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Public Preference for Increasing Natural Gas Generation for Reducing CO_2 Emissions in South Korea

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Abstract: To meet international efforts to prevent climate change, the South Korean government is seeking to transform its main power source from coal to natural gas (NG), which emits less carbon dioxide (CO_2) than coal. The government needs information about public preferences for increasing NG-fired generation. Therefore, the purpose of this paper is to provide the government with this information by gathering the data on public preferences for increasing NG-fired generation for reducing CO_2 emissions, analyzing these data, and obtaining the implications from the analysis. To this end, a survey of 1000 people, after explaining the merits and demerits of NG-fired power, were asked to determine the proper ratio of NG-fired generation by choosing one of six examples: lower than 10%, 10%–20%, 20%–30%, 30%–40%, 40%–50%, and higher than 50%. An interval data model was employed to deal with the data. The average value of the ratio was estimated to be 26.7% with statistical significance, which is greater than the actual value of 22.2% from 2017. Finally, whether and how much some variables such as education level, age, gender, and income level of the respondent affected their preferences for NG-fired generation were investigated.

Keywords: natural gas generation; public preference; determinants; interval data model

1. Introduction

Natural gas (NG) is a vital input to human survival and industrial production. Furthermore, the increase in NG consumption is known to induce economic growth [1–3]. Looking at a case study in South Korea, the hypothesis that NG consumption causes economic growth was statistically significantly accepted [4]. According to the International Energy Agency [5], consumption of NG is and will continue to be increasing worldwide, and in particular, NG-fired generation is expected to grow rapidly until 2040.

South Korea's shares of coal and NG in the total power generation were 43.1% and 22.2% in 2017, respectively, with the former roughly double that of the latter [6]. Despite having little coal produced in the country, there are two reasons why this has happened. First, as of 2017, the coal- and NG-fired generation costs stood at KRW 78,500 (USD $73.5) and KRW 111,600 (USD $104.4) per MWh, respectively, with the former only about 70 percent of the latter. Since NG is imported in the form of liquefied NG (LNG) after going through the process of liquefaction for transportation, the liquefaction increases NG-fired generation costs. Thus, the share of coal generation is much larger than that of NG. Second, while coal has the advantage in that can be imported easily from all over the world such as Australia, Indonesia, Russia, and the United States, NG is highly dependent on the Middle East such as Qatar and Oman, with weak supply stability due to geopolitical risks.

As the high proportion of coal power generation has guaranteed a cheap and stable supply of electricity in the past, the industrial sector secured price competitiveness of products for export and people could enjoy the benefits of low electricity rates. However, the benefits were not without sacrifice. The main power generation source in the country is coal, which is responsible for the significant amount of carbon dioxide (CO_2) emissions in the power generation sector. CO_2 emissions from coal and NG-fired generation came to 823.0 and 362.5 kg per MWh, with the former about 2.3 times, according to Korea Ministry of Environment. The country was ranked seventh in the world with 678.8 million tons of CO_2 (tCO_2) in 2017, following China (9228.8 million tons of CO_2), the United States (5014.4 million tons of CO_2), India (2316.9 million tons of CO_2), the Russian Federation (1488.4 million tons of CO_2), Japan (1171.8 million tons of CO_2), and Germany (762.6 million tons of CO_2) [7]. In response, the country is under heavy pressure to join international efforts to reduce CO_2 emissions to prevent climate change.

The South Korean government has come to the conclusion that coal generation should be drastically reduced to join international efforts to reduce CO_2 emissions. In response, the Government is trying to reduce coal generation that produces large amounts of CO_2 and increase NG-fired generation that produces less CO_2. In other words, the Government is seeking to change the power source mix by transforming its main power source from coal to NG [8]. The change will enable abatement of air pollutants as well as CO_2 emissions [9–18].

However, it will raise electricity rates significantly [19–21]. In fact, it is highly uncertain as to whether South Koreans will smoothly accept the increase in electricity prices to reduce CO_2 emissions. Many people still believe that electricity is currently expensive, and recognize electricity as a public good that the Government should naturally supply at a low price, not as an economic good to buy at a reasonable price. This is not because private companies supply electricity, but because a government-run company, Korea Electric Power Corporation (KEPCO), exclusively supplies electricity. In short, people seem to be less receptive to higher electricity prices. For this reason, real electricity bills have been falling over the past 20 years, and even nominal electricity bills have fallen over the past decade, causing KEPCO to experience a deficit.

In the last five years, the Government and KEPCO have tried several times to raise the electricity rates, which are less than the electricity supply costs, to induce reasonable electricity consumption and address KEPCO's deficit problems, but have been thwarted each time in the face of opposition from political circles and the public. Electricity consumers are opposed to raising electricity rates as it could increase consumption expenditure and decrease real income, while opposition parties as well as the ruling party are opposed to raising electricity rates in consideration of the voters' votes. If the Government fails to raise electricity prices, the policy of reducing cheap coal power generation and increasing expensive NG-fired generation will be difficult to guarantee and will eventually fail. The policy of increasing the proportion of NG-fired generation and thereby raising electricity bills can gain momentum only if the public agrees to the policy, and politicians who are wary of the public can support the policy if it is backed by public support. In other words, public approval of the policy is becoming one of the key factors in determining whether the policy will succeed or not.

