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Ageing Society and SARS-CoV-2 Mortality: Does the Healthcare Absorptive Capacity Matter?

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Abstract: This study examines the effect of the elderly population on SARS-CoV-2 Disease (COVID-19) mortality for a sample of 146 countries. It shows that the elderly population is robustly associated with higher COVID-19 mortality. This effect, however, decreases significantly in countries with higher health care absorptive capacity. The results are robust to control for a set of economic, institutional and regional variables.

Keywords: COVID-19; SARS-CoV-2 pandemic; disaster; old-age demographic structure; mortality; healthcare absorptive capacity; hospital beds

1. Introduction

The outbreak of SARS-CoV-2 virus was first reported in the middle of December 2019 in Wuhan of China, caused by the severe acute respiratory syndrome coronavirus 2 (Yang et al. 2020). By 15 October 2020, COVID-19 has affected 38,581,234 people and has caused more than a million deaths worldwide (ECDC 2020). COVID-19 can be classified under natural group of disasters and within the biological disaster subgroup. According to EM-DAT of Centre for Research on the Epidemiology of Disasters, biological disasters include "*hazards caused by the exposure to living organisms and their toxic substances or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses*" (e.g., malaria or COVID-19)[1]. Classification of COVID-19 under a natural disaster has been discussed by different interest groups, especially commercial insurance companies. For example, the Pennsylvania Supreme Court argued that the SARS-CoV-2 pandemic can be considered a natural disaster because of its significant risk for human life and because it fits within a definition under the Emergency Code, rejecting counter-arguments from petitioners, who believed the Emergency Code should not have been triggered by the crisis[2]. On 30 January 2020, the World Health Organization declared the outbreak as a public health emergency of international concern and later on 11 March 2020 announced it as pandemic.

There are significant and ongoing efforts in different disciplines to understand and research causes and effects of SARS-CoV-2 pandemic. The International Monetary Fund's (IMF) economic counsellor, Gita Gopinath, illustrated coronavirus as the worst crisis since the Great Depression. The latest report of the IMF in World Economic Outlook of October 2020 estimated a −4.4% of global growth in 2020. Of course, the report acknowledges a high degree of uncertainty in these estimations because of difficulties of predicting influencing factors in public health and economic factors in forthcoming

1 https://www.emdat.be/classification.
2 https://www.reinsurancene.ws/pennsylvania-classifies-covid-19-as-natural-disaster/.

months under the SARS-CoV-2 pandemic[3]. The estimations of the IMF imply that the final bill for the pandemic would total $28tn in lost economic output[4]. These figures include both the lost GDP and the economic and workforce cost of a large number of COVID-19 deaths worldwide[5]. A recent study by Chudik et al. (2020) also shows that the "*COVID-19 pandemic will lead to a significant fall in world output that is most likely long-lasting, with outcomes that are quite heterogeneous across countries and regions*" Their empirical estimations show that "*no country is immune to the economic fallout of the pandemic because of global interconnections*". The long run effects of the SARS-CoV-2 pandemic on income inequality, poverty, quantity and quality of education, mental health and political stability among others need to be taken into account as well.

While part of literature has focused on the economic effects of SARS-CoV-2 pandemic, another line of research is studying the main drivers behind this costly pandemic. Which factors are associated with outbreak of SARS-CoV-2 pandemic and its intensity and human costs? Farzanegan et al. (2020c) highlight the role of international tourism in expansion of SARS-CoV-2 pandemic. They examined the relationship between international tourism and COVID-19 cases and associated death in more than 90 countries. Controlling for other factors which may shape the COVID 19 fatalities such as health, demography and level of income, they found a significant positive association between past records of openness to tourism and current numbers of countries regarding COVID-19. They show that a 1% higher level of inbound and outbound tourism is associated with 1.2% and 1.4% higher levels of confirmed COVID-19 cases and deaths, respectively. Globalization of markets also has been shown as a relevant factor in understanding cross-country variation in the SARS-CoV-2 outbreak worldwide. Farzanegan et al. (2020a) use multiple regressions and show that countries with higher levels of socio-economic globalization are exposed more to outbreak of SARS-CoV-2. However, they could not establish a significant link between the cross-country differences of globalization and cross-country differences in COVID-19 confirmed deaths. The role of public education and flow of information about the SARS-CoV-2 pandemic is also shown to be an important factor in explaining different levels of the SARS-CoV-2 outbreak. In a case study of Iran, using panel data of provinces of Iran during February and March 2020, Farzanegan et al. (2020b) show a robust negative association between the intensity of Google searches for disinfection methods and materials in the past at province levels and current confirmed cases of the COVID-19. They also find a positive and robust association between the intensity of the searches for symptoms of COVID-19 and the number of confirmed cases within the Iranian provinces. Other studies also emphasize the role of social determinants in the expansion and costs of COVID-19. McNeely et al. (2020) show that "*people in disadvantaged communities are generally more prone to occupational exposure to the virus and tend to have limited access to health care and higher rates of comorbidities*". Da Silva and Tsigaris (2020) examine the policy determinants of COVID-19 pandemic–induced fatality rates across countries. They show that delaying policies for international travel restrictions, public information campaigns and testing policies increased the fatality rate. According to their results, a 10% delay time to act resulted in a 3.7% higher case fatality rate. In addition, the role of national culture on the outbreak of COVID-19 is investigated by Huynh (2020). He shows that countries with higher 'Uncertainty Avoidance Index' explain the lower share of people gathering in public. The role of environmental factors on transmission rates of the COVID-19 outbreak is also investigated by Poirier et al. (2020). They show that weather condition (i.e., increase of temperature and

