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Economies of scale in the Korean district heating system: A variable cost function approach

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HIGHLIGHTS

- We examine economies of scale in the South Korean district heating sector.
- We focus on Korea District Heating Corporation (KDHC), a public utility.
- We estimate a translog cost function, using a variable cost function.
- We found economies of scale to be present and statistically significant.
- KDHC will enjoy cost efficiency and expanding its supply is socially efficient.

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ABSTRACT

This paper aims to investigate the cost efficiency of South Korea's district heating (DH) system by using a variable cost function and cost-share equation. We employ a seemingly unrelated regression model, with quarterly time-series data from the Korea District Heating Corporation (KDHC)—a public utility that covers about 59% of the DH system market in South Korea—over the 1987–2011 period. The explanatory variables are price of labor, price of material, capital cost, and production level. The results indicate that economies of scale are present and statistically significant. Thus, expansion of its DH business would allow KDHC to obtain substantial economies of scale. According to our forecasts vis-à-vis scale economies, the KDHC will enjoy cost efficiency for some time yet. To ensure a socially efficient supply of DH, it is recommended that the KDHC expand its business proactively. With regard to informing policy or regulations, our empirical results could play a significant role in decision-making processes.

1. Introduction

While experiencing two energy crises in the 1970s, the South Korean government began to recognize that fundamental energy-saving measures were required in the housing, industrial, and commercial sectors. As part of establishing those energy-saving measures, the government promoted district heating (DH), which uses high-efficiency equipment that leverage combined heat and power (CHP). The use of CHP equipment can improve energy use efficiency by producing heat and power simultaneously. DH through CHP can use low-priced renewable energy, including waste heat from industrial processes and heat from waste incineration—other renewable energy sources include wood chips, landfill gases, solar heat, and sewage.

DH has a number of advantages. First, the availability of a variety of energy sources for CHP facilitates reduction of oil dependency and better use of renewable energy. Second, the use of DH reduces production costs by using waste energy. Third, DH has been evaluated as a clean and eco-friendly energy form and the energy sources used in CHP help save fossil fuels and reduce air pollutants. Thus, the application of DH improves air quality. By utilizing CHP, DH produces only 39% of the air pollutants (e.g., nitrogen oxides, sulfur oxides, and dust) that individual heating systems (IHSs) do (e.g., Haichao et al., 2013; Ilic and Trygg, 2014). Fourth, DH can help resolve the problem of global warming, since DH can reduce greenhouse gas emissions in South Korea by 49.2%, compared to IHSs (Korean Ministry of Trade, Industry & Energy,

Abbreviations: CHP, Combined heat and power; DH, District heating; DHS, District heating system; IHS, Individual heating system; KDHC, Korea District Heat Corporation; SCE, Scale economies; SUR, Seemingly unrelated regression

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2014) Finally, CHP plants are usually sited in closer proximity to consumers than existing heating systems (e.g., thermal power plants, hydropower plants, and nuclear plants); this results in reduced transmission losses and lower transmission investment costs.

For these environmental and economic reasons, the South Korean government has been interested in expanding the use of DH and has promoted the introduction of DH to local residents. Existing apartments have been retrofitted to use DH systems (DHSs), thus replacing IHSs; additionally, newly planned cities have constructed new DHS plants. South Korean residents prefer DHSs to IHSs for three reasons. First, the price rates of the former are lower than those of the latter. Second, the former does not require the use of an individual boiler. Finally, the average value of houses in DHS-serviced areas is higher than that of houses in IHS-serviced areas, all else being equal. In summary, DHSs are expected to proliferate throughout South Korea to meet residents' increasing demand for them, and there is a national plan in place to build more CHP plants.

The DH industry is a network industry that requires pipelines to deliver energy to users. Some public goods suppliers—the so called public utilities in the economic literature such as electricity, railway, natural gas, water, and sewage companies—are also categorized as network industries. Generally, network firms construct delivery systems to connect plants to users. Large investments in the construction of plants and pipelines are required in the early stages of a project; this investment-based barrier can foster a natural or legal monopoly. The average cost of a monopolistic company reduces to low levels over time, on account of those investments initially made in the facilities. The monopolistic firm usually retains its monopolistic position and increases its production scale while enjoying profits.

