Which are factors determining a low COVID-19 mortality in society? High health expenditure and lower exposure of population to air pollution as critical factors for an effective strategy to cope with future pandemics similar to COVID-19

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Abstract

One of the problems hardly clarified in the scientific field of Coronavirus Disease 2019 (COVID-19) is inter-related factors associated with a lower mortality of COVID-19 to design effective strategies to cope with unforeseen pandemic crises. The main goal of this study is to explain these factors determining a lower fatality rate of the Coronavirus disease 2019 (COVID-19) in society with a global analysis based on more than 160 countries worldwide. This study reveals a novel finding: countries with a low average COVID-19 mortality have high investments in health sectors as % of GDP (>7.5%), high health expenditures per capita (>$2,300) associated with a lower exposure of population to days exceeding safe levels of particulate matter ($PM_{2.5}$), reinforcing these factors with a policy response of lockdown. In addition, these countries have lower fatality rates of COVID-19, regardless a higher percentage of population aged more than 65 years in these countries. Overall, then, this study must conclude that an effective strategy to reduce the negative impact of future epidemics similar to COVID-19 has to be based on a reinforcement of healthcare sector to have an efficient organization prearranged to cope with pandemics of new viral agents and to be able to minimize fatality rates in a context of sustainable environment having low air pollution.

Problem And Goal Of This Investigation

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the strain of novel coronavirus that causes Coronavirus disease 2019 (COVID-19) in society (Coccia, 2020). In 2020, COVID-19 pandemic has generated more than 1,800,000 deaths and roughly 85,000,000 cases worldwide (Johns Hopkins Center for System Science and Engineering, 2020).

The fundamental question in this field of research is which countries, how and why have reduced COVID-19 mortality and as a consequence the negative impact of COVID-19 pandemic crisis in society. This study confronts this question here by developing a global analysis based on more than 160 countries, which endeavors to clarify the factors associated with a lower COVID-19 mortality in countries. In particular, the main goal of this study is to explain the driving socioeconomic factors and determine health and environmental policy, and containment measure that have reduced fatality rate of the Coronavirus disease 2019 (COVID-19) in society. The development of this study flows from a recognition that current literature does not clarify the complex economic, social and institutional factors that can mitigate the negative effects of COVID-19 pandemic crisis in society. Lessons learned from this study can be important to design effective strategies for copying with future epidemics similar to the COVID-19.

Theoretical Framework

What is already known on these topics is based on manifold studies. Asirvatham et al. (2020) estimate an adjusted case fatality rate and determining factors associated with policy responses of COVID-19 in India. Results suggest that urban population and population aged more than 60 years were associated with increased adjusted case fatality rate. In addition, performance of healthcare systems and level of public health expenditure were not associated with adjusted case fatality rate. In this context, health interventions directed to test elderly, people with comorbidities (e.g., diabetes, cardiovascular diseases, cancer, etc.) and population of cities are critical measures to constrain negative effects of COVID-19 pandemic in society. Stribling et al. (2020)