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3 https://www.imf.org/en/Publications/WEO/Issues/2020/09/30/world-economic-outlook-october-2020.

4 https://www.theguardian.com/business/2020/oct/13/imf-covid-cost-world-economic-outlook.

5 The economic costs depend also on structure of affected economies. For example, these with higher dependence on tourism and international mobility may suffer more from various restrictions under SARS-CoV-2 pandemic. Based on WDI (2020), the international tourism revenues was around 14% to export revenues in low-income countries while this number is around 7% in high-income group. The share of revenues from international tourism in the economy of high-income countries is relatively low or moderate. Thus, they are much less vulnerable with respect to COVID-19 negative shock compared to low income countries. For example, the share of tourism receipts in GDP in Lebanon is 16%, and in Jordan is 15%. In contrast, the share of tourism revenues in GDP of France (the most attractive destination for tourists) is only 2.6% and in USA, this ratio is about 1.2%.

humidity) will not necessarily cause a decline in COVID-19 case counts without the implementation of significant public health interventions. By using Google mobility data, Maloney and Taskin (2020) provide a global view on determinants of social distancing and economic activity during COVID-19.

This current study focuses on the role of demographic structure of countries as a possible explanatory factor for outbreak of SARS-CoV-2 and associated human costs. The main contribution of this study is the consideration of the moderating role of healthcare absorptive capacity in shaping the final effect of old-age demographic structure on COVID-19. While there is a growing discussion on the importance of age structure in the level of COVID-19 costs, an empirical investigation of the conditional effect of old-age demographic structure at different levels of healthcare absorptive capacity of countries is missing in the COVID-19 literature. Earlier studies such as Sarkheil et al. (2020) have emphasized the importance of health and safety management system for increasing the resistance of economic system against external shocks. Palmi et al. (2018) refer to the role of organizational resilience in responding to unexpected shocks, while preserving business sustainability. Khan et al. (2020) used data for 86 countries which had at least 1000 confirmed cases on 30th April 2020. They employed a negative binomial regression model to examine the association between COVID-19 case fatality and healthcare capacity index, adjusting for other covariates. They conclude that "building effective multidimensional healthcare capacity is the most promising means to mitigate future case fatalities". Golinelli et al. (2017) also suggest that sustainability of healthcare systems captured by per capita public healthcare expenditure in the Italian regions matter for the all-cause mortality rate, determining which expenditure item most affected mortality. This study builds on these studies and focus on COVID-19 human costs and demographic structure in interaction with healthcare absorptive capacity.

Does an ageing society associate with higher COVID-19 fatalities? How much earlier investments of countries in their healthcare system and capacity matter? There is an increasing attention in the literature on understanding the association between SARS-CoV-2 outbreak and demographic profile of countries. Dowd et al. (2020) use population pyramids and show how the population age structure interacts with the high COVID-19 mortality rates at older ages in selected countries such as Nigeria, South Korea, USA and Italy. They conclude that large COVID-19 mortality rates would differ across populations due to age structure. They suggest "that social distancing and other policies to slow transmission should consider the age composition of local and national contexts as well as intergenerational interactions". Their research approach does not take into account the other socio-economic and institutional determinants of the SARS-CoV-2 outbreak and mortality. Palloni and Walter (2020) also provide a review of possible contributing factors in differences between regions within a country and between countries regarding COVID-19 fatality rates. They suggest that both demography and biology are important in helping us to explain the patterns of deaths caused by the pandemic. Blagosklonny (2020) shows that COVID-19 mortality increases exponentially with age, which is the strongest predictor of mortality.

