

Price and Income Elasticities of Residential Heat Demand from District Heating System: A Price Sensitivity Measurement Experiment in South Korea

Seul-Ye Lim ¹, Jeoung-Sik Min ² and Seung-Hoon Yoo ^{3,*}

¹ Research Strategy Department, Frontier Research & Training Institute, Korea District Heating Corporation, 92 Gigok-Ro, Giheung-Gu, Yongin 17099, Korea; sylim@kdhc.co.kr

² Department of Energy and Environment Convergence, Graduate School of Convergence Science, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 01811, Korea; jsmin@seoultech.ac.kr

³ Department of Energy Policy, Graduate School of Convergence Science, Seoul National University of Science & Technology, 232 Gongreung-Ro, Nowon-Gu, Seoul 01811, Korea

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

Abstract: Since the price for residential heat (RH) from district heating system in South Korea is regulated by the government rather than being freely determined in the market, it is difficult to estimate the demand function for RH properly using the distorted market data. Thus, undistorted data on price and demand are required in obtaining the demand function. This article tries to estimate the demand function for RH by applying the price sensitivity measurement (PSM) technique, with some variation, and then use this to obtain information about the price and income elasticities. To this end, in the PSM survey 1000 households were first asked about their consumption of RH and their expenditure on that consumption and then asked about how much they would lower their demand for RH in response to four hypothetical increases in the price for RH (10%, 20%, 50%, and 100%). Thus, five sets of price and consumption of RH were available for each household. The demand function for RH was estimated using a total of 5000 observations. The price and income elasticities were estimated with statistical significance to be about -0.478 and 0.033 , respectively. These values can be utilized in decision-making and/or policy-making related to RH management.

Keywords: residential heat; price elasticity; income elasticity; demand function; price sensitivity measurement



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1. Introduction

Residential heat (RH) from district heating system (DHS) is an essential commodity, consumed in the form of heating and hot water [1]. In South Korea, hot water is consumed in all four seasons of the year; heating is consumed mainly in the winter and intermittently in the spring and fall. Since a household's spending on RH accounts for a large portion of its total energy expenditure, the demand analysis for RH is an important part of energy policy-making [2,3]. One of the key tasks in demand analysis is to determine the price elasticity of demand [4].

To do this, the demand function needs to be defined. The dependent variable of the demand function is the quantity demanded, and the independent variables may include price, household characteristics such as income, housing characteristics, and so on. Nevertheless, the most important independent variable is price. Microeconomic theory establishes the "law of demand" which states that price is inversely proportional to demand. However, if price is controlled by different factors rather than being freely determined in the market, it is difficult to estimate the demand function properly from market data. Moreover, the demand function derived using the distorted price does not properly reflect consumer

demand. The price for RH from DHS in South Korea is strongly controlled by the government and the ruling party to curb inflation and manage public opinion, respectively, it is perceived as distorted. The reason is as follows.

In South Korea, the RH is supplied by 36 district heating companies. Interestingly, Korea District Heating Corporation (KDHC), a public company owned by the government, has about a half market share. The other 35 companies are almost privately owned. The price for RH is strongly regulated by the government in two respects. First, the government directly sets and announces the price level itself. The district heating companies are not allowed to change the price according to changes in cost. Therefore, the price for RH from DHS is not determined by the principle of demand and supply in the market. Second, despite the fact that there are big differences in the cost structure depending on the company, the government controls all companies' prices for RH to be about the same. The government has made and applied the so-called '110% price cap system', which allows district heating companies with particularly difficult business conditions to set the price for RH up to 10% higher than the KDHC's price for RH.

The government and the ruling party maintain strong control over the RH rate to curb inflation and manage public opinion, respectively. Although a change in the international market price of natural gas, which is the main fuel for RH production, or an increase or decrease in demand and supply, which would be expected to change the customer price for RH, RH price change is not likely to happen. In addition, it is quite difficult to obtain the data necessary for estimating the demand function for RH. Data on the RH demand of the private district heating companies is currently not available because it is treated as commercially sensitive information, and it is almost impossible to obtain the data. Nonetheless, since KDHC is a public utility, the data can be obtained through a request for information disclosure. In short, the government and the researchers are faced with two complications in estimating the demand function for RH and computing the price elasticity of demand: first, the price itself is distorted; second, the data on demand itself is difficult to obtain.

