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Segmenting the South Korean Public According to Their Preferred Direction for Electricity Mix Reform

Qingchang Li [1], Seungkook Roh [2] and Jin Won Lee [1,*]

[1] Marketing Department, School of Business Administration, Jimei University, Xiamen 361021, China; alflqc@jmu.edu.cn

[2] Department of Public Administration, Korean National Police University, Asan 31539, Korea; skroh@police.ac.kr

* Correspondence: nevermean@empas.com

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Abstract: The current South Korean government headed by President Moon Jae-in has put a great deal of effort into electricity mix reform by pushing forward the phasing out of coal and nuclear power and the expansion of natural gas and new renewable energy in the country's electricity generation processes. Noting the importance of understanding public responses to energy policy, the present study segmented the South Korean public according to their preferred direction for electricity mix reform using a nationwide sample. Through a series of latent class analyses, we extracted four distinct segments: Gradual Reformists, Drastic Reformists, Selective Gradual Reformists, and Status-quo Seekers. Overall, apart from the Status-quo Seekers segment (8.75%), support for the transition from coal and nuclear power to natural gas and new renewable energy seems to be the prevailing opinion of the Korean public. However, the degree of such preferences varies across the segments. In addition, regardless of the segment, the South Korean public generally seems to categorize the energy sources in a manner consistent with the underlying framework of the government's electricity mix reform: they tend to treat coal and nuclear power similarly and natural gas and new renewable energy similarly.

Keywords: electricity mix reform; public support; preferred reform direction; preferred direction for electricity mix reform; segmentation; latent class analysis; Korea

1. Introduction

1.1. Research Background: Electricity Mix Reform in South Korea

The international community's efforts to mitigate climate change (e.g., the 1997 Kyoto Protocol and the 2015 Paris Agreement) have accelerated the worldwide trend to shift to a low-carbon economy [1]. This shift necessitates either (1) capturing and isolating carbon dioxide that is a byproduct of large point sources, such as factories or power plants, via methods such as carbon capture and storage (CCS) [2,3], (2) reducing the by-production of carbon dioxide itself, or (3) involving both strategies. Regarding the second approach, the phasing out of electricity generation using fossil fuels (i.e., coal, oil, etc.) is being pushed globally as such fuels are one of the main sources of greenhouse gas (GHG) emissions. Fossil fuels contribute greatly to the emission of carbon dioxide, which is the primary culprit behind anthropogenic climate change [4]. Globally, fossil fuels generate a large portion of the electricity supply: as of 2019, they accounted for around 64% of the world's gross electricity generation [5,6]. Thus, the phasing out of their usage requires the introduction or expansion of alternative electricity generation sources. Thereby, reforming the electricity mix (also referred to as the electricity generation mix or power generation mix), which refers to the combination of various primary sources used to generate electricity in a given region, is necessary [7–9].

South Korea (hereafter, Korea), one of the world's top-ten highest electricity-consuming countries as of 2018 [10], is also putting a great deal of effort into electricity mix reform [11]. The current Korean government under President Moon Jae-in has set a goal to increase the share of natural gas and new renewable energy, along with phasing out not only coal but also nuclear power in the country's electricity mix [12]. The category of renewable energy refers to energy sources whose stocks are replenished through natural circulation loops [13]. Compared to hydroelectric power, which has a relatively long history, "new" renewable energy generally encompasses sources such as sunlight, wind, geothermal heat, rain, tides, waves, etc. [14,15]. Recently, in several countries, the levelized cost of electricity (LCOE) generated by new sources of renewable energy, particularly those involving photovoltaics (sunlight) and wind power, has been dramatically reduced due to continuous research and development and subsequent technological progress [16,17]. Along with this, the proportion of new renewable energy in the global electricity mix has been expanding, which is projected to accelerate further [16]. Such expansion entails the growth of markets and industries related to relevant infrastructures, such as generation facilities, electricity grids, and energy storage systems (ESSs), which are essential to broaden the reach of new renewable energy. Thus, the current direction of the Korean government's electricity mix reform is driven not merely by political motivations but also by economic changes and motivations.

However, these government reforms have riled the country in a major social controversy, particularly regarding the phasing out of nuclear power. As of 2016, the year before the launch of the Moon government and the beginning of the government's electricity mix reform, Korea ranked sixth in the world regarding the number of nuclear power plants and 13th in its proportion of nuclear power in the national electricity mix [18]. This nuclear power infrastructure was the fruit of decades of efforts [19]. Although Korea is a high-growth economy representative of "compressed development," it is also a country lacking economically feasible resources to stably support such development. Korea is gradually suffering more and more from importing energy resources. The overseas dependence rate was 47.5% in 1970 (p. 13, [20]) and rose to 93.7% in 2018 (p. 5, [21]). Thus, in the past, Korea strived to expand nuclear power generation, which can supply electricity in an economically viable and stable manner and reduce dependency on fossil fuel imports that accounted for most of the country's energy imports [22]. Thus, due to the importance of nuclear power in Korea, the current government's nuclear phase-out policy has become the subject of intensive discussion [23]. Various opinion leaders, scholars, politicians, the media, and industries are engaged in this argument. The nuclear science academic community, related industries, and the conservative press are concerned about the government's nuclear phase-out policy. Their points of criticism are largely twofold. First, they question whether the transition to natural gas and new renewable energy can replace nuclear power to meet the electricity demand while reducing environmental pollution. Second, these parties are concerned that the nuclear phase-out policy will reduce the country's competitiveness in nuclear technology into stranded assets and destroy the credibility of Korean nuclear reactors among potential importers of those reactors [23–25].