Therefore, it is necessary to look into the public preference for expanding the proportion of NG-fired generation to reduce CO_2 emissions, which could entail higher electricity prices. In particular, the Government desperately needs information about the preference. Of course, policies should not be determined based solely on public preferences, but preferences of the public who will bear the increased costs of changing policies must be an important reference in policymaking. Even if information about public preference for increasing NG-fired generation is not the only or the most important determinant for deciding the proper mix of future power generation sources, it helps in making the decision.

Thus, the main objectives of this study are two-fold: first, to obtain information on the ratio of NG power generation that people think is appropriate; and second, to analyze the determinants of the ratio using the interval data. If these two objectives can be achieved, the authors judge that this article can contribute to the literature in three respects. First, so far as the authors know, this article is the first to analyze the proper ratio of NG-fired generation as judged by people. On the other hand, some previous studies are found in the literature that address the role of NG-fired generation to reduce CO_2 emissions [12–14] or analyze the proportion of renewable energy generation [22–27].

Second, an interval data model, which was designed in consideration of the nature of the dependent variable and applied in this study, was statistically significant and well fitted to the data, as will be explained in Section 3. Moreover, all estimated coefficients were statistically distinguishable from zero and the mean estimate for the proper proportion of NG-fired generation in the total power generation was estimated with statistical significance. Thus, the application of the interval data model was an appropriate strategy and contributes to the related literature.

Third, analysis of the statistical significance and magnitude of the effects of respondents' socioeconomic variables such as income, age, gender, and education level on the ratio of NG-fired generation provides useful policy implications, although they may be unique for South Korea. This is also a policy contribution of this study to the literature, which is not found in former studies.

The rest of the paper is organized as follows. Section 2 describes how the data employed in this study were gathered and the basic statistics for the gathered data, and reports the interval data model. The mean estimate for the proper proportion of NG-fired generation and the results of analyzing whether and how much some determinants affect the proportion are presented in the penultimate section. The conclusions are reported in the last section.

2. Methodology

2.1. Method

This study strives to collect data on public preference for increasing NG-fired generation to reduce CO_2 emissions in South Korea based on a survey of 1000 people nationwide and investigate the determinants of the public preference. It is necessary to find out whether there are any related studies in the literature. In this regard, several related studies can be found. Table 1 presents a summary of the findings from some previous related studies. The results of a survey of the general public asking about the preference of each power source were analyzed for the United States [22], Turkey [23], Switzerland [24], and Great Britain [25]. Information on the appropriate mix among power generation sources in Tunisia was derived by applying the multi-criteria decision analysis technique [26]. Kim et al. [27] analyzed the South Korean public's willingness to pay for increasing or decreasing the proportion of each power source by 1%p by using the choice experiment method.

Table 1. Summary of the findings from some previous related studies.

Countries	Sources	Main results
United States	Greenberg [22]	A survey of 2701 United States residents on their preference for energy sources showed that they wanted an increase in solar, wind, and hydropower generation, a decrease in oil and coal, and some increase in natural gas.
Turkey	Ediger et al. [23]	According to the survey of 1204 Turkish households, they preferred natural gas (63%) and solar (21%) as energy sources.
Switzerland	Jobin et al. [24]	A survey of preference for the future electricity mix of 100 Swiss people showed that they wanted the energy portfolio to be composed of wind, solar, imported renewable energy, biomass, and natural gas, excluding new nuclear power and non-renewable electricity imports.
Great Britain	Roddis et al. [25]	A nationally representative dataset spanning six years (2012–2018) show that energy sources are supported by the public in the order of renewable energy, wave and tidal, offshore wind, onshore wind, and biomass, and nuclear and fracking are rarely supported.
Tunisia	Brand and Missaoui [26]	According to multi-criteria decision analysis, an electric scenario consisting of 15% wind, 15% solar, and 70% natural gas-generated power was chosen as the most preferred in the national power mix by 2030.
South Korea	Kim et al. [27]	A nationwide survey of 1000 South Korean households on a mix of power generation sources shows that the government's energy transition policy has overall support from the public. Specifically, it was preferred to reduce the proportion of nuclear power and coal, and to increase the ratio of natural gas and renewable energy.

However, former studies, whose purposes exactly match the prime purpose of this study, deriving quantitative information about public preference for proper ratio of NG-fired generation using the data from a nationwide survey of 1000 persons, were difficult to find in the literature. This is an interesting feature of this study. Respondents were asked multiple-choice questions, not subjective ones, to reduce the cognitive burden on their responses and to induce relatively easy and accurate answers. Moreover, data on preferences for NG-fired generation were obtained as interval values, not point values.

