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Economic Effects of Individual Heating System and District Heating System in South Korea: An Input-Output Analysis

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Featured Application: This work investigates the economic effects of the same amount of production or investment in the individual heating system and the district heating system in South Korea using an input-out analysis.

Abstract: When South Korea develops a new city, the government has made a preliminary decision on one of two heating systems, an individual heating system (IHS) or a district heating system (DHS). However, it is still unclear which system is desirable in terms of maximizing the national economic effect. Thus, this article aims to derive quantitative information about the economic effects of the same amount of production or investment in the two systems through an input-output (IO) analysis using the recently published 2017 IO table. More specifically, the production-inducing effects, value-added creation effects, and wage-inducing effects are systematically analyzed focusing on the IHS and DHS sectors. The results show that one dollar of production or investment in IHS or DHS causes about 1.073 and 1.388 dollars of production, about 0.228 and 0.658 dollars of value-added, and about 0.051 and 0.108 dollars in wages, respectively, throughout the national economy. Overall, the economic effects of the DHS sector are greater than those of the IHS sector. That is, when the same amount of investment or production is made in the two sectors, DHS produces more economic effects than IHS.

Keywords: individual heating system; district heating system; economic effect; input-output analysis

1. Introduction

The heating systems of South Korea have evolved into various forms with economic development. Before the 1980s, the primary fuels for residential heating were wood thicket and briquette. However, after the second oil crisis and in accordance with the South Korean government's energy diversification policy, natural gas was introduced in order to lower dependence on oil consumption. Since the 1980s, with economic development, heating fuel has started to change from oil to natural gas. Because of this, the heating system was mainly changed to an individual heating system (IHS). Natural gas was supplied to the metropolitan area for the first time with the establishment of an acquisition base and a pipeline network. Since then, it has spread to metropolitan areas, and the number of households that have been supplied with IHS was 17.75 million as of 2017 [1].

Two oil crises caused an energy crisis in the 1970s. This also led the South Korean government to recognize the need for fundamental energy-saving measures in the residential, commercial, and industrial sectors. As a result, since the mid-1980s, the government introduced a district heating system (DHS) that can dramatically improve energy efficiency compared to a central heating system or an

IHS. At the time of the introduction of the combined heat and power (CHP) generation-based DHS, the South Korean government made an important goal to secure eco-friendly features such as saving energy and improving environmental pollution in dense residential areas.

Thus, as new towns have expanded since the mid-1980s, DHS has become a heating system that can satisfy economic efficiency and convenience in the construction of apartments, which are large-scale public housing buildings with high a population density. As of 2017, DHS is supplied to 2.8 million households. This is about 16.4% of the total number of households in South Korea. The DHS is provided through a district energy business. The district energy business refers to a business in which energy (heat or heat and electricity) is produced by one or more concentrated energy production facilities such as CHP plants or incinerators. It is supplied and sold to a large number of users in residential, commercial, or industrial complexes [2].

There was no data comparing IHS and DHS as in this study, but information on DHS supply in several countries is provided only by Euroheat and Power [3]. Due to their high energy efficiency and reduction of greenhouse gas emissions, DHS are also distributed in many countries, and Euroheat and Power [3] data are the only data that provide information on the rate of prevalence of DHS in residential sector as far as the authors know. In general, the rate of prevalence of DHS in countries that operate large-scale DHS was high. For example, in Europe, the rate of prevalence of DHS in the residential sector was 90% in Iceland, 90% in Sweden, 65% in Denmark, 38% in Finland, 15% in Austria, and 13.8% in Germany as of 2017. In addition, countries with large-scale DHS have a high proportion of CHP. As of 2017, the share of CHP in DHS was 70% in Finland, 59% in Austria, and 83% in Germany [3]. As an exception, in Iceland, which uses a lot of geothermal heat, the share of CHP is low, and in Sweden and Denmark, which have a high dependency on waste heat, CHP has a relatively low share of 46% and 51%, respectively.

On the other hand, the rate of prevalence of DHS in countries that operate small-sale DHS was relatively low. For instance, the rate of prevalence of DHS in residential sector was 2% in UK as of 2013 and 3% in the US as of 2011. In Japan, no information on the rate of prevalence of DHS was given, but the area of DHS supply increased by 3.6% in 2013 compared to 2009. In China, 98% of the total DHS was distributed in the northern regions, and the rate of prevalence of DHS in that region was about 55% in 2013. In countries with small DHS, there is no information on the share of CHP in DHS. However, several countries have implemented various policies to support CHP considering the advantages of CHP. The UK is implementing a policy to exempt climate change contributions for high-efficiency CHP. Japan has established a roadmap with the goal of expanding CHP power generation to 5 times the level of 2010 by 2030. In the US, funding for some of the project's costs is supported when installing high-efficiency CHP, and some states offer tax-free benefits when operating CHP.