Therefore, researchers need to obtain data on undistorted price and demand if they are to estimate the demand function. In this regard, the price sensitivity measurement (PSM) technique proposed by Lewis and Shoemaker [5] can be considered as an alternative. The PSM technique was originally used to price new goods or services during the marketing phase, by analyzing the data obtained from a survey of potential consumers. This technique asks consumers about the price at which they would purchase the goods, the price they think is expensive, and the price they think is cheap [6].

This study tries to contribute to the literature on estimating the demand function for RH from DHS using the PSM technique with some variation and then deriving information about price and income elasticities from it. There are four sections in the remainder of this paper. A brief review of the literature dealing with heat demand is presented in the first of these. The PSM methodology used in the study is described in the second section. The results are explained and discussed in the penultimate section. The final section reports the conclusions.

2. Brief Review of the Literature Dealing with Heat Demand

There are four main kinds of studies dealing with heat demand in the literature. First, some studies analyzed heat demand in terms of DHS planning rather than the heat demand function itself. Using data for the United States, Liao and Chang [7] analyzed space-heating and water-heating energy demands (natural gas, fuel oil, and electricity), not heat demand. Andrić et al. [8] assessed the feasibility of using the heat demand-outdoor temperature function for forecasting heat demand using a specific case of a district in Portugal. The main focus of the paper was the impact of outdoor temperature on heat demand. Möller et al. [9] analyzed 'Heat Roadmap Europe' identifying local heat demand and supply areas using a European thermal atlas. Meha et al. [10] developed a new geographic information system-based bottom-up model for mapping the heat demand.

The second type of studies focused on determining the amount of heat demand required instead of estimating the heat demand function. Heitkoetter et al. [11] computed residential heat demand and the share covered by electric heating technologies for each administrative district in Germany. The objective of the study was to evaluate power-to-heat capacities as means of avoiding curtailment of power from renewable energies. Canet et al. [12] proposed and applied a method for estimating the heat demand of domestic buildings. Kurek et al. [13] calculated heat demand for the Warsaw District Heating Network using artificial neural network, ridge regression, and fuzzy logic.

The third kind of studies explored the patterns and components of heat demand. Arnaudo et al. [14] looked into heat peak demand shaving in urban areas that can be achieved through two demand side management options: heat storage system and the use of geothermal energy. Clegg and Mancarella [15] analyzed the intraday pattern and seasonal pattern of the heat demand in 404 regions of the United Kingdom. Furthermore, they examined the impact of heat demand pattern on regional power and gas suppliers. Ivanko et al. [16] presented and investigated a method of splitting the total heat demand in the hotel into space heating heat use and hot water, and found that the method was useful.

Therefore, our research, which directly estimates the demand function for RH, is different from the previous researches addressed above. The last kind of studies sought to estimate the heat demand function, which is line with the purpose of this study. To the best of the authors' awareness, two studies have been found in the literature. First, Lim et al. [2] estimated the demand function for RH in South Korea and short- and long-run price elasticities employing a lagged dependent variable model and using the quarterly time-series data from 1988 to 2013. Second, Kim et al. [17] investigated the demand function for industrial heat in the South Korean manufacturing sector using 257 cross-sectional observations and obtained an estimate of price elasticity of about -0.85 .

The purpose of the two studies is similar to that of our study. However, the two studies utilized data on demand and price for heat revealed in the market, which may have been distorted, as mentioned earlier. This study seeks to avoid the possibility of using distorted data by applying the PSM technique that uses households' stated preference data rather than the market's revealed data. In this regard, the authors think that this study has a clear distinction from prior researches.

