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IMPACTS OF SOCIAL DISTANCING RESTRICTIONS FOR THE COVID-19 ON RESIDENTIAL BUILDING ELECTRICITY ENERGY USE IN SEOUL

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ABSTRACT

Social distancing (SD) is one of the main policies in response to coronavirus disease 2019 (COVID-19). People spend more time indoors due to this policy. However, such a behavior change can vary in different social groups due to their socioeconomic conditions. This study examines the relationship among SD policy, socioeconomic factors, and building electricity energy use before–after the COVID-19 outbreak in Seoul to reveal the impacts of the city SD policy on residential daily behaviors. Using a panel model, the study found that among the three SD levels in Seoul, SD levels 2 and 2.5 had a significantly positive effect on building electricity energy use, whereas SD level 1 had no significant influence. This result is in line with the observation that people have more at-home activities and more residential electricity energy uses when a high level of SD restrictions was announced. The findings with the interaction term variables provide a deep understanding of how the SD policy changed the electricity energy use patterns of different social groups, where the unequal impact of SD policy on residential behavior can be inferred. Particularly, expensive apartments had more electricity energy use increase, and apartments with more elderly people tended to have less increase when SD level 2 was applied compared with the period without SD policy, suggesting that high income changed their daily behavior more greatly, whereas the elderly had the opposite response. This study provides new evidence from the perspective of building energy to inform policymakers on how the SD policy affects the residential daily behaviors and building energy use for different social groups. Such information sets the basis for a more comprehensive evaluation of the current SD policy and proposals of future post-COVID-19 recovery policy.

Keywords: pandemic response, building energy, socio-economic groups, panel analysis, residential behavior, policy evaluation

NOMENCLATURE

Abbreviations	
SD	*Social distancing*
FAR	*Floor area ratio*
CR	*Cover ratio*

1. INTRODUCTION

Coronavirus disease 2019 (COVID-19) is one of the most challenging public health emergencies. On March 11, 2020, the World Health Organization declared COVID-19 a pandemic, announcing the sustained risk of further global spread. The Korean Disease Control and Prevention Agency announced that the most important means to reduce the spread of infections is personal hygiene management and social distancing (SD), and they implemented the SD policy on March 23, 2020 [1]. The level of SD was announced by the government in accordance with the number of confirmed cases and the situation (Fig. 1). With the increasing SD level, outdoor activities are more limited. Under SD level 2.5, the