There are two more issues to discuss regarding presenting examples regarding the proportion of adequate NG-fired generation to respondents. First, how many examples should be taken. Too few examples will result in less information from the responses, and too many examples will weaken the meaning of this study's strategy of adopting multiple choice questions instead of an open-ended question to reduce the cognitive burden of respondents [28]. In this regard, it appears to be appropriate to use six examples. Second, how to set the interval in each example should be determined. For example, the interval of each example can be set to 5%, 10%, and 20%. There are four major power sources in South Korea: coal, nuclear power, NG, and renewable energy. The authors believe that it is desirable for each power source to play a role of about a quarter, or 25%, considering the supply stability of power generation sources in countries with less energy such as South Korea. The government's long-term power development plan is also aimed at doing so. Therefore, it was decided to present a total of six examples while maintaining a constant interval of 10% for each example. Finally, in the survey, interviewees were asked to determine the proper ratio of NG-fired generation by choosing one of the following six examples: lower than 10%, 10%–20%, 20%–30%, 30%–40%, 40%–50%, and higher than 50%.

Compared to point data, interval data are more convenient for respondents to state their preference with, but causes complications for researchers to analyze. For example, it is difficult to compute the sample mean of the appropriate ratio of NG-fired generation using interval data. In addition, because it is not possible to apply the ordinary least squares method to estimating a model in which the dependent variable is interval data, application of a more appropriate model is necessary. Interval data model is quite useful in dealing with these complications. Thus, an interval data model was applied in this paper. The dependent variable in the model was interval data concerning the appropriate proportion of NG-fired generation, and independent variables were socioeconomic factors of respondents, which may influence the proportion.

2.2. Data

The debate over the pros and cons of the Government's policy of decreasing coal generation and increasing NG generation is still under way in South Korea. It is therefore necessary to take the utmost care in collecting data on public preferences for this policy. In this regard, four important points were considered. First, there were two ways of selecting interviewees: the general public and a specific group of stakeholders. On one hand, the survey can reflect the opinions of the people who are randomly selected. On the other hand, the survey can be conducted for a specific group, limiting the scope of those interviewed or dividing interviewees into specific groups. For example, the survey can be limited to one of experts, public officers, and power industry workers groups or separately carried out for each group. The main purpose of this study was to analyze the preferences of the general public who directly pay for the electricity charge. Thus, the randomly selected general public were chosen for the interviewees.

Second, the sample size was set as 1000, referring to two cases. With the development of modern statistics and survey techniques, decision making is possible with a sample of 1000 observations in the United States [29]. In particular, Arrow et al. [29] recommended the use of a sample size of 1000. The Korea Ministry of Strategy and Finance also offers a survey of 1000 people nationwide as a guideline in implementing this kind of survey. Therefore, the sample size of 1000 used in this study is judged to be consistent with the two cases and appropriate.

Third, to ensure the representativeness of the sample, a professional polling company conducted sampling based on census data gathered in 2015 by Statistics Korea. The survey company managed and supervised the whole process of the survey. A sample may be biased if researchers conduct the sampling arbitrarily. Thus, it may be desirable to commission a professional survey firm with an experienced and well-trained supervisor who have taken a number of sampling and supervised the whole process of the survey in order to conduct the survey. Of course, in order to do this, a sufficient amount of survey budget is required, and this study has been able to do so with sufficient budget.

Fourth, the interview experts affiliated with the polling company executed the survey through face-to-face interviews to elicit reliable responses from the interviewees. The choice of survey method is critical in eliciting reliable responses from sampled respondents. Usually, face-to-face individual interviewing, telephone interviewing, mail survey, and Internet survey are available. Of them, this study adopted face-to-face interviewing, so as to facilitate interviewees' responses while delivering sufficient information. Arrow et al. [29] and the Korea Ministry of Strategy and Finance suggested that face-to-face interviewing be used when conducting such surveys. In particular, since the role of skilled interviewers is important in face-to-face individual interviews, experienced interviewers were used to carry out the survey in this study.

Visits and contacts to a total of 5539 households were attempted to obtain 1000 usable observations. That is, the number of individuals who responded properly in the survey was 1000, and the number of individuals who failed to respond in the survey was 4509. The main reasons for the failure were as follows. First, 2411 persons (53.1%) refused to respond to the survey. Second, this study limited the respondents to those aged between 20 and 65, but when visiting the households, 1225 households (27.0%) did not have a qualified person. Third, there were no people in 862 households (19.0%) when the interviewers visited. Fourth, 41 people (0.9%) stopped responding in the course of conducting the survey.

The survey was implemented in three steps from July to August 2019. First, the advantages and disadvantages of NG-fired generation were described in detail to the interviewees. The main advantages were presented to them as follows.