3. Method and Data

3.1. Method: PSM

Lewis and Shoemaker [5] proposed the PSM technique. This uses a survey of consumers to collect data about how much consumers would change their purchasing behavior for a good in response to a change in the price of that good. The data are used to obtain information about price sensitivity, which can be used as a proxy for price elasticity. The technique has mainly been applied in the area of marketing science, based on the idea that price sensitivity, which means the extent to which prices affect the amount of consumption, can be identified when a consumer consumes a particular good. For example, Lewis and Shoemaker [5] and Raab et al. [6] used PSM to estimate the price sensitivity for goods supplied in the tourism sector and the restaurant sector, respectively, and presented the appropriate price range for an effective marketing strategy.

The authors believe that PSM can usefully be employed to obtain the demand function for RH from DHS and to derive the price elasticity from this. This study applies the PSM technique adopting three steps. First, data on the consumption of RH (in Gcal) and the expenditure on that consumption (in Korean won) during the year 2018 were collected from a nationwide survey of 1000 households. Interviewers affiliated with a professional polling firm visited each of these households for the purpose of checking their utility bills for RH. The average price was easily computed by dividing the expenditure by the consumption.

Second, the households were asked how much they would lower their demand for RH in response to four hypothetical increases in the price for RH (10%, 20%, 50%, and 100%). Once the households had responded by giving the percentage reduction

in their consumption for a 10% increase in price, for example, the levels of the price and consumption after the change were calculated. We obtained one set of price and consumption of RH from the first step and four sets of price and consumption of RH from the second step. The former and the latter correspond to revealed and stated preference data, respectively. Thus, five sets of price and consumption of RH were available for each household.

In the third step, the demand function for RH was estimated using the total of 5000 observations, after combining the revealed and the stated preference data. For each household, $s = 1, 2, \dots, S$, the demand function can be formulated as:

$$\ln RH_s = a_0 + a_1 \ln P_s + a_2 \ln Y_s + a_3 \ln F_s + a_4 C_s + a_5 H_s + \varepsilon_s \quad (1)$$

where RH , P , Y , F , C , and H denote, respectively, the consumption of RH during the year 2018 (unit: Gcal), the price for RH (unit: Korean won per Gcal), the household income (unit: million Korean won = USD 870), the number of people in the household, the number of people aged under 18 in the household, and the current type of heating (1 = DHS; 0 = others), a 's are the parameters to be estimated, and ε_s is the disturbance term. The price and income elasticities become a_1 and a_2 , respectively.

The procedures of applying the PSM technique are shown in Figure 1. There are five steps: (i) setting up the good to be assessed, for which the PSM technique will be applied; (ii) producing the survey instrument for potential consumers; (iii) collecting data on price and demand through performing surveys; (iv) analyzing the collected data to estimate the demand function; and (v) deriving price and income elasticities of the demand.

