The Moderating Effect of Demographic and Environmental Factors in the Spread and Mortality Rate of COVID-19 during Peak and Stagnant Periods

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Abstract: This study explores the demographic and environmental factors affecting the spread and mortality rate of COVID-19 in countries around the world. We performed a hierarchical regression by adding interaction terms to such factors as the proportion of people aged 65 or older, the ratio of foreign migrants, the number of hospital beds available, population density, the Gini index, smoking rate among the population, mean population exposure to $PM_{2.5}$ and NO_x emissions in each country. We found that countries with a higher proportion of people over 65 had a higher rate of confirmed positive cases, a higher mortality rate, and a higher case fatality rate. We also found that there was a positive and significant statistical correlation between the number of foreign migrants in a country and the rate of confirmed positive COVID-19 cases and the number of deaths but an inverse relationship between this variable and the case fatality rate. We found a negative relationship between the number of hospital beds and mortality and case fatality rate while but a positive relationship between the level of nitrogen oxides in the environment and the rate of confirmed positive cases, the mortality rate, and the case fatality rate, although there was no such relationship for ultrafine dust. Overall, the variables affecting the spread and mortality of COVID-19 in June, during which it was expected there would be a lull after the virus had reached its peak in May, were similar to those affecting its spread and mortality in May, but the model's explanatory power and significance were higher in May.

Keywords: COVID-19, mortality rate, migrants, environment, NOx

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INTRODUCTION

The coronavirus (COVID-19), the first known case of which is believed to have occurred in Wuhan, China, in December 2019, has spread around the world, with 282 deaths in Korea as of June 30, 2020, and 503,457 deaths worldwide. The current case fatality rate (CFR) varies widely between countries from 0.2% in Germany to 7.7% in Italy, and the global mortality rate peaked at 7.3% (Lazzerini & Putoto, 2020). Recently, through case studies of one country or several countries, scholars in various fields have been trying to uncover the causes of the spread of the virus and the mechanisms that render it fatal. There is much debate among scholars about exactly which pathways COVID-19 is spreading through and what cases lead to death. For example, China and Italy both had about 80,000 confirmed cases by March, but there is a significant difference between them when it comes to the mortality rate. More than 10,000 people died in Italy by March, far exceeding the 3,300 deaths in China in the same time period (Rubino et al., 2020).

The main cause of death from coronavirus-19 turns out to be pneumonia. According to the World Health Organization (WHO), pneumonia is an infectious disease caused by germs or viruses that produces inflammation of the lung tissue and usually occurs when the immune system is degraded especially in the elderly or in people with preexisting conditions. However, the difference in COVID-19 mortality rates among countries probably owes to a combination of diversity in sociocultural practices, the proportion of vulnerable groups, and the availability of health facilities. In this study, we explore factors contribute to the spread of virus and to higher death rates. Specifically, this study investigates whether there are any significant variables that influence the spread of COVID-19 among the various factors mentioned in previous studies on respiratory diseases, what new factors might contribute to the spread of the virus and the mortality rate, which varies from country to country, and whether environmental and demographical factors significantly affect the rate of spread and the CFR. Our results could enhance the ability of the governments to prevent similar outbreaks in the future.

LITERATURE REVIEW

Research on demographic and environmental factors affecting COVID-19 mortality is currently under way all over the world in various fields. Most studies are in the form of manuscripts or seminar presentations; there are not many journal articles yet. Therefore, we introduce key variables through a review of studies on

SARS and MERS and then consider recent prepress studies on COVID-19. So far, these publications can largely be divided into ones the explore environmental factors and demographic factors in COVID-19 mortality rates.

Previous Studies on Infectious Diseases

Due to major catastrophes such as SARS and MERS in the early 2000s, risk management for controlling the spread of infectious diseases has attracted attention in the social sciences. In the fields of policy studies and public administration in particular, scholars have highlighted the critical importance of having the resources to effectively respond to crises. The reason the Chinese government was unable to curb the spread of SARS in the early stages was in part because nonprofit organizations were saddled by regulations which made them difficult to access information needed to effectively respond to infectious diseases (Li, 2004, pp. 45-51). Hyeung-Wook Boo and Larkin S. Dudley (2012) have also emphasized the importance of strategic network management in the early stages of a disaster. Furthermore Dalgon Lee (2015, pp. 127, 143) has argued that both the autonomy of and cooperation between not only the central government but also local governments, public institutions, enterprises, and civic groups are essential if the response to a crisis is to be comprehensive.

Jiyoun Chang (2017, p. 46) has pointed out that the lesson learned from the Korean government's failure to respond to MERS in the early stage is that network-type approaches —in which crisis communication channels and information sharing systems figure—are needed for disaster management. A knowledge-based crisis management is the key to preventing infectious diseases, and a network approach that enables cooperation among different organizations facilitates the shoring up of knowledge. In their comparison of the response to SARS and MERS in Korea, Dae Yoo Go & Jaehee Park (2018, pp. 272-275) point out that the way infectious disease disaster governance is managed can change depending on the information, leadership, manpower and budget in the response stage. Ju Young Koo and Tae Jun Na (2017, pp. 7-21) claim that the initial response to MERS was a failure because the Korean government did not actively disclose relevant information to the public and related organizations. After the MERS outbreak in Korea, white papers published by the Ministry of Health and Welfare as well as the Korean Medical Association detailed the initial response failure, the lack of solid leadership due to absence of a control tower, the shortage of quarantine personnel such as epidemiologists, and the government's method of communicating with the public that only caused anxiety.[1] The Korean government appears to have learned from its experience with MERS; its response to COVID-19, grounded in a model called "K-quarantine" that focuses on controlling spread, has been seen as a marked improvement.

Studies on the path of infection and cause of death of MERS and SARS tended to focus on specific countries and regions (Chang, 2017; Li, 2004), attending primarily to the response systems and risk governance protocols of individual countries and specifically emphasized governance reform, such as the need to expand the heath care infrastructure and to improve information sharing, communication, and cooperation with related organizations. However, it is difficult to apply lessons learned from previous infectious diseases, since COVID-19 is spreading indiscriminately in countries that experienced SARS and MERS.

Socioeconomic Factors Affecting the COVID-19 Mortality Rate

A number of studies have analyzed the effect of demographic factors, such as age, gender, and the number of available hospital beds on the rate of confirmed positive cases and mortality rate. Daniel Promislow (2020) conducted a regression analysis using data from China, Italy, and New York City and found that age and gender are significant factors in the COVID-19 mortality rate. According to the study, the health risks posed by the virus vary with age. The mortality rate in children was less than 0.1%, but in older people it increased to more than 10%. The CFR in Italy, the infection fatality rate in China, and the mortality rate in New York City was exponentially higher among both older men and women. In addition, the male mortality rate was higher in all age groups, suggesting that men are more vulnerable to COVID-19 than women.[2]

A study conducted by Angelo Cagnacci and Anjeza Xholli (2020) showed similar results. According to their analysis of the effect of gender and age (10s to 80s) on the COVID-19 mortality rate in Italy from February 22 to April 19, 2020, women died in fewer numbers. Anthony Hauser and his colleagues (2020) compared Hubei in China with northern Italy and found that the mortality rate for symptomatic and asymptomatic infections was 3.0% in the former and 3.3% in the latter and that the mortality rate increased with age, predicting that before the pandemic is over among those aged 80 and older, 39% will die in Hubei and 89% in northern Italy. Gianluca Rinaldi and Matteo Paradisi (2020) analyzed the mortality

1. Young-jong Hyeon, 'Have you already forgotten MERS lesson,' *Halla Ilbo*, March 2, 2020.
2. In particular, in Italy, men were 1.7 to 2.6 times more likely to die than women over 30.

rate in Italy using the Bayesian model and estimated that for those 60 or younger it was 0.05%.