- First of all, NG-fired generation can reduce CO_2 emissions to less than half that of coal-fired generation.
- NG-fired generation greatly reduces particulate matter emissions and other air pollutants compared to coal-fired generation.
- NG-fired generation requires less than half of the land compared to coal-fired generation.

The main disadvantages were offered to them as follows.

- NG-fired power generation costs 1.43 times more than coal-fired power generation.
- Since South Korea is the world's third-largest importer of LNG and its LNG imports depends largely on the Middle East, a stable supply of LNG is highly vulnerable to political risks and price volatility. On the other hand, coal is imported from all parts of the globe, making it less vulnerable to supply-related political risks and price variability risks than LNG. The country's energy dependency, which is defined as the ratio of imported energy in primary energy consumption, in 2017 was 94.0% excluding nuclear power and 83.5% including nuclear power. The increase in NG-fired generation can increase the country's energy dependency.
- Coal power generators are almost entirely localized, while NG power generators depend on imports for the most part.

Judging from the interviewers' comments, the respondents could understand the main advantages and disadvantages without any difficulties.

Second, people were asked to determine the proper ratio of NG-fired generation by choosing one of the following six intervals: lower than 10%, 10%–20%, 20%–30%, 30%–40%, 40%–50%, and higher than 50%. As asking respondents to answer a specific value for the ratio may embarrass them and make it difficult to derive responses, examples of ranges for the ratio were presented to reduce their cognitive burden. Distribution of their responses regarding the proper ratio of NG-fired generation is shown in Table 2.

Table 2. Distribution of responses regarding the proper ratio of natural gas generation.

	Lower than 10%	10 to 20%	20 to 30%	30 to 40%	40 to 50%	Higher than 50%	Total
Number of responses	26	85	383	281	106	119	1000

Third, the interviewees were asked questions about their characteristics and perceptions. This was to identify the independent variables for estimating the equation of determining the appropriate proportion of NG-fired generation. In other words, this study identified factors in advance that would affect the determination of the appropriate proportion, and then included them in the questionnaire. The nine variables related to the characteristics or perceptions of respondents employed for this paper are reported in Table 3.

Table 3. Description of the variables related to the characteristics or perceptions of respondents.

Variables	Definitions	Mean	Standard deviation
Education	Dummy for the interviewee's education level's being higher than junior college graduate (0 = no; 1 = yes)	0.479	0.500
Age	Dummy for the interviewee's being older than forty (0 = no; 1 = yes)	0.790	0.408
Gender	The interviewee's gender (0 = male; 1 = female)	0.500	0.500
Income	The interviewee's household's income per month (unit: million Korean won = USD 827)	4.864	5.587
Metro	Dummy for the interviewee's living in Seoul Metropolitan area (0 = no; 1 = yes)	0.497	0.500
Solar	Dummy for the interviewee's household's being equipped with photovoltaic generator for home (0 = no; 1 = yes)	0.035	0.184
Electricity	Monthly electricity consumption of the interviewee's household (unit: MWh)	0.329	0.096
Progress	The interviewee's judgment about whether she/he is progressive or conservative (0 = conservative; 1 = progressive)	0.551	0.498
Environment	The interviewee's judgment about which is more important of new jobs or the environment (0 = new jobs; 1 = the environment)	0.327	0.469

Note: The total number of respondents is 1000.

2.3. Interval Data Model

We needed to do two things with the 1000 observations obtained as shown in Table 2. First, the average value of the appropriate ratio of NG-fired generation should be estimated. Second, an equation that determines the appropriate ratio of NG-fired generation should be estimated to examine the impact of each variable given in Table 3 on the ratio. As mentioned earlier, one major difficulty associated with this type of estimation is that the dependent variable has the nature of the interval data. Thus, the following explanation is based on the theoretical aspect of the interval data model that can be applied when the dependent variable is interval data.

The dependent variable under investigation is the percentage of NG-fired generation out of the total generation that respondents deem appropriate. However, the variable cannot be observed and is thus latent. For each interviewee, $s = 1, 2, \cdots, S$, the latent variable, y_s^*, can be specified as:

$$y_s^* = z_s'\beta + \varepsilon_s \tag{1}$$

where z_s denotes a vector of independent variables that affect y_s^*; β is a vector of the parameters corresponding to z_s; and ε_s is the disturbance or error term.

We can observe not y_s^* but y_s, which is defined as:

$$y_s = \begin{cases} 1 & \text{if } y_s^* \leq 10, \\ 2 & \text{if } 10 < y_s^* \leq 20, \\ 3 & \text{if } 20 < y_s^* \leq 30, \\ 4 & \text{if } 30 < y_s^* \leq 40, \\ 5 & \text{if } 40 < y_s^* \leq 50, \\ 6 & \text{if } 50 < y_s^*. \end{cases} \quad (2)$$

where y_s is observed with six values. That is, the only thing that can be observed is the range within which range y_s^* falls. The dependent variable in Equation (1) is an interval data. This type of model can be called an interval data model [30,31].