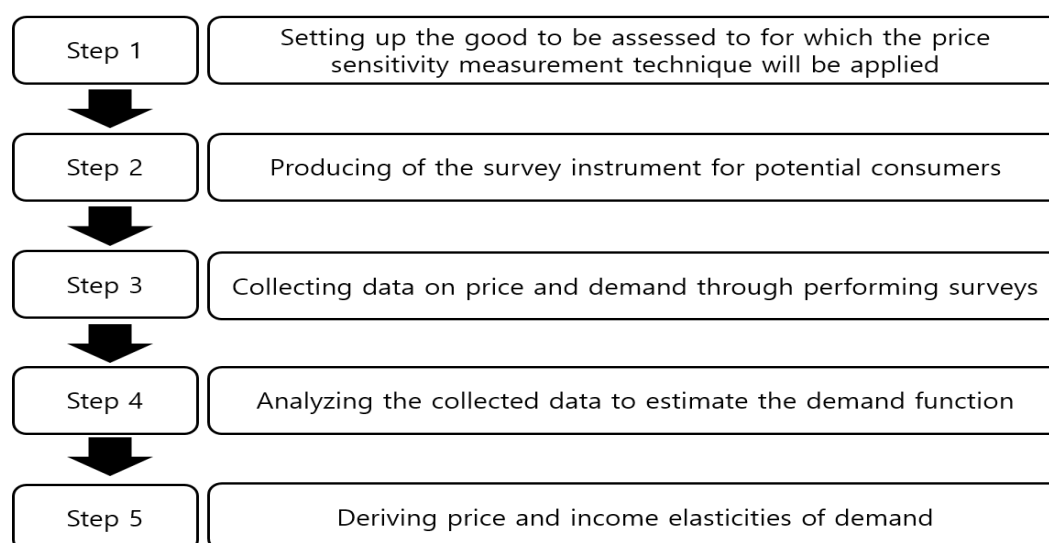


Figure 1. Procedures of applying the price sensitivity measurement technique.

Existing techniques of estimating the demand function mainly use the revealed preference data. In other words, time-series data analysis, cross-sectional data analysis, and panel data analysis were applied depending on the nature of the data, utilizing past price and consumption data. On the other hand, the PSM technique uses the stated preference data. This is an important distinction between the existing techniques and the PSM techniques. If the government intentionally regulates the price for a good for various reasons, such as RH price in South Korea, the price does not function properly in the market. In this case, using the revealed preference data can distort the estimation of the demand function. However, the PSM technique has the advantage of being free from this problem of distortion, as they capture changes in demand due to price changes through conducting surveys rather than observing market.

3.2. Data

There is a total of 17 provinces in South Korea. One of them is Jeju, which is a volcanic island with a smaller population than other provinces, and there is no possibility of DHS being supplied because city gas is already distributed. Therefore, a survey of households was conducted in 16 provinces, excluding Jeju. Moreover, the areas subject to the survey were determined, which consisted mainly of cities where DHS was already available or is likely to be distributed in the future. This is because RH in the country has been or will be distributed in only urban areas where large-scale apartment complexes are built, and there is no possibility of DHS being distributed in rural areas.

The survey had to be conducted by visiting each household in person and looking at the DHS bill. Thus, the survey was organized by a professional survey agency. In other words, sampling was implemented by the agency's supervisor, and well-experienced interviewers were employed, educated, trained, and then sent to the field survey. The survey of households was administered during July and August 2019 across the country. Each interviewee in the survey was conducted with the head of a household, or the spouse of the head of a household, aged between 20 and 65, and the interviewees were deemed to have the power to decide on the economic activities of the household concerned.

In the survey, the 1000 households reported that they used 1 of 4 types of heating system: individual heating (846 households), district heating (103), central heating (26), and electric heating (25). For district heating consumers, information about the consumption of and expenditure on RH could be collected relatively accurately, but this was not the case for households with other types of heating. Therefore, consumers with other types of heating were asked about their change in consumption as the result of price changes after being given information about the average price for RH, which was KRW 73,000 (USD 63.5) per Gcal. The dependent and independent variables employed in Equation (1) are described in Table 1.

Table 1. Description of variables in the model.

Variables	Definitions	Mean	Standard Deviation
<i>RH</i>	The consumption of residential heating during the year 2018 (unit: Gcal)	8.10	1.90
<i>P</i>	The price for residential heating (unit: Korean won per Gcal)	99,280.00	26,363.62
<i>Y</i>	The income of the household (unit: million Korean won = USD 870)	4.91	2.14
<i>F</i>	The number of people in the household	3.27	1.12
<i>C</i>	The number of children attending elementary, middle, or high schools in the household	0.73	0.91
<i>H</i>	The type of heating (1 = district heating system; 0 = others)	0.10	0.30

4. Results and Discussion

4.1. Results from Estimating the Demand Function

The estimation results for a total of six demand functions according to the choice of explanatory variables are shown in Table 2. Six models were estimated because it is necessary to examine how estimates of price elasticity vary under different specifications [18]. All the coefficient estimates show statistical significance at the 5% level. The *F*-values calculated under the null hypothesis that the estimated equation has no significance imply that all the equations are significant. The finding that the adjusted- R^2 is near 0.2 in all the six estimated equations indicates reasonable goodness-of-fit when considering the use of cross-sectional data.

