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Short communication

The demand function for residential heat through district heating system and its consumption benefits in Korea

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HIGHLIGHTS

- Demand for residential heat (RH) from district heating system (DHS) is expanding.
- We estimate the demand function for and consumption benefits of DHS-based RH.
- Short-run price and income elasticities are −0.700 and 0.918, respectively.
- Long-run price and income elasticities are −1.253 and 1.642, respectively.
- Consumption benefits of DHS-based RH are KRW 150,634 (USD 144.2) per Gcal.

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ABSTRACT

The demand for residential heat (RH) through a district heating system (DHS) has been and will be expanded in Korea due to its better performance in energy efficiency and the abatement of greenhouse gas emissions than decentralized boilers. The purposes of this paper are two-fold. The first is to obtain the demand function for DHS-based RH in Korea and investigate the price and income elasticities of the demand employing the quarterly data covering the period 1988–2013. The short-run price and income elasticities are estimated as −0.700 and 0.918, respectively. Moreover, the long-run elasticities are −1.253 and 1.642, respectively. The second purpose is to measure the consumption benefits of DHS-based-RH employing the economic theory that they are the sum of the actual payment and consumer surplus for the consumption. Considering that the average price and estimated consumer surplus of the DHS-based RH use in 2013 are computed to be KRW 87,870 (USD 84.1) and KRW 62,764 (USD 60.1) per Gcal, the consumption benefits of the DHS-based RH are calculated to be KRW 150,634 (USD 144.2) per Gcal. This information can be beneficially utilized to conduct an economic feasibility study for a new DHS project related to RH supply.

1. Introduction

The district heating system (DHS) is considered to be best for the supply of residential heat (RH), a vital part of a human being's life, in urban areas with high population density (Behnaz and Rosen, 2012). Plants for the DHS can give us better performance in energy efficiency than decentralized boilers and an abatement of air pollutant emissions (Gebremedhin, 2014). Moreover, the DHS is a more effective measure for mitigating greenhouse gas emissions than the individual heating system (IHS), contributing greatly to the enhancement of public convenience and energy saving (e.g., Knutsson et al., 2006; Ilic and Trygg, 2014; Euroheat and Power, 2015).

The Korean government established a public utility, the Korea District Heating Corporation (KDHC), in 1985 in order to expand the DHS nationwide, focusing on new satellite cities in the Metropolitan areas. The DHS has been provided for existing apartments, replacing IHSs, and newly planned cities are constructing new plants. Korean residents prefer the DHS to IHSs according to three aspects. First, the rate of the former is lower than that of the latter. Second, the former does not demand an individual boiler. Finally, the overall price of houses in DHS areas is higher than that in IHS areas with other things being equal (Yoon et al., 2015).

Although DHS gives a variety of advantages to households, the households using individual heating system have some difficulties in replacing IHS with DHS because the replacement demands a considerable investment and they should live in the areas with

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access to DHS. However, the supply of RH through DHS will be expanded in Korea to meet residents' increasing demand for RH. For example, according to the mid- and long-term financial plan of the KDHC, the amount of RH supplied by the KDHC will be doubled in 2024 compared with that in 2010.

In order to complete the tasks, the KDHC is constructing and planning to construct several DHS facilities. Because the KDHC is a public utility, whether to build a new DHS facility should be decided in the context of an economic feasibility analysis, namely a cost-benefit analysis. To this end, uncovering the costs and benefits ensuing from the DHS construction is required. Information on the costs can be more easily obtained than that on the benefits. However, so far as the authors know, the consumption benefits of the RH have rarely been estimated in the literature, leading researchers to be asked to supply usable and quantitative information on them for policymakers.

Therefore, our study attempts to value the consumption benefits of the RH in Korea. The economic theory implies that the economic benefit of the RH consumed is the sum of consumer surplus (CS) and actual payment and for the consumption (Lee and Yoo, 2013). The computation of CS for RH consumption is quite a complicated work. This study will use an estimate of CS proposed by Alexander et al. (2000), which will be explained in detail in the next section. In calculating the estimate, we need information on the price elasticity of RH demand that can be derived from the demand function for RH.

Thus, the purposes of the paper are two-fold. The first is to obtain the demand function for DHS-based RH in Korea and find the price and income elasticities of the demand. The second purpose is to measure the consumption benefits of DHS-based-RH using the estimated price elasticity of the RH demand. The remainder of the paper is structured as follows. The methodology adopted here and the data used are explained in Section 2. The results and discussion are reported in Section 3. The paper is concluded in the final section.

