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COVID-19: A Relook at Healthcare Systems and Aged Populations

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Abstract: Using data from the WHO's Situation Report on the COVID-19 pandemic from 21 January 2020 to 30 March 2020 along with other health, demographic, and macroeconomic indicators from the WHO's Application Programming Interface and the World Bank's Development Indicators, this paper explores the death rates of infected persons and their possible associated factors. Through the panel analysis, we found consistent results that healthcare system conditions, particularly the number of hospital beds and medical staff, have played extremely important roles in reducing death rates of COVID-19 infected persons. In addition, both the mortality rates due to different non-communicable diseases (NCDs) and rate of people aged 65 and over were significantly related to the death rates. We also found that controlling international and domestic travelling by air along with increasingly popular anti-COVID-19 actions (i.e., quarantine and social distancing) would help reduce the death rates in all countries. We conducted tests for robustness and found that the Driscoll and Kraay (1998) method was the most suitable estimator with a finite sample, which helped confirm the robustness of our estimations. Based on the findings, we suggest that preparedness of healthcare systems for aged populations need more attentions from the public and politicians, regardless of income level, when facing COVID-19-like pandemics.

Keywords: COVID-19; healthcare systems; aged populations

1. Introduction

The rapid COVID-19 outbreak since late February 2020 has posed critical challenges for public health, politics, and medical communities [1,2]. Although old lessons (such as quarantine, isolation, social distancing, and travel restrictions) are still helpful, the roles of hospital beds, medical staff (i.e., nurses and physicians) and aging population on the severity of this pandemic has not yet been studied systematically.

Is the number of deaths related to COVID-19 the consequence of overwhelmed healthcare systems and aging populations? In Europe and USA, the healthcare systems have been restructured toward centralization and budget cutoff. Aged populations are a clear evidence of this in these countries. Since the outbreak of COVID-19, several studies found that the fatality rate has been significantly higher with an increasing profile of age [3,4]. Furthermore, concerns about the healthcare systems in such countries as Italy, Spain, France, UK, and USA currently have been a hot topic on public media. The importance of the healthcare systems has been emphasized by [5,6] and [7].

Given these concerns, this study aims to examine the factors associated with the death rates of the COVID-19 infected people, in which we emphasize healthcare systems and aged populations along with other covariates. In the next section, we present a literature review on healthcare systems, aged populations, and important factors supposed to have direct correlations with the death rate from COVID-19 and some previous epidemics. We then introduce data, research methods, and discussed empirical results. Finally, we conclude and share our perspectives on healthcare systems and aged populations.

2. Literature Review

2.1. Health Systems and Pandemics

Discussing about the roles of human resources and healthcare infrastructure, [7] argued that staffing and supplies should be critically and carefully planned because COVID-19 patients should be discharged only to designated facilities or to those already caring for such patients. Practically, however, it might be that non-institutional care systems (such as home-based) were not capable to deal with a large number of discharged patients. In addition, since healthcare workers and supplies were critically important in mitigating the outbreak, it would be also crucial to prepare supplies protecting health workers who work with infected patients, and this in turn would help reduce infection and death rates.

Reviewing the history of pandemics in 1918, 1957, and 1968 [8] showed that, in recent flu seasons, hospital emergency departments faced limits in emergency rooms and inpatient beds when the number of patients increased substantially. For the US healthcare system in pandemic, one of the most concerning issue was human resources at institutional care facilities because home-care and community-care settings did not have enough experienced nurses and managers when facing a surge of patients at communities. Healthcare workers are extremely important for fighting outbreak. In pandemics with an increasing number of patients, hospital intensive care unit (ICU) beds and ventilators would not be useful if there are inadequate numbers and types of healthcare personnel.

Also discussed the US healthcare system, [9] argued that only 15 states could be able to respond fully to emergency, while others would run out of beds or face a shortage of nurses in similar situations. More critically at national level, if the country faces a 1918-like pandemic, hospital beds would increase about twice and patients in the intensive care unit (ICU) would increase about 4.6 times. Staff shortages would exacerbate the pandemic situation because it was also possible that some healthcare workers might expose themselves to infectious patients. At the same time, facing drained resources, healthcare workers would have to make important and difficult decisions about allocating limited resources while prioritizing and triaging patients.

Developing computational models with data collected from the 2014–2015 Ebola outbreak in Guinea, Liberia, and Sierra Leone, [10] estimated the repercussions of the outbreak on the populations at risk for three diseases (malaria, HIV/AIDS, and tuberculosis). They showed that accessibility to healthcare services is important to reduce the number of deaths. The simulated results indicated that if there was a 50% reduction in access to healthcare services, the Ebola outbreak would have exacerbated malaria, HIV/AIDS, and tuberculosis mortality rates by additional death counts of 6269 in Guinea, 1535 in Liberia, and 2819 in Sierra Leone.