The DHS produces heat from a specific sized centralized heat production facility and then sends the heat to the users through an underground heat transport pipeline. A CHP plant, which is a facility that produces electricity and heat simultaneously, is mainly utilized to produce heat in DHS. The use of CHP significantly increases energy efficiency compared to producing heat and electricity separately. According to the United States Environmental Protection Agency [4], energy efficiency is 51% when producing heat and electricity separately, while energy efficiency is 75% for CHP, which produces heat and electricity at the same time.

In other words, DHS is energy efficient. Therefore, energy consumption of DHS is less than that of IHS, and DHS has the advantage of reducing air pollutant emissions and abating greenhouse gas emissions [5–10]. In addition, CHP is equipped with a device for air pollution reduction, so there are fewer air pollutant emissions such as sulfur oxides, nitrogen oxides, and particulate matters from CHP than from individual boilers [11]. Furthermore, DHS can provide convenience to the consumer, because DHS does not need extra space for the installation of an individual boiler [12,13].

IHS, on the other hand, is a structure that supplies fuel to the individual boiler of users through a gas pipeline network. The individual boiler is convenient to use because it allows the user to operate and stop the boiler directly. However, it is inconvenient because there is a need for separate installation space, and it requires operation and maintenance costs. In particular, consumers using IHS can suffer a great inconvenience when the boiler breaks down in winter.

In South Korea, when developing new residential complexes, such as new city construction, redevelopment and reconstruction, it is necessary to decide in advance which heating system will be installed. That is, when supplying heat in urban areas with high population density, policy makers must decide whether to provide IHS or DHS to the areas. Usually, the latter has been preferred to the former because the latter uses cogeneration to dramatically reduce energy use; although both heating systems use natural gas as fuel. However, it is still unclear which system is desirable in terms of maximizing the national economic effects. Therefore, the policy makers need quantitative information about the national economic effects of IHS and DHS sectors. That is, we must reach a rational conclusion by persuading the people with scientific and objective results by analyzing the economic effects of the two sectors.

This study tries to respond to these government needs. For this purpose, the input-output (IO) analysis is applied using the most recently published IO table from 2017. The IO table represents the flow of goods and services between sectors of a country's economy in a single table [14]. Using IO analysis, various economic effects related to energy can be examined [15–19]. In particular, this study seeks to take two approaches to applying IO analysis. First, the three economic effects, the production-inducing effect, value-added creating effect, and wage-inducing effect, for the two sectors are systematically analyzed. Second, the economic effects focusing on the two sectors are dealt with by applying techniques to specify the IHS and DHS sectors as exogenous ones. The two sectors are endogenous sectors in the original IO table.

To the best of the authors' awareness, this is the first study to investigate this subject quantitatively and compare the national economic effects of IHS and DHS, which are the two key alternative heating system. There are various factors to consider in determining which heating system is more suitable, such as energy efficiency [20,21], convenience benefits for the consumers [12,13], benefits of decentralized generation [22], the effect of reducing greenhouse gas emissions [8,10,23], the effect of mitigating air pollutants emissions [11], the effect of abating particulate matter, and economic effects, etc. However, this study tries to look at the economic effects of IHS and DHS among the factors mentioned above. The findings from this study could at least be used to determine which of the two sectors is better in terms of economic effects.

This article tries to contribute to the literature by comparing the economic effects of the IHS and DHS sectors by using the IO analysis. There are three sections in the rest of the article. An explanation of the methodology is given in Section 2. In particular, the theoretical background and application procedures of IO analysis as the main technique used in this article will be described. Section 3 explains the data, addresses the results, and reports the implications of the results. Conclusions are presented in the final section.

2. Materials and Methods

2.1. Method: IO Analysis

IO analysis, also called inter-industry analysis, has been widely applied to find the economic impacts of a particular sector within an economy. This is because the IO model is useful for analyzing and forecasting the overall economic impacts of a change in production or investment of a sector because it is characterized by a general equilibrium model that emphasizes the link between sales and purchase of inputs [24]. More specifically, the model can be utilized to identify the impacts of changes in final demand or output of a particular sector on the production, value-added, employment, wages, income, etc. of the economy as a whole, as well as in each sector. In particular, the IO table, which is used as an input to the IO model, contains details of the flow of goods and services between industries, which can effectively reveal the processes of production, the use of goods and services, and the income generated from production in each sector [25].