Although it seems efficient to have a single large firm generate DH, the disadvantages inherent in a monopoly could lead to several problems for energy users. For example, the average cost of the firm increases rather than decreases at some threshold scale; at that threshold value, production is not socially efficient. If a monopolistic firm produces DH in excess of that scale, granting permission to market entrants and dividing the monopolistic firm into several smaller firms would result in cost reductions and efficiency enhancements. In such a scenario, government officials may insist upon introducing a competition system to the DH industry as a part of liberalization.

The issues of privatization and competition have arisen among network industries in South Korea. Indeed, in 1999, a monopolistic power generation public utility was divided into six generation companies, based on empirical results that concluded that returns to scale were decreasing. Additionally, a competition scheme was introduced to the country's natural gas supply industry, whereupon the government allowed large-scale private consumers to import liquefied natural gas directly. Additionally, a national railway company was embroiled in a privatization controversy in 2013. As to the current study's focus, however, the South Korean government established KDHC in 1985 to expand DHSs nationwide, while focusing specifically on new satellite cities in metropolitan areas. KDHC owns 12 CHP plants and buys heat from three CHP plants owned by other generation companies, and recently, private DHS suppliers have emerged in the market. In 2013, 10,895,352 Gcal was supplied to 1,248,846 households by KDHC, who enjoyed a 59% market share in the DHS market; thus, the DH industry was suspected of being monopolistic.[3] Reducing the government's equity share of KDHC and/or strictly limiting the expansion of KDHC into the DH market have been considered.

What is important in introducing a competitive system or denationalizing a network industry is whether doing so will increase, reduce, or maintain returns to scale. As noted earlier, network industries require large investments at their onset, and they usually experience a decreasing average cost for some time afterwards. Identifying and using a social efficiency scale would assist in removing the social loss that can occur when supplying resources or services. When an industry experiences decreasing returns to scale, the government would allow new entrants into its market. On the other hand, increasing returns to scale would imply that the presence of multiple suppliers would give rise to socially inefficient conditions; in such a case, the merging of firms or expansion into the supply area would be recommended, to create one or several firms that have healthy economies of scale.

The objective of this study is to generate empirical data and determine the implications of economies of scale in KDHC. A competition issue always arises in any industry in which there appears to be a monopoly. The aforementioned industries have often been called network industries, all of which require initial infrastructure investments; like other network firms and industries, DH suppliers should have power plants and a network of pipelines in place. Given the nature of these essential facilities, DH has conventionally been considered a naturally monopolistic industry: these facilities are very large and expensive, and so only very large companies can afford them. Now would be an appropriate time to undertake an economic analysis of economies of scale for KDHC in South Korea: doing so could help inform policymakers as they make decisions vis-à-vis energy plans or policy restrictions.

This paper is organized into four distinct parts. Section 2 provides a literature review and details the estimation model, variable cost function, and variable definitions used in this study. Section 3 presents our estimation results and our predictions of future scale economies; it also discusses policy implications with regard to KDHC, a South Korean DH utility, and makes suggestions for its efficient management. Section 4 concludes the paper.

2. Method

2.1. Literature review

Many researchers have focused on economies of scale in a variety of industries, including electricity, water, railway transportation, telecommunications, airlines, and public transportation. The starting point is the study by Christensen and Greene (1976), which addresses the cost function of U.S. electric power generation by using ordinary least squares. The most popular focus in this body of literature has been on water utilities: since 2000, more than 40 papers have been published with respect to water and sewage (Bottasso and Conti, 2008; Kim and Lee, 1998; Martins et al., 2006; Renzetti, 1999; Saal et al., 2007; see a review in Saal et al., 2013). The railway transportation industry is an interesting research area with regard to privatization and liberalization (Caves et al., 1981; Ida and Suda, 2004; Loizides and Tsionas, 2002). Many studies focus on the telecommunications industry (Charnes et al., 1988; Evans and Heckman, 1988), the airline industry (Berry, 1992; Oum et al., 1993) and on public transport, including bus and metro transportation (Cambini et al., 2011; Di Giacomo and Ottoz, 2010; Farsi et al., 2007; Ottoz and Di Giacomo, 2012).

However, little research has been done on economies of scale in the DH industry. With regard to cost, Sjödin and Henning (2004) calculated the marginal costs of a DH utility. While a few papers address cost efficiency by using data envelopment analysis, only

[3] There are 35 suppliers in the market of 2015 and about 70% of suppliers suffer from their deficit. Their total deficit is KRW 34,219 million (Korea Energy Agency, 2015). The second biggest supplier, GS power co., Ltd, has 12.7% of the market and SH corporation, which has a 8.8% market share, is in the third place.