Using observations from various data sources and reports, [11] reviewed how countries responded to COVID-19 by combining containment and mitigation activities along with delaying major surges of patients and levelling the demand for hospital beds. This proposition was also supported by [5,6]. The success of South Korea in controlling the COVID-19 with high detection rate, which required the readiness of healthcare systems, should be a guiding reference [12]. This view was also supported by [13].

Health care workers and supplies would be critically essential in mitigating the outbreak. Preparing supplies, such as N95 respirator masks and other personal protective equipment, is important to protect health workers while working with infected patients. This in turn would help reduce infection and death rates. More importantly, the emergency need of Intensive Care Units (ICU) could collapse the healthcare system [14].

2.2. Aged Population, Health Conditions and Fatality in COVID-19

Using demographic and health-related data of 191 COVID-19 adult inpatients (aged 18 and over) from Jinyintan Hospital and Wuhan Pulmonary Hospital in Wuhan, of which 137 were discharged and 54 died in hospital by 31 January 2020, [4] explored risk factors associated with in-hospital death. They found that 91 patients (48% of the studied sample) had a comorbidity, in which hypertension was the most common, and then diabetes and coronary heart disease. Multivariable regression showed increasing odds of in-hospital death associated with older age, higher Sequential Organ Failure Assessment (SOFA) score, and d-dimer greater than 1 g/mL on admission. The authors concluded that those risk factors could help clinicians to identify patients with poor prognosis at an early stage.

Similarly, extracting data and analyses from other studies, [11] emphasized that older people (particularly those aged 80 and over) and people with comorbidities (such as cardiac disease, respiratory disease, and diabetes) were at the highest risk of serious disease and death. As shown in the US, the authors were concerned that individuals in aged care facilities were at particular risk of serious disease when the healthcare system faced a surge in COVID-19 patients.

Exploring data from 13 January to 12 February 2020 in China, [15] analyzed data on 799 patients with confirmed COVID-19 who were transferred to or admitted in Tongji Hospital. As of 28 February 2020, 113 of the 799 patients died (a mortality rate of 14.1%) and 161 patients recovered and were discharged. The statistics showed that the median age of deceased patients was 68, which was significantly older than that of recovered patients, with a median age of 51. Of these patients, 71 persons (or 63% of patients who died) and 62 persons (or 39% of patients who recovered) had at least one chronic medical condition. Among deceased patients, hypertension, cardiovascular disease, and cerebrovascular disease were much more frequent than the other diseases.

Doing similar research with data from 138 patients with confirmed COVID-19 hospitalized at Zhongnan Hospital from 1 January to 28 January 2020 and followed-up by 3 February 2020, [16] described epidemiological and clinical characteristics of those patients. The median age was 56 years, and 54.3% were men. A total of 36 patients (26.1%) were transferred to the ICU because of complications, including acute respiratory distress syndrome, arrhythmia, and shock. Compared with patients not treated in ICU, those treated in ICU were older (median age 51 for the former vs 66 for the latter) and were more likely to have underlying comorbidities (72.2% vs 37.3%). Such a medical situation suggests that age and comorbidity might be risk factors for poor outcome. There was no difference in the proportion of men and women between ICU patients and non-ICU patients.

2.3. Travelling and Other Control Measures in COVID-19

To estimate COVID-19 outbreak size in Italy, [17] used data on non-residential travelers and their average length of stay with an assumption that the epidemic began in late January 2020. They found that the COVID-19 case exportations from Italy were larger than the official case counts.

For the case of China, [18] showed that, up to mid-January 2020, more than 95% of the daily exposing risk of CoV-19 was due to international travel. The authors also showed that the travel restrictions decreased the daily rate of exportation.

With data from 28 countries which imported COVID-19 cases, [19] argued that travel restrictions were not effective enough to prevent the global spread of COVID-19 in most airports. Their study highlighted the need to strengthen local capacities for disease monitoring and control rather than controlling the importation of COVID-19 at national borders via the airline network. Similarly, [20] argued that a lock-down along with nationwide traffic restrictions and a stay-at-home movement had a determining effect on the spread of COVID-19.

3. Study Data and Methods

3.1. Data

We manually downloaded the situation reports from the World Health Organization (WHO) from Report no.1 (21 January 2020) to Report no.70 (30 March 2020). With the extracted data, we then combined them with data from the World Bank's Development Indicators and the WHO's Application Programming Interface (API) for the selected variables. Due to the availability from data source, we took the value of the most recent year. The description of variables is presented in Table 1.