In this study and by using a multiple regression analysis, the association between old-age demographic structure and COVID-19 fatalities is re-examined for 146 countries[6], controlling for other important factors. Furthermore, this paper tests the hypothesis that the final effect of the elderly population on COVID-19 fatalities depends on the available absorptive capacity of health sector of countries, proxied by the number of hospital beds per 1000 of population. According to the Organization for Economic Co-operation and Development (OECD), hospital beds provide a measure of the resources available for delivering services to inpatients in hospitals in terms of number of beds that are maintained, staffed and immediately available for use. Total hospital beds include curative care beds, rehabilitative care beds, long-term care beds and other beds in hospitals[7].

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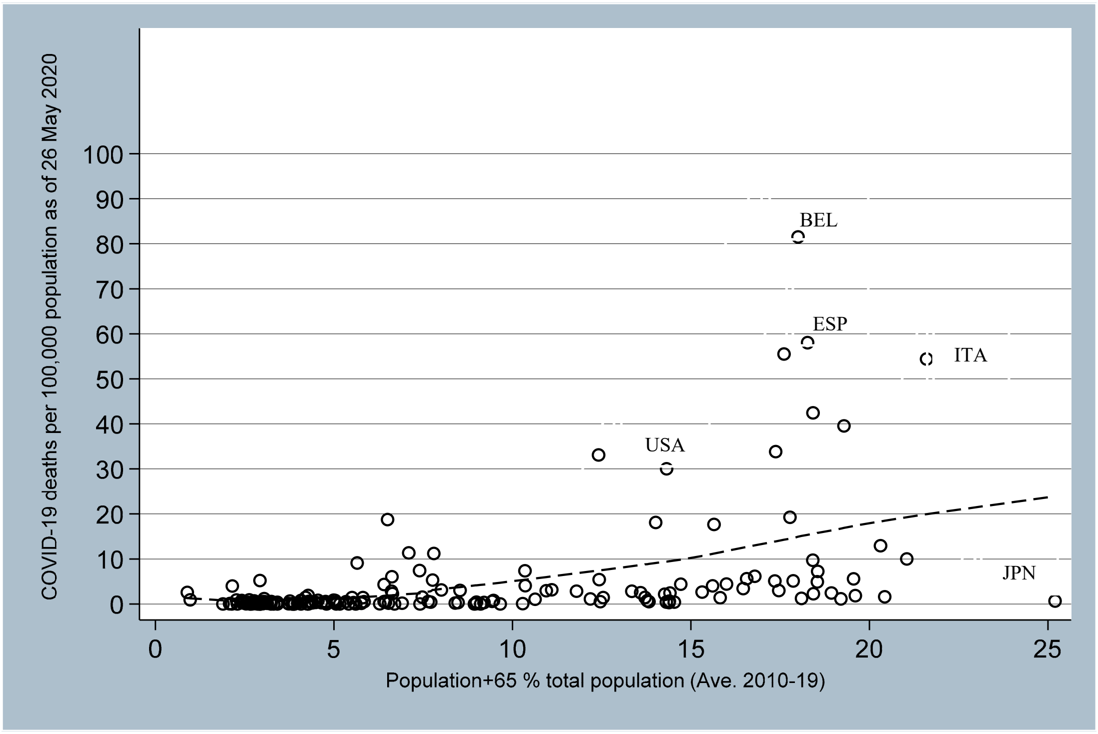
[6] The number of countries in estimations varies from 179 to 146, depending on specification and inclusion of control variables. My general model in which we have the full set of control variables covers 146 countries.

[7] https://data.oecd.org/healtheqt/hospital-beds.htm.

The main results show that having an old-age demographic structure does not necessarily associate with higher human cost of COVID-19. It depends on the capacity of the healthcare system in accommodating the affected cases and addressing the disease symptoms in an efficient way.[8] This is a new empirical finding which shows that countries with an old-age demographic structure may still be able to register lower levels of fatalities, given their earlier investment in health sector.

Figure 1a,b illustrate the relationship between *Cumulative COVID-19 death per 100,000 population* (as of 26 May 2020) and average of *elderly population share from 2010–2019* using *Lowess*, which is a nonparametric regression method that fits simple models to localized subsets of the data and then smooths these localized estimates into the curves provided in Figure 1a,b.

Figure 1a illustrates the relationship for the full sample of countries. There is a positive and statistically significant correlation of 0.47 between these two variables in our worldwide sample. We can also observe that there are significant cross-country variation in COVID-19 mortality at around the comparable demographic profile, indicating the importance of controlling for other explanatory factors. One of these important moderating factors is the number of hospital beds per 1000 of population which is a proxy for capacity of healthcare system in dealing with affected persons. Figure 1b provides the curve for the subsample of countries with measured values of *hospital beds per 1000 people* less than sample average (<3). For this subsample, the correlation between COVID-19 deaths and elderly share of population is stronger (0.64).



