\left(T_k^L; m_0, m_1\right)\right] + \left(I_k^{NNY} + J_k^{NY}\right) \ln\left[F_S\left(T_k^L; m_0, m_1\right)\right. \\ & \left. - F_S(0; m_0, m_1)\right] + \left(I_k^{NNN} + J_k^{NN}\right) \ln F_S(0; m_0, m_1) \} \end{aligned} \tag{1}$$

where using the logistic function $F_S(\cdot)$ is defined as:

$$F_S(T; m_0, m_1) = \begin{cases} [1 + \exp(m_0 - m_1 T)]^{-1} & \text{if } T > 0 \\ [1 + \exp(m_0)]^{-1} & \text{if } T = 0 \\ 0 & \text{if } T < 0 \end{cases} \tag{2}$$

where m_0 and m_1 are the parameters of $F_S(\cdot)$.

4. Data and Results

4.1. Data

The numbers regarding responses obtained in this study are summarized in Table 1. A preliminary survey of the focus group enabled this study to determine a total of seven sets of bid amounts. The 1000 interviewees were roughly equally divided into seven groups. Each group consisted of a similar number of observations. Each set was presented to each group. The upper and lower parts of the table refer to the case where a higher and lower bid were offered first, respectively. The "no-no-no" and "no-no" responses mean $S = 0$, corresponding to 681 (=342 + 339) of the total.

Table 1. Number of responses obtained in this study.

Bids [1]		**Number of Responses**				
First	**Second**	**"Yes"**	**"No-Yes"**	**"No-No-Yes"**	**"No-No-No"**	**Totals**
7000	2000	13	14	9	35	71
12,000	5000	5	11	13	43	72
17,000	9000	4	3	16	48	71
24,000	14,000	3	4	10	55	72
34,000	20,000	2	5	10	54	71
45,000	28,000	4	0	13	54	71
58,000	40,000	4	0	15	53	72
	Totals	35	37	86	342	500
First	Second	"yes-yes"	"yes-no"	"no-yes"	"no-no"	Totals
2000	7000	6	14	6	46	72
5000	12,000	2	19	7	44	72
9000	17,000	3	5	11	52	71
14,000	24,000	2	4	13	52	71
20,000	34,000	3	4	16	49	72
28,000	45,000	2	4	17	48	71
40,000	58,000	4	3	16	48	71
	Totals	22	53	86	339	500

[1] The bids are shown in Korean won (USD 1.0 = KRW 1122 at the time of the survey).

4.2. Results

For the sake of estimating the parameters of the distribution presented in Equation (2), the maximum likelihood estimation method to obtain a parameter that maximizes the

log-likelihood function presented in Equation (1) is applied. Equation (2) represents a representative WTP distribution function of the spike model. Therefore, estimating the CV model means maximizing Equation (1) after inserting Equation (2) into Equation (1). In particular, in the case of a model in which covariates reflecting the characteristics of the respondent are contained m_0 given in Equation (2) is replaced with $m_0 + z'm_u$, where z is a vector of the covariates and m_u is a vector of parameters corresponding to z.

Two models can be constructed depending on whether or not covariates are included. Table 2 reports information on the seven covariates employed here. The results from estimating these two 1.5B models are presented in Table 3. The Wald statistics imply that both models hold statistical significance. Combining Equation (2) and the well-known mean formula, the average AWTP is derived as $(1/m_1)[1 + \exp(m_0)]$. Looking at the results from estimating the covariate-free model, both the two coefficients and the average AWTP secure statistical significance. The spike also possesses statistical significance. The value is 0.6899, which is not much different from the sample ratio of 0.681.

Table 2. Explanation of the variables.

Variables	Definitions	Mean	Standard Deviation
Education	The interviewee's education level in years	14.36	2.15
Gender	The interviewee's gender (0 = male; 1 = female)	0.50	0.50
Age	The interviewee's age	48.14	9.65
Head	Whether the interviewee is head of household or not (0 = no; 1 = yes)	0.53	0.50
Income	The interviewee household's monthly income (unit: million Korean won)	5.22	2.10
Environment	Which is more crucial to the interviewee: jobs or environment (0 = jobs; 1 = environment)	0.39	0.49
Inclination	The interviewee's political inclination (0 = conservatism; 1 = progressives)	0.40	0.49

Table 3. Results from estimating the one-and-one-half-bounded model.