Let R_J^U and R_J^L be the upper and lower bounds of the percentage of NG-fired generation. In addition, let $G(\cdot)$ be the standard normal cumulative distribution function. Assuming that ε_s follows a normal distribution with mean zero and standard deviation σ, the probabilities of $y_i = J$ can be derived as:

$$\text{Prob}(y_s = J) = G\left(\frac{R_J^U - z_s'\beta}{\sigma}\right) - G\left(\frac{R_J^L - z_s'\beta}{\sigma}\right) \quad (3)$$

where R_1^U, R_2^U, R_3^U, R_4^U, R_5^U, and R_6^U are 10, 20, 30, 40, 50, and 100, respectively, and R_1^L, R_2^L, R_3^L, R_4^L, R_5^L, and R_6^L are 0, 10, 20, 30, 40, and 50, respectively.

To deal with this kind of data, we need to apply the maximum likelihood (ML) estimation method. The first step in applying the ML estimation method is to create a likelihood function or a log-likelihood function. The log likelihood function for the interval data model is expressed as:

$$\ln L = \sum_{s=1}^{S} \sum_{J=1}^{6} I_s^J \, \text{Prob}(y_s = J) \quad (4)$$

where $I_s^J = \mathbf{1}(y_s = J)$ for $J = 1, 2, \cdots, 6$ where $\mathbf{1}(\cdot)$ is an indicator function. The indicator function means a function that returns 1 if a proposition in parentheses is true or returns 0 otherwise.

The second step in applying the ML estimation method is to find β, which maximizes the log-likelihood function. It is a well-known fact that the ML estimator (β_{ML}) is consistent and asymptotically efficient [32]. The final step is to estimate the variance matrix for estimator (β_{ML}) and then compute *t*-values for the elements of β_{ML}.

3. Results and Discussions

3.1. Results

The variables given in Table 4 can be divided into two types. First, education, age, gender, metro, solar, progress, and environment variables are dummy variables with values of 0 or 1. These variables are used as independent variables in their original form. Second, income and electricity variables have non-negative continuous values. These two variables are not used as they are, but the natural logarithm is taken to cover the entire area of the real number. In other words, log of income and log of electricity variables are used here.

A total of ten variables, the nine variables reported in Table 3 and the constant term, were used as independent variables presented in Equation (1). The correlation matrix for the nine independent variables except the constant term and the dependent observed variable is shown in Table 4. The largest one of the absolute values of all the correlation coefficients was between A and B, at only 0.299. Since it was less than 0.5, it seems that the data used in this study will not suffer from any serious multi-collinearity problem.

Table 4. Correlation matrix for the variables in the model.

Variables [a]	Ratio	Education	Age	Gender	Log of Income	Metro	Solar	Log of Electricity	Progress	Environment
Ratio	1.000									
Education	0.070	1.000								
Age	−0.039	−0.258	1.000							
Gender	−0.002	−0.158	−0.079	1.000						
Log of Income	0.100	0.258	0.086	0.030	1.000					
Metro	0.202	0.204	0.017	0.014	0.139	1.000				
Solar	0.054	0.003	0.031	−0.005	0.041	0.050	1.000			
Log of Electricity	0.017	0.003	0.112	0.032	0.299	−0.125	−0.039	1.000		
Progress	−0.016	0.157	−0.184	0.026	0.071	−0.003	−0.025	−0.033	1.000	
Environment	0.076	0.108	−0.049	0.117	0.081	0.100	0.041	−0.005	0.085	1.000

Note: [a] Ratio indicates the category for which the percentage of natural gas generation in the total generation that the respondents deemed appropriate belongs to (1 = lower than 10%, 2 = 10% to 20%, 3 = 20% to 30%, 4 = 30% to 40%, 5 = 40% to 50%, and 6 = higher than 50%) and the remaining nine variables are explained in Table 2.

The observations from estimating the interval data model are shown in Table 5. First, the meaningfulness of the model should be examined. For this purpose, a likelihood ratio test can be employed. The null hypothesis is that all of the parameter estimates except for the constant term are zero. That is, the hypothesis implies that the model is not significant. The test statistic was computed to be 788.82. The hypothesis can be rejected at the 1% level, considering that $\chi^2_{0.01}(9) = 21.67$. This reveals that the model is statistically significant. The data are ideally well modeled by the interval data model. Interestingly, all of the estimated coefficients are statistically meaningful when using a significance level of 10%. This confirms the statistical significance of the estimated model.

Table 5. Results of estimating the interval data model.