IO analysis has been often applied to analyze the economic effects of energy sectors in the literature. Han et al. [26], Yoo and Yoo [27], and Heo et al. [28] examined the roles of four electric power sectors, nuclear power generation, and the oil industry in the South Korean national economy, respectively. Yuan et al. [29] investigated the impact of the Global Financial Crisis on Chinese economic growth and energy consumption. Sabiroglu and Bashirli [30] provided empirical research to identify the linkages between final demand and total output, final demand and total supply, and value-added ratios and prices in quarrying of energy-producing materials in Azerbaijan. Ozkan et al. [31] conducted energy IO analysis in Turkish agriculture. Markaki et al. [32] dealt with the impact of clean energy investments on the Greek economy. Kim and Yoo [33] and Ju et al. [34] looked into the economic cost of unsupplied diesel product and electricity shortage costs in South Korea, respectively. Lim and Yoo [35] inspected the impact of electricity price increase on industrial prices and general price levels in South Korea.

Thus, the method employed in this study, IO analysis, is consistent with previous case studies found in the literature. This study, however, differs in three respects from the previous studies. First, the study analyzes various economic effects of the two sectors and compares them. Second, in the absence of a case study from South Korea, the policy implications for the two sectors are updated by conducting a case study of South Korea using the most recently published IO table.

Third, various economic effects focusing on the two sectors are analyzed through exogenous specification of the two sectors, which deals with the two sectors as an exogenous sector rather than as one of the endogenous sectors. Thus, the economic effects of the change in production or investment in the two sectors, rather than the change in the final demand or value-added for the two sectors, could be analyzed. The conventional IO analysis that deals with a sector as an endogenous sector creates contradictions so that an exogenous shock such as production or investment in the sector affects the production, value-added, and wages of the sector again. These points are thought to be notable parts of this article.

2.2. Demand-Driven Model

Using the demand-driven model, which is the basic model of IO analysis, this study investigates three economic effects: production-inducing effects, value-added creation effects, and wage-inducing effects. When there are n sectors in the economy, the basic equation of the demand-driven model is:

$$Z = BZ + Y \text{or} Z = (I - B)^{-1}Y \tag{1}$$

where Z is an $n \times 1$ output matrix whose elements are Z_i for $i = 1, \ldots, n$; B is an $n \times n$ input coefficient matrix whose elements are b_{ij} defined as x_{ij}/Z_j, where x_{ij} means intermediate demand running from the ith sector to the jth sector; Y is an $n \times 1$ final demand matrix whose elements are Y_i; and I is an $n \times n$ identity matrix. $(I - B)^{-1}Y$ is usually called a Leontief inverse matrix or input inverse matrix [14,36].

2.3. Production-Inducing Effects

"Production-inducing effects" refers to how much one dollar of production or investment in a particular sector increases production in other sectors. For convenience, the particular sector of interest is denoted as sector L. Manipulating Equation (1) to treat the sector as an exogenous sector gives us [37]:

$$\Delta L = (D - C)^{-1}(C_L \Delta Z_L) \tag{2}$$

where ΔL is an $(n-1) \times 1$ matrix showing changes in output of other sectors except for the sector, D is an $(n-1) \times (n-1)$ identity matrix, C is an $(n-1) \times (n-1)$ matrix that remains after removing the sector-related rows and columns from B. C_L is an $(n-1) \times 1$ column vector that is left after eliminating the sector's row from the sector-related column vector of B, and ΔZ_L denotes the change in output of the sector.

2.4. Value-Added Creation Effects

"Value-added creation effects" indicates how much one dollar of production or investment in sector L leads to the creation of value-added in other sectors. Let $\hat{K}$ be a diagonal matrix of value-added coefficients, which are defined as $K_j = k_j/Z_j$ for $j = 1, \ldots, n$, where k_j means the value-added of the jth sector. Manipulating Equation (2) and using $\hat{K}$ to treat the sector as exogenous produces [38]:

$$\Delta H = C_K(D - C)^{-1}(C_L \Delta Z_L) \quad (3)$$

where ΔH is an $(n-1) \times 1$ column vector signifying changes in the value-added of other sectors except for the sector, and C_K represents the $(n-1) \times (n-1)$ matrix that remains after excluding the sector-related row and column from $\hat{K}$.