Variables [1]	Model without Covariates [2]	Model with Covariates [2]
Constant	−0.7997 (−11.91) *	−3.0616 (−3.57) *
Bid amount [3]	−0.0853 (−16.15) *	−0.0872 (−16.23) *
Education		0.0710 (1.89) *
Gender		0.7920 (2.25) *
Age		−0.0026 (−0.33)
Head		0.9668 (2.73) *
Income		0.0815 (2.40) *
Environment		0.3762 (2.72) *
Inclination		−0.3678 (−2.52) *
Spike	0.6899 (48.04) *	0.6970 (47.69) *
Mean additional willingness to pay per Gcal of heat	KRW 4353 (USD 3.88) 12.94 *	KRW 4141 (USD 3.69) 12.78 *
t-values	KRW 3758 to 5064	KRW 3476 to 4954
95% confidence interval [4]	(USD 3.35 to 4.51)	(USD 3.10 to 4.42)
Wald statistics (*p*-values) [5]	167.43 (0.000)	163.25 (0.000)
Log-likelihood	−968.63	−948.91
Sample size	1000	1000
McFadden's pseudo-R^2		0.020

[1] They are described in Table 2. [2] The values are the coefficient estimates, and the *t*-values corresponding to them are reported in the parentheses. [3] The unit is 1000 Korean won (USD 1.0 = KRW 1122 at the time of the survey). [4] They are obtained from adopting the method given in Krinsky and Robb [26]. [5] The null hypothesis is that the model is incorrectly specified. * Implies that the estimate holds statistical significance at the 10% level.

In order to explicitly deal with the uncertainty associated with the average AWTP estimation, a confidence interval (CI) for this can be computed. Therefore, Table 3 also provides 95% CIs for the average AWTP derived by applying the method presented in Krinsky and Robb [26]. The results from estimating the model with covariates do not significantly differ from those from estimating the model without covariates. The R^2, which is most widely used in relation to the goodness-of-fit of an estimated equation, cannot be defined for the covariate-free model. On the other hand, McFadden's pseudo-R^2 suggested by Herriges [27] is defined for the model including covariates. It was calculated to be 0.02.

The coefficient estimate for a covariate itself does not mean much, but its sign has an important meaning. If the sign is positive, the size of the variable is positively associated with the likelihood of responding "yes" to the presented bid amount. For instance, the coefficient for the Income term has a positive sign, which means that the greater the income, the greater the likelihood of accepting the payment of the suggested bid amount. In addition, the estimated coefficient for the Gender term is positive, which suggests that women are more likely to state "yes" to the presented bid amount than men.

Deciding which to use of the two models is an issue. In the case of the model with covariates, there is the problem that the estimation results of the average AWTP vary, depending on which set of covariates is to be determined. On the other hand, the former is free from this problem because it does not include any covariates. Consequently, the subsequent analysis is intended to be based on a model without covariates. A summary of the results of this study is shown in Figure 2.

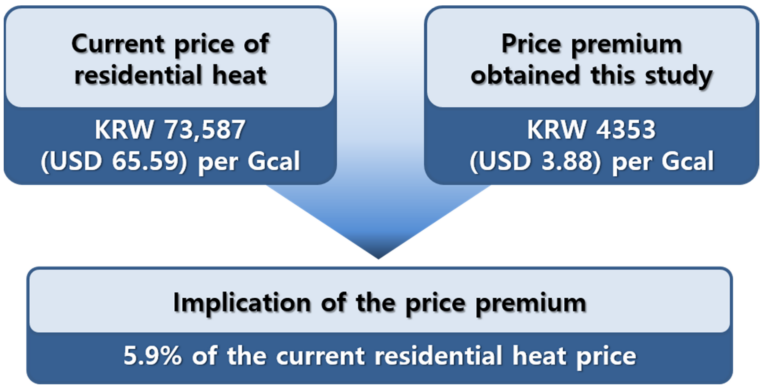

Figure 2. Summary of the main results of this study.

5. Discussion

Three major discussions will be made on the results. First, the 1.5B model can suffer from the response effect [28]. To deal with this, the comparison of the results from the 1.5B model with those from the single-bounded (SB) model that uses only the response to the first bid, is needed. To this end, the results from estimating the SB model are contained in Table 4. The average AWTP estimated from the SB model are larger than that from the 1.5B model. Looking at the 95% confidence interval, they overlap with each other. Using the overlap test, the null hypothesis that the two estimation results are the same cannot be rejected. In other words, the estimation results of the two models do not differ significantly. Thus, the response effect is not a problem in the 1.5B model used in this study.