Table 1. Description of variables.

Explanatory Variable	Definition	Source
Death rate	Total deaths/total cases, calculated by daily report	WHO reports on COVID-19
Hospital beds	Hospital beds (per 1000 citizens)	World Bank Development Indicator (WDI)
HR (Human Resources)	Sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens)	WDI
DoC (Death due to non-communicable diseases)	Probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease	WHO
Population 65	Proportion of population aged 65 and above in the total population (%)	WDI
GDP capita	GDP per capita (constant 2010 US$)	WDI
Air passengers	Air transport, passengers carried (1000)	WDI

In the following step, we computed the death rate from each report and selected a sample of countries that had more than 100 confirmed cases (so we had 95 countries in the studied sample). The final panel data set consisted of 70 points of observation, in which the least minimum country-time observation of variable was 3447 (Table 2). In this table, n is the number of country-report observations; other values are at country level (such as the highest cases of 122,653 was of the US at the 70th report). At the date of the 70th report, the country with the highest confirmed number of cases was the US with 122,653 cases, and the country with the highest number of deaths was Italy with 10,781 cases. The average death rate for the whole sample was 1.44%.

Table 2. Descriptive statistics.

Explanatory Variable	n	mean	sd	min	max	se
Total cases	3529	2458	11,315	1	122,653	190.54
Total deaths	3530	97	584	0	10,781	9.82
Death_rate	3529	0.0144	0.0444	0	1	0.0007
Hospital_beds	3515	38.3772	27.942	3	134	0.4713
HR	3530	8.6846	5.3958	0	22.478	0.0908
DoC	3515	15.6049	5.4477	8.4	29.8	0.0919
Population_65	3467	12.77	6.63	1.09	27.58	0.11
GDP capita	3447	25,858.96	23,168.084	563.82	110,742.31	394.61
Air passengers	3530	68,978	156,841	0	889,202	2639.81

Note: HR: sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens); DoC: probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease. Source: Authors' calculations from the collected data.

On average, countries in the sample had 38.38 hospital beds per 1000 citizens and 8.68 medical staff (including nurses and physicians) per 1000 citizens. The average proportion of people aged 65 and over for the whole studied sample was 12.77%.

3.2. Methods

We first estimated three models with pooled estimator. Then, we compared our interested model by employing pooled, fixed-effects (FE) and between-estimator methods.

As different countries at various income levels have different healthcare systems and aged populations, for further analysis, we divided the sample into two sub-samples according to the income classification by [21]: high income countries (HICs) and middle- & low-income countries (MLICs).

We also employed Pesaran's cross section dependence (CD) test to detect cross-sectional dependence. As the results suggested the possibility of the problem, we applied Robust Covariance Matrix Estimators to check the standard errors. With the properties of a finite sample, the method provided in [22] was the most suitable estimator, compared with the White method [23].

Finally, we compared the results for the pooled estimation without and with Robust Standard Errors.

4. Empirical Results

4.1. Main Results

In Table 3, we present the results obtained from different estimations. In all models, four variables (hospital beds, human resources (HR), death due to non-communicable diseases (DoC), and population 65) showed their consistent impacts on the death rate of COVID-19 infected persons. In regard to health systems, variables "hospital beds" and "HR" implied that the better the healthcare infrastructure and human resources, the lower the death rate. Such a situation is clearly illustrated in the case of Italy, Spain, and the US during the studied period, as reported in [24].

Table 3. Pooled estimations with baseline and extended models.

Explanatory Variable	**Dependent Variable: Death_Rate**		
	(1)	**(2)**	**(3)**
Hospital beds	−0.00004	−0.0002***	−0.0002***
	(0.00003)	(0.00004)	(0.00005)
HR	−0.0003***	−0.001***	−0.001***
	(0.0002)	(0.0003)	(0.0003)
DoC	0.001***	0.002***	0.003***
	(0.0002)	(0.0002)	(0.0002)
Population_65		0.001***	0.002***
		(0.0002)	(0.0002)
Log(GDP per capita)			0.004***
			(0.001)
Log(Air passengers)			0.003***
			(0.0004)
Constant	−0.004	−0.019***	−0.108***
	(0.004)	(0.004)	(0.014)
Observation	3220	3210	3032
R^2	0.050	0.066	0.091
Adjusted R^2	0.049	0.065	0.089
F Statistic	55.87***	56.42***	50.47***

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. HR: sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens); DoC: probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease. Source: Own calculations.