2.5. Wage-Inducing Effects

"Wage-inducing effects" refers to how much one dollar of production or investment in the sector increases wages in other sectors. Let $\hat{W}$ be the diagonal matrix of wage coefficients, which are defined as $W_j = w_j/Z_j$ where w_j is the wage in the jth sector. Manipulating Equation (2) and $\hat{W}$ to treat the sector as an exogenous sector produces [39]:

$$\Delta N = C_W(D - C)^{-1}(C_L \Delta Z_L) \quad (4)$$

where ΔN is the $(n-1) \times 1$ matrix, meaning changes in wages in other sectors except for sector L, and C_W indicates the $(n-1) \times (n-1)$ matrix left after excluding the sector-related row and column from $\hat{W}$.

3. Results and Discussion

3.1. Data

This article utilizes the most recently published IO table for 2017 [40]. The IO table used in this study is downloadable from the Bank of Korea (www.bok.or.kr). There are 381 sectors in the South Korean IO table. Thus, for IO analysis, sectors must be classified properly, not arbitrarily. In this regard, the Bank of Korea provides four classification methods: large-scale, medium-scale, small-scale, and basic scale classifications. This study aims to perform IO analysis using a large-scale 33-sector classification method and a 35-sector IO table that additionally includes one of the city gas supply and steam and hot water supply sectors. The 35-sector IO table is basically constructed using a basic-scale 381-sector IO table.

In the large-scale 33-sector IO table, sector 17 is "electricity, gas, and steam supply." The city gas supply and steam and hot water supply sectors are extracted from sector 17 using the basic-scale 381-sector IO table. Thus, the sector classification adopted in this study including 33 large-scale sectors and the two sectors is shown in Table 1. In South Korea, IHS sector belongs to the city gas supply sector as fuel for IHS is supplied by the city gas industry. On the other hand, DHS sector belongs to the steam and hot water supply sector since DHS is provided by the steam and hot water supply industry. Thus, this article regards IHS and DHS sectors as the city gas supply and steam and hot water supply sectors, respectively.

Table 1. Sector classification adopted in this study.

Sectors	
1.	Agricultural, forest, and fishery goods
2.	Mined and quarried goods
3.	Food, beverages and tobacco products
4.	Textile and leather products
5.	Wood and paper products, printing and reproduction of recorded media
6.	Petroleum and coal products
7.	Chemical products
8.	Non-metallic mineral products
9.	Basic metal products
10.	Fabricated metal products, except machinery and furniture
11.	Computing machinery, electronic equipment and optical instruments
12.	Electrical equipment
13.	Machinery and equipment
14.	Transport equipment
15.	Other manufactured products
16.	Manufacturing services and repair services of industrial equipment
17.	Electricity
18.	Water supply, sewage and waste treatment and disposal services
19.	Construction
20.	Wholesale and retail trade and commodity brokerage services
21.	Transportation
22.	Food services and accommodation
23.	Communications and broadcasting
24.	Finance and insurance
25.	Real estate services
26.	Professional, scientific, and technical services
27.	Business support services
28.	Public administration, defense, and social security services
29.	Education services
30.	Health and social care services
31.	Art, sports, and leisure services
32.	Other services
33.	Others
34.	City gas supply
35.	Steam and hot water supply

3.2. Results

A total of two analysis results will be presented, including one for the IHS sector and the other for the DHS sector. Furthermore, as explained above, all results will be derived from analysis that specifies the city gas supply or steam and hot water supply sector as exogenous, not endogenous. The results of analyzing the production-inducing effects of the IHS and DHS sectors through Equation (2) using the demand-driven model are shown in Table 2.

For example, one dollar of production or investment in the two sectors induces 0.00220 and 0.01457 dollars of production in sector 7, "Chemical products," respectively. The sums of production-inducing effects for the two sectors are computed to be 0.07293 and 0.38770. The self-induced effect is naturally one. Thus, the total production-inducing effects of one dollar of production or investment in the IHS and DHS sectors are about 1.073 and 1.388 dollars. Interestingly, the latter is greater than the former.

The results of assessing the value-added creation effects of the two sectors on other sectors through Equation (3) are presented in Table 3. For instance, one dollar of production or investment in the two sectors produces 0.00198 and 0.01182 dollars of value-added in sector 26, "Professional, scientific, and technical services," respectively. One dollar of production or investment in the IHS and DHS sectors produces a total of 0.03597 and 0.14736 dollars of value-added in other sectors, respectively.

The value-added ratio of a sector is defined as the value-added of the sector over the total input of the sector and denoted as self-induced effect in Table 3. The value-added ratios of the two sectors are 0.19168 and 0.51060, respectively. Therefore, the total value-added creation effects are about 0.228 and 0.658, respectively. One dollar of production or investment in the DHS sector creates more value-added in the national economy than that in the IHS sector.