(a)

Figure 1. *Cont.*

[8] For a policy brief on the COVID-19 and demographic structure in Europe see Balbo et al. (2020).

(**b**)

Figure 1. (**a**) COVID-19 mortality per 100,000 people and elderly share of population (Full Sample). (**b**) COVID-19 mortality per 100,000 people and elderly share of population (Sample of countries with hospital beds per 1000 of people <3 (sample average)). Note: Cumulative COVID-19 death and share of elderly population. These two figures plot the total COVID-19 deaths per 100,000 population (as of 26 May 2020) against elderly population (the proportion of population beyond the age of 65 years in the total population from 2010 to 2019). The figures also include the locally weighted scatterplot smoothing curve (lowess), in which simple regressions are fitted to localized subsets of data to produce the nonlinear curve.

The illustration and background note lead to the following hypothesis which will be examined using a sample of worldwide data:

Hypothesis 1 (H1). *The final effect of the old-age demographic structure on COVID-19 fatalities depends on the healthcare absorptive capacity. The higher the levels of healthcare absorptive capacity, the lower is the impact of old-age demographic structure on COVID-19 mortality rate, ceteris paribus.*

2. Data and Method

For the empirical analysis of the effect of old-age demographic structure on COVID-19 mortality, this paper used data for 146 countries in the general specification, including full set of control variables. The data for the dependent variable were collected at the end of May 2020. Following Coronavirus Resource Center of the Johns Hopkins, we used the number of COVID-19 deaths per 100,000 population (including both confirmed cases and healthy population) to measure COVID-19 mortality[9]. The data on COVID-19 deaths were taken from European Centre for Disease Prevention and Control Data (ECDC 2020). We have used the cumulative sum of daily number of confirmed death as of 26 May 2020. The data on the explanatory variables were averaged over 2010–2019. We examined

[9] https://coronavirus.jhu.edu/data/mortality.

how the past records of socio-economic and institutional performance of countries can explain the cross-country variation which we observe today in the mortality rate of COVID-19. Using past records of explanatory variables helped to capture the long run effect of these predicators in explaining the current fatalities of COVID-19. In addition, considering the past development of age structure of population reduced the risk of reverse feedback. Major pandemic may influence the age structure of a country contemporaneously, complicating the direction of effect.

The summary statistics and data sources of all variables are documented in Table 1.

Table 1. Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Deaths per 100,000 population	146	4.85	11.95	0.00	81.53
Population+65 % total population	146	8.96	5.94	0.89	25.20
Log of GDP per capita (PPP, US$)	146	9.44	1.14	6.70	11.61
People using at least basic sanitation services (% of population)	146	78.15	26.96	6.52	100
Hospital beds (per 1000 people)	146	3.07	2.40	0.10	13.40
Governance index	146	0.06	0.85	−1.60	1.83
Log of international tourism, number of arrivals	146	14.52	1.77	10.04	18.24

The main hypothesis was that the higher share of elderly population in total population can increase the COVID-19 mortality but only significantly in countries with low healthcare absorptive capacity.

We used regressions to condition on a range of country characteristics and assess the independent relationship between cumulative levels of COVID-19 mortality and share of population beyond 65 years, where we used subscript i to represent an individual country.

The main specification to test this hypothesis is as follows:

$$\begin{aligned} covid19\_mortality_i &= cons + \beta_1.age65plus_i + \beta_2.hospital\_beds_i \\ &+\beta_3.(age65plus_i \times hospital\_bed_i) + \beta_4.controls_i + u_i \end{aligned} \tag{1}$$

According to Dowd et al. (2020) and several other studies, it is expected that $\beta 1 > 0$ (societies with higher elderly in their population, on average, suffer more from COVID-19). The hypothesis implies a conditional effect of population+65 as % total population (*age65plus)* on COVID-19 deaths per 100,000 population (*covid_mortality)* and we expected that the higher elderly population–higher COVID-19 mortality hypothesis would not apply when there was a relatively strong healthcare absorptive capacity, controlled with number of hospital beds per 1000 of population (*hospital_beds*). The hospital beds indicator provides a measure of the resources available for delivering services to inpatients in hospitals in terms of number of beds that are maintained, staffed and immediately available for use. Thus, the expected sign of $\beta 3$ is negative. We also controlled for other determinants of COVID-19 mortality as mentioned in Table 1 besides the continent dummies. It was expected that countries with higher levels of economic activities controlled by logarithm of GDP per capita are more prone to SARS-CoV-2 outbreak. Such economies are associated with higher international trade and mobility which are associated with outbreak of SARS-CoV-2 (Farzanegan et al. 2020c, 2020a). Higher share of population with at least basic sanitation services should help to reduce the virus fatalities. Governance index which is an unweighted average of six dimensions of governance from the World Governance Indicators (WGI 2020) (i.e., control of corruption, regulatory quality, voice and accountability, political stability, government effectiveness and rule of law) was also expected to be negatively correlated with COVID-19 mortality. The role of governance in the COVID-19 literature is explained by Kaufmann (2020) among others. Kaufmann suggests that among high-income countries, many European countries that have excelled in various governance dimensions, have also addressed the pandemic well. He relates the poor performance of the US in control of pandemic to its declining quality of governance over recent years. WGI data for the index of voice and accountability shows that by 2018 the U.S. ranked only 29th in the world, and 25th in control of corruption, following a decline over the past two decades.