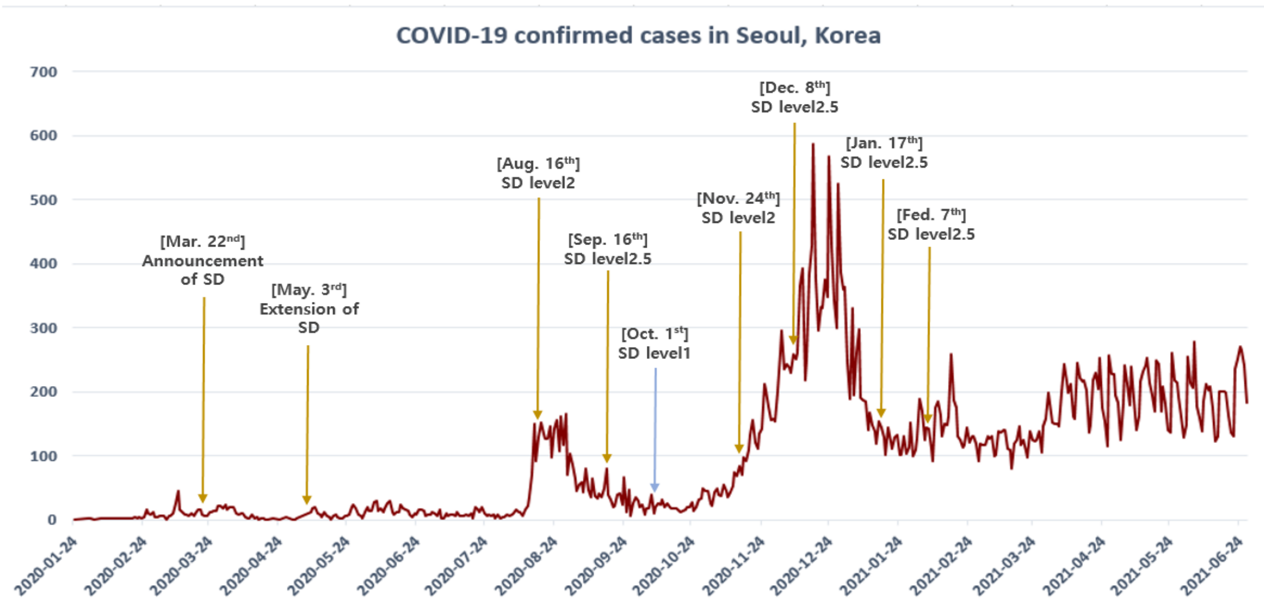

Fig 1. COVID-19 confirmed cases and SD level in Seoul, Korea [2]

highest level of SD in Korea, commercial facilities are closed at 10 pm, educational facilities, such as schools, attend only one-third of the total number of students, and companies limit the number of employees through telecommuting. Following these restrictions, people increase indoor activities in their homes.

In general, people stayed longer at their homes under the SD policies. However, the policy imposed different financial burdens depending on the personal socioeconomic level. As a response, different residential groups adjusted their behaviors in various ways. Low-income people choose to be economically active rather than staying at home [3]. Different age groups exhibit distinctive behavior changes because they have different economic conditions and education levels [4].

The increase in residential building energy use follows the general increase in residential indoor activities under the SD policy due to the significant effect of indoor activities on building energy use [5, 6]. Unlike the factors affecting building energy consumption that have been revealed to date, COVID-19 affects people differently depending on their socio-economic conditions. Thus, a more comprehensive understanding of the impacts of SD policy is needed to better manage the energy system during the pandemic. The new evidence from building energy allows a glance into residential daily behavior changes for different social groups under different SD policies.

This study aims to find the influence of SD policies on the building energy use of Seoul apartments for different socioeconomic groups. The panel analysis using time-series data is used to consider the changes under different SD policies. This study extends the discussion from energy policy implications to an assessment of broader SD policy impacts on different social groups.

2. VARIABLES AND METHODOLOGY

2.1 Analysis scope and unit

The case area of Seoul, the capital city of South Korea, is a global megacity with a population of 10 million, approximately one-fifth of the total population in the country. After the COVID-19 outbreak, Seoul has been strictly regulated on the SD level rather than other regions due to the high population density, as one of many actions the Korean government takes to reduce confirmed cases.

This study focuses on the residential energy use of apartment buildings. An apartment is a common residential type in Korea, and detailed data are abundant for this residential type than the others. One apartment complex is usually one parcel in urban management systems in Seoul; therefore, the spatial unit of the study is parcel. Each month from 2019 to 2020 (a total of 24 months) was chosen as the temporal scope to consider the before–after COVID-19 situation. A total of 875 parcels were included in the analysis considering the data availability (Fig. 2).

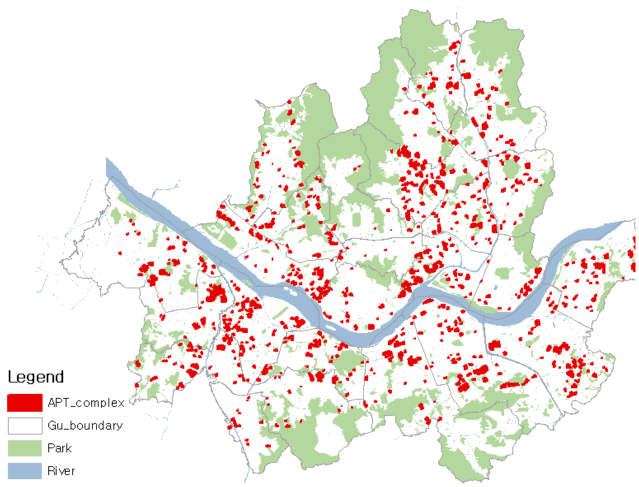

Fig 2. Research target areas

2.2 Variables

In this study, the dependent variable is the natural logarithm of building electricity energy use intensity (EUI). It is calculated by using the apartment electricity energy use data and total floor area provided by the Ministry of Land, Infrastructure, and Transport (MOLIT) [7]. Only electricity use is considered because of data availability. Besides for cooling, lighting, plug load, and appliance purposes, electricity is also used as the main or complementary heating energy source in Seoul.