Factors representing demographic ("population 65") and health ("DoC") aspects also reflected the real situations: older people accounted for the majority of deaths, and most of those had various comorbidities, particularly non-communicable diseases (such as cancer, diabetes, or chronic respiratory disease) [15].

When adding logarithm of real GDP per capita (Model 2 in Table 3), its coefficient was positive and statistically significant, meaning that, given other demographic and healthcare system conditions, higher income countries experienced higher death rates than did those at lower income levels. This has been true in practice where both the number of deaths and the death rates in such high-income countries as the US, UK, Italy, and Spain were much higher than those of lower income countries.

One of the key channels for spreading out the COVID-19 pandemic has been domestic and international travels. The results from Model 3 with an addition of the variable showing the rate of passengers carried by air indicated that the countries which had a higher rate of passengers experienced higher rate of deaths. This finding reflected the real situation that the virus is transmitted from human to human, and the countries where a lot of people moving in and out for various purposes like businesses, travelling, and visiting, like Italy, Spain, the US, the UK, and China (especially in the spring holiday season), had an increasing number of people infected during the studied period. The recent social distancing and isolation in many countries and their regions have proved that less travelling and movement helped reduce the infection rates, and thus—to some extent—reduced the death rates [15,20].

A new approach in this paper was to apply the between-estimator estimation in order to explore the relationships of the model. In recent years, this method has been a new edge in evaluating the long-run effects of macroeconomic factors (see, for instance, [25–28]). This methodology, using the time-averaged data, was suitable with the dataset of this study since all independent variables were collapsed at one time.

Table 4 presents the results from pooled, fixed-effects (FE) and between-estimator methods. The results clearly showed the confirmation on the sign and significance of variables "hospital beds", "HR" and "population 65". More importantly, the R^2 was at 0.599, meaning that the model was better than the other. It is worth noting, however, that we could not apply this estimator when splitting the sample for further analyses since we had limited observations.

Table 4. Different estimation methods.

Explanatory Variable	**Dependent Variable: Death_Rate**		
	Pooled	**FE**	**Between**
Hospital beds	−0.0002***	−0.0002***	−0.002***
	(0.00005)	(0.00005)	(0.0003)
HR	−0.001***	−0.001***	−0.012***
	(0.0003)	(0.0003)	(0.003)
DoC	0.003***	0.003***	0.004
	(0.0002)	(0.0002)	(0.002)
Population_65	0.002***	0.002***	0.011***
	(0.0002)	(0.0002)	(0.002)
Log(real GDP per capita)	0.004***	0.003**	0.037***
	(0.001)	(0.001)	(0.021)
Log(Air passengers)	0.003***	0.003***	−0.006***
	(0.0004)	(0.0004)	(0.003)
Constant	−0.108***		−0.282
	(0.014)		(0.202)
Observation	3032	3032	70
R^2	0.091	0.091	0.599
Adjusted R^2	0.089	0.068	0.561
F Statistic	50.47*** (df = 6;3025)	49.52*** (df = 6;2956)	15.70*** (df = 6;63)

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. HR: sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens); DoC: probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease. Source: Own calculations.

4.2. Further Results

Since countries at different income levels have different healthcare systems and strategies to deal with COVID-19 pandemic, we were interested in exploring how the aforementioned factors influenced the death rates of the COVID-19 infected persons in those different countries. Table 5 shows the results estimated for two groups of countries by income levels: high-income countries (HICs) and middle- & low-income countries (MLICs).

These results were different from those in the FE models for all countries as presented in Table 4. The negative coefficient for HICs was kept, meaning that healthcare system infrastructure was important to reduce the death rates of COVID-19 infected people in these countries.

Regardless of income levels, the coefficients for variable "HR" were negative and statistically significant in both groups of countries, meaning that the number of medical staff available in the pandemic has been extremely important for reducing death rates.

Except for HI countries, the coefficient of variable "DoC" for MLICs was positive and statistically significant, and this could be explained with the same reason discussed in the FE models in Table 4.

The coefficient for variable "Population 65" was positive and statistically significant in HICs, while it was not the case for MLICs. Such results could be elucidated the same as in FE models in Table 4. HICs had a higher rate of older people, who have been at highest risk of death under COVID-19.

In both groups of countries, coefficients for variable "real GDP per capita" were positive and statistically significant, meaning that higher income countries had higher death rates than those at lower income levels in the same group. This could be explained by various facts, including a higher proportion of people aged 65 and over and a higher number of air passengers—among others—in higher income countries.

Table 5. Estimations for two groups of income.