The number of arrival of tourists was also controlled and expected to be positively correlated with SARS-CoV-2 outbreak and fatalities (see Farzanegan et al. 2020c for empirical evidence). A comprehensive discussion on the role of cruise tourism in the outbreak of SARS-CoV-2 is provided by Mallapaty (2020). The news media in many countries has reported many of such cases (Cain et al. 2020). The source of data for explanatory variables, if not otherwise mentioned, was WDI (2020). We used the ordinary least squares (OLS) method[10] and robust standard errors in the estimations[11]. Table A1 in Appendix A summarizes data description.

3. Results

OLS Estimation Results: COVID-19 Mortality-Elderly Population and the Hospital Beds

Using ordinary least squares (OLS), Table 2 shows that there is a positive and statistically significant relation between current cumulative COVID-19 deaths (per 100,000 population) and share of persons aged 65 years and over in total population. This association is robust after controlling for other socioeconomic determinants of COVID-19 fatalities and the continent dummies.

An important finding is the significant interaction term between the share of elderly population and an objective measure of healthcare capacity, namely the number of hospital beds per 1000 of population. While the main effect of elderly population on COVID-19 mortality is positive and significant in all models, this effect is reducing at higher levels of availability of hospital beds. This finding reminds us the aging population is not the main concern in COVID-19 fatalities. More important is the capacity of health sector and earlier investment in health care system. Availability of hospital beds is especially critical for the case of COVID-19 patients. The severe acute respiratory syndrome coronavirus 2 mainly attacks healthy cells located in the lungs, causing respiratory problems. In the majority of cases, and to control breathing difficulties, the levels of oxygen in the lungs should increase by using a ventilator. Approximately 20% of infected patients need hospitalization and approximately 5–8% of the infected population need intensive care unit (ICU) admission, which lasts an average of 3–4 weeks[12]. Such lengthy treatment time for COVID-19 infected patients will stress health resources during an extended outbreak and higher numbers of arrival rates in hospitals.

The question is how the final association between COVID-19 mortality and old-age demographic structure changes at different levels of capacity to absorb patients with COVID-19. Is the final effect statistically significant? Is there a threshold capacity level of healthcare system to absorb patients with COVID-19, where beyond it the final effect of old age structure on mortality becomes insignificant? To answer these questions, this paper uses Model 9 (which includes the full set of control variables) in Table 2. Table 1 shows the summary statistics of the sample which is used to estimate Model 9, covering 146 countries. The number of hospital beds is changing from minimum level from 0.10 per 1000 of population (Mali) to maximum of 13.40 (Japan) and average value of 3.07.

The final effect of elderly population on COVID-19 death per 100,000 people, based on Model 9, is estimated through the following derivative:

$$\frac{\partial\ (covid19\_mortality_i)}{age65plus_i} = 1.373 - 0.136 \times (hospital\_beds_i) \tag{2}$$

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[10] OLS is an estimator generating the set of values of the parameters that minimizes the sum of squared residuals. For the reasons behind popularity of OLS as an estimation method, see Studenmund (2017).

[11] Population density as a control variable is also used in some studies such as Farzanegan et al. (2020c) which is shown to be statistically insignificant. They also used number of nurses per 1000 population besides hospital beds in their analysis of COVID-19 and tourism. Hospital beds in their study is a significant factor in reducing COVID-19 fatalities, while the number of nurses do not show a significant effect. To save the space, we did not include population density and number of nurses which are shown to be statistically insignificant in related studies.

[12] https://www.europeandataportal.eu/en/impact-studies/covid-19/pressure-healthcare-systems-coping-demand-icu-and-hospital-beds.