Other studies have focused on the effect of a country's demographics and health resources on the COVID-19 mortality rate. Salvatore Rubino and colleagues (2020) found that Italy's CFR rate was 10.6% while China's was 4%. Italy has one of the oldest populations in the worlds, the median age being about 46. Given that the average age of Italians who die from COVID-19 is 81, it can be predicted that Italy will have a higher mortality rate than China. In addition, the dearth of beds in the intensive care unit in each region and the lack of respirators may have been attributed to an increase in deaths during the surge in cases of COVID-19.

A number of studies have focused on racial distribution across regions. Gregorio A. Millett and colleagues (2020) compared the COVID-19 mortality rate across U.S. counties. The analysis showed that counties with a higher proportion of black citizens, who comprise 13% of the U.S. population, were subject to greater air pollution than counties with a higher proportion of whites and that they experienced greater number comorbidities. COVID-19 deaths were also higher in counties with a higher proportion of black citizens.

Environmental Factors Affecting the COVID-19 Mortality Rate

Since environmental factors usually affect the human body only after extended periods, there are not many studies on how environmental factors affect the COVID-19 mortality rate. Prior studies on the effect of the environment on respiratory diseases largely fall into two categories: those that assert a causal relationship between environmental factors and death in patients with respiratory illnesses and those that deny such a causal relation. Xiao Wu and colleagues (2020) used data from more than 3,000 U.S. counties to determine whether prolonged exposure to $PM_{2.5}$ was related to an increase in the risk of death from COVID-19 in Americans. The study took 20 potential socioeconomic factors into account, including population size, age distribution, population density, time since the onset of the virus, time after stay-at-home order, number of patients tested, weather, obesity, whether the patients smoked, and so forth. The analysis showed that an increase of 1 μg/m3 in $PM_{2.5}$ resulted in an 8% increase in COVID-19 mortality.

Yaron Ogen (2020) undertook a similar study for Europe, analyzing the relationship between NO_2 levels and COVID-19 mortality in 66 administrative districts in Italy, Spain, France, and Germany.[3] Ogen used the concentration of NO_2 in the

3. NO_2 is a gas that is emitted in small amounts in the course of human activity. Long-term

troposphere extracted from Sentinel-5P satellites to explain the spatial variation of deaths across the 66 administrative districts and found that 3,487 (78%) of 4,443 deaths occurred in five regions in northern Italy and central Spain that had the highest levels of NO_2. These five areas are also surrounded by mountain ranges. Combined with atmospheric conditions, mountains can prevent the dispersion of airborne pollutants, increasing the incidence of respiratory diseases and inflammation in people living in such regions.

Jong-Il Choe & Young Sou Lee (2015) use age, children, gender, household income level, temperature and humidity, pollution index, and $PM_{2.5}$ as explanatory variables through the tobit and probit model to explore factors affecting the number of hospitalizations for respiratory illness in Seoul. According to the analysis, there is a statistically significant positive relationship between $PM_{2.5}$, children, and average peak temperatures, on the one hand, and hospitalizations for respiratory disease on the other. In addition, indices of contamination of SO_2, NO_2, CO show statistically significant positive effects on respiratory diseases. However, the income level of households was not statistically significant.

Hyun-Joo Bae (2014) analyzed the effects of PM_{10} and $PM_{2.5}$ concentrations on cardiovascular deaths using air pollution, weather, and mortality data from Seoul over the period from 2006 to 2010. According to her analysis, there is a high correlation between cardiovascular death as the concentration of PM_{10} and $PM_{2.5}$ increases across all ages. In particular, she found that increases of concentrations of PM_{10} and $PM_{2.5}$ in people 65 or older increased the risk of death due to cardiovascular conditions by 0.80 percent and 1.75 percent, respectively. However, Se Jeong Um and colleagues (2017) argue that there is no causal relationship between fine dust and death in patients with respiratory illnesses. They suggest that the findings of a correlation between the concentration of fine dust and respiratory diseases is questionable given that the number of deaths from respiratory diseases had generally increased but the concentration of fine dust goes throughs periods of decrease and increase.

exposure to NO_2 can lead to widespread health problems such as high blood pressure, diabetes, and heart and cardiovascular disease.

RESEARCH MODELS AND DATA ANALYSIS

Data Collection

The purpose of this study is to analyze the effect of sociodemographic and environmental factors on the spread and mortality rate of COVID-19 in 147 countries affected by the virus as of May 16, when global mortality peaked, and June 30, 2020, the end of a lull in the infection rate. Because prior studies on the effects of environmental and socioeconomic factors on respiratory disease mortality mainly focused on case studies in one country or several national groups, we sought to develop a generalized model that can be applied to the current global pandemic. Given our purpose, we chose the national level as our analysis unit. We ended up analyzing a total of 147 countries, 36 OECD countries and 111 non-OECD countries, omitting countries for which relevant data was not available.[4]

Data for each variable were collected from December 2019 to May 16, 2020 and December 2019 to June 30, 2020 from the websites of internationally reputable organizations such as WHO, the OECD, the United Nations Department of Economic and Social Affairs, and the World Bank. The COVID-19 rate of confirmed positive cases, mortality rate, and CFR were used as dependent variables.[5] Among these variables, CFR was predicted to be more heavily affected by age and preexisting conditions than by sociodemographic and environmental factors.[6] All dependent variables were out of the normal distribution range of skewness and kurtosis values, and three variables were log-transformed.[7] As of May 16, 2020, there were 17 countries out of 147 with zero COVID-19 deaths. As of June 30, the number of

4. See the appendix for the list of countries we analyzed.
5. According to WHO, the definition of CFR is the proportion of death among the identified confirmed cases (number of deaths from diseases divided by number of confirmed cases of diseases) × 100) and the mortality rate is the ratio of the number of people with the infection who died divided by the total population.
6. Jean-Louis Vincent and Fabio Taccone (2020) point out that case fatality rates need to be interpreted carefully. For example, in countries such as Korea and Switzerland where large-scale testing was undertaken or in cases in which the denominator (the number of patients) included mild or asymptomatic cases, the CFR was less than 1%, but in countries such as Spain and Italy where testing was limited to only those who needed hospitalization, the CFR was more than 5%.
7. For the mortality rate, kurtosis was 7.37 and skewness was 66.41, but after log transformation, it was close to the normal distribution at 2.72 and 0.20, respectively.

countries with zero deaths was 13 out of 147.[8] If the number of deaths is 0, such an instance can be generally excluded as an outlier, but in this case, these instances were judged to have implications for estimating the causal relationship between sociodemographic and environmental factors and death from COVID-19, and so we included them in the analysis.