argue that health policy and involvement of nurse leaders have a main role to mitigate COVID-19 pandemic. Kapitsinis (2020) investigates the diffusion of the novel coronavirus in nine European countries and pinpoints that health investments play a vital role to alleviate mortality rate of COVID-19. Ahmed et al. (2020) focus on different demographic, socioeconomic, and lifestyle health factors in countries to explain the variety of COVID-19 effects in society. This study by Ahmed et al. (2020) suggests that health expenditure per capita has a positive relation with case recovery; in particular, countries having high healthcare investments associated with high average age and proportion of urban population have high number of case fatality; as a consequence, investment in health sector is one of the factors that plays a vital role to control the spread of COVID-19 pandemic. Barrera-Algarín et al. (2020) state that in Europe lower investment in health per capita is associated with high numbers of COVID-19 deaths per million inhabitants; in general, a high negative impact of COVID-19 in terms of mortality is due to low expenditure in public health associated with high socioeconomic inequality. In this research field, Kavitha and Madhavaprasad (2020) underline the main role of preventive health care measures and social distancing applied on a vast portion of population to constraint the spread of COVID-19. Iyanda et al. (2020) argue that developing public health and epidemiological surveillance programs for the outbreak can both reduce COVID-19 and prevent unnecessary deaths. Gaffney et al. (2020, p. 396) maintain that: "the United States' underfunded public health infrastructure, fragmented medical care system, and inadequate social protections impose particular impediments to mitigating and managing the outbreak. . .. While the United States has a relatively generous supply of Intensive Care Unit beds and most other health care infrastructure, such medical resources are often unevenly distributed or deployed, leaving some areas ill-prepared for a severe respiratory epidemic". Moreover, González-Bustamante (2021) shows in South America that pressure on the health system affects interventions of government and strong economic lobbies of countries can delay appropriate policies of containment. Jin and Qian (2020) measure: "the Chinese public-health expenditure at national and provincial levels …, and then compare it with the expenditures of other countries. The results show that: (1) the level of public-health expenditure in China is relatively low and far lower than that in developed countries; (2) Chinese governments have not paid enough attention to the prevention and control of major public-health emergencies, which may be an important reason for the outbreak of COVID-19; (3) Chinese public-health expenditure shows a fluctuating growth trend, but the growth rate is so slow that it is lower than that of GDP and fiscal expenditure; (4) although the Chinese government inclines the public-health expenditure to the poor provinces in central and western regions, the imbalance and inequity of public-health resource allocation are still expanding among provinces; (5) there is a lot of waste of resources in the public-health system, which seriously reduces the efficiency of public-health expenditure in China. Therefore, the Chinese government should improve the quantity and quality of public-health expenditure in the above aspects". Siddiqui et al. (2020) analyze India in the presence of COVID-19 pandemic and show that: "low public health expenditure combined with a lack of infrastructure and low fiscal response implies several challenges to scale up the COVID-19 response and management. Therefore, an emergency preparedness and response plan is essential to integrate into the health system of India".

Overall, the, the vast literature shows different results but what *is hardly known* is to explain manifold factors determining a lower mortality in society to design an effective strategy to constrain future epidemics similar to COVID-19. This investigation is part of a large research project on factors determining the transmission dynamics of the COVID-19 pandemic and socioeconomic impact of public policies to cope with COVID-19 pandemic crisis. Results of the study here can clarify factors to reduce mortality rates of infectious diseases to design effective strategies to constrain future epidemics similar to COVID-19.

Materials And Methods

This study has the primary objective to explain factors determining a lower fatality rate of the COVID-19 in countries. The study is based on a sample of 161 countries worldwide that is categorized in two sub-samples according to the level of Gross Domestic Product per capita (wealth of individuals) to have a comparable institutional and socioeconomic framework of investigation between countries.

1.1 Research setting and measures

Sample, *N*=161 countries worldwide.

The measures under study are:

- *Number of COVID-19 infected individuals* is measured with confirmed cases (%) of COVID-19 divided by population of countries under study on 14 December 2020. Source of data: Johns Hopkins Center for System Science and Engineering (2020).
- *Number of COVID-19 deaths* is measured with fatality rate (%) of COVID-19 given by deaths divided by total infected individuals in countries on 14 December 2020. Source of data: Johns Hopkins Center for System Science and Engineering (2020).
- Wealth of population is measured with Gross Domestic Product (GDP) per capita, Purchasing Power Parity, PPP (current international $) in 2019 (last year available in dataset). GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars. Source of data: World Bank (2020).
- The structure of health sector is measured: a) current health expenditure (% of GDP) in 2017: Level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT and stocks of vaccines for emergency or outbreaks. Source of data: World Bank (2020a); b) Domestic general government health expenditure per capita, PPP (current international $) in 2017 (last year available): Public expenditure on health from domestic sources per capita expressed in international dollars at purchasing power parity (PPP time series based on ICP2011 PPP). Source: World Bank (2020b).
- Elderly is measured with population aged 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 in 2019 (last year available). Source: World Bank (2020c). Population aged 65 and above is an important factor because many studies argue negative effects of COVID-19 on older population (Cohen-Mansfield, 2020).
- Air pollution is measured by $PM_{2.5}$ air pollution, population exposed to levels exceeding WHO guideline value (% of total) in 2017 (last year available): Percent of population exposed to ambient concentrations of $PM_{2.5}$ that exceed the WHO guideline value is defined as the portion of a country's population living in places where mean annual concentrations of $PM_{2.5}$ are greater than 10 micrograms per cubic meter, the

guideline value recommended by the World Health Organization as the lower end of the range of concentrations over which adverse health effects due to $PM_{2.5}$ exposure have been observed. Source: World Bank (2020d). Studies reveal that areas with frequently high levels of air pollution — exceeding safe levels of ozone or particulate matter — had higher numbers of COVID-19 related infected individuals and deaths (Coccia, 2020, 2020a, 2020b, 2020c, 2020d; Coccia, 2021; Martelletti and Martelletti, 2020). Moreover, high concentrations of nitrogen dioxide and particulate air pollutant induce serious damages to the immune system of people, weakening it to cope with infectious diseases of viral agents (Glencross et al., 2020)