Table 2. COVID-19 mortality and elderly population.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent variable: cumulative COVID−19 deaths (per 100,000 population)								
Population+65 as % total population (*age65plus*)	0.592 **	1.083 ***	1.491 ***	1.190 **	1.323 ***	1.505 ***	1.181 **	1.141 ***	1.373 **
	(2.39)	(3.28)	(3.22)	(2.48)	(2.78)	(3.03)	(2.07)	(2.78)	(2.35)
Hospital beds per 1000 of population (*hospital_beds*)		−1.509 ***	−0.454	−0.829 **	−0.172	−0.428	−0.499	−0.258	0.471
		(−2.75)	(−1.39)	(−2.03)	(−0.48)	(−1.21)	(−1.56)	(−0.56)	(0.87)
age65plus × *hospital_beds*			−0.090 **	−0.063	−0.100 **	−0.091*	−0.077	−0.092 *	−0.136 **
			(−2.03)	(−1.34)	(−2.12)	(−1.92)	(−1.64)	(−1.90)	(−2.32)
Log of GDP per capita (PPP)				2.054 ***	−29.07 ***				−28.03 ***
				(3.12)	(−3.59)				(−3.59)
Log of GDP per capita (PPP)^2					1.67 ***				1.66 ***
					(3.64)				(3.77)
Basic sanitation (%)						−0.004			−0.092 **
						(−0.22)			(−2.41)
Governance index							1.897		−1.183
							(1.46)		(−0.56)
Log of arrival int'l tourism								1.683 ***	1.545 ***
								(3.15)	(2.76)
Asia	2.235	6.564 **	7.991 **	8.176 **	8.633 *	7.991 **	9.040 **	5.590	5.896
	(1.31)	(2.11)	(2.12)	(2.11)	(1.80)	(2.10)	(2.24)	(1.55)	(1.19)
Europe	8.041 ***	10.416 ***	10.51 ***	11.446 ***	11.099 **	10.457 ***	12.229 ***	10.646 ***	9.424 *
	(2.73)	(2.99)	(2.76)	(2.91)	(2.40)	(2.72)	(2.79)	(2.85)	(1.82)
Africa	2.953	6.489 **	8.496 **	10.568 **	9.886 **	8.370 **	9.643 **	8.554 **	7.586
	(1.56)	(2.01)	(2.14)	(2.53)	(2.02)	(2.16)	(2.28)	(2.17)	(1.53)
America	3.463 **	5.930 **	6.701 **	7.604 **	9.190 **	6.687 **	7.817 **	6.683 **	8.491 *
	(2.08)	(2.11)	(2.03)	(2.22)	(2.07)	(2.01)	(2.13)	(2.10)	(1.82)
Countries	179	156	156	151	151	156	156	150	146
R-sq.	0.24	0.27	0.28	0.30	0.33	0.28	0.29	0.31	0.37

All specifications are estimated using OLS with heteroscedasticity consistent standard errors. *t* values are reported in parentheses. *, ** and *** indicate significance at the 10, 5 and 1% levels, respectively.

Figure 2 shows the marginal effect of a one percentage point increase in share of elderly population in total population on COVID-19 confirmed deaths per 100,000 population at different levels of hospital beds per 1000 people.