Variables in the Model

The dependent variables in our study are the rate of confirmed positive cases, the death rate, and the CFR of COVID-19 among the total population of each country. We used the following sociodemographic factors as independent variables: the ratio of people aged 65 or older to total population, the ratio of immigrants to total population, population density, the smoking rate among the population, the Gini coefficient (to take into account variables in previous studies), mean population exposure to $PM_{2.5}$, and levels of NO_x emissions.[9] First we created multiple regression models, and then we performed a hierarchical analysis by adding interaction terms with environmental factors such as the proportion of people aged 65 or older, the number of beds and ultrafine dust, and nitrogen oxide.

We used the proportion of migrants in each country as a proxy variable because COVID-19 is not acquired only from one's fellow citizens but also by contact with people from outside the country who have entered it. Migrant groups also face many health challenges (see Jung, 2018, Choi & Lee, 2018, and Shin, Hasegawa, & Choi, 2019). The International Organization for Migration (IOM) has emphasized the importance of taking cross-border and population migration perspectives into account in developing cross-border infection control systems (Shin, 2020). The migrant population used in this study was calculated as the percentage of migrants living in each country.[10] In addition, since population density can indicate the level of contact and social interaction among people in an individual country, it was

8. The 17 countries include Bhutan, Cambodia, Fiji, Laos, Lesotho, Madagascar, Mongolia, Mozambique, Namibia, Nepal, Papua New Guinea, Rwanda, Saint Lucia, Seychelles, East Timor, Uganda, and Vietnam.
9. The reason we excluded SO2 from the research model is that there is a strong correlation of more than 0.9 between NO_x and SO_2.
10. According to UN Population Division, migrant populations are mostly data on foreign-born immigrant populations, or when that data is difficult to obtain, it is measured based on foreign nationality. (https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates19.asp; https://migrationdataportal.org/themes/international-migrant-stocks)

added as an explanatory variable in the spread of COVID-19 and the increase in mortality. We included the Gini coefficient because when income discrepancies are severe among a given population, the health level of lower-income classes is generally compromised and even the overall health level may be low. However, we excluded gender because the analysis unit of this study is the country and there was no significant correlation between the ratio of men to the total population and COVID-19 mortality.

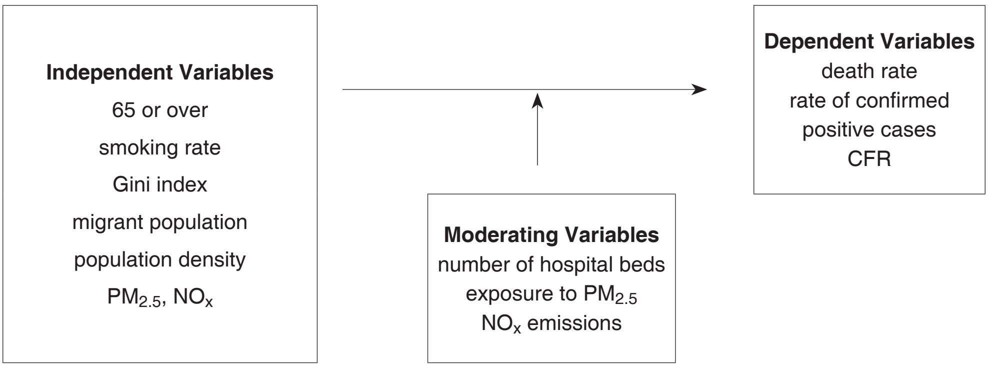
Table 1. Variables and Data Source

	Variables	Data Source	Date
Indepen-dent Variables	65 or over (%)	World Bank https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS	2018
	migrant population (%)	UN https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates19.asp	2019
	Gini index	Index Mundi https://www.indexmundi.com/facts/indicators/SI.POV.GINI/rankings	2017
	mean poluation exposure to $PM_{2.5}$	OECD https://stats.oecd.org/index.aspx?queryid=72722#	2007-15 (average)
	NO_x emissions	Environmental Performance Index https://epi.yale.edu/downloads	2014
	smoking rate (%)	World Population Review https://worldpopulationreview.com/countries/smoking-rates-by-country/	2020
	population density	UN https://population.un.org/wpp/Download/Standard/Population/	2020
	number of hospital beds per 1,000	WHO https://data.worldbank.org/indicator/SH.MED.BEDS.ZS	
Dependent Variables	COVID-19 mortality rate; rate of confirmed positive cases; CFR	WHO, Oxford University https://github.com/owid/covid-19-data https://covidtracker.bsg.ox.ac.uk/	May 16, 2020; June 30, 2020

Research Model and Hypothesis

Our hypotheses are the following: that the higher the concentration of each pollutant ($PM_{2.5}$ and NO_x), the higher the rate of confirmed positive cases, the death rate, and the CFR of COVID-19 will be, that the number of people aged 65 or older will have a positive effect on these rates, that the higher the population of migrants, the higher these rates, and that the effect of all these variables will be moderated by the health condition and air quality of each country.

Table 2. Potential Research Model



We measured the effect of the migrant population on the rate of confirmed positive cases, the death rate, and the CFR by adding the proportion of migrants in each country, which was not done in previous research. Among the various factors that play a role in the appearance of a new infectious disease in a given country, many of them are related to human migration, which can be an important medium for the spread of a disease because it can change its form (Barnett & Walker, 2008, p. 1448; Brauer & Driessche, 2001, pp. 143-144). The model reflects the fact that the higher the ratio of migrants, the more people are able to cross borders.

We also added air pollutants that can cause respiratory diseases as explanatory variables. Nitrogen oxide causes air pollution and is mainly emitted from cars and steel mills. Long-term inhalation of NO_x gas may cause asthma and respiratory infections, and its ill effects may be aggravated when combined a COVID-19 infection.[11] According to a recent study examining changes in air pollutants before and

11. https://toxtown.nlm.nih.gov/chemicals-and-contaminants/nitrogen-oxides.

after the lockdown in eastern China, the early epicenter of COVID-19, although normally in winter in cities in China, nitrogen oxides react with ozone to reduce levels of ozone, as the concentration of nitrogen oxides decreased due to lockdown, ozone concentrations rose. Owing to high ozone levels, chemical reactions in the atmosphere continued, resulting in a high concentration of ultrafine dust in Beijing. (Le et. al. 2020).