In order to perform further analysis, it is necessary to select one of the six estimation results. In this regard, three indicators are intended to be used here. First, adjusted- R^2 is examined. The larger the value, the higher the goodness-of-fit. Among the six models, Models 5 and 6 have the highest adjusted- R^2 . Table 2 shows the value of adjusted- R^2 up to the third decimal place for simplicity. If we increase the number of valid decimal places to the fourth digit of the decimal point, the adjusted- R^2 values for Models 5 and 6 are 0.2619 and 0.2611, respectively. Thus, the goodness-of-fit of Model 5 is greater than that of Model 6.

Table 2. Estimation results of the model.

Variables ¹	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	7.141 * (41.74)	7.175 * (41.85)	7.208 * (40.53)	7.016 * (41.44)	7.053 * (41.57)	7.099 * (40.35)
ln <i>P</i>	−0.478 * (−39.80)	−0.478 * (−39.82)	−0.478 * (−39.80)	−0.478 * (−40.29)	−0.478 * (−40.32)	−0.478 * (−40.30)
ln <i>Y</i>	0.027 * (4.05)	0.024 * (3.61)	0.022 * (2.83)	0.036 * (5.42)	0.033 * (4.93)	0.029 * (3.87)
ln <i>F</i>			0.011 (1.39)			0.014 (1.74)
<i>C</i>		0.009 * (2.66)			0.010 * (2.94)	
<i>H</i>				−0.110 * (−11.23)	−0.110 * (−11.30)	−0.110 * (−11.28)
<i>F</i> -value (<i>p</i> -value)	800.10 * (0.000)	536.40 * (0.000)	534.14 * (0.000)	588.82 * (0.000)	444.46 * (0.000)	442.54 * (0.000)
Adjusted- <i>R</i> ²	0.242	0.243	0.242	0.261	0.262	0.261
Standard error of regression	0.211	0.211	0.211	0.208	0.208	0.208
Akaike information criterion	−683.1	−689.65	−683.08	−744.47	−747.8	−744.98
Sample size	5000	5000	5000	5000	5000	5000

Notes: ¹ the variables are described in Table 1. * denotes statistical significance at a significance level of 5%. The figures in parentheses below the estimates are *t*-values.

Second, the standard error of regression can be investigated. A model with a smaller value is preferable. Of the six models, the smallest standard error of regression is found in Model 5. Therefore, this result confirms the finding from the first indicator. Therefore, this result confirms the finding from the first indicator. Third, Akaike information criterion in Model 5 is the smallest of the six models. Interestingly, the Akaike information criterion in Model 6 is the smallest of the six models. Therefore, this result also makes the finding from the first indicator more solid. In summary, the results of applying the three indicators would suggest that Model 5 would be better used among the six models. Therefore, subsequent analyses are based solely on the estimation results from Model 5.

It is now necessary to investigate the estimates for the price and income elasticities. The price elasticity was estimated to be −0.478. Two conclusions can be drawn from this. First, the law of demand is established for RH. Second, the demand for RH is price-inelastic. Price elasticity can be used to predict how much variation in the price for RH due to changes in the price of natural gas used to produce RH, will change the heat demand. The income elasticity is estimated to be 0.033. This presents two implications. First, RH is a normal good whose demand increases as income increases. Second, the demand for RH is quite income-inelastic. The income elasticity can be used to predict how RH demand will change in the future with economic growth. The finding that both the absolute value of price elasticity and income elasticity are lower than one suggests that RH is an essential good that is not significantly affected by price changes and income changes, although the latter is much smaller than the former.

The signs of the coefficient estimates for the variables ln *F*, *C*, and *H* are positive, positive, and negative. The number of people in the household has a positive relation to the demand for RH. This seems to be reasonable since the RH consumption will be higher if there are more people. The number of children in the interviewee's family attending elementary, middle, or high schools also positively affects the demand for RH. The positive sign seems natural, as children are sensitive to the cold and require more heating and use more hot water. Households that currently use a DHS have a lower demand for RH than those that do not if the other conditions are equal. This is because households using DHS are satisfied with DHS in the country and will consume less RH than others.