1.2. Research Purpose: Segmenting the Korean Public According to Their Preferred Direction for Electricity Mix Reform

Understanding the divergent public preferences regarding the electricity mix reform and their patterns is important not only to allow policymakers and bureaucrats to build momentum for such reform but also for players or sectors that support other energy sources than those pushed by the reform. Although the public does not comprise direct decision makers that have influence over the national energy policy, their support has a significant influence on such decision making, particularly in representative governments. In addition, enforcing an energy infrastructure that faces public opposition is likely to cause political and administrative resistance among the public, which in the end will impede its implementation [26–29]. Thus, for both the reform's promoters and protesters, it is important to bring public support to their sides through communication. The importance of public support is especially true for the Korean electricity mix reform, which is a combination of

reforms regarding different energy infrastructures [30]. Effective communication that enhances public support begins with an understanding of the communication target: the public [31,32], which is not a homogeneous group with uniform preferences [33].

Emerging from this need, the present study segmented the Korean public according to their preferred direction for electricity mix reform. Particularly, we focused on the following aspects.

- What are the segments found among the Korean public regarding their preferred direction for electricity mix reform?
- What are the characteristics of these segments?
- Across the whole sample and in each segment, what patterns are found between the preferred reform directions for individual energy sources? For example, regarding which energy sources does the Korean public seem to respond similarly? Which specific energy sources do they seem to recognize as an alternative to another?

We analyzed a nationwide sample in mid-2018, the year after the launch of the current Korean government and its electricity mix reform. We segmented the sample based on the respondents' preferred reform directions for the individual energy sources of coal, nuclear power, natural gas, and new renewable energy in Korea. Specifically, we organized the remainder of this study as follows. In the Theoretical Background section, we detailed public acceptance of energy source/technology and its importance. The Methodology section described our analysis model, dataset, and variables of interest. In the Results section, adopting latent class analysis that used the preferred energy source reform directions as segmentation criteria, we extracted four distinctive segments: Gradual Reformists (45.52%), Drastic Reformists (23.75%), Selective Gradual Reformists (21.98%), and Status-quo Seekers (8.75%). The Discussion section drew out interpretations of the results, thereby providing answers to the questions raised above. In the segments we identified, a positive coupling was consistently found between a preference for coal and that for nuclear power. This was also evident between a preference for natural gas and that for new renewable energy, implying that the Korean public regards coal and nuclear power, and natural gas and renewable energy as entities that should be considered together. The Korean public seemed to recognize the latter sources as alternatives to the former sources. In addition, support was widespread for the expansion of natural gas and new renewable energy along with the phasing out of coal and nuclear power. However, the degree of this tendency varied across the segments. Combining these findings with existing theoretical frameworks and findings, the Conclusion section provided implications to be considered by energy scholars and practitioners.

2. Theoretical Background

Regarding the development of energy infrastructures, support from the diverse players or sectors in society (e.g., policymakers, key stakeholders, the public, local residents, local authorities, consumers, firms, investors, etc.) is crucial. This support or the processes of such support are frequently referred as social acceptance (e.g., [34–36]). Such acceptance is crucial since it may promote the execution of energy technology or potentially be a powerful barrier to such execution [26–28,37].

Among the diverse players or sectors that impact or are impacted by the development of energy infrastructure, the public is an important actor group. The public does not consist of policymakers, technology developers, nor infrastructure builders. However, their opinions have a significant influence on political decision making, which in turn determines support for technology development and sanctions for infrastructure construction that occur through political, legal, administrative, institutional, and financial mechanisms. In addition, when attaining public support fails, enforcing an energy infrastructure is likely to cause resistance from the public that manifests political and administrative mechanisms, which in the end would impede the implementation of such infrastructure. Thus, the public acceptance of an energy source/technology, which in general refers to the public's perceptions of the given energy source/technology as something worth accepting, has received much research attention [26–28].

Usually, the subject of public acceptance accounts for all the people in a particular country, and the object of such acceptance is the given energy source or technology. However, to clarify these ideas more specifically, two distinguished terms are occasionally used: national acceptance (or general acceptance) and local acceptance (or community acceptance). In the context of electricity generation, national acceptance of an energy source/technology is generally measured as the degree to which the respondent, as a citizen of the country, agrees with the use of that source/technology for electricity generation in the country. The local acceptance is generally measured as the degree to which the respondent, as a local resident, agrees with the use or installation of a power station using the given energy source/technology in the respondent's residential area [38–41].

The main variables in our study were based on the above concept and measure of national acceptance. Conceptually, they were about which direction the respondent, as a citizen of the country, prefers the reform of the proportion of a given energy source in the country's electricity mix. We termed each of these variables as the individual's preferred reform direction for an energy source (in short, preferred energy source reform direction). We measured an individual's preferred energy source reform direction by asking the respondent's opinion on whether and how drastically the proportion of a given energy source (i.e., coal, nuclear power, natural gas, or new renewable energy in the Korean context) in the electricity mix should be reduced or expanded. We refer to the collective set of these directions as the individual's preferred direction for electricity mix reform.

3. Methodology

3.1. Analytical Strategy

As we stated, in our research context, an individual's preferred direction for electricity mix reform is collectively represented by the set of his/her preferred energy source reform directions. To segment the sample by these multiple variables, we adopted latent class analysis (LCA) [42]. LCA identifies and extracts unobservable subgroups (i.e., latent classes) within the sample based on multiple observed variables, which can be either categorical or metric [42,43]. Individuals within the same latent class share a pattern in the observed variables, whereas those from different classes are distinct in the values of observed variables. In a latent class model with n_c classes from a set of M variables of preferred energy source reform directions, the vector $\mathbf{Y_i} = (Y_{i1}, \ldots, Y_{im}, \ldots, Y_{iM})$ represents individual i's values for these M variables (in other words, the individual's preferred direction for electricity mix reform). The vector's component, Y_{im}, denotes that an individual's preferred reform direction for the mth energy source and its possible values are $1, \ldots, k, \ldots,$ and r_m. The variable Li, whose values are $= 1, 2, \ldots, l, \ldots,$ and n_c, denotes the latent class membership of individual i; and $I\,(y = k)$ is the indicator function (i.e., takes 1 if y equals k, and 0 otherwise). Then, the probability that individual i has the current responses as $\mathbf{y}_i$ is expressed as in Equation (1):

$$P\left(\mathbf{Y}_i = \mathbf{y}_i\right) = \sum_{l=1}^{n_c} \gamma_l \prod_{m=1}^{M} \prod_{k=1}^{r_m} \rho_{mk|l}^{I(y_{im}=k)}. \quad (1)$$

The γ_l parameter denotes the probability that individual i belongs to class l. The $\rho_{mk|l}$ parameter represents the probability that the individual prefers reform direction k for the mth energy source, given that he/she belongs to class l.