The following equations capture our research model.

$$LogRCC=\alpha+\beta_1 P65+\beta_2 LogMP+\beta_3 LogPD+\beta_4 SR+\beta_5 GNI+\beta_6 HB+\beta_7 LogPM_{2.5}+\beta_8 LogNitrogen+\varepsilon$$

$$LogDR=\alpha+\beta_1 P65+\beta_2 LogMP+\beta_3 LogPD+\beta_4 SR+\beta_5 GNI+\beta_6 HB+\beta_7 LogPM_{2.5}+\beta_8 LogNitrogen+\varepsilon$$

$$LogCFR=\alpha+\beta_1 P65+\beta_2 LogMP+\beta_3 LogPD+\beta_4 SR+\beta_5 GNI+\beta_6 HB+\beta_7 LogPM_{2.5}+\beta_8 LogNitrogen+\varepsilon$$

RCC = rate of confirmed cases, DR = death rate, CFR = case fatality rate, P65 = aged 65 or older, MP = migrant population, PD = population density, SR = smoking rate, GNI = Gini coefficient, $PM_{2.5}$ = $PM_{2.5}$, nitrogen = NO_x HB = number of hospital beds per 1,000, α = constant, ε = error

RESULTS AND DISCUSSION

Descriptive Analysis

Descriptive statistics for the variables included in this study are shown in table 3. Skewness and kurtosis of dependent variables and independent variables such as migrant population, population density, ultrafine dust ($PM_{2.5}$), nitrogen oxide (NO_x), are outside the normal distribution range. We converted these variables to natural logarithms. Prior to our conducting the regression analysis, we measured the variance inflation factor(VIF) to determine whether there was multicollinearity among variables constituting the model. The result showed that the VIF of all independent variables was less than 10, that the tolerance was also greater than 0.1, and that the mean VIF was 2.51 to 2.66, which confirmed that multicollinearity was not an issue in either model I (May 16) or model II (June 30).

Table 3. Descriptive Statistics for Variables

Variable (Observations=147)	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
Rate of Confirmed Positive Cases (05.16)	0.08	0.15	0.00	1.02	2.98	14.26
CFR (05.16)	4.18	4.43	0.00	32.00	2.49	13.31
Death Rate (05.16)	0.00	0.01	0.00	0.08	3.93	19.48
Rate of Confirmed Positive Cases (06.30)	0.17	0.35	0.00	3.30	5.62	46.97
CFR (06.30)	3.39	3.83	0.00	26.95	2.86	14.22
Death Rate (06.30)	0.01	0.01	0.00	0.08	3.25	14.28
Smoking Rate (%)	22.10	9.72	0.00	45.90	0.22	2.61
Gini Index	38.45	8.01	25.00	63.00	0.55	2.84
Number of Hospital Beds per 1,000	2.95	2.43	0.10	13.40	1.50	5.65
65 or Over	9.41	6.57	1.09	27.58	0.65	2.09
Population Density	198.45	705.99	2.11	8357.63	10.66	123.12
Migrant Population	7.87	12.37	0.04	87.89	3.72	21.12
$PM_{2.5}$	27.73	19.27	6.00	98.90	1.80	6.36
NO_x	694.49	2961.15	2.05	32629.48	9.11	94.92

Table 4 shows the results of the correlation analysis between the dependent variables and the independent variables in this study.

Table 4. Correlations

	Smoking Rate	Gini Index	Number of Hospital Beds per 1,000	65 or Over	Population Density	Migrant Population	$PM_{2.5}$	NO_x
Rate of Confirmed Positive Cases 05.16)	0.040	**-0.195***	**0.173***	**0.380****	**0.204***	**0.641****	-0.144	0.021
	0.632	0.018	0.036	0.000	0.013	0.000	0.083	0.802
CFR (05.16)	-0.051	-0.084	-0.009	**0.210***	-0.093	-0.068	-0.161	0.043
	0.540	0.310	0.913	0.011	0.263	0.414	0.051	0.607
Death Rate (05.16)	0.043	**-0.226****	**0.162***	**0.466****	-0.015	**0.204***	**-0.285****	0.033
	0.606	0.006	0.050	0.000	0.855	0.013	0.000	0.696
Rate of Confirmed Positive Cases (06.30)	0.001	-0.009	0.049	0.126	0.123	**0.579****	0.075	0.019
	0.995	0.918	0.557	0.129	0.136	0.000	0.369	0.815
CFR (06.30)	0.023	**-0.219****	0.099	**0.355****	-0.082	-0.015	-0.126	0.076
	0.780	0.008	0.232	0.000	0.324	0.858	0.128	0.358
Death Rate (06.30)	0.012	-0.158	0.129	**0.439****	-0.038	**0.178***	**-0.280****	0.051
	0.889	0.056	0.120	0.000	0.652	0.031	0.001	0.543

The proportion of the population over 65 was found to have a positive correlation with the rate of confirmed positive cases, the mortality rate, and the CFR. The migrant population was also found to have a positive relationship with the rate of confirmed positive cases and the mortality rates. The number of hospital beds was likewise positively correlated with the rate of confirmed positive cases and the mortality rate as of May 16. $PM_{2.5}$ was found to have a significant correlation with mortality but the relationship was negative, contrary to the results of previous studies. Population density showed a correlation with the rate of confirmed positive cases as of May 16, but there was no significant correlation with the mortality rate or the CFR.

Multiple Regression Analysis

The results of multiple regression analysis for the rate of confirmed positive cases, the mortality rate, and the CFR as of May 16 and June 30 are presented in tables 5 and 6, respectively. In both models, the F value was found to be significant at the level of 0.01, and the model fit was considered satisfactory. In model I, the adjusted R-squared value was 0.511 for the rate of confirmed positive cases, 0.527 for the mortality rate, and 0.169 for the CFR. In model II, the rates were 0.331, 0.298, and 0.239, respectively, indicating that its explanatory power was generally lower than that of model I.

The proportion of the population 65 and over was found to be statistically significant in both models. That is, as the proportion of the population 65 and over increases, the rate of confirmed positive cases, the mortality rate, and the CFR increase.[12] The migrant population was also estimated to have a statistically significant effect in both models 1 and 2. As the percentage of migrants increases, the rate of confirmed positive cases and the mortality rate of COVID-19 increase.[13] However, we found that the CFR had a negative relationship with the migrant populations. The number of beds in hospitals was statistically significant in the mortality and CFR rates of model I and CFR rates of model II, suggesting that the COVID-19 mortality rate and the CFR decrease as the number of beds increases. When the number of hospital beds per 1,000 population increased by 1, the mortality rate of COVID-19 decreased by 16% in model I and the case fatality rate decreased by 11.7% and 10.5% in models 1 and 2, respectively. NO_x was statistically significant for both the rate of confirmed positive cases and the mortality rate in models 1 and 2. If NO_x increases by 1%, the rate of confirmed positive cases increases by 0.158% in model I and 0.197% in model II. In addition, when NO_x increased by 1%, the mortality rate was estimated to increase by 0.158% in model I and 0.172% in model II. However, the smoking rate, the Gini index, population density, and $PM_{2.5}$ were not found to be statistically significant.