In the independent variables, building factor variables include the building age, total floor area ratio (FAR), coverage ratio (CR), building structure, building use, ownership, and heating system type. The socioeconomic variables include the apartment price, population density, and elderly ratio. For the social factor part, the De Facto Population data provided by Seoul

Table 1. Variables

Division		Variables	Measurement (Unit)	Scale	Source
Dependent variable		APT EUI	Ln(Electricity consumption / total apartment floor area) (unit: kWh/m^2)	Parcel	MOLIT*
Independent variables	Social distancing	SD	SD Level: None, 1, 2, and 2.5	City	Seoul
	Socio-economic	APT price	Ln(APT price / total floor area) (unit: KRW/ m^2)	Parcel	MOLIT*
		Population density	Population / m^2 (Night time [11pm–6am])	Neighborhood	Seoul
		Elderly ratio	Elderly population / total population (Night time [11pm–6am])	Neighborhood	Seoul
	Interaction term	SD * APT price	Interaction term	-	-
		SD * Elderly ratio	Interaction term	-	-
	Building	Building use	Dummy variable, Pure APT = 1, Others (Mixed usage) = 0	Parcel	MOLIT*
		APT ownership	Dummy variable, own = 1, rental = 0	Parcel	MOLIT*
		APT age	Building age based on usage year	Parcel	MOLIT*
		Heating system	Dummy variable, Central heating = 1, others = 0	Parcel	MOLIT*
		APT structure	Dummy variables, RC = 1, others = 0	Parcel	MOLIT*
		FAR	Total floor area / parcel	Parcel	Calculate
		CR	Building footprint area / parcel area	Parcel	Calculate
	Climate	HDD	A measure of how cold the temperature was on a given day or during a period (Standard temperature: 18℃).	City	KMA**
		CDD	A measure of how hot the temperature was on a given day or during a period of days (Standard temperature: 26℃).	City	KMA**
	Environment	Dis Water body	Distance to near water space (m)	Parcel	MOIS***
		Dis Green space	Distance to near green space (m)	Parcel	MOIS***

*MOLIT: Ministry of Land, Infrastructure and Transport, **KMA: Korea Meteorological Administration,
***MOIS: Ministry of Interior and Safety

were used. These data are provided at 1-h intervals for each age group. The resident population was estimated as the average population, and the sleep time is assumed as 11 pm–6 am [8]. The SD variable is categorized with 0 for no regulation, 1 for level 1, 2 for level 2, and 3 for level 2.5. The SD policy for each month is defined as the one with its effective period of more than one-half of the number of days in the month. In November 2020, the SD level 2 was applied before it was changed to level 2.5 on the 24th, and the SD policy for that month was considered to be SD level 2, which had an effective period of 23 days. The environmental variables include the distance to water and the distance to green space. The climate variables include the heating degree days (HDD) and cooling degree days (CDD). In this study, interaction terms are used to find the joint influence of socioeconomic factors and SD on building electricity energy use. Table 1 shows the details of variables included in this study.

2.3 Model specifications

Significant differences exist between before and after COVID-19 in people's lives. Therefore, the panel model is used in this study to reveal the relationship between the six categories of independent variables and building electricity use. The panel analysis can consider cross-sectional and time series [9]. After the tests on serial autocorrelation and heteroskedasticity, the panel model of random-effects-feasible generalized least squares was selected as the final model type.

Two models are run on the dataset; Model 1 excluding the interaction term and Model 2 including the interaction term. The models were implemented by using STATA 15 with the *xtgls* command.

3. RESULTS

The results of the two models are presented (Table 2). Models 1 and 2 show similar results, except for SD variables. In Model 1, SD levels 2 and 2.5 have a significantly positive relationship with building EUI. In Model 2, levels 1 and 2 have no such significant relationships, and only level 2.5 has a significantly positive relationship with EUI. In socioeconomic factors, APT price, which is used as a proxy for the income level in this study, has a significantly positive relationship with EUI. Population density and elderly ratio have a significantly positive effect on EUI. Among the building factors, building use, APT ownership, APT age, APT structure, and CR have significantly positive relationships, whereas heating system and FAR have negative relationships. Among the environmental and climate factors, HDD, CDD, and distance to green space have significantly positive effects on energy use, whereas the distance to the water body shows a significantly negative effect on EUI.