4.2. Discussion of the Results

Two points will be discussed in this subsection. First, the main findings obtained from this study with those from a previous study. The price elasticity and income elasticity found in this study are -0.478 and 0.033 , respectively. In the study by Lim et al. [2], the demand function for RH was estimated using annual time series data and -0.699 , and 1.190 were obtained for price elasticity and income elasticity, respectively. Our study and the study by Lim et al. [2] are consistent in that the demand for RH is price-inelastic, but the price elasticity values are considerably different. That is, the absolute value of price elasticity obtained from our study is only about half the price elasticity obtained from the study by Lim et al. [2].

The difference in the income elasticity estimates is even greater. In particular, the research by Lim et al. [2] suggests that the demand for RH is income-elastic, but our study indicates that the demand for RH is income-inelastic. Of course, the former study used time series data revealed by RH consumers, and this study used cross-sectional data stated by RH consumers and potential RH consumers. Thus, there is significant difference in the nature of the data used, considering that the estimated demand function in both studies is the same as RH from DHS. This is an interesting finding from this study.

If there were no significant differences between the two studies, even if the government intervened in the RH market and controlled the price for RH, there would be no significant distortion of prices and demand observed in the market. However, since significant differences have been observed, the reasons for the differences need to be examined. One important reason for the differences is the possibility that the price and demand have been distorted due to government intervention in the market. Of course, it is not an easy task to pinpoint the reason for the differences. Moreover, direct comparisons may be difficult because there is a structural difference in the nature of the data used to estimate the RH demand functions in both studies.

In this study, the demand function for RH from DHS was estimated by applying the PSM technique asking how to change demand for RH in response to a change in the price for RH. To this end, the data were collected from a survey of 1000 households nationwide. The use of stated preference data may imply the possibility of respondents' showing strategic behavior. However, the strategic behavior is not a big issue, as it targets private good—RH, which is restricted to the others' consumption, not a public good. The fact that the price elasticity and income elasticity obtained from this study were statistically significant and that there is a significant difference from the former study suggests that the findings from this study can contribute significantly to the literature.

The second point to be discussed in this subsection is the potential uses of the findings from this study. The price elasticity of the demand, obtained above, has two important uses. First, price elasticity can be used proactively for demand side management to diagnose the effects of price increases. In 2019, South Korea introduced an energy efficiency resource standard (EERS) scheme, which requires RH suppliers to reduce the heat consumption of consumers through demand management projects such as financial support for the replacement of old-fashioned equipment with energy-efficient equipment. Since the costs incurred by the EERS scheme will eventually be reflected in the price for RH, price elasticity is a key element in predicting the total effect of the scheme. Moreover, considering that in South Korea the most widely used energy source for RH is natural gas, price elasticity can be utilized to predict how much the demand for RH will be affected by changes in the price of RH resulting from changes in the price of natural gas.

Second, price elasticity is the key information needed for computing the RH consumption benefit. According to microeconomic theory, the consumption benefit of a good is defined as the area below the demand function, which is made up of consumer surplus and expenditure. Alexander et al. [19] proposed an equation for approximating consumer

surplus. Using the equation and letting θ and P_0 be the price elasticity of RH demand and the RH price per Gcal, respectively, the RH consumption benefit per Gcal is derived as:

$$\left(1 - \frac{1}{2\theta}\right)P_0 = \left(1 - \frac{1}{2 \times (-0.478)}\right)P_0 = 2.05P_0. \quad (2)$$

Therefore, the benefit ensuing from consuming RH amounts to 2.05 times the price for RH, or KRW 149,659 (USD 130.18) per Gcal of RH. This information makes it easy to calculate the economic benefits of any new project to supply RH.