In a run of LCA, the number of classes, n_c, is pre-assumed. Assuming that there exist n_c classes among the whole sample, a run of the LCA model yields a solution in which each individual is allocated to the class with the highest γ among those n_c classes. Thus, a latent class solution can be compared to a list showing which individual belongs to which class among the n_c classes. For each solution, various types of goodness-of-fit indexes are calculated. A goodness-of-fit index describes how well the solution fits the actual data. Different latent class models assuming different n_c yield different values of goodness-of-fit indexes. Varying the n_c, the researcher can compare goodness-of-fit indexes among

different latent class solutions. Then, the researcher selects the solution that has the best goodness-of-fit index values [43–45].

3.2. Sample and Data Collection

We used a survey dataset that the Hyundai Research Institute [46], an influential economic research institute in Korea, compiled in May of 2018, the year after the launch of the current Korean government and its electricity mix reform. The survey targeted the Korean population aged 20 years and over. Data collection was carried out through telephone interviews conducted by a professional opinion research firm. The surveyors contacted the respondents through random digit dialing of landlines. The sampling was conducted by proportionated quota sampling with consideration for the population sizes by region, gender, and age. The quota proportions were based on the resident registration population announced by the Korean Ministry of Government Administration and Home Affairs in September of 2017. The confidence level was 95%, and the margin of error was ± 3.1% points. Among the original sample of 1009 respondents, we screened out 49 respondents whose responses included missing values. Regarding each of our main variables (i.e., preferred energy source reform directions), age, gender, and area did not significantly differ between the respondents who had a missing value and those who did not. The difference in age was tested using analysis of variance, and gender was tested using cross-tab analysis. Table 1 summarizes the characteristics of the study sample (N = 960).

Table 1. Sample profile.

Variable	Description	Distribution	
Gender	Respondent's gender	Male	51.56%
		Female	48.44%
Age	Respondent's age (measured in specific age)	20–29	18.85%
		30–39	18.75%
		40–49	22.30%
		50–59	19.89%
		60+	20.21%
Residential Area	Respondent's residential area	Seoul	21.15%
		Busan	7.50%
		Daegu	4.69%
		Incheon	5.63%
		Gwangju	3.02%
		Daejeon	2.92%
		Ulsan	2.19%
		Gyeonggi Province	22.29%
		Gangwon Province	3.44%
		Chungcheongbuk Province	3.23%
		Chungcheongnam Province	3.96%
		Jeollabuk Province	3.75%
		Jeollanam Province	3.96%
		Gyeongsangbuk Province	4.90%
		Gyeongsangnam Province	6.25%
		Jeju Province	1.15%

Note: N = 960.

3.3. Measures

3.3.1. Preferred Reform Directions for Individual Energy Sources

The survey measured the respondents' preferred reform directions for the four energy sources that are the targets of the present government's electricity mix reform. These four energy sources are coal, nuclear power, natural gas, and new renewable energy. Surveyors asked the respondents the following

question: "What do you think the proportion of OOO (note: the energy source asked) for electricity generation should be?" for each of the four energy sources. For a given energy source, a respondent chose his/her preferred reform direction on a five-point scale: 1 = "should be reduced drastically"; 2 = "should be reduced gradually"; 3 = "should be maintained at the current level"; 4 = "should be expanded gradually"; 5 = "should be expanded drastically."

3.3.2. Demographic Variables

Gender, age, and residential area were measured. Table 1 includes the distributions of these variables.

4. Results

4.1. Coupling between Preferred Energy Source Reform Directions

Before our main analysis, which involved segmenting the sample based on the respondents' preferred energy source reform directions, we conducted two preliminary analyses. First, we regressed these directions on the respondents' demographic variables. If we solely relied on *p*-values without considering effect size, especially when the sample is sufficiently large, a statistical test is likely to demonstrate a significant difference or effect even if they are meaningless. Thus, we also considered the effect size. Among the demographic variables (gender, age, and residential area, which we divided into either metropolis or non-metropolis), only age revealed an effect that was both significant ($p < 0.001$) and not trivial (standardized coefficient no smaller than 0.10 [47]): the more aged the respondent was, the more favorable he/she was to the expansion of nuclear power. Second, we analyzed the correlations among the respondents' preferred energy source reform directions. As shown in Table 2, the preferred reform directions for coal and nuclear power were positively correlated; those of natural gas and new renewable energy were also positively correlated. The preferred reform directions for coal and nuclear power were negatively correlated with that for new renewable energy.

Table 2. Correlations and descriptive statistics of the preferred reform direction variables.

Preferred Reform Direction for	a	b	c	d
a. Coal				
b. Nuclear power	0.31 *			
c. Natural gas	0.04	0.02		
d. New renewable energy	−0.19 *	−0.26 *	0.31 *	
Mean	2.00	2.30	3.65	4.08
Standard deviation	0.75	0.83	0.87	0.78

Note: $N = 960$. The variables used a five-point scale: 1 = "should be reduced drastically"; 2 = "should be reduced gradually"; 3 = "should be maintained at the current level"; 4 = "should be expanded gradually"; 5 = "should be expanded drastically." * $p < 0.001$.