12. Because the logarithm was taken for the dependent variable, when the population 65 and over increases by 1%, the rate of confirmed positive cases of COVID-19 increases by approximately 16.5% in model I and 12.8% in model II. Mortality rate is estimated to increase by 17% in model I, 14.9% in model II, and CFR by 6.2% in model I and 9.5% in model II.
13. When the percentage of the migrant population increases by 1%, the rate of confirmed positive cases of COVID-19 increases by 0.546% in model I and 0.524% in model II. When the percentage of the migrant population increases by 1%, the mortality rate increases by 0.199% in model I and 0.194% in model II.

Table 5. Model I: Multiple Regression Analysis (May 16, 2020)

Dependent Variables / Independent Variables	Rate of Confirmed Positive Cases (Logged)				Death Rate (Logged)				Case Fatality Rate (Logged)			
	Coefficient (Standard. Error)	t	P	Beta	Coefficient (Standard Error)	t	P	Beta	Coefficient (Standard Error)	t	P	Beta
65 and Over (%)	0.165 (0.038)	4.346	0	0.502***	0.17 (0.035)	4.926	0	0.662***	0.062 (0.027)	2.348	0.02	0.403*
Migrant Population (%, Logged)	0.546 (0.093)	5.891	0	0.384***	0.199 (0.082)	2.427	0.017	0.173*	-0.254 (0.062)	-4.086	0	-0.366***
Number of Hospital Beds per 1,000	-0.041 (0.074)	-0.552	0.582	-0.046	-0.16 (0.065)	-2.452	0.016	-0.232*	-0.117 (0.05)	-2.327	0.022	-0.278*
Population Density (Logged)	0.132 (0.1)	1.328	0.186	0.082	0.007 (0.088)	0.074	0.941	0.005	-0.141 (0.068)	-2.082	0.039	-0.176*
Smoking Rate (%)	-0.013 (0.015)	-0.834	0.406	-0.056	-0.013 (0.014)	-0.941	0.349	-0.072	0.001 (0.01)	0.055	0.957	0.005
Gini Index	0.001 (0.019)	0.066	0.948	0.005	-0.012 (0.017)	-0.687	0.494	-0.053	-0.017 (0.013)	-1.298	0.197	-0.127
NOx (Logged)	0.158 (0.078)	2.015	0.046	0.125*	0.158 (0.066)	2.396	0.018	0.161*	0.02 (0.051)	0.401	0.689	0.034
PM2.5 (Logged)	-0.073 (0.298)	-0.243	0.808	-0.021	-0.417 (0.266)	-1.567	0.12	-0.157	-0.176 (0.206)	-0.856	0.394	-0.107
Constant	-7.066 (1.545)	-4.574	0	-	-7.209 (1.37)	-5.261	0	-	2.861 (1.056)	2.708	0.008	-
Observations	146				116				130			
R^2	0.538				0.56				0.221			
Adjusted R^2	0.511				0.527				0.169			
F Value	F(8, 137)= 19.905				F(8, 107)= 17.048				F(8, 121)= 4.284			
Probability > F	0				0				0			

*** p<0.01, ** p<0.05, * p<0.1

Table 6. Model II: Multiple Regression Analysis (June 30, 2020)

Dependent Variables / Independent Variables	Confirmed Rate (logged)				Death Rate (logged)				Case Fatality Rate (logged)			
	Coefficient (Standard Error)	t	P	Beta	Coefficient (Standard Error)	t	P	Beta	Coefficient (Standard Error)	t	P	Beta
65 and Over (%)	0.128 (0.04)	3.184	0.002	0.428**	0.149 (0.041)	3.642	0	0.575***	0.095 (0.024)	4.02	0	0.653***
Migrant Population (%, Logged)	0.524 (0.097)	5.392	0	0.409***	0.194 (0.095)	2.041	0.043	0.17*	-0.186 (0.055)	-3.383	0.001	-0.286***
Number of Hospital Beds	-0.073 (0.078)	-0.936	0.351	-0.091	-0.123 (0.077)	-1.601	0.112	-0.177	-0.105 (0.045)	-2.331	0.021	-0.264*
Population Density (Logged)	0.039 (0.105)	0.374	0.709	0.027	-0.123 (0.106)	-1.153	0.251	-0.09	-0.145 (0.061)	-2.378	0.019	-0.19*
Smoking Rate (%)	0.019 (0.02)	0.933	0.352	0.076	0.006 (0.02)	0.315	0.753	0.029	-0.019 (0.012)	-1.636	0.104	-0.152
Gini Index	-0.018 (0.016)	-1.172	0.243	-0.092	-0.014 (0.016)	-0.881	0.38	-0.078	-0.006 (0.009)	-0.705	0.482	-0.063
NO_x (Logged)	0.197 (0.082)	2.413	0.017	0.174*	0.172 (0.078)	2.195	0.03	0.172*	0.042 (0.046)	0.906	0.366	0.072
$PM_{2.5}$ (Logged)	0.211 (0.314)	0.672	0.503	0.067	-0.097 (0.31)	-0.312	0.756	-0.036	0.058 (0.181)	0.321	0.749	0.038
Constant	-6.781 (1.625)	-4.172	0	-	-7.609 (1.621)	-4.694	0	-	1.601 (0.94)	1.702	0.091	-
Observations	147				127				134			
R^2	0.368				0.342				0.2841			
Adjusted R^2	0.331				0.298				0.239			
F Value	$F(8, 138) = 10.045$				$F(8, 118) = 7.683$				$F(8, 125) = 6.207$			
Probability > F	0				0				0			

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Hierarchical Regression Analysis

In light of the vulnerability of the elderly to COVID-19, we performed a hierarchical regression analysis on models 1 and 2, by adding an interaction variable between the proportion of people 65 and over and environmental variables, respectively. In order to deal with the multicollinearity problem of the moderator variable, we created a new variable through the mean centering method, which allowed us to verify the moderating effect. Tables 7, 8, and 9 record the hierarchical regression analysis on the rate of confirmed positive cases, mortality rate, and CFR of model I (May 16). The explanatory power of the model generally increased at each stage in which variables were introduced. The results of the hierarchical regression analysis for the cumulative rate of confirmed positive cases, mortality rate, and CFR that we performed on model II (June 30) are tables 10, 11, and 12. In both models, the Durbin-Watson statistic was between 0 and 4, thus confirming that there is no autocorrelation problem, because the assumption of independence of the residual is met. Also, the model fit was found to be statistically significant. Since the focus of the hierarchical regression model is the moderating effect of the interaction terms, we next turn to the moderator variables.