5. Conclusions and Policy Implications

Since the price for RH in South Korea is not determined in the market but is controlled by the government, estimating the demand function for RH from DHS with market data can give us distorted results. In this situation, this article tried to apply the PSM technique to obtain the demand function for RH using data gathered from 1000 households. Considering that all of the coefficient estimates for the demand functions were statistically meaningful and their signs were reasonable, the trialed use of the PSM was successful. Moreover, the price elasticity was estimated, with statistical significance, to be -0.48 , which means that the demand is inelastic to changes in the price.

This paper provides three important policy implications. First, in a situation where the price information observed in the market was distorted by the government's price control, information about price elasticity needed by policy-makers was reasonably derived. This study made an important contribution to the literature in that it is difficult to find research on estimating the demand function for RH in the literature. In particular, the price elasticity could be consistently obtained as approximately -0.48 for different specifications of the demand function. This value can be useful for diagnosing the impact of pricing policies in advance. For example, it can be used to predict how demand will change when adjusting the price for RH due to rising or falling prices of natural gas, the main fuel used to produce residential heat in South Korea. The price elasticity can be used for the government to establish natural gas supply and demand policies and for district heating and cooling (DHC) operators to develop marketing strategies.

Second, this study ascertained the usefulness of PSM techniques that could be applied in obtaining information about price elasticity. To the authors' knowledge, this study was the first attempt to apply the PSM technique in estimating the demand function for RH. Households responded with little difficulty to the question of how much they would adjust their demand for RH according to hypothetical changes in the price of RH. Moreover, the estimated demand function was statistically significant. This study demonstrated that the PSM is a useful technique for estimating the demand function in situations where market data are distorted. Thus, the application of PSM may be extended to other energy sources, such as electricity and natural gas. In South Korea, prices of electricity and natural gas are also controlled by the government, and information on the price elasticity of demand for them is required. Since it is easy for researchers to employ the PSM technique to provide useful results, the application of PSM could be expanded to other energy sources in the future.

Third, the consumption benefit of RH was quantitatively assessed using the estimated demand function. This value can be useful for conducting the economic feasibility analysis of new RH supply projects. In South Korea, because the source of producing residential heat is combined heat and power (CHP) plants, which are known to be quite efficient [20–22], almost all new towns are legally required to supply RH through DHC using CHP plants. Therefore, there are often new RH supply projects. From an economic standpoint, initiating a new RH supply project can be justified only if the economic benefits ensuing from the project are greater than the costs involved in the project. Although it is difficult to estimate the economic benefits of the project, this study revealed that the consumption benefit of RH is worth 2.05 times the price of RH. For instance, if a new project of supplying 100,000 Gcal of RH per year is proposed and the RH price is USD 63.5 per Gcal, the economic benefits

arising from the implementation of the project are calculated to be USD 13.0 million per year. The detailed derivation process of this value is as follows. First, if 100,000 Gcal is multiplied by the price of USD 63.5 per Gcal for RH, the revenue from RH sales is computed. Next, the multiplication of the revenue by 2.05 obtained in Equation (2) gives us the value.