Second, the level of the estimated price premium needs to be addressed. In other words, the consumers' price premium of DHS compared to IHS is 5.9%. It would also be meaningful to compare this value with the results of previous studies. As far as the authors know, no foreign research comparable to the results of this research exists in the literature. However, there are two researches relevant to South Korea. In a study by Yoon et al. [13], the price premium of DHS was derived from 4.03% to 12.52% of the price of IHS. However, in terms of the detailed valuation targets and models used, Yoon et al.'s [13] study differs from this study.

Table 4. Estimation results of the single-bounded model.

Variables [1]	Model without Covariates [2]	Model with Covariates [2]
Constant	−0.7879 (−11.70) *	−0.2367 (−0.24)
Bid amount [3]	−0.0754 (−13.94) *	−0.0771 (−14.01) *
Education		0.0730 (1.94) *
Gender		0.8335 (2.33) *
Age		−0.0027 (−0.34)
Head		−1.0064 (−2.79) *
Income		0.0749 (2.19) *
Environment		0.3801 (2.73) *
Inclination		−0.3598 (−2.45) *
Spike	0.6874 (47.49) *	0.6970 (47.69) *
Mean additional willingness to pay per Gcal of heat	KRW 4974 (USD 4.43) 11.77 *	KRW 4731 (USD 4.22) 11.66 *
t-values	KRW 4218 to 5906	KRW 3947 to 5750
95% confidence interval [4]	(USD 3.76 to 5.26)	(USD 3.52 to 5.12)
Wald statistics (*p*-values) [5]	138.42 (0.000)	163.25 (0.000)
Log-likelihood	−839.08	−819.61
Sample size	1000	1000
McFadden's pseudo-R^2		0.023

[1] They are described in Table 2. [2] The values are the coefficient estimates, and the *t*-values corresponding to them are reported in the parentheses. [3] The unit is 1000 Korean won (USD 1.0 = KRW 1122 at the time of the survey). [4] They are obtained from adopting the method given in Krinsky and Robb [26]. [5] The null hypothesis is that the model is incorrectly specified. * Implies that the estimate holds statistical significance at the 10% level.

Kim et al.'s study [7] resembles this study. The price premium of DHS found in the former was 6.0%, based on the price of KRW 95,510 per Gcal of IHS as of 2013. The price of IHS used in this study was KRW 73,587 per Gcal as of 2020, down about 23% from 2013. The price premium estimate from this study is 5.9%, which is almost the same as 6.0% of the previous study. In other words, although seven years have passed, the level of price premium remains unchanged and stable. Therefore, it does not seem unreasonable to use the results of this study in making decisions for the future.

Third, the results obtained in this research can be used as a cornerstone for policies to vitalize DHS. In the past, South Korea relied mainly on oil for heating and heat production, but suffered from a sharp rise in oil prices due to the first and the second oil shocks in the 1970s. Thus, in the mid-1980s, natural gas began to be introduced in earnest to reduce South Korea's oil dependence, and IHS based on city gas began. Then, in the late 1980s, more efficient DHS than IHS began to be introduced. Since then, when housing sites are developed on a large scale or the old cities are redeveloped, these areas have been designated as a DHS zone so that only DHS can be introduced as the heating method.

It has been pointed out that the designation restricts consumers' right of choice and inhibits the business activities of city gas operators. In particular, city gas operators have raised legal issues regarding the inhibition. However, this study revealed that a large number of consumers prefer DHS to IHS, and even place price premiums on the former. Thus, the results of this study suggest that it may be desirable to designate a DHS zone for energy efficiency reasons. To match this atmosphere, city gas operators have recently entered the area of DHS, which is expected to expand in the future.

6. Conclusions

Heating operators, as well as the central and local governments of South Korea, are trying to accurately grasp residents' preferences for DHS versus IHS and use them in marketing and policy decisions. Thus, this research attempted to empirically assess the residents' price premium of DHS over IHS through a survey of 1000 South Korean households nationwide. To this end, CV was applied. Moreover, the method of eliciting AWTP and the model for dealing with the AWTP data, which are reasonably accepted in

the literature, were applied. The derived average of the price premium was, with statistical significance, 5.9% of the IHS price.

The South Korean residents have put a higher value on using DHS instead of IHS in various aspects, such as convenience, safety, and space utilization. In other words, apart from the good efficiency and environmental performance of DHS compared to IHS, they evaluated DHS higher than IHS in terms of residence. This was an interesting discovery in this study. In South Korea, IHS and DHS operators have existed together in history and are currently competing with each other. Globally, there may not be many such countries, but it is hoped that more studies similar to this study and applied to other countries will emerge in the future. The comparison between them and this study can provide interesting implications.

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