4.2. Finding and Characterizing the Segments

Based on the four variables for preferred energy source reform directions, we conducted a series of latent class analyses. For different numbers of pre-assumed classes, we ran latent class analyses using the LCA Stata Plugin developed by Lanza et al. [48]. Based on the comparison of the goodness-of-fit indexes among the different latent class solutions, we adopted the solution with four classes, which fit the data best (Appendix A). Table 3 presents the distributions of the respondents' preferred energy source reform directions in the extracted latent classes. The classes are ordered according to size: 437 respondents (45.52%) in Class 1; 228 (23.75%) in Class 2; 211 (21.98%) in Class 3; and 84 (8.75%) in Class 4.

Table 3. Preferred reform directions for energy sources according to the latent classes.

	Class 1: Gradual Reformists (45.52%)	Class 2: Drastic Reformists (23.75%)	Class 3: Selective Gradual Reformists (21.98%)	Class 4: Status-Quo Seekers (8.75%)	Whole (100.00%)
Coal					
Should be reduced drastically	13.27	***66.67***	9.48	15.48	25.31
Should be reduced gradually	***85.58***	21.05	23.22	30.95	***51.77***
Should be maintained at the current level	1.14	10.09	***62.56***	***44.05***	20.52
Should be expanded gradually	0.00	1.32	4.74	9.52	2.19
Should be expanded drastically	0.00	0.88	0.00	0.00	0.21
Nuclear Power					
Should be reduced drastically	2.97	***39.04***	1.42	11.90	11.98
Should be reduced gradually	***91.99***	***39.04***	22.75	3.57	***56.46***
Should be maintained at the current level	4.58	12.28	***58.29***	***58.33***	22.92
Should be expanded gradually	0.23	4.82	17.54	20.24	6.88
Should be expanded drastically	0.23	4.82	0.00	5.95	1.77
Natural Gas					
Should be reduced drastically	0.00	4.82	0.00	4.76	1.56
Should be reduced gradually	14.42	8.77	0.00	4.76	9.06
Should be maintained at the current level	26.09	17.11	13.74	***64.29***	24.58
Should be expanded gradually	***58.35***	25.44	***81.04***	17.86	***51.98***
Should be expanded drastically	1.14	***43.86***	5.21	8.33	12.81
New renewable Energy					
Should be reduced drastically	0.00	4.82	0.00	0.00	1.15
Should be reduced gradually	4.12	0.00	0.00	15.48	3.23
Should be maintained at the current level	6.18	0.00	0.00	***83.33***	10.10
Should be expanded gradually	***77.80***	11.40	***89.10***	0.00	***57.71***
Should be expanded drastically	11.90	***83.77***	10.90	1.19	27.81

Note: $N = 960$. Figures in cells represent relative frequencies (%) of the corresponding responses. A figure in bold italic font is the relative frequency of the mode.

In Class 1, the most frequent responses (i.e., modes) for coal and nuclear power were "should be reduced gradually" (85.58% and 91.99%, respectively); those for natural gas and new renewable energy were "should be expanded gradually" (58.35% and 77.80%, respectively). Overall, Class 1 is characterized by a preference for the gradual phasing out of coal and nuclear power and the gradual expansion of natural gas and new renewable energy. Thus, we designated Class 1 as the Gradual Reformists segment.

In Class 2, the response of "should be reduced drastically" (66.67%) was the most frequent for coal, and "should be reduced drastically" (39.04%) and "should be reduced gradually" (39.04%) were the equally most frequent responses regarding nuclear power. "Should be expanded drastically" was the most frequent response for natural gas (43.86%) and new renewable energy (83.77%). Overall, compared to that of Class 1, the preferred direction in Class 2 corresponded with the phrase "should be reduced drastically" for coal and nuclear power and "should be expanded drastically" for natural gas and new renewable energy. That is, Class 2 is characterized by a preference for the more drastic phasing out of coal and nuclear power and the more drastic expansion of natural gas and new renewable energy. Therefore, we designated Class 2 as the Drastic Reformists segment.

In Class 3, "should be maintained at the current level" was the most frequent response for coal (62.56%) and nuclear power (58.29%). The phrase "should be expanded gradually" corresponded to natural gas (81.04%) and new renewable energy (89.10%). That is, this class shows a relative preference for maintaining coal and nuclear power at their current levels and a strong preference for the gradual expansion of natural gas and new renewable energy. In other words, the dominant preference for gradual energy source reform is found selectively for natural gas and new renewable energy. Thus, we designated Class 3 as the Selective Gradual Reformists segment.

In Class 4, "should be maintained at the current level" was the most frequent response regardless of the energy source (44.05% for coal; 58.33% for nuclear power; 64.29% for natural gas; and 83.33% for new renewable energy). Thus, we designated Class 4 as the Status-quo Seekers segment.

Figure 1, using radar charts, visualizes the characteristics of the four segments. A circle point closer to the center (the outside) means that the class's dominant opinion is more supportive of drastic reduction (expansion) of the corresponding energy source. For example, the circle points of Class 2 show that the segment dominantly supports the drastic expansion of natural gas and new renewable energy but also the drastic reduction of coal and gradual-to-drastic reduction of nuclear power.