Table 2. Production-inducing effects of steam and hot water supply and city gas supply sectors.

Sectors		City Gas Supply		Steam and Hot Water Supply	
		Values	Ranks	Values	Ranks
1.	Agricultural, forest, and fishery goods	0.00046	25	0.00215	22
2.	Mined and quarried goods	0.00578	3	0.00021	32
3.	Food, beverages and tobacco products	0.00101	18	0.00475	18
4.	Textile and leather products	0.00042	26	0.00172	25
5.	Wood and paper products, printing and reproduction of recorded media	0.00068	21	0.00266	21
6.	Petroleum and coal products	0.00171	17	0.03906	2
7.	Chemical products	0.00220	13	0.01457	5
8.	Non-metallic mineral products	0.00038	27	0.00213	33
9.	Basic metal products	0.00176	15	0.00490	17
10.	Fabricated metal products, except machinery and furniture	0.00223	12	0.00602	14
11.	Computing machinery, electronic equipment and optical instruments	0.00174	16	0.00861	10
12.	Electrical equipment	0.00092	19	0.00543	15
13.	Machinery and equipment	0.00251	8	0.00875	9
14.	Transport equipment	0.00052	23	0.00145	27
15.	Other manufactured products	0.00022	32	0.00071	30
16.	Manufacturing services and repair services of industrial equipment	0.00282	6	0.00638	13
17.	Electricity and city gas supply	-	-	0.17271	1
17.	Electricity, and steam and hot water supply	0.00223	11	-	-
18.	Water supply, sewage and waste treatment and disposal services	0.00028	30	0.00395	19
19.	Construction	0.00030	29	0.00297	20
20.	Wholesale and retail trade and commodity brokerage services	0.00249	9	0.01116	7
21.	Transportation	0.00266	7	0.00732	11
22.	Food services and accommodation	0.00247	10	0.01263	6
23.	Communications and broadcasting	0.00213	14	0.00648	12
24.	Finance and insurance	0.01842	1	0.01769	4
25.	Real estate services	0.00321	5	0.00533	16
26.	Professional, scientific, and technical services	0.00396	4	0.02368	3
27.	Business support services	0.00695	2	0.00996	8
28.	Public administration, defense, and social security services	0.00049	24	0.00142	28
29.	Education services	0.00006	33	0.00057	31
30.	Health and social care services	0.00032	28	0.00190	23
31.	Art, sports, and leisure services	0.00024	31	0.00124	29
32.	Other services	0.00076	20	0.00168	26
33.	Others	0.00061	22	0.00177	24
Sum (A)		0.07293		0.38770	
Self-induced effect (B)		1.00000		1.00000	
Total (A+B)		1.07293		1.38770	

Table 3. Value-added creation effects of steam and hot water supply and city gas supply sectors.

Sectors		City Gas Supply		Steam and Hot Water Supply	
		Values	Ranks	Values	Ranks
1.	Agricultural, forest, and fishery goods	0.00025	22	0.00119	20
2.	Mined and quarried goods	0.00296	3	0.00011	31
3.	Food, beverages and tobacco products	0.00026	21	0.00122	19
4.	Textile and leather products	0.00009	30	0.00036	28
5.	Wood and paper products, printing and reproduction of recorded media	0.00021	23	0.00083	24
6.	Petroleum and coal products	0.00054	16	0.01224	2
7.	Chemical products	0.00063	15	0.00419	8
8.	Non-metallic mineral products	0.00012	28	0.00065	33
9.	Basic metal products	0.00034	18	0.00095	23
10.	Fabricated metal products, except machinery and furniture	0.00080	12	0.00216	15
11.	Computing machinery, electronic equipment and optical instruments	0.00068	14	0.00337	11
12.	Electrical equipment	0.00027	20	0.00160	17
13.	Machinery and equipment	0.00075	13	0.00263	14
14.	Transport equipment	0.00011	29	0.00032	29
15.	Other manufactured products	0.00006	31	0.00019	30
16.	Manufacturing services and repair services of industrial equipment	0.00136	6	0.00309	12
17.	Electricity and city gas supply	-	-	0.05662	1
17.	Electricity, and steam and hot water supply	0.00088	10	-	-
18.	Water supply, sewage and waste treatment and disposal services	0.00015	25	0.00208	16
19.	Construction	0.00013	27	0.00127	18
20.	Wholesale and retail trade and commodity brokerage services	0.00135	7	0.00604	6
21.	Transportation	0.00101	9	0.00278	13
22.	Food services and accommodation	0.00085	11	0.00434	7
23.	Communications and broadcasting	0.00117	8	0.00356	10
24.	Finance and insurance	0.01085	1	0.01042	4
25.	Real estate services	0.00238	4	0.00395	9
26.	Professional, scientific, and technical services	0.00198	5	0.01182	3
27.	Business support services	0.00475	2	0.00680	5
28.	Public administration, defense, and social security services	0.00037	17	0.00107	21
29.	Education services	0.00004	32	0.00040	27
30.	Health and social care services	0.00017	24	0.00101	22
31.	Art, sports, and leisure services	0.00013	26	0.00066	26
32.	Other services	0.00034	19	0.00076	25
33.	Others	0.00000	33	0.00000	32
Sum (A)		0.03597		0.14736	
Self-induced effect (B)		0.19168		0.51060	
Total (A+B)		0.22764		0.65796	