Variables [a]	**Estimates**	***t*-values**
Constant	23.385	69.67**
Education	0.388	3.31**
Age	−1.261	−9.27**
Gender	0.522	4.93**
Log of Income	1.827	15.13**
Metro	1.340	12.42**
Solar	0.578	1.96*
Log of Electricity	−1.059	−5.83**
Progress	−1.051	−9.97**
Environment	−0.194	−1.71*
Number of observations	1000	
Log-likelihood	−27,422.89	
Likelihood ratio test statistic (*p*-value)	788.82 (0.000)	

Notes: The dependent variable is the percentage of natural gas generation in the total generation that the respondents deemed appropriate, which is given in Table 1. [a] The variables are explained in Table 2. * and ** indicate statistical significance at the 10% and 5% levels, respectively.

It is necessary to look into the impact of each determinant with the estimated coefficients' signs. The coefficients for education, gender, log of income, metro, and solar variables were estimated to have positive signs. Several interesting points emerged from this finding. First, the higher the respondent's education level, the higher the appropriate ratio of NG-fired generation. Second, women were more positive about expanding the proportion of NG-fired generation than men. Third, the respondent's income level had a positive relation with the appropriate ratio of NG-fired generation. Fourth, people living in the Seoul Metropolitan area rated the appropriate ratio of NG-fired generation higher than the others. Fifth, households equipped with photovoltaic generator installed in their homes were more favorable to expanding the proportion of NG-fired generation than those who were not.

However, the coefficients for age, log of electricity, progress, and environment were estimated to be negative. This has several implications. First, the age of the interviewee had a negative correlation with the proper ratio of NG-fired generation. Second, the amount of the interviewee's household's electricity use was negatively related to the proper ratio of NG-fired generation. Third, those who considered themselves to be progressive rather than conservative judged the proper ratio of NG-fired generation lower than the others. Fourth, those who believed that the environment was more important than jobs set the proper ratio of NG-fired generation lower than the others.

3.2. Discussion of the Results

Finally, the important information to be derived from the results is the sample mean of the proper ratio of NG-fired generation assessed by the respondents. It can be easily estimated as $\bar{x}'\hat{\beta}$, where $\bar{x}$, a sample mean vector for x, is reported in Table 3 and $\hat{\beta}$, an ML estimate vector for β, is given in Table 5. The mean estimate for the ratio is estimated to be 26.7%, indicating that it is higher than the 2017 value of 22.2%. Using the delta method, the t-value for the estimate is 521.12. Thus, it has statistical significance at a significance level of 1%. Considering the public's opinion, it is desirable to raise the ratio of NG-fired generation in the total power generation from the current level, and the Government's policy to increase the ratio is supported by the public.

As explained above, 1000 interviewees were asked about the proper share of NG-fired generation offering several possible answers: lower than 10%, between 10% and 20%, between 20% and 30%, between 30% and 40%, between 40% and 50%, and higher than 50%. In this regard, one might question whether the resulting average value of 26.7% would be different if the width of the six examples was changed. For example, fives cases of lower than 20%, between 20% and 40%, between 40% and 60%, between 60% and 80%, and higher than 80% or eight cases of lower than 5%, between 5% and 10%, between 10% and 15%, between 15% and 20%, between 20% and 25%, between 25% and 30%, between 30% and 35%, between 35% and 40%, and higher than 40% were offered to the respondents. Unfortunately, the survey failed to take this point into account and did not collect data that could be tested for whether presenting different intervals to interviewees could substantially alter the results or not. However, as discussed in Section 2, the authors think that it is appropriate to provide six examples at 10% intervals to the respondent. Further experiments can be attempted in future studies.

As a matter of fact, in order to raise the proportion of NG-fired generation in South Korea, we have to overcome many difficulties. For example, there are expected to be five major challenges. First, people's acceptability of higher electricity bills should be fully guaranteed. Even those who supported increasing the share of NG-fired generation on the condition of higher electricity prices could reverse their stance if electricity prices actually increase. In such a case, the policy of increasing the proportion of NG-fired generation may not be supported by the public and may not be pursued halfway. Since this can cause major social confusion, it is imperative to persuade the public to understand the increase in electricity prices caused by the increase in the proportion of NG-fired generation.

Second, it should be able to stably import NG, which is rarely produced in the country, from abroad. The country imports NG mainly from the Middle East such as Qatar and Oman, which is a politically risky region, as shown by the recent Iranian crisis. Therefore, a strategy to diversify the sources of imports is needed. As an alternative, expanding imports of shale gas from the United States is being discussed in earnest. However, since LNG carriers have to pass through the Panama Canal or turn to the Cape of Good Hope to come to South Korea, it takes longer to transport and costs more than imports from the Middle East. In this regard, it is not easy to considerably expand imports of shale gas from the United States. As another alternative, expanding imports from Russia, geographically closer to South Korea than the Middle East or the United States, needs to be considered as one of the possible alternatives.