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References

1. United Nations Environment Programme. *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*; UNEP DTIE: Paris, France, 2015.
2. Lim, S.Y.; Kim, H.J.; Yoo, S.H. The demand function for residential heat through district heating system and its consumption benefits in Korea. *Energy Policy* **2016**, *97*, 155–160. [\[CrossRef\]](#)
3. International Energy Agency. *Renewable Heat Policies: Delivering Clean Heat Solutions for the Energy Transition*; IEA Publications: Paris, France, 2018.
4. Liu, W. Estimating the elasticities of gasoline demand: An instrument variable approach. *Appl. Econ. Lett.* **2016**, *23*, 1153–1156. [\[CrossRef\]](#)
5. Lewis, R.C.; Shoemaker, S. Price-sensitivity measurement: A tool for the hospitality industry. *Cornell Hotel. Restaur. Adm. Q.* **1997**, *38*, 44–54. [\[CrossRef\]](#)
6. Raab, C.; Mayer, K.; Kim, Y.S.; Shoemaker, S. Price-sensitivity measurement: A tool for restaurant menu pricing. *J. Hosp. Tour. Res.* **2009**, *33*, 93–105. [\[CrossRef\]](#)
7. Liao, H.C.; Chang, T.F. Space-heating and water-heating energy demands of the aged in the US. *Energy Econ.* **2002**, *24*, 267–284. [\[CrossRef\]](#)
8. Andrić, I.; Pina, A.; Ferrão, P.; Fournier, J.; Le Corre, O. Assessing the feasibility of using the heat demand-outdoor temperature function for a long-term district heat demand forecast. *Energy Procedia* **2017**, *116*, 460–469. [\[CrossRef\]](#)
9. Möller, B.; Wiechers, E.; Persson, U.; Grundahl, L.; Connolly, D. Heat Roadmap Europe: Identifying local heat demand and supply areas with a European thermal atlas. *Energy* **2018**, *158*, 281–292. [\[CrossRef\]](#)
10. Meha, D.; Novosel, T.; Duić, N. Bottom-up and top-down heat demand mapping methods for small municipalities, case Glogoc. *Energy* **2020**, *199*, 117429. [\[CrossRef\]](#)
11. Heitkoetter, W.; Medjroubi, W.; Vogt, T.; Agert, C. Regionalised heat demand and power-to-heat capacities in Germany—An open dataset for assessing renewable energy integration. *Appl. Energy* **2020**, *259*, 114161. [\[CrossRef\]](#)
12. Canet, A.; Qadrdan, M.; Jenkins, N. Heat demand mapping and assessment of heat supply options for local areas—The case study of Neath Port Talbot. *Energy* **2021**, *217*, 119298. [\[CrossRef\]](#)
13. Kurek, T.; Bielecki, A.; Świrski, K.; Wojdan, K.; Guzek, M.; Białek, J.; Brzozowski, R.; Serafin, R. Heat demand forecasting algorithm for a Warsaw district heating network. *Energy* **2021**, *217*, 119347. [\[CrossRef\]](#)
14. Arnaudo, M.; Topel, M.; Puerto, P.; Widl, E.; Laumert, B. Heat demand peak shaving in urban integrated energy systems by demand side management—A techno-economic and environmental approach. *Energy* **2019**, *186*, 115887. [\[CrossRef\]](#)
15. Clegg, S.; Mancarella, P. Integrated electricity-heat-gas modelling and assessment, with applications to the Great Britain system. Part I: High-resolution spatial and temporal heat demand modelling. *Energy* **2019**, *184*, 180–190.
16. Ivanko, D.; Lekang, S.; Nord, N. Splitting measurements of the total heat demand in a hotel into domestic hot water and space heating heat use. *Energy* **2020**, *219*, 119685. [\[CrossRef\]](#)
17. Kim, H.J.; Paek, J.S.; Yoo, S.H. Price elasticity of heat demand in South Korean manufacturing sector: An empirical investigation. *Sustainability* **2019**, *11*, 6144. [\[CrossRef\]](#)
18. Mazzanti, M.; Montini, A. The determinants of residential water demand: Empirical evidence for a panel of Italian municipalities. *Appl. Econ. Lett.* **2006**, *13*, 107–111. [\[CrossRef\]](#)
19. Alexander, D.L.; Kern, W.; Neil, J. Valuing the consumption benefits from professional sports franchises. *J. Urban Econ.* **2000**, *48*, 321–337. [\[CrossRef\]](#)

-
20. Agrell, P.J.; Bogetoft, P. Economic and environmental efficiency of district heating plants. *Energy Policy* **2005**, *33*, 1351–1362. [[CrossRef](#)]
 21. International Energy Agency. *Combined Heat and Power: Evaluating the Benefits of Greatest Global Investment*; IEA Publications: Paris, France, 2008.
 22. Bianchi, M.; Branshini, L.; Pascale, A.D.; Peretto, A. Application of environmental performance of CHP systems with local and global approaches. *Appl. Energy* **2014**, *130*, 774–782. [[CrossRef](#)]