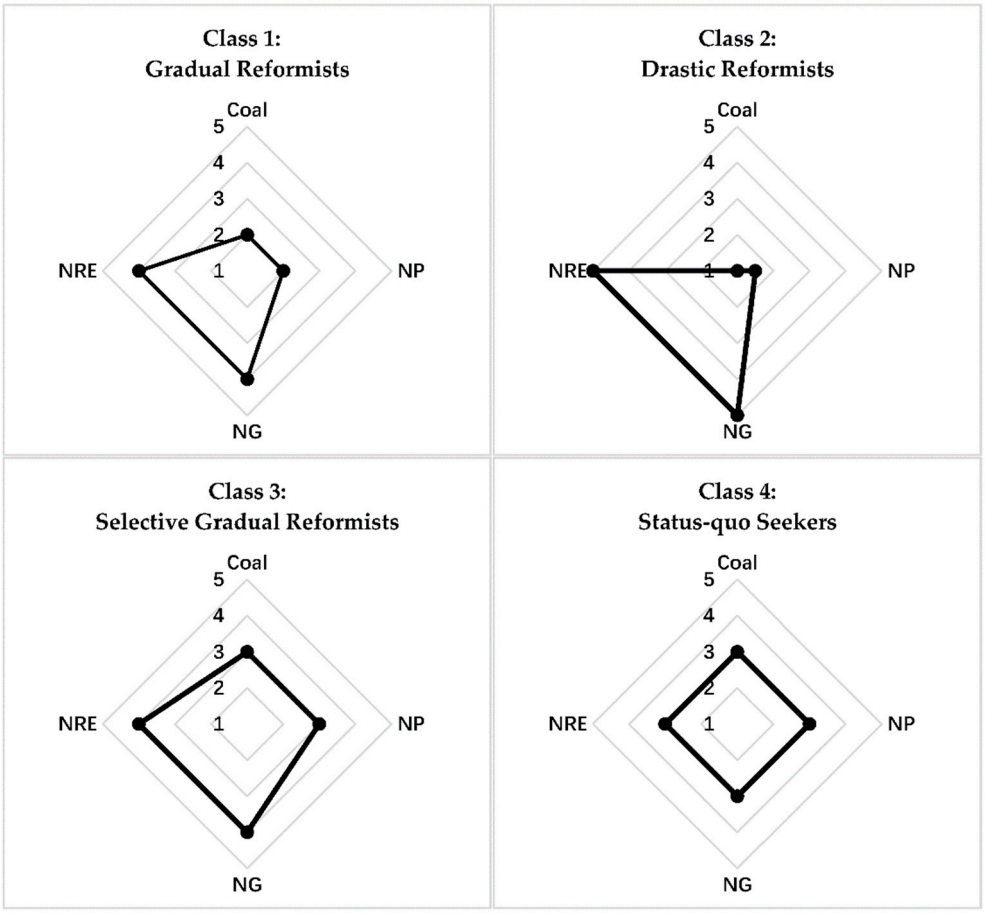


Figure 1. Radar charts of the segments. NP: nuclear power; NG: natural gas; NRE: new renewable energy. Scale: 1 = "should be reduced drastically"; 2 = "should be reduced gradually"; 3 = "should be maintained at the current level"; 4 = "should be expanded gradually"; 5 = "should be expanded drastically." A circle point represents the mode(s). For Class 2, the circle point for NP is dotted at 1.5 since there are two modes (1 and 2) for NP.

Table 4 summarizes the demographic characteristics of the segments. The average age of the Status-quo Seekers segment was significantly higher than those of the Gradual Reformists ($p < 0.01$) and the Drastic Reformists segments ($p < 0.05$). Gender revealed a more complicated effect. The proportion of males was significantly higher for both the segments demonstrating the most favorable support for electricity mix reform (i.e., the Drastic Reformists: 62.28%) and the least favorable support (i.e., the Status-quo Seekers: 65.48%) than for the segments with moderate assent for the reform (i.e., the Gradual Reformists (45.54%) and the Selective Gradual Reformists (46.92%)). In other words, compared to females, males were more likely to have extreme opinions on electricity mix reform.

Table 4. Demographic characteristics of the segments.

		Class 1: Gradual Reformists (45.52%)	Class 2: Drastic Reformists (23.75%)	Class 3: Selective Gradual Reformists (21.98%)	Class 4: Status-Quo Seekers (8.75%)	Whole (100.00%)
Gender	Male	45.54% [a,b]	62.28% [a,c]	46.92% [c,d]	65.48% [b,d]	51.56%
	Female	54.46%	37.72%	53.08%	34.52%	48.44%
Age	Mean	43.70 [e,f]	44.36 [g]	47.43 [f]	49.50 [e,g]	45.18
	SD	13.72	13.17	15.32	15.28	14.22

Note: N = 960. SD: standard deviation. [a,b,c,d] Gender ratio is significantly different from each other at the 0.01 level. [e] Age is significantly different from each other at the 0.01 level; [f,g] at the 0.05 level.

5. Discussion

The present study extracted four distinctive segments in the Korean public based on their preferred direction for electricity mix reform. These segments are the Gradual Reformists (45.82%), Drastic Reformists (23.75%), Selective Gradual Reformists (21.98%), and Status-quo Seekers (8.75%). Examining these segments' profiles along with the respondents' preferred reform directions for individual energy sources yields some notable points, as follows.

First, the Korean public tends to respond similarly regarding coal and nuclear power. The correlation between the preferred reform direction for coal and that for nuclear power is significantly positive (see Table 2). In addition, in each segment and the whole sample, the mode of the preferred reform direction for coal and that for nuclear power coincide (see Table 3). For example, in the Gradual Reformists segment, 85.58% of the respondents answered that (the proportion of) coal generation "should be reduced gradually," and 91.99% answered that nuclear power generation should proceed in the same manner. In the other segments and the whole sample, the dominant responses regarding coal and nuclear power also coincide. This positive coupling between the respondents' preferred reform directions for coal and nuclear power implies that the Korean public generally does not recognize nuclear power as an alternative to coal. On the contrary, they tend to treat coal and nuclear power together; those who think coal should be reduced (or expanded) tend to think nuclear power should also be reduced (or expanded).

Second, the Korean public seems to respond similarly regarding natural gas and new renewable energy. The correlation between the preferred reform direction for natural gas and that for new renewable energy is significantly positive (see Table 2). In addition, in each segment and the whole sample, the modes of the preferred reform directions for these two energy sources coincide (see Table 3). For example, in the Gradual Reformists segment, 58.35% of the respondents answered that natural gas generation "should be expanded gradually," and 77.80% answered that new renewable energy generation should proceed similarly.

Third, a large portion of the Korean public seems to recognize natural gas and new renewable energy as alternatives to coal and nuclear power, which is consistent with the present Korean government's energy policy. In the Gradual Reformists and Drastic Reformists segments, which amount to around 70% of the whole sample, the answer for natural gas contrasts those for coal and nuclear power. For example, in the Gradual Reformists segment, 58.35% of the respondents answered that natural gas generation "should be expanded gradually," and 85.58% and 91.99% answered that coal generation and nuclear power generation "should be reduced gradually," respectively. A similar pattern is found for answers regarding new renewable energy and coal/nuclear power.