Explanatory Variable	Dependent Variable: Death_Rate	
	HICs	**MLICs**
Hospital beds	0.00004*	0.0002
	(0.00002)	(0.0002)
HR	−0.001***	−0.008***
	(0.0002)	(0.001)
DoC	0.0001	0.005***
	(0.0002)	(0.0004)
Population_65	0.001***	0.0003
	(0.0001)	(0.001)
Log(real GDP per capita)	0.007***	0.026***
	(0.002)	(0.003)
Log(Air passengers)	0.002***	0.0003
	(0.0002)	(0.001)
Observation	1604	1428
R^2	0.211	0.132
Adjusted R^2	0.172	0.084
F Statistic	67.915*** (df = 6;1528)	34.406*** (df = 6;1352)

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. HR: sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens); DoC: probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease. Source: Own calculations.

For the variable showing travelling impact (i.e., "Air passengers"), the coefficient for HICs was positive and statistically significant, showing the fact that these countries experienced huge flows of immigrants and emigrants during the studied period, and thus have experienced more infected people and more deaths. In contrast, MLICs started quarantine at the early stage of COVID-19 spreading so that they could limit the number of infected people via international and domestic travelling flows.

To check the robustness for all above estimations, we conducted different methods to see whether the standard errors of the same variables were significantly different. The results are presented in Table 6. We could see clearly a small difference in the standard errors of the same variables between estimations. These results confirmed that the main results in Table 4 were robust; that is, the correlations between the death rate and important explanatory variables (such as number of hospital beds, number of medical staffs, DoC, aged population, and air passengers) were significant strongly. Furthermore, there was only one difference in the significance but not the sign of the variable "real GDP per capita". This implied that we could not confirm strongly the correlation between real GDP per capital and the death rate. Meanwhile, among countries with different income levels, the heterogeneity did exist in some variables.

Table 6. Robust covariance matrix estimators.

Explanatory Variable	Dependent Variable: Death_Rate		
	FE	**Driscoll-Kraay**	**White**
Hospital beds	−0.0002***	−0.0002***	−0.0002
	(0.00005)	(0.0001)	(0.0002)
HR	−0.001***	−0.001***	−0.001*
	(0.0003)	(0.0002)	(0.001)
DoC	0.003***	0.003***	0.003
	(0.0002)	(0.001)	(0.002)
Population_65	0.002***	0.002***	0.002***
	(0.0002)	(0.0002)	(0.001)
Log(GDP per capita)	0.003***	0.003*	0.003
	(0.001)	(0.002)	(0.006)
Log(Air passengers)	0.003***	0.003***	0.003***
	(0.0004)	(0.0002)	(0.0002)
Observation	3032		
R^2	0.091		
Adjusted R^2	0.068		
F Statistic	49.522***		

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. HR: sum of physicians (per 1000 citizens) and nurses and midwives (per 1000 citizens); DoC: probability (%) of dying between age 30 and exact age 70 from any of cardiovascular disease, cancer, diabetes, or chronic respiratory disease. Source: Own calculations.

5. Concluding Remarks

In this paper, we used the daily statistics on the death rates of the COVID-19 infected people in various countries which had more than 100 infected cases from 21 January 2020 to 30 March 2020, and explored their possible associated factors. Although the results were different when we controlled for various factors (such as income levels), we still found consistent results that healthcare system conditions, particularly the number of hospital beds and the number of medical staff, played extremely important roles in reducing death rates of COVID-19 infected persons. In addition, both mortality rates due to different non-communicable diseases (NCDs) and the rate of people aged 65 and over were significantly related to the death rates in all countries, meaning that aged populations along with prevalent NCDs would exacerbate the situation of death under any pandemics related to pneumonia like COVID-19. We also found that controlling international and domestic travelling by air along with increasingly popular anti-COVID-19 actions (i.e., quarantine and social distancing) helped reduce the death rates in all countries. Last but not least, the danger of COVID-19 has made clear that the preparedness of healthcare systems and aged populations needs more attention from public and politicians, regardless of income level, when facing COVID-19-like pandemics. In any country, timely and strong cooperation between government, civil society, and private individuals are important in building up the trust in fighting public health crisis like COVID-19 [29].

Given the nature of global research with cross-sectional data, this study could not avoid some key limitations, as follows. First, we could not disaggregate the data on death by sex and age groups since the used statistics did not cover these important indicators for all countries in the studied sample. Second, some non-health and non-demographic factors such as culture and living styles could not explore due to unavailable data; those could be studied at a country-specific level. Third, due to limited timeline for the study (up to 30 March 2020), the impact of various measures coping with COVID-19 such as social distancing and lock-down could not be explored. We hope to integrate these factors in the coming studies with a specific group of countries or a single country.

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