Moderating Effect as of May 16

Table 7 shows the results for model I in connection with the rate of confirmed positive cases as of May 16. Based on the interaction model 5, the variables that significantly influenced the rate of confirmed cases were the population 65 and over, the migrant population, GINI index, NO_x emissions, and an interaction term of the population 65 and over x the number of hospital beds ($p = 0.05$). The variables affecting the mortality rate included the population 65 and over, NO_x, and an interaction term of the population 65 and over x the number of hospital beds, as shown in table 8. For CFR, the results for which are reported in table 9, however, several variables show inverse relationships, and the model's explanatory power is also significantly reduced. First, the population 65 and over and the number of beds both have a significant effect on the rate of confirmed positive cases and CFR. In addition, for CFR the population 65 and over x NO_x emerges as a significant interaction term. However, the migrant population and population density variables show a negative relationship, contrary to our expectation. The older the population and the higher the level of the NO_x emissions, the more likely the rate of confirmed positive cases, the mortality rate, and the CFR will increase. The greater the number of hospital beds, the more likely it is that the rate of confirmed positive cases and the number of deaths will be lower. However, the migrant population variable appears to that increase the rate of confirmed positive cases but decreases the case fatality rate, a result that requires further investigation. The population density variable also showed a negative value, which we did not predict—that is, in areas that are densely populated, the case fatality rate decreases. As of May 16, the interaction term of the population 65 and over x the number of hospital beds had a significant effect on the rate of confirmed positive cases and the mortality rate. With respect to the case fatality rate, the interaction term of the population 65 and over x NO_x emissions have a significant effect.

Moderating Effect as of June 30

Table 10 shows the results from model II of the rate of confirmed positive cases as of June 30. Based on the interaction model 5, the variables that significantly influenced the rate were the population 65 and over, the migrant population, and NO_x emissions ($p = 0.05$). The variables significantly affecting the mortality rate included the population 65 and over and NO_x emissions shown in table 11. For case fatality rate, it was found that some variables had a statistically significant effect, but the explanatory power was not increased when we took into account the R2 value. Also, similar to model I, several variables show inverse relationships inconsistent with previous models. First, the population 65 and over, the number of hospital beds, and the population 65 and over x NO_x were found to have the similar significant effect as in model I. However, the migrant population and population density showed a negative relationship, which makes it difficult to interpret. For migrant populations, the rate of confirmed positive cases increased, as in model I, but the CFR decreased. Population density also showed negative value, which suggests that the CFR is higher in areas with densely populated. As of June 30, the interaction term of the population 65 and over x the number of hospital beds had no significant effect on the rate of confirmed positives cases, mortality rate and CFR, indicating a departure from model I. For the CFR, the interaction term of the population 65 and over x NO_x emission has a significant effect, as shown in model I.

Table 7. Rate of Confirmed Positive Cases (May 16, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.181	0.55***	0	0.165	0.502***	0	0.188	0.572***	0	0.175	0.532***	0	0.17	0.516***	0	4.72
Migrant Population (%)	0.507	0.356***	0	0.546	0.384***	0	0.517	0.363***	0	0.481	0.338***	0	0.486	0.341***	0	1.478
Number of Hospital Beds per 1,000	-0.039	-0.044	0.597	-0.041	-0.046	0.582	0.067	0.076	0.396	0.096	0.108	0.256	0.108	0.121	0.209	2.893
Population Density	0.117	0.072	0.229	0.132	0.082	0.186	0.168	0.104	0.085	0.194	0.12	0.056	0.193	0.119	0.058	1.22
Gini Index	0.001	0.002	0.978	0.001	0.005	0.948	0.005	0.018	0.793	0.012	0.044	0.548	0.015	0.055*	0.456	1.706
Smoking Rate (%)	-0.014	-0.061	0.366	-0.013	-0.056	0.406	-0.02	-0.091	0.171	-0.016	-0.07	0.313	-0.018	-0.079	0.262	1.549
NOx				0.158	0.125*	0.046	0.164	0.13*	0.032	0.156	0.123*	0.044	0.157	0.124*	0.042	1.155
PM2.5				-0.073	-0.021	0.808	0.128	0.037	0.666	0.061	0.017	0.842	0.005	0.001	0.987	2.484
65 or Over x Number of Hospitals Beds per 1,000							-0.025	-0.226**	0.002	-0.027	-0.247**	0.001	-0.024	-0.222**	0.005	1.923
65 or Over x NOx										-0.047	-0.077	0.327	-0.047	-0.078	0.321	1.949
65 or Over x PM2.5													-0.013	-0.064	0.323	1.316
Constant	-4.155			-4.159			-3.892			-3.991			-3.994			
R2	0.524			0.538			0.57			0.573			0.576			
Adjusted R2	0.503			0.511			0.541			0.541			0.541			
F Value	25.471			2.05			10.164			0.968			0.985			
Significance Probability	0			0.133			0.002			0.327			0.323			

*p<0.05, **p<0.01, ***p<0.001

Table 8. Death Rate (May 16, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.212	0.823***	0	0.17	0.662***	0	0.177	0.689***	0	0.163	0.634***	0	0.164	0.638***	0	5.165
Migrant Population (%)	0.18	0.157*	0.031	0.199	0.173*	0.017	0.174	0.151*	0.036	0.136	0.119	0.131	0.132	0.115	0.145	1.529
Number of Hospital Beds per 1,000	-0.162	-0.235*	0.015	-0.16	-0.232*	0.016	-0.075	-0.108	0.337	-0.036	-0.052	0.679	-0.037	-0.054	0.667	3.919
Population Density	-0.031	-0.023	0.727	0.007	0.005	0.941	0.022	0.017	0.801	0.048	0.036	0.601	0.052	0.039	0.572	1.199
Gini Index	-0.006	-0.029	0.712	-0.012	-0.053	0.494	-0.011	-0.048	0.531	-0.003	-0.016	0.852	-0.005	-0.023	0.786	1.751
Smoking Rate (%)	-0.018	-0.097	0.211	-0.013	-0.072	0.349	-0.017	-0.092	0.232	-0.012	-0.064	0.431	-0.01	-0.054	0.51	1.683
NO_x				0.158	0.161*	0.018	0.156	0.159*	0.018	0.145	0.148*	0.03	0.14	0.143*	0.037	1.139
$PM_{2.5}$				-0.417	-0.157	0.12	-0.316	-0.119	0.24	-0.375	-0.141	0.173	-0.347	-0.131	0.213	2.713
65 or Over x Number of Hospital Beds per 1,000							-0.014	-0.173	0.052	-0.017	-0.21*	0.029	-0.019	-0.233*	0.023	2.553
65 or Over x NO_x										-0.042	-0.093	0.307	-0.044	-0.096	0.292	2.044
65 or Over x $PM_{2.5}$													0.008	0.051	0.497	1.375
Constant	-7.113			-7.124			-6.969			-7.044			-7.04			
R^2	0.531			0.56			0.576			0.58			0.582			
Adjusted R^2	0.506			0.527			0.54			0.54			0.538			
F Value	20.6			3.527			3.873			1.054			0.464			
Significance Probability	0			0.033			0.052			0.307			0.497			