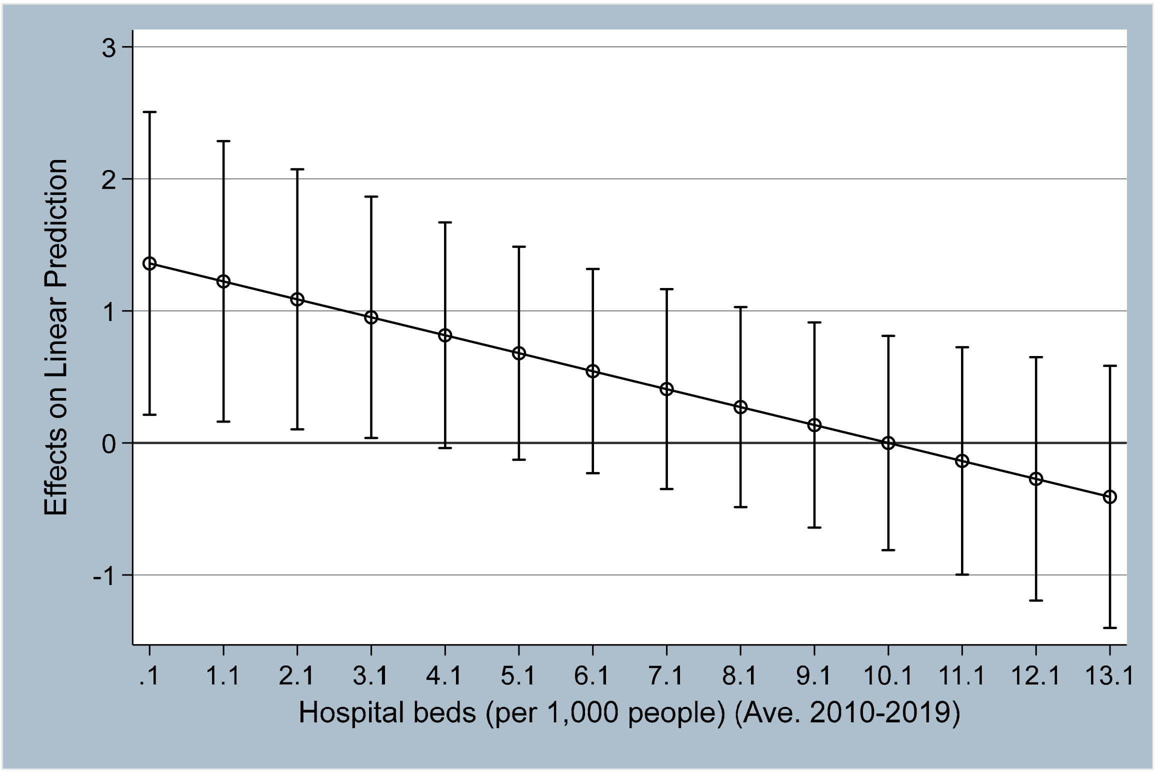

Figure 2. Marginal effect of elderly population on COVID-19 mortality with 95% confidence intervals.

Among control variables, we can observe that there is a nonlinear relationship between income per capita and COVID-19 fatalities. The dominant effect is negative (Models 5 and 9). A higher level of income per capita (in the past) is associated with lower levels of COVID-19 fatalities. However, this decreasing trend is not linear. Countries with higher levels of income per capita (beyond a threshold level) are also showing a higher levels of openness to global trade and tourism which are shown to be positively correlated with outbreak of SARS-CoV-2 (Farzanegan et al. 2020c, 2020a). A higher share of population with access to basic sanitation is also shown to be negatively correlated with COVID-19 fatalities (Model 9). This result is also in line with a regional analysis for the case of Iran, implying that regions with a higher intensity of Google searches for disinfection methods and materials have lower records of COVID-19 fatalities. The effect of the governance index is statistically insignificant. The higher levels of openness to international tourism is positively correlated with COVID-19 death rates across countries, implying a significant importance of human-to-human interactions in expansion of the virus. Finally, the effects of continent dummies are also important. There is a positive association between all continent dummies and COVID-19 fatalities, indicating the pandemic nature of SARS-CoV-2. There is no exception. However, when we include a full set of control variables in Model 9, only continent dummies of Europe and America remain statistically significant. Our general model explains approximately 40% of cross-country variation in COVID-19 fatalities in our sample.

Figure 2 shows that, keeping other variables constant at their average, the marginal effect of an increase in the share of older age cohorts in total population on COVID-19 mortality is positive and statistically significant only in countries where the average number of hospital beds over the period of 2010–2019 was less than approximately 3.5 beds per 1000 of people. For countries which have been invested in their healthcare absorptive capacity in the past, an aging population is not significantly associated with higher levels of COVID-19 fatalities.

Which countries in our sample have had less than 3.5 hospital beds per 1000 of their population and thus may be candidates for higher mortality of COVID-19 because of an increase in their old age population? Table 3 presents these countries in addition to their average level of hospital beds over the last decade and their mortality rate. The table includes countries which have higher than average of elderly population (>9%).[13]

Table 3. Countries with less than or equal to 3.5 hospital beds per 1000 people and elderly population greater than or equal to 9%.

Country	COVID-19 Deaths per 100,000 People	Population +65 (% of Total Population) (Ave. 2010–2019) ≥9%	Hospital Beds per 1000 People (Ave. 2010–2019) ≤3.5
Albania	1.1	12.2	2.9
Bosnia and Herzegovina	4.4	14.7	3.5
Canada	17.7	15.6	2.7
Chile	4.1	10.4	2.1
Cyprus	1.4	12.5	3.5
Denmark	9.7	18.4	3.1
Georgia	0.3	14.4	2.7
Iceland	2.8	13.3	3.3
Ireland	33.1	12.4	2.9
Israel	3.2	11.1	3.1
Mauritius	0.8	9.5	3.4
New Zealand	0.4	14.3	2.6
Portugal	12.9	20.3	3.4
Saint Lucia	0.0	9.1	1.5
Spain	58.0	18.3	3.1
Sweden	39.6	19.3	2.7
Thailand	0.1	10.3	2.1
Trinidad and Tobago	0.6	9.4	2.6
UK	55.5	17.6	2.9
USA	30.0	14.3	2.9
Uruguay	0.6	14.4	2.4