Fourth, the Korean public seems to be largely supportive of the transition from coal and nuclear power to natural gas and new renewable energy in the following ways. First, preferences for the expansion of natural gas and new renewable energy are generally found in most segments. Only in the Status-quo Seekers segment (8.75%) do the modes for these energy sources indicate that their proportions "should be maintained at the current level." In the other three segments (Gradual Reformists (45.52%), Drastic Reformists (23.75%), and Selective Gradual Reformists (21.98%)), preferences for expansions of natural gas and new renewable energy are commonly found. Second, no segment is

characterized as preferring the expansion of coal or nuclear power. Even in the Status-quo Seekers and Selective Gradual Reformists segments who are relatively favorable toward coal and nuclear power, the status quo is dominantly preferred for these energy sources. Of course, some respondents insisted that coal or nuclear power should be expanded: however, the proportion of these respondents was not substantial enough to fill the requirements for a well-defined segment. In other words, the voices supporting the expansion of coal and nuclear power seem to be actually weak among the Korean public.

Overall, except for the Status-quo Seekers segment, support for the transition from coal and nuclear power to natural gas and new renewable energy seems to have prevailed among the Korean public. However, the degree of such preferences varies across the segments. In addition, regardless of the segment, a positive coupling between the preferences for coal and nuclear power and that between natural gas and new renewable energy are consistently found, which is also supported by the correlation coefficients between the preferred reform directions for the relevant energy sources. These couplings imply that, whether they oppose or support the present government's energy policy, the Korean public generally seems to categorize energy sources in a manner consistent with the underlying framework of such a policy: coal and nuclear power are energy sources that should be treated together, as are natural gas and new renewable energy sources.

6. Conclusions

When combined with existing theoretical frameworks and previous findings, our findings provide several implications, as follows. First, the fact that the Status-quo Seekers segment is higher in age may be due to the following causes. One possible cause may be the lock-in effect among aged generations. People and actors may be influenced by and adhere to the systems that they previously experienced, which might limit their perceptions of new alternatives [49,50]. Over the last decades of compressed economic development, Korea had been using fossil fuel generation, which has been economically viable while entailing low technological difficulty, as a basic option to meet the electricity demand. Additionally, Korea has been striving to expand nuclear power generation in the long run to reduce its dependence on fossil fuel. Korea's first nuclear power plant began operating in 1978 and already accounted for around 50% of the electricity mix by the mid-1980s (p. 192, [20]). Furthermore, in Korea, nuclear power generation has been an icon of the era, symbolizing the nation's technological independence and energy security [51]. However, natural gas is an electricity generation source whose settling in Korea was relatively late: it reached a 20% share only by the 2010s. New renewable energy is a completely new alternative in Korea, which broke a 1% share in 2011 and reached 5.0% in 2017 [21]. As such, older generations in Korea are accustomed to the era of fossil fuels and nuclear power being the mainstream. Thus, they may have become locked-in [49,50] to their field of vision for an electricity mix that combines coal and nuclear power. Another possible cause may be that one's values vary with age. In several countries, it has been found that the aged generations tend to be more conservative [52–55]. In addition, one of the common characteristics of conservatism is status-quo seeking [56]. As such, the Status-Quo Seekers segment's higher average age can be explained by the fact that older generations are more conservative and thus more status-quo seeking.

Each of these two possible causes is supported by its own reasoning. Thus, the development of a research model that can disentangle the effects of these two causes through survey design is necessary. This development needs the attention of energy scholars not only in Korea but also in other countries. Depending on whether nuclear power plants are operational in a country, the status quo is either (a) the maintenance of existing nuclear power or (b) its continued absence. In whichever cases, a lock-in effect, if one occurs, is likely to affect the public acceptance of nuclear power, although the direction would depend on which is the status quo.

Second, our finding that the Korean public generally tends not to treat coal as an alternative to nuclear power provides implications regarding the benefit–risk framework of energy acceptance. According to this framework, the perception of the benefits or advantages of a given energy source leads to a favorable response for that energy source, whereas that of the risks or disadvantages leads to

an unfavorable response [27,57,58]. The risk factors of coal generation that have caused opposition are its fine dust and GHG emissions. Abundant scientific research has suggested that nuclear power is an electricity generation source that contributes to the mitigation of these two problems [59–61]. Considering this, the positive coupling between the preferred reform directions for coal and nuclear power is quite counter-intuitive.

Combining our results with extant findings provides a couple of possible reasons for this counter-intuitive phenomenon. One possibility is that the Korean public may have significantly misunderstood the characteristics of nuclear power. A recent study by Chung and Kim [22] found that a larger portion of the Korean sample (43%) agree that nuclear power generation exacerbates climate change (34% "disagree" and 24% "do not know"). Combining this with the benefit–risk framework (i.e., benefit perception increases acceptance), the situation can be inferred as follows: the Korean public's poor perceptions of nuclear power's contributions to reducing environmental problems may have led them into thinking that nuclear power is not differentiated from coal.

Another possibility is also related to the benefit–risk framework. The Korean public's acceptance of nuclear power substantially declined after the 2011 Fukushima accident in Japan [62]. According to the benefit–risk framework, this decline can be attributed to the fact that the Fukushima accident deepened the Korean public's perceptions of risk associated with nuclear power. In addition, as seen in the trade dispute between Korea and Japan over the safety of seafood from Fukushima [63], the Koreans are concerned that the aftereffects of the Fukushima accident have not been adequately resolved. This strong perception of ongoing nuclear risks may have led the Korean public to think that nuclear power, like coal, is environmentally harmful.