2. Methodology and data

2.1. Consumption benefits of RH

A rational consumer maximizes his/her utility under income or budget constraints. The demand for a good or service is derived as a solution to the utility maximization problem when the market exists and the price is exogenously given. It is natural that if the price changes the demand should also change. Thus, we can define the demand function where the price is an independent variable and the demand is a dependent variable. The demand function is assumed to be smooth and continuous. Given that there exists the demand function and we can obtain it, microeconomic theory shows that we can utilize the demand function to assess the economic benefits of the RH consumption (e.g., Ku and Yoo, 2012; Park and Yoo, 2013).

The inverse demand function or demand curve means the marginal benefit function or marginal willingness to pay (WTP) function (Willig, 1976). The height of the demand curve indicates a consumer's benefit or WTP to get one unit of the goods in question. Thus, the area below the demand curve implies a consumer's total benefit from or WTP for the consumption of a specified quantity of goods. The CS is defined as the gap between a consumer's maximum WTP and the actual price, as shown in Fig. 1. In other words, the economic benefits of the RH consumed are the sum of the CS and actual consumer expenditure.

When one unit of RH is consumed at a price, the economic benefit of RH use can be computed by dividing the sum of the CS and actual consumer expenditure by the amount of RH consumed.

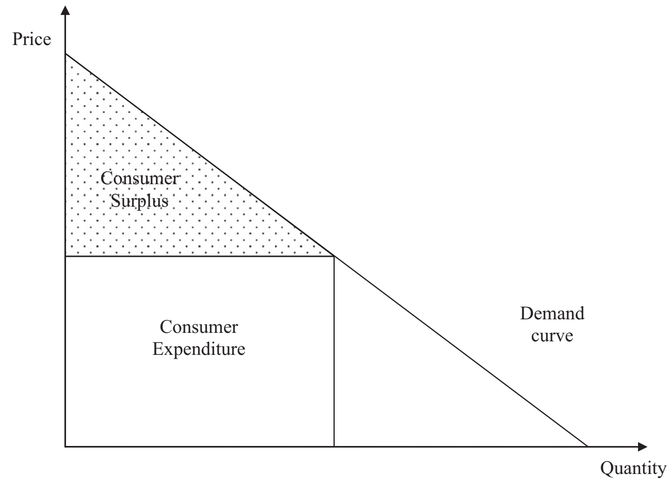

Fig. 1. Demand curve and consumer surplus.

It is quite difficult to measure the CS for RH use, while the consumer expenditure is easily obtainable information. This is because the consumer's choke price, defined as the price at which demand is zero, should be computed to estimate the CS. However, this computation is almost impossible to implement in the real world because of the insufficiency of available data. Thus, usually, the choke price has been assumed using a proxy, which may significantly reduce the reliability of measured CS. Accordingly, an alternative to estimating the CS is needed.

2.2. Estimation of CS

Interestingly, Alexander et al. (2000) suggested a simple formula for CS that is based on only two values: the revenue from a commodity sale and the price elasticity of demand for the commodity. Let P, X, and T be the price for RH, the demand for RH, and a vector of other variables that may affect the demand, respectively. A continuous and differentiable inverse demand function can be formulated as $P = P(X, T)$. If we assume that the levels of price and demand for RH are P_0 and X_0, respectively, and omit T for brevity, then the first-order Taylor's expansion produces:

$$P(X) = P(X_0) + P'(X - X_0) + O(X) \tag{1}$$

Integration of this function from 0 to X_0 and subtraction of the consumer's actual payment, P_0X_0, yields the CS (CS) as:

$$CS = \int_0^{X_0} P(X)dX - P_0X_0 = -\frac{P_0X_0}{2\lambda} + \int_0^{X_0} O(X)dX \tag{2}$$

where λ is the price elasticity of demand when the price is P_0. When the second term in the last equality of (2) is sufficiently small, the first term in that is an approximation of the CS. For example, if the demand function has a linear form, the CS is exactly $-P_0X_0/2\lambda$. Thus, the approximation of consumption benefits can be derived as:

$$P_0X_0 + CS \approx P_0X_0 - \frac{P_0X_0}{2\lambda} = P_0X_0\left[1 - \frac{1}{2\lambda}\right] \tag{3}$$

In applying Eq. (3) and assessing the consumption benefit, we require the information on λ, which can be obtainable from the demand function for RH. Thus, we need to estimate the demand function for RH.

2.3. Estimation of the demand function for RH

There are only a few studies that deal with the heat demand