The results of computing the wage-inducing effects of the IHS and DHS sectors through Equation (4) are summarized in Table 4. For example, one dollar of production or investment in the two sectors induces 0.00269 and 0.00385 dollars of wage in sector 27, “Business support services,” respectively. One dollar of production or investment in the IHS and DHS sectors produces a total of 0.01525 and 0.04850 dollars of wages in other sectors, respectively. It also leads to 0.03598 and 0.05975 dollars of self-induced wages, respectively. Thus, it causes about 0.051 and 0.108 dollars of wages in the national economy overall, respectively. The wage-inducing effect of one dollar of production or investment in the DHS sector is bigger than that in the IHS sector.

Table 4. Wage-inducing effects of steam and hot water supply and city gas supply sectors.

Sectors		City Gas Supply		Steam and Hot Water Supply	
		Values	Ranks	Values	Ranks
1.	Agricultural, forest, and fishery goods	0.00004	28	0.00019	27
2.	Mined and quarried goods	0.00097	4	0.00003	31
3.	Food, beverages and tobacco products	0.00008	23	0.00039	21
4.	Textile and leather products	0.00004	29	0.00016	28
5.	Wood and paper products, printing and reproduction of recorded media	0.00009	21	0.00036	22
6.	Petroleum and coal products	0.00002	32	0.00047	20
7.	Chemical products	0.00019	15	0.00126	10
8.	Non-metallic mineral products	0.00004	27	0.00024	33
9.	Basic metal products	0.00012	19	0.00032	25
10.	Fabricated metal products, except machinery and furniture	0.00036	11	0.00097	12
11.	Computing machinery, electronic equipment and optical instruments	0.00015	17	0.00073	16
12.	Electrical equipment	0.00010	20	0.00058	18
13.	Machinery and equipment	0.00036	10	0.00125	11
14.	Transport equipment	0.00005	25	0.00014	29
15.	Other manufactured products	0.00003	31	0.00011	30
16.	Manufacturing services and repair services of industrial equipment	0.00087	5	0.00198	7
17.	Electricity and city gas supply	-	-	0.01065	1
17.	Electricity, and steam and hot water supply	0.00016	16	-	-
18.	Water supply, sewage and waste treatment and disposal services	0.00007	24	0.00093	13
19.	Construction	0.00009	22	0.00088	14
20.	Wholesale and retail trade and commodity brokerage services	0.00068	6	0.00306	5
21.	Transportation	0.00059	7	0.00162	8
22.	Food services and accommodation	0.00047	8	0.00243	6
23.	Communications and broadcasting	0.00044	9	0.00134	9
24.	Finance and insurance	0.00434	1	0.00417	3
25.	Real estate services	0.00021	14	0.00035	23
26.	Professional, scientific, and technical services	0.00134	3	0.00803	2
27.	Business support services	0.00269	2	0.00385	4
28.	Public administration, defense, and social security services	0.00023	12	0.00067	17
29.	Education services	0.00003	30	0.00034	24
30.	Health and social care services	0.00013	18	0.00074	15
31.	Art, sports, and leisure services	0.00005	26	0.00025	26
32.	Other services	0.00022	13	0.00049	19
33.	Others	0.00000	33	0.00000	32
Sum (A)		0.01525		0.04850	
Self-induced effect (B)		0.03598		0.05975	
Total (A+B)		0.05123		0.10825	

3.3. Discussion of the Results

Three issues need to be examined in accepting the results reported above. First, the structure of comparing the economic effects of DHS and IHS may be not scientific but political. Comparing economic effects of two sectors is quite natural in the literature of economics. In South Korea, as the government determines one heating system of DHS and IHS before developing new towns. Therefore, the authors believe that providing useful basic information that can be used for the determination is meaningful in terms of both research and policy.