*p<0.05, **p<0.01, ***p<0.001

Table 9. CFR (May 16, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.078	0.507***	0	0.062	0.403*	0.02	0.058	0.375*	0.03	0.065	0.421*	0.025	0.068	0.442*	0.018	5.437
Migrant Population (%)	-0.252	-0.364***	0	-0.254	-0.366***	0	-0.24	-0.346***	0	-0.222	-0.321***	0.001	-0.234	-0.338***	0.001	1.52
Number of Hospital Beds per 1,000	-0.123	-0.291*	0.015	-0.117	-0.278*	0.022	-0.17	-0.402**	0.005	-0.188	-0.444**	0.005	-0.193	-0.456**	0.003	3.772
Population Density	-0.156	-0.194*	0.019	-0.141	-0.176*	0.039	-0.15	-0.187*	0.028	-0.162	-0.202*	0.023	-0.157	-0.196*	0.025	1.205
Gini Index	-0.015	-0.111	0.248	-0.017	-0.127	0.197	-0.018	-0.133	0.171	-0.021	-0.158	0.133	-0.025	-0.19	0.07	1.752
Smoking Rate (%)	-0.001	-0.01	0.914	0.001	0.005	0.957	0.003	0.025	0.794	0	0.002	0.981	0.004	0.037	0.717	1.664
NOx				0.02	0.034	0.689	0.022	0.037	0.661	0.027	0.045	0.598	0.02	0.034	0.687	1.136
PM2.5				-0.176	-0.107	0.394	-0.243	-0.148	0.245	-0.214	-0.13	0.32	-0.147	-0.089	0.493	2.711
65 or Over x Number of Hospital Beds per 1,000							0.009	0.179	0.098	0.01	0.205	0.077	0.006	0.117	0.336	2.349
65 or Over x NO_x										0.021	0.073	0.523	0.019	0.065	0.562	2.02
65 or Over x $PM_{2.5}$													0.019	0.195*	0.035	1.352
Constant	1.124			1.126			1.02			1.058			1.071			
R^2	0.216			0.221			0.238			0.241			0.269			
Adjusted R^2	0.177			0.169			0.181			0.177			0.201			
F Value	5.635			0.398			2.784			0.411			4.538			
Significance Probability	0			0.672			0.098			0.523			0.035			

*p<0.05, **p<0.01, ***p<0.001

Table 10. Rate of Confirmed Positive Cases (June 30, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.123	0.414***	0	0.128	0.428**	0.002	0.145	0.486***	0	0.138	0.462***	0.001	0.132	0.444**	0.003	4.732
Migrant Population (%)	0.474	0.37***	0	0.524	0.409***	0	0.502	0.392***	0	0.508	0.396***	0	0.494	0.386***	0	1.46
Number of Hospital Beds per 1,000	-0.064	-0.08	0.417	-0.073	-0.091	0.351	0.008	0.009	0.929	0.024	0.03	0.778	0.035	0.044	0.701	2.897
Population Density	0.045	0.031	0.664	0.039	0.027	0.709	0.066	0.045	0.527	0.063	0.043	0.548	0.073	0.049	0.503	1.219
Gini Index	0.013	0.051	0.528	0.019	0.076	0.352	0.021	0.087	0.281	0.026	0.107	0.189	0.029	0.118	0.178	1.693
Smoking Rate (%)	-0.019	-0.095	0.234	-0.018	-0.092	0.243	-0.024	-0.12	0.127	-0.027	-0.134	0.091	-0.025	-0.126	0.129	1.523
NOx				0.197	0.174*	0.017	0.202	0.178*	0.013	0.203	0.179*	0.013	0.2	0.176*	0.015	1.146
PM2.5				0.211	0.067	0.503	0.36	0.114	0.258	0.279	0.089	0.386	0.253	0.08	0.447	2.484
65or Over x Number of Hospital Beds per 1,000							-0.019	-0.186*	0.029	-0.014	-0.145	0.106	-0.015	-0.153	0.1	1.917
65 or Over x NOx										-0.02	-0.107	0.161	-0.02	-0.108	0.16	1.315
65 or Over x PM2.5													-0.018	-0.032	0.727	1.922
Constant		-3.141			-3.144			-2.944			-2.945			-2.983		
R^2		0.335			0.368			0.39			0.399			0.399		
Adjusted R^2		0.306			0.331			0.35			0.354			0.35		
F Value		11.734			3.646			4.885			1.988			0.123		
Significance Probability		0			0.029			0.029			0.161			0.727		

*p<0.05, **p<0.01, ***p<0.001

Table 11. Death Rate (June 30, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.164	0.632***	0	0.149	0.575***	0	0.155	0.601***	0	0.156	0.602***	0	0.139	0.538**	0.002	5.282
Migrant Population (%)	0.16	0.139	0.094	0.194	0.17*	0.043	0.173	0.151	0.074	0.172	0.15	0.077	0.129	0.112	0.225	1.529
Number of Hospital Beds per 1,000	-0.113	-0.161	0.147	-0.123	-0.177	0.112	-0.05	-0.072	0.58	-0.051	-0.072	0.579	-0.008	-0.011	0.937	3.726
Population Density	-0.139	-0.102	0.186	-0.123	-0.09	0.251	-0.109	-0.08	0.307	-0.108	-0.08	0.311	-0.078	-0.058	0.481	1.204
Gini Index	0.008	0.038	0.674	0.006	0.029	0.753	0.008	0.034	0.703	0.007	0.033	0.72	0.015	0.068	0.49	1.737
Smoking Rate (%)	-0.014	-0.079	0.371	-0.014	-0.078	0.38	-0.017	-0.093	0.296	-0.016	-0.091	0.313	-0.01	-0.057	0.552	1.661
NOx				0.172	0.172*	0.03	0.169	0.169*	0.033	0.168	0.168*	0.034	0.156	0.156	0.052	1.135
PM2.5				-0.097	-0.036	0.756	-0.001	0	0.998	0.004	0.002	0.989	-0.064	-0.024	0.844	2.697
65 or Over x Number of Hospital Beds per 1,000							-0.013	-0.153	0.128	-0.013	-0.157	0.148	-0.017	-0.198	0.089	2.395
65 or Over x NOx										0.001	0.009	0.919	0.002	0.013	0.886	1.357
65 or Over x PM2.5													-0.05	-0.106	0.323	2.039
Constant		-6.412			-6.434			-6.287			-6.285			-6.377		
R2		0.316			0.342			0.355			0.355			0.361		
Adjusted R2		0.281			0.298			0.306			0.3			0.3		
F Value		9.223			2.413			2.346			0.01			0.985		
Significance Probability		0			0.094			0.128			0.919			0.323		

*p<0.05, **p<0.01, ***p<0.001

Table 12. CFR (June 30, 2020)