Particularly, the first possibility implies significant research opportunities. In reality, before its current government, Korea was a country that nationally promoted the benefits of nuclear power generation in reducing fine dust and GHG emissions (e.g., the former Korean governments of Presidents Lee Myung-bak and Park Geun-Hye) [64,65]. However, if public perceptions of these benefits of nuclear power are low even in Korea, as found by Chung and Kim [22], we cannot rule out the possibility that such perceptions are also low or even lower in other countries.

This issue is also relevant to the pro-nuclear factions in Korea, such as the pro-nuclear academia, related institutions, and companies. For both coal- and nuclear power-related factions in Korea, improving the public's perceptions regarding the risks associated with these energy sources seems to be less feasible. Regarding the risks from coal generation, concerns about health problems caused by fine dust have emerged as a major social problem in Korea, particularly during the last decade [66]. Thus, the reduction of fine dust became a common campaign pledge of the candidates in the 2017 presidential election [67]. Regarding the risks of nuclear power, the Fukushima accident serves as an example of such a risk being realized. In such a situation, public perceptions of risks regarding coal and nuclear power are bound to be negative, which is likely to have contributed to the weakness of public voices for maintaining the status quo of coal and nuclear power, as shown by the relatively small portions of the Status-quo Seekers (8.75%) and the Selective Gradual Reformists (21.98%) segments. However, at least for nuclear power, there may still be hope. The fine dust and GHG emissions of nuclear power generation are significantly low, as is widely scientifically accepted. Rather than focusing on messages that are likely to be refuted by real cases (i.e., "nuclear power is free from accidents"), it would be more convincing to focus on consistent messages that are difficult to deny (i.e., "nuclear power is free from fine dust and GHG"). Thus, if our finding that the public's exclusion of nuclear power from the list of coal substitutes is due to the public's significant lack of knowledge of the nuclear power's benefits of reducing fine dust and GHG emissions, the centerpiece of the communication strategies by the pro-nuclear sides should be to address this lack of knowledge.

Third, our finding that the Korean public responds similarly to natural gas and new renewable energy also provides implications regarding the benefit–risk framework. Like coal and oil, natural gas is also a fossil fuel, whose burning to produce energy emits carbon dioxide, a GHG [60,68]. Taking into account the perspective that the preferences for new renewable energy come from the expectation that

it would emit only a small amount of GHG [69], the positive coupling between the preferred reform directions for natural gas and new renewable energy seems counter-intuitive.

There are a couple of possibilities for this finding. The first possibility is that the Korean public misunderstands natural gas as a "relatively" low-carbon energy source, noting that its GHG emissions are at least lower than those of other fossil fuels, such as coal and oil [60,70]. The second possibility is that the environmental attention of the Korean people is focused on fine dust problems rather than GHG emissions. GHG is blamed for causing global warming (or climate change), but its consequences are relatively difficult to determine in a citizen's everyday life [71]. In contrast, fine dust problems appear more relevant to Koreans' daily lives, as many have experienced not only their visual impacts but also health problems, such as respiratory disease, headache, dizziness, skin disease, eye disease, etc. Thus, the reduction of fine dust was a common campaign pledge in the 2017 presidential election [66,67]. In light of this, the Korean public may note that both the expansion of new renewable energy and natural gas can reduce fine dust emissions [72] rather than observing that natural gas is far from a sustainable solution in terms of GHG emissions [12,60].

The third possibility is that the Korean public perceives natural gas as a complementary energy source for new renewable energy. Even the Korean government's optimistic forecast is that Korea will reach grid parity, which is the point when a new renewable energy source can generate electricity at an LCOE less than or equal to those of electricity generated by conventional energy sources such as fossil fuels [73], around 2030 [74]. The Korea Economic Research Institute, an influential economic research institute, predicts that such parity will be reached around 2040 [75]. This uncertainty regarding new renewable energy may make the public feel the need for a "bridge" energy until such uncertainty is resolved. In addition, solar and wind power, the new renewable energy sources that the Korean government is focusing on, are naturally an intermittent energy source; they are not continuously available for conversion into electricity. Therefore, it is difficult to employ these resources as constant, stable generation sources. Because electricity generation using natural gas is highly controllable, it can compensate for the intermittent nature of new renewable energy [76,77], especially before the ESSs spread so that electricity from intermittent energy sources can be stored and released flexibly. Consistent with this, scholars, media, related companies, and bureaucrats that advocate for natural gas in Korea are positioning it as a complementary energy source for new renewable energy (e.g., [78,79]). This promotional strategy could have encouraged the Korean public's opinions regarding natural gas and new renewable energy as "companions."

All three possibilities call for a future research model based on the benefit–risk framework of energy acceptance that can disentangle and compare the effects of different kinds of benefit/risk perceptions regarding natural gas. Is natural gas's benefit of imperfect but "relatively" low GHG emissions important? Is its benefit of fine dust reduction more important than its risk of GHG emissions? Is it perceived as beneficial because of its complementary position to new renewable energy?

As such, our findings provide implications for both promoters and protesters of the Korean electricity mix reform. In addition, our findings can be a starting point for future research. Korea is still a world-class nuclear power, but it is also a country that has begun an ambitious drive toward new renewable energy sources. With such a dynamic country as the research background, future research on public preferences regarding electricity mix will contribute to more abundant implications for energy research. Such research would benefit from the consideration of variables that the present study disregarded, but that could be useful for refining the potential underlying mechanisms of the study's findings. Potential variables include a variable that can measure the degree of an individual's lock-in, values, and perceptions of benefits and risks from energy sources, as we have discussed in the above.

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Appendix A

Figure A1 shows how several types of goodness-of-fit indexes change as the number of pre-assumed classes changes. In the case of the goodness-of-fit indexes presented here, a lower value means a better fit between the solution and data. For example, in the panel for the Akaike information criterion (AIC), the latent class solution that assumed there exists only one class in the sample yielded an AIC value of 1096.66. The solution that assumed two classes yielded an AIC value of 776.79. These mean that the two-class solution fits the data better than the one-class solution. As Figure A1 shows, the best model varies depending on the types of goodness-of-fit indexes. Judging by the AIC, the five-class solution fits the data better than the other solutions since the AIC is the lowest for the five-class solution. In terms of the Bayesian information criterion (BIC) and the consistent Akaike information criterion (CAIC), the three-class solution is the best. According to the adjusted BIC, the four-class solution fits the data best. Thus, we need additional comparisons between the solutions.