Third, although South Korea has localized almost all of its coal-fired generators, most of the NG-fired generators rely on imports from abroad. The main countries from which South Korea imports NG-fired generators are Germany, Japan, and the United States. Increasing the ratio of NG generation in South Korea may eventually contribute to the increase in value-added and employment in these countries, but local companies involved in producing coal-fired generators will be kicked out of the market and eventually result in a reduction in gross domestic product and employment in South Korea. It is also true that the expansion of NG-fired generation is faced with opposition to a huge outflow of national wealth. Therefore, it is necessary to push for the localization of NG-fired generators or to induce companies producing NG-fired generators from Germany, Japan, and the United States to build production plants in South Korea.

Fourth, since the rise in the proportion of NG-fired generation means a decrease in that of coal generation, measures to utilize the dwindling workforce should be taken. This is because NG power plants require only half the operational manpower compared to coal power plants of the same capacity in South Korea. Without proper measures, it would cause anxiety about mass layoffs and unnecessary social conflicts could arise in the event of unemployment. Instead of shutting down and tearing down existing coal power plants to increase NG generation, the use of manpower may be considered to stop, conserve, and manage them so that they can be operated at any time in case of a sudden increase in electric power demand or unstable NG supply.

Fifth, the amount of NG-fired generation in 2019 (143.8 TWh) has decreased compared with that in 2018 (152.9 TWh). The reasons are largely summarized in two ways. First, as a number of nuclear power plants failed to operate for maintenance and the amount of coal-fired generation was reduced to mitigate particulate matters emissions in 2018, the amount of NG-fired generation increased significantly to 152.9 TWh in 2018 compared with 126.0 TWh in 2017. Second, due to increased demand for electricity for cooling during the severely hot summer of 2018, the amount of power generation increased from 553.5 TWh in 2017 to 570.6 TWh in 2018, and consequently, the amount of NG-fired generation has also increased. Therefore, high NG-fired generation in 2018 can be seen as a rather special phenomenon.

The NG-fired generation over the past five years has been on the rise since it was 118.7 TWh in 2015, 121.0 TWh in 2016, 126.0 TWh in 2017, and 143.8 TWh in 2019. Although new nuclear power plants are expected to enter the electricity generation market in the future as nuclear power plants that are being abolished at the end of their lives are expected to emerge and coal-fired power plants that will turn 30 years old after construction are scheduled to be abolished. As electricity demand will continue to grow smoothly [8], NG-fired generation is expected to continue to increase. However, if the Government is confronted with the public backlash against the increase in electricity prices, or the supply insecurity of NG as a power generation source, it could change its policy of not building new nuclear power plants and coal power plants, but expanding NG-fired generation.

As a final step, it is now necessary to compare the results from this study with those from previous studies. However, to the best of the authors' knowledge, it is difficult to find any studies of which purpose and structure is similar to ours in the literature. In addition, the environment surrounding the choice of fuel for power generation is different from country to country and decisions on the choice that are appropriate for each country have been made. Nevertheless, the findings from this study are consistent in three respects with those from previous studies. First, countries around the world prefer NG-fired generation to coal-fired generation in terms of CO_2 emissions reduction if they should choose one of coal and NG. Second, despite this increasing the financial burden on the people, the public prefers to reduce coal-fired generation and instead increase NG-fired generation. Third, the characteristics of respondents such as education level, age, gender, and income level had a statistically significant effect on their preference for NG-fired generation.

4. Conclusions

The South Korean government is trying to expand NG-fired generation to mitigate the effects of coal-fired generation and reduce CO_2 and air pollutant emissions. This strategy could, however, raise electricity bills and/or reduce jobs. Public support for the expansion is therefore crucial for its successful implementation. This paper collected data on the public assessment of the proper percentage of NG-fired generation out of the total generation and examined the data to analyze the determinants and sample mean of the percentage using an interval data model. All of the coefficient estimates were statistically meaningful. Furthermore, the model fitted the data well. The mean of the percentage was 26.7%, which had statistical significance. Interestingly, this value was greater than the actual value of 22.2% from 2017. Overall, it therefore appears that the public has positive perceptions about increasing NG-fired generation.

It seems that this paper has presented a simple summary of the survey data, but in the usefulness of its motivation and results, the authors think that this paper has made considerable contributions in both policy and research aspects. From a policy perspective, the study provided three important implications. First, we found that people support expanding the proportion of NG-fired generation, which is fortunately consistent with the Government's policy. This finding will be useful for South Korea. This is because if a policy lacks acceptance, without public support, its implementation is likely to be delayed or eventually fail even if it is implemented. There are various factors to consider in determining the proportion of NG-fired generation and people's preference is only one of them. Adjustments in the proportion of NG-fired generation cannot be made based solely on public opinion and should be made in consideration of costs involved and the environment. In spite of that, it is clear that public opinion is also a factor of concern. Consequently, the main results of this paper confirmed public support for the expansion of NG-fired generation.