	1			2			3			4			5			
	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	Coefficient	Beta	P	VIF
65 or Over (%)	0.092	0.63***	0	0.095	0.653***	0	0.092	0.63***	0	0.095	0.652***	0	0.095	0.653***	0	5.469
Migrant Population (%)	-0.197	-0.304***	0	-0.186	-0.286***	0.001	-0.173	-0.266**	0.002	-0.182	-0.28***	0.001	-0.182	-0.279**	0.003	1.552
Number of Hospital Beds per 1,000	-0.1	-0.251*	0.026	-0.105	-0.264*	0.021	-0.147	-0.369**	0.006	-0.153	-0.384**	0.004	-0.154	-0.385**	0.009	3.786
Population Density	-0.142	-0.187*	0.017	-0.145	-0.19*	0.019	-0.151	-0.199*	0.014	-0.15	-0.197*	0.014	-0.15	-0.198*	0.017	1.202
Gini Index	-0.02	-0.158	0.082	-0.019	-0.152	0.104	-0.02	-0.159	0.089	-0.024	-0.191*	0.041	-0.024	-0.192	0.056	1.782
Smoking Rate (%)	-0.006	-0.056	0.525	-0.006	-0.063	0.482	-0.005	-0.047	0.6	-0.002	-0.017	0.854	-0.002	-0.017	0.857	1.679
NO_x				0.042	0.072	0.366	0.043	0.076	0.343	0.039	0.068	0.39	0.039	0.068	0.395	1.137
$PM_{2.5}$				0.058	0.038	0.749	0.007	0.004	0.972	0.062	0.04	0.736	0.063	0.041	0.739	2.686
65 or Over x Number of Hospital Beds per 1,000							0.007	0.151	0.135	0.004	0.073	0.495	0.004	0.074	0.517	2.299
65 or Over x NO_x										0.016	0.179*	0.039	0.016	0.179*	0.04	1.346
65 or Over x $PM_{2.5}$													0.001	0.003	0.98	2.029
Constant	0.877			0.869			0.782			0.795			0.797			
R^2	0.278			0.284			0.297			0.321			0.321			
Adjusted R^2	0.244			0.239			0.246			0.266			0.26			
F Value	8.159			0.533			2.259			4.337			0.001			
Significance Probability	0			0.588			0.135			0.039			0.98			

*p<0.05, **p<0.01, ***p<0.001

CONCLUSION

Our analysis shows that the proportion of the population over 65 had a significant effect on the rate of confirmed positive cases, the mortality rate, and the CFR in each country. The second most important variable is the proportion of foreign migrants. The percentage of foreign migrants had a significant effect on the rate of confirmed positive cases and mortality rate, but there is an inverse relationship with the CFR. Third, the number of hospital beds was found to have a negative effect on the mortality rate and CFR. Among the environmental factors, we found that nitrogen oxides have a statistically significant effect on the rate of confirmed positive cases and the mortality rate but that ultrafine dust had no significant effect. Also, the smoking rate had no significant effect. Population density were found to have a marginal effect on the CFR. Since they showed a negative relationship, further research is necessary. The variables that influenced the rate of confirmed positive cases, the mortality rate, and the CFR in May, a period that has been considered a peak stage of the spread of COVID-19, and in June, which has been seen as a stagnant period, were similar. However, model explanatory power and variable significance were high in May.

Our analysis has the following implications. First, the age group with the highest rate of confirmed positive cases, the highest mortality rate, and the highest CFR is that of 65 years or over. Members of this group are usually more vulnerable to infectious diseases than other age groups because they tend to have underlying diseases. Therefore, countries with a high proportion of elderly people ought to develop a system that can protect the elderly from contracting infectious diseases and to encourage the elderly to practice social distancing and refrain from visiting dense areas.[14] Second, if governments are to respond effectively to infectious disease, it is necessary for them to understand that there are different types of global population migration. Governments have to improve their ability to identify the routes of international population migration (origin, transit, destination, return), vulnerable areas, and denser areas of international migrants.[15] Third, given that the number of hospital beds moderates the effect of COVID-19 on the elderly, ensuring that the number

14. Out of the 147 countries in our study, those with the highest proportion of people over 65 are mostly European (the one exception is Japan) and include Italy, Portugal, Finland, Greece, and Germany. More than 20% of the population is over 65 years old in these countries. The proportion of the population over 65 years old in Korea is about 14.4%, slightly higher than the average of 9.5%, while China is about 11%, closer to the average.
15. Previous studies note that people enter countries in other ways than through physically regulated areas such as entry areas (Shin, 2020).

of hospital beds in areas densely populated by older people is critical to reducing the mortality rate of COVID-19. NO_x, which is a known cause of lung disease, appeared to have a direct effect on COVID-19 as well as a moderating effect. Therefore, in areas with high NO_x generation, direct national supervision is required.

Although this study provides an empirical basis for estimating the effect of the key variables affecting the COVID-19 mortality rate, in light of the fact the COVID-19 began to spread again in July, further research should be conducted on factors affecting its reproliferation. Recently, Korea's efforts to minimize the spread of COVID-19 have been recognized worldwide for successfully controlling spread in the early stages. The spread and mortality rate of infectious diseases thus may vary depending on each country's policy responses. Future research ought to attend to various policy reactions as well as to risk management governance.

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Appendix: Countries Included in the Data Analysis (147)

OECD (36)	Non-OECD Countries (111)		
Australia	Afghanistan	Guatemala	Paraguay
Austria	Albania	Guinea-Bissau	Peru
Belgium	Algeria	Guyana	Philippines
Canada	Angola	Haiti	Qatar
Chile	Argentina	Honduras	Romania
Colombia	Armenia	India	Russia
Czech Republic	Azerbaijan	Indonesia	Rwanda
Denmark	Bangladesh	Iraq	Saint Lucia
Estonia	Belarus	Jamaica	Saudi Arabia
Finland	Belize	Jordan	Senegal
France	Benin	Kazakhstan	Serbia
Germany	Bhutan	Kenya	Seychelles
Greece	Bolivia	Kyrgyzstan	Sierra Leone
Hungary	Bosnia and Herzegovina	Lao People's Democratic Republic	Singapore
Iceland	Botswana	Lebanon	South Africa
Ireland	Brazil	Lesotho	Sri Lanka
Israel	Bulgaria	Liberia	Suriname
Italy	Burkina Faso	Madagascar	Eswatini
Japan	Cambodia	Malawi	Syrian Arab Republic
Korea	Cameroon	Malaysia	Tajikistan
Latvia	Cabo Verde	Mali	Tanzania
Lithuania	China (People's Republic of)	Malta	Thailand
Luxembourg	Comoros	Mauritania	Timor-Leste
Mexico	Congo	Mauritius	Togo
Netherlands	Democratic Republic of the Congo	Moldova	Trinidad and Tobago
New Zealand	Costa Rica	Mongolia	Tunisia
Norway	Côte d'Ivoire	Montenegro	Uganda
Poland	Croatia	Morocco	Ukraine
Portugal	Cuba	Mozambique	United Arab Emirates
Slovak Republic	Djibouti	Myanmar	Uruguay
Slovenia	Ecuador	Namibia	Uzbekistan
Spain	Egypt	Nepal	Venezuela
Sweden	El Salvador	Nicaragua	Viet Nam
Switzerland	Ethiopia	Niger	Yemen
United Kingdom	Fiji	Nigeria	Zambia
United States	Gambia	Pakistan	Zimbabwe
	Georgia	Panama	
	Ghana	Papua New Guinea	