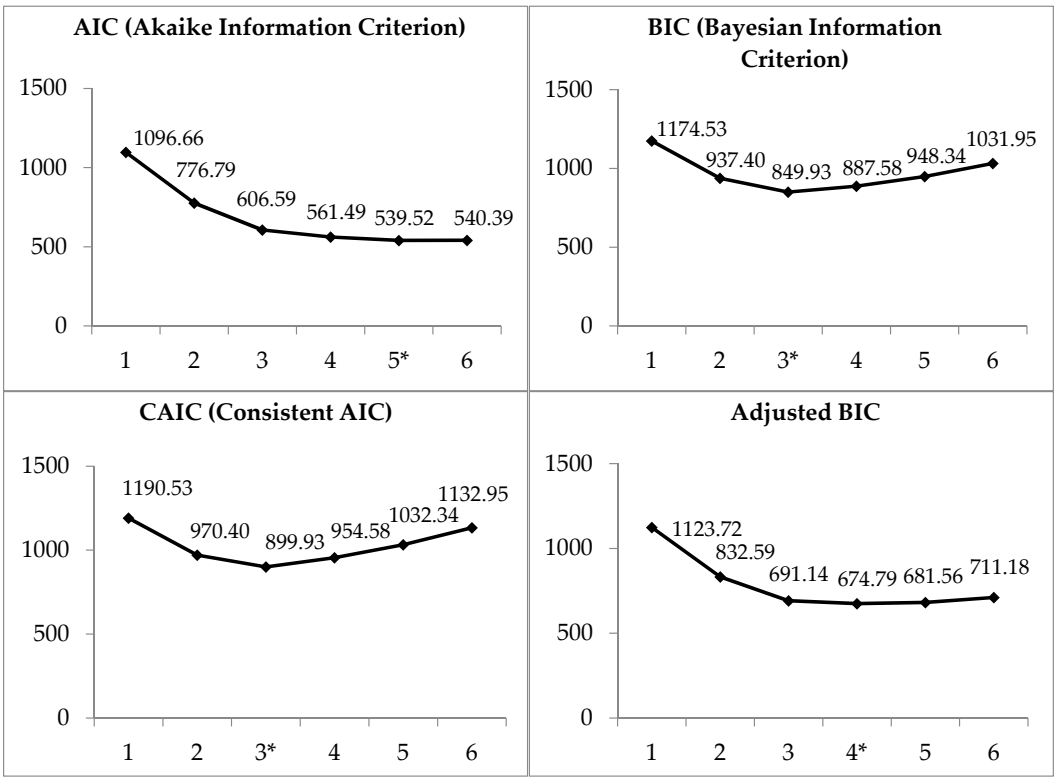


Figure A1. Goodness-of-fit index values according to the number of classes. The X-axes denote the number of pre-assumed latent classes. * This solution has the best goodness-of-fit.

Table A1 compares the three-, four-, and five-class solutions in terms of the two indexes most often used to compare models (AIC and BIC [45]) and secondary indexes derived from these two indexes. For example, Δ_j(AIC) was calculated from the j-class solution's AIC value and the AIC values of the other solutions considered. From Δ_j(AIC) and those of other solutions, the j-class solution's Akaike weight, w_j(AIC), was calculated. In a similar manner, the j-class solution's Schwarz weight, w_j(BIC), was calculated. Between the three- and four-class solutions (see section A of the table), the ratio of the two solutions' AIC weights (i.e., w_4(AIC)/w_3(AIC) = $(1.69 \times 10^{-5})/(2.73 \times 10^{-15}) = 6.19 \times 10^{9}$) shows that the four-class solution has a 6.19×10^{9} times higher likelihood of being a better model than the three-class solution. The ratio of the solutions' BIC weights (i.e., w_3(BIC)/w_4(BIC) = $1.00/(6.69 \times 10^{-9}) = 1.49 \times 10^{8}$) shows that the three-class solution has a 1.49×10^{8} times higher likelihood of being a better model than the four-class solution [44]. The fact that the former ratio is much greater than the latter indicates

that the four-class solution has an overall better fit than the three-class solution. In a similar vein, the comparison between the four- and five-class solutions revealed that the four-class solution fits the data better overall than the five-class solution (see B section of the table). As such, we adopted the four-class solution. A latent class solution provides the information on which of the classes each individual belongs. Based on this, we divided the 960 respondents in the sample to Classes 1 to 4.

Table A1. Akaike information criterion (AIC) and Bayesian information criterion (BIC) analyses between the competing solutions.

Number of Classes (= j)	AIC_j	Δ_j(AIC)	w_j(AIC)	BIC	Δ_j(BIC)	w_j(BIC)
3	606.59	67.07	2.73×10^{-15}	849.93	0	1.00
4	561.49	21.97	1.69×10^{-5}	887.58	37.64	6.69×10^{-9}
(A). The three- and four-class solutions						
Number of Classes (= j)	**AIC_j**	**Δ_j(AIC)**	**w_j(AIC)**	**BIC**	**Δ_j(BIC)**	**w_j(BIC)**
4	561.49	21.97	1.69×10^{-5}	887.58	37.64	6.69×10^{-9}
5	539.52	0	1.00	948.34	98.41	4.27×10^{-22}
(B). The four- and five-class solutions						

Note: For j-class solution, Δ_j(AIC) = [AIC_j–min(AIC)]; w_j(AIC) = Akaike weight. Δ_j(BIC) = [BIC_j–min(BIC)]; w_j(BIC) = Schwarz weight. See [44] for the calculation details.

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