Second, this study ascertained that the majority of the people confirmed their willingness to endure the increased cost burden for the expansion of NG-fired generation. The public's support for reducing cheap coal-fired generation and increasing expensive NG-fired generation, even at the expense of higher electricity bills, suggests much to the Government that is responsible for drawing up a mid- and long-term national power planning. For example, the Government is currently working on the 9th Long-term Power Supply Basic Plan for the next 15 years from 2020 to 2034, in which the results can be used as an important reference. The plan will be finalized in the second half of 2020, with a mix of power sources until 2034.

Third, by discussing the four side effects caused by the increase in NG-fired generation, government officials were presented with things to prepare before increasing NG-fired generation. Furthermore, this study discussed four possible side effects that can take place in increasing the share of NG power generation and some measures to overcome them. In order for the policy of reducing coal-fired generation and increasing NG-fired generation to reflect the public's preference to reduce CO_2 emissions to succeed, the Government should prepare and implement measures to overcome side effects with full consideration. If we fail to overcome the side effects, the power generation sector could fail to cut CO_2 emissions and cause unnecessary social conflicts.

In terms of research, this study has three important values. First, within the scope of the author's knowledge, this paper appears to be the first to analyze the percentage of NG-fired generation that the public consider appropriate. After conducting a literature review, only studies that examined the simple preference or usefulness of NG-fired generation itself could be found, and no studies that derived the proper proportion based on people's preference could be found. Second, from a statistical point of view, a model that can be applied when the dependent variable is an interval data rather than a continuous point data, was designed for our data and named as the interval model, and a likelihood function for the model was derived. The interval data model does not have many examples of applications in the literature. In addition, the estimated results of the interval data model were statistically significant. Thus, the interval data model presented in this study could be expanded for similar cases. Third, the effects of various characteristic variables of respondents such as income, age, gender, and education level, on the appropriate percentage of NG-fired generation were analyzed, all of which were statistically significant and provided various implications. For example, because the respondent's age was negatively correlated to the appropriate percentage of NG-fired generation, it could be seen that there is a need for persuasion or promotion efforts to get older people to understand the policy of expanding NG-fired generation before implementing the policy.

As a follow-up to this study, the following five topics need to be studied. First, since the power generation source mix should be determined by comprehensively reflecting the various criteria to be considered rather than just reflecting public opinion, it is necessary to compare the results of this study with those analyzed using techniques such as multi-criteria decision analysis or multi-objective optimization programming. In South Korea, as in other countries, power generation source mix is a result of political decision-making reflecting experts' opinions and medium to long-term analyses, which attempts to take into account various factors such as the domestic industry, the economy and the general consumption, the energy prices, the energy availability and supply security as well as international relations and agreements. The public preference only shows if the Government's decisions are supported or opposed by voters, and cannot be considered a fundamental factor in the planning of a country's energy policy. Therefore, it would be appropriate to regard the information obtained from this study as one of the factors that determines whether the Government proceeds with the decisions or not, rather than one that determines the power generation source mix. This is because the public preference was based on the opinion determined by the people who will shoulder the financial burden caused by a sharp increase in the electricity rate after explicitly explaining that decreasing coal-fired generation and increasing NG-fired generation will raise the electricity price.

Second, although this study paid attention to public preference, it is necessary to gather and systematically analyze the data on how energy policy experts judge the power generation source mix, and provide these results to energy policy-makers. The work of investigating whether public preferences and expert judgments are similar or different, why they are different if they are different, and why they are similar if they are similar will also provide an interesting point of view concerning the power generation mix.

Third, it would be interesting to further explore the various factors affecting people' preferences. For example, a dynamic study of how people's preferences change over time can be done using the data collected from a multi-year survey. In particular, the impact of the level of electricity charges at the time of the survey on people's preference may be examined. Moreover, it would be interesting to see how people's preferences vary, depending on the region through a large scale of nationwide survey. Whether the opinions of local residents near coal (nuclear) power plants differ from those of local residents who do not have coal (nuclear) power plants or not can also be investigated. One can also look into whether there are differences of opinion between those who join environmental groups and those who do not.

Fourth, since substituting coal-fired power with NG-fired power will lower the operating rate of coal-fired generators that still have life, a solution to the problem of worsening the profitability of coal-fired power plant operators should be prepared. We have to decide whether or not to compensate for the worsening profitability, and if we do, we have to come up with a plan on how much we should compensate with what resources. Turning a blind eye to the worsening profitability of coal-fired power plant operators could eventually undermine the power supply stability, and power generation operators would distrust the Government and thus avoid making investments in time.

Fifth, as a decline in coal-fired generation in South Korea means an increase in NG-fired generation, an increase in renewable energy generation means a decrease in nuclear power, so an investigation of people's preference for the proportion of renewable energy generation is also needed. In particular, the cost of renewable energy generation such as solar and wind power is about three times that of nuclear power in the country. Therefore, as the replacement of nuclear power with renewable energy could lead to a sharp rise in electricity charges, whether the acceptability of this rise is ensured or not should be examined.

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