The results of the interaction terms suggest that APT price with SD level 2 has a positive relationship with building energy use, whereas APT price with SD level 1 and that with SD level 2.5 show insignificant relationships with EUI. The SD level 2*elderly ratio has a negative effect, whereas the SD level 1*elderly ratio and SD level 2.5 *elderly ratio seem to have no significant effects on building energy use.

4. DISCUSSION

This research indicates the complex effect of the SD policy on building electricity energy that can be explained by residential behavior changes. The findings from Model 1 suggest that as the regulation becomes stronger, its influence on building electricity energy use becomes greater. The findings from Model 2 show that the effect of SD regulation can vary in different social groups. The results suggest that the current and future urban energy management needs to consider such effects by adopting new energy policies, such as subsidizing electricity bills.

The results from the building energy study reveal the residential behavior changes under different SD policies. The finding that expensive apartments had more electricity energy use increase under SD level 2 suggests that high-income residents experience a greater behavior change of increasing their at-home activities than their low-income peers who generally had to continue their on-site jobs for a living despite the risk of contracting the COVID-19. Therefore, it calls for more attention to this underprivileged group in future government policymaking.

The result about the interaction term concerning age groups shows that the residential behavior change of increasing at-home activities is less prominent for the elderly group than for the younger group under SD policies. It is possibly because the latter had to switch their large amount of activities, such as work and school to the in-home mode. This suggests particular health care for the elderly in their daily activities with a large proportion of out-of-home activities. Great support is needed for all residential groups to adapt to behavior changes induced by the SD policy.

Table 2. Result

Variables	Model 1			Model 2		
	Coef.	S.E	Sig.	Coef.	S.E	Sig.
cons	.267	.030	.000	.267	.032	.000
SD						
Level 1	-.005	.003	.057	.015	.032	.633
Level 2	.012	.004	.007	-.049	.045	.278
Level 2.5	.113	.003	.000	.121	.038	.001
APT price	.057	.005	.000	.055	.005	.000
Population density	3.587	.745	.000	3.489	.741	.000
Elderly ratio	.210	.067	.002	.263	.076	.001
Building use	.052	.011	.000	.052	.011	.000
APT ownership	.048	.004	.000	.049	.004	.000
APT age	.007	.000	.000	.007	.000	.000
Heating type	-.067	.008	.000	-.066	.008	.000
APT structure	.034	.008	.000	.034	.008	.000
FAR	-.008	.001	.000	-.008	.001	.000
CR	.087	.033	.007	.086	.033	.008
HDD	.000	.000	.000	.000	.000	.000
CDD	.004	.000	.000	.004	.000	.000
Dis Water body	-.000	.000	.000	-.000	.000	.000
Dis Green space	.000	.000	.000	.000	.000	.000
SD*APT price						
Level 1				-.002	.006	.773
Level 2				.039	.009	.000
Level 2.5				.001	.007	.886
SD*Elderly ratio						
Level 1				-.090	.103	.386
Level 2				-.527	.144	.000
Level 2.5				-.074	.123	.548
Wald Chi^2(17)	21566.16			21842.84		
Prod>chi^2	.000			.000		

5. CONCLUSION

Seoul has implemented strict SD policies to control the spread of the COVID-19. These policies have wide impacts on many aspects of society. This study examines how SD policy influences residential building electricity energy use before–after the COVID-19 outbreak for different socioeconomic groups in Seoul. Using a panel model, the study found that among the three SD levels in Seoul, SD levels 2 and 2.5 had a significantly positive effect on building electricity energy use, whereas SD level 1 had no significant influence. This result is in line with the observation that people have more at-home activities and more residential energy uses when a high level of SD restrictions was announced. The findings with the interaction term variables show how the SD policy changed the electricity energy use patterns for different social groups, which can help to better understand the unequal impact of SD policy on residential behavior. In particular, expensive apartments had more electricity energy use increase, and apartments with more elderly people tended to have less such an increase when SD level 2 was applied compared with the period without SD policy, suggesting that the high-income group changed their daily behavior more greatly, whereas the elderly group had the opposite response. This study provides new evidence from the perspective of building electricity energy to inform policymakers on how the SD policy affects different social groups on residential building electricity energy use and residential behavior changes in accordance. Such information sets the basis for a more comprehensive evaluation of the current SD policy and proposals of the post-COVID-19 recovery policies.

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