Second, the research methodology used in this study may not be scientific but political. The IO analysis used in this study was developed by Wassily Leontief, who won the Nobel Prize in economics in 1973. It is widely accepted as one of the great scientific achievements in economics because the IO analysis allows us to understand the relationship between all transactions and outputs of goods and services in a country's economy. In particular, the IO table, which is employed in the IO analysis, is a comprehensive statistical chart that systematically records the interrelated relationships between the industrial sectors, such as nets, and is prepared and disclosed by the government or a government-owned agency with public confidence. The IO table and the IO analysis, which are the data and the methodology adopted in this research, respectively, do not contain any political perspective. The research used data with public confidence and applied a methodology that was scientifically standardized without much controversy in the literature. Therefore, the authors think that the data and methodology do not diminish the value of the research, but rather enhance it.

Third, the analysis in the paper may support the results and conclusions only partially. There can be a variety of factors to consider in order to choose between DHS and IHS. For example, there are factors such as cost, environmental impacts, consumer convenience and preference, governmental policy direction, and economic effects. The factors except for economic effects have been sufficiently analyzed for DHS and IHS. However, the economic effects have not been fully investigated and the government is in dire need of quantitative information about them. This study analyzed this quantitative information by applying the IO analysis and reported a finding that the economic effects of DHS were greater than those of IHS. Thus, the authors simply mentioned that DHS can be superior to IHS when considering economic effects as the only factor. The study did not argue that DHS is always superior to IHS or that economic effects are the most important of many factors to consider.

The IO models employed in this study are quite intuitive and relatively easy to apply because they do not require complicated statistical analysis. Nevertheless, since the IO model makes use of an IO table that summarizes inputs and outputs among sectors within a country's whole economy in a single table, the quantitative findings from IO analysis are suitable for various uses in policy planning and evaluation related to IHS and DHS sectors. Furthermore, this study aimed to update the implications of the results by using the most recently published 2017 IO table. The economic effects of the two sectors derived by the demand-driven model of IO analysis, which are summarized in Table 5, have five important implications.

Table 5. Summary of the economic effects of steam and hot water supply and city gas supply sectors.

	City Gas Supply	Steam and Hot Water Supply
Production-inducing effects		
Effect on other sectors	0.07293	0.38770
Self-induced effect	1.00000	1.00000
Total	1.07293	1.38770
Value-added creation effects		
Effect on other sectors	0.03597	0.14736
Self-induced effect	0.19168	0.51060
Total	0.22764	0.65796
Wage-inducing effects		
Effect on other sectors	0.01525	0.04850
Self-induced effect	0.03598	0.05975
Total	0.05123	0.10825

First, the production-inducing effects of one dollar of production or investment in the two sectors on the national economy were estimated to be about 1.073 and 1.388 dollars, respectively. This quantitative information indicates how much production or investment in the two sectors causes increased production for the national economy. Thus, the results of this study can be useful in predicting in advance the economic effects from the perspective of increased production when a new IHS or DHS project, or when a company starts up or enters the economy.

More interestingly, the production-inducing effect for the DHS sector is greater than that for the IHS sector. Since this suggests that the production-inducing effect of the DHS sector is greater than that of the IHS sector when investing the same amount in each of the two sectors, it can be seen as preferable to invest limited resources in the DHS sector in terms of boosting production rather than investing them in the IHS sector. The finding means that the argument that DHS are more conducive to revitalizing the domestic economy than IHS is supported by our results.

Second, we examined the value-added creation effects of the IHS and DHS sectors. Given that the benchmark for a country's wealth is gross domestic product (GDP) and GDP consists of the sum of value-added value, the value-added creation effect may be more important than the production-inducing effect. The value-added creation effects of one dollar of production or investment in the two sectors on the national economy were calculated to be about 0.228 and 0.658 dollars, respectively. The second is bigger than the first, which is consistent with the finding for the production-inducing effects.

Third, the wage-inducing effects of the IHS and DHS sectors were estimated. This study discovered that one dollar of production or investment in the two sectors produces about 0.051 and 0.108 dollars of wages in the national economy. The wage-inducing effect of the DHS sector is larger than that of the IHS sector. As South Korea is suffering from the problem of jobless growth, the government is focusing its policy attention on job creation. Comparing the wage-inducing effects of the IHS and DHS sector with each other is an important task in determining which of the two heating systems to choose.