4. Conclusions

The results show that countries with an old-age demographic structure, on average, have a higher mortality rate because of the SARS-CoV-2 Disease (COVID-19). However, we also found that this positive effect is statistically significant only for countries with low levels of hospital beds which is a critical indicator for absorptive capacity of healthcare system for COVID-19 patients. Countries that have invested in their healthcare capacity in the past are less prone to mortality of COVID-19 as a result of their old age demographic structure. We showed that the risk of COVID-19 death is higher in aging societies with lower than 3.5 hospital beds per 1000 of population. The results were robust to the control of socio-economic and institutional characteristics of countries and continent dummies.

Low levels of earlier investments in health system capacity may show its significant costs during major pandemics. Deficits in hospital beds may lead to higher numbers of COVID-19 deaths because those who should have been hospitalized are not able to do it. Demographic models can help governments to simulate future development of age structure in their societies. These types of early warning systems can send important signals to policy makers to increase the absorptive capacity of their health system well in advance of future natural disasters. Governments can enhance the level of resistance against the pandemic by spending more in the fields of public health and education,

[13] In our estimated model for calculations of marginal effects, 1% of the values of the variable hospital beds (per 1000 of people) are equal to or less than 0.2. In total, 25%, also known as the first quartile, of the values of this variable in our sample are equal to or less than 1.3. One-half of observations for hospital beds per 1000 of people are equal to or less than 2.38 while 75% of its values are equal to or less than 4.25.

reducing allocation of budget to military especially in lower income countries. Underspending in key health sectors may mean a higher degree of vulnerability at the time of pandemic.

It is likely that the world will continue to experience outbreaks of diseases that most countries are weakly prepared to combat. Different real factors will expedite the expansions of pathogens worldwide such as climate change, fast urbanization besides globalization, expansion of international tourism, wars and mass displacements among others. Our world may also experience an increase in accidental or deliberate release of fatally engineered pathogens in laboratories, leading to even more damages than a naturally occurring pandemic. To this list, one should also add the lack of attention of policy makers to biological threats, reducing the level of preparation of the system against forthcoming shocks. Finally, the role of governance cannot be neglected. Political systems with high level of corruption and low level of political openness may tend to overspend on military and security and less on public health infrastructure. A global movement to improve the quality of governance by reducing corruption, improving rule of law and government effectiveness can increase the absorptive capacity of system in dealing with future pandemics.

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Appendix A

Table A1. Data description.

Variable	Definition	Source
Cumulative COVID-19 deaths (per 100,000 population)	Number of COVID-19 deaths per 100,000 population (including both confirmed cases and healthy population) is used to measure COVID-19 mortality. We have used cumulative sum of daily number of confirmed death as of 26 May 2020.	European Centre for Disease Prevention and Control Data (ECDC 2020).
Age65plus	Population ages 65 and above as a percentage of the total population. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. (Average 2010–2019)	WDI (2020)
Hospital_beds	Hospital beds (per 1000 people). Hospital beds include inpatient beds available in public, private, general and specialized hospitals and rehabilitation centers. In most cases beds for both acute and chronic care are included. (Average 2010–2019)	WDI (2020)
Log of GDP p.c.	Logarithm of GDP per capita, PPP (constant 2017 international $). GDP per capita based on purchasing power parity (PPP). PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. GDP at purchaser's prices is the sum of gross value added by all resident producers in the country plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2017 international dollars. (Average 2010–2019)	WDI (2020)

Table A1. *Cont.*

Variable	Definition	Source
Basic sanitation	People using at least basic sanitation services (% of population). The percentage of people using at least basic sanitation services, that is, improved sanitation facilities that are not shared with other households. This indicator encompasses both people using basic sanitation services as well as those using safely managed sanitation services. Improved sanitation facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines; ventilated improved pit latrines, compositing toilets or pit latrines with slabs. (Average 2010–2019)	WDI (2020)
Governance	Governance index which is an unweighted average of six governance dimension from the World Governance Indicators (WGI 2020) (i.e., control of corruption, regulatory quality, voice and accountability, political stability, government effectiveness and rule of law). (Average 2010–2019)	WGI (2020)
Log of international tourism (arrival)	International tourism, number of arrivals. International inbound tourists (overnight visitors) are the number of tourists who travel to a country other than that in which they have their usual residence, but outside their usual environment, for a period not exceeding 12 months and whose main purpose in visiting is other than an activity remunerated from within the country visited.	WDI (2020)

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