The most important reason for the government's pushing for DHS as a heating system of large-scale public housing is to reduce air pollutant emissions, abate greenhouse gas emissions, and improve public convenience. In South Korea, however, there is strong opposition to DHS on the grounds that DHS will ultimately have a negative impact on the economy by destroying the IHS industrial ecosystem. After all, it is necessary to determine whether to actively pursue or stop this DHS by unifying public opinion, in which scientific and accurate information plays an important role.

However, at present, such information is not sufficient to reach a proper conclusion. In this study, the economic effects of the IHS and DHS were analyzed in terms of creating production, value-added, and wage. Overall the economic effects of the DHS sector were greater than those of the IHS sector. Therefore, considering the sole criterion of maximizing the economic effects, investment in the DHS sector appears to be economically preferable to investment in the IHS sector. The government needs to put an end to unnecessary social disputes with the results of this study and make efforts to continue pursuing for DHS.

4. Conclusions

When South Korea develops a new city, the government has made a preliminary decision on one of two heating systems, IHS and DHS. Usually, the latter has been preferred to the former because the latter has more advantages for reducing energy use, mitigating air pollutant emissions and abating greenhouse gas emissions than the former. As a result, while a portion of IHS has been converted to DHS and DHS has been increasing recently, it is still unclear which system is desirable in terms of maximizing the national economic effects.

DHS is known to be better than IHS in terms of energy efficiency, convenience benefits to the consumer, benefits of decentralized generation, the effect of reducing greenhouse gas emissions, the effect of mitigating air pollutant emissions, and the effect of abating particulate matters. However, the IHS industry opposes DHS and the criticism is that expanding DHS will ultimately have a negative impact on the economy. More specifically, the main reason for opposing the expansion of DHS is that it will shrink the IHS industry, reducing the nation's overall value-added and employment, and ultimately affect the economy adversely.

Thus, this study intended to analyze and provide accurate information on the economic effects of the IHS and DHS sectors in order to respond appropriately to the debate. In particular, in order to answer the question about how much production or investment in the two sectors affects the production, value-added, and wages of other sectors and the national economy, this article applied the demand-driven model that is at the heart of an IO analysis using the recently published 2017 IO table, making the two sectors exogenous instead of endogenous. It was found that one dollar of production or investment in the DHS sector induced more production, value-added, and wages throughout the economy than that in the IHS sector. That is, when the same amount of investment or production is made in the IHS and DHS sectors, the economic effects of the DHS sector are greater than those for the IHS sector. This is an interesting discovery from this study. The government's DHS policy can be supported in terms of economic effects.

As mentioned earlier, the aim of this paper was not to develop innovative methodologies or to present creative ideas, but to share South Korea's situation and provide evidence that can be used to choose between DHS and IHS. In other words, in the situation where IHS and DHS are at odds with each other in residential heating system, this paper tried to analyze quantitatively what each role of IHS and DHS is in terms of economic effects using an IO analysis.

Since the methodology used in this study was developed long ago and its framework is well established to some extent, and the models specifically used here were demand-driven and supply-driven models that are well developed in the literature, the methodology and the models cannot be considered innovative. Nevertheless, the implications of this paper can be useful in three aspects. First, within the scope of the authors' knowledge, this is the first attempt in the literature at the direct comparison of the economic effects of IHS and DHS. Although quite a number of studies have applied IO analysis to energy issues, it is difficult to find a case in which IO analysis has been applied in comparing IHS and DHS. Second, this paper provided policy officials with basic data for making comprehensive decisions about IHS and DHS and supplied the general public with easy-to-understand quantitative information about the economic effects. Not only policy officials but also the general public have been demanding information that directly compares the economic effects of IHS and DHS, but so far this information has not been available. Third, other countries that may experience conflicts similar to those in South Korea may refer to the findings from this study. Furthermore, similar or opposite results can be obtained by performing the same analysis as the structure of this study.

As a follow-up to this study, future related studies may be carried out in three directions. First, because the study performed a static IO analysis using the 2017 IO table, it is necessary to collect IO tables for a number of years and perform multi-period IO analyses using them. For example, a dynamic IO model may be considered [41]. Second, although the study used the national IO table, multi-regional IO analysis can be carried out by employing a multi-regional IO table. This would allow quantitative analysis of inter-regional effects as well as intra-regional effects [42,43]. Third, various further implications can be obtained if comparative IO analysis is performed using IO tables for other countries with economic structures similar to that of South Korea, considering that this article utilized the IO table only for South Korea. The advantages and disadvantages of the country's IHS and DHS sectors in terms of the economic effects could be clarified through a comparative analysis.

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