- Containment measure of COVID-19 lockdown is measured with total days of lockdown across countries over 2020-2021 period (until January 2021). Tobías (2020, p. 2) states that: "Lockdown, including restricted social contact and keeping open only those businesses essential to the country's supply chains, has had a beneficial effect". Flaxman et al. (2020) show that lockdowns seem to have effectively reduced transmission of the COVID-19. Atalan (2020) argues that countries can start the policy response of lockdown when there is an acceleration of daily confirmed cases beyond a critical threshold and can end it when there is a strong reduction of Intensive Care Unit (ICU) admissions (cf., Chaudhry et al., 2020). Source: COVID-19 pandemic lockdowns (2020).

1.2 Data analysis procedure

The sample *of N=161 countries* is divided in two sub-samples (group 1 and 2) as follows:

- *Countries with a Gross Domestic Product per capita higher than arithmetic mean of the sample* (group 1)
- *Countries with a Gross Domestic Product per capita lower and/or equal than arithmetic mean of the sample* (group 2)

Firstly, data are analyzed with descriptive statistics by arithmetic mean (M) and standard deviation (SD), using a comparative approach between two groups of countries just mentioned. In addition, to check the normality of distribution and apply correctly parametric analysis the skewness and kurtosis coefficients are computed and in the presence of not normal distributions, variables are transformed in logarithmic scale.

Secondly, to assess whether the difference of arithmetic mean of variables between group 1 and 2 is significant, the Independent Samples *t*-Test is performed. In particular, the Independent Samples *t*-Test compares the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The Independent Samples *t* Test requires the assumption of homogeneity of variance – i.e., both groups have the same variance and as a consequence Levene's Test is performed. The hypotheses for Levene's test are:

H_0: $\sigma_1^2 - \sigma_2^2 = 0$ (the population variances of group 1 and 2 are equal)
H_1: $\sigma_1^2 - \sigma_2^2 \neq 0$ ("he population variances of group 1 and 2 are not equal)

This implies that if we reject the null hypothesis of Levene's Test, it suggests that the variances of the two groups are not equal; i.e., that the homogeneity of variances assumption is violated. If Levene's test indicates that the variances are equal across the two groups (i.e., *p*-value large), Equal variances assumed. If Levene's test indicates that the variances are not equal across the two groups (i.e., *p*-value small), the assumption is: Equal variances not assumed. After that, null hypothesis (H_0) and alternative hypothesis (H_1) of the Independent Samples *t*-Test are:

H_0: $\mu_1 = \mu_2$, the two population means are equal in countries with a higher and lower GDP per capita

H_1: $\mu_1 \neq \mu_2$, the two population means are not equal in countries having a higher and lower GDP per capita

Statistical analyses are performed with the Statistics Software SPSSâ version 26.

Results

The arithmetic mean (M) of the GDP per capita of the sample (*N*=155 valid countries and 6 missing values) is M=$22,794; as consequence the two homogenous groups under study are:

- *Countries with a Gross Domestic Product per capita in 2019 >* $22,794, *N*= 58 countries
- *Countries with a Gross Domestic Product per capita in 2019 £* $22,794, *N*=98 countries

Table 1. Descriptive statistics

	Countries with *a Gross Domestic Product per capita in 2019 £* $22,794		Countries with *a Gross Domestic Product per capita in 2019 >* $22,794	
	M	SD	M	SD
Cases/population, % 2020	0.81	1.11	2.39	1.66
Fatality rate, % 2020	2.28	1.57	1.68	0.88
GDP per capita PPP ($), 2019	$8,538.85	$6,035.58$	4$46,634.61	$20,215.07
Health expenditure (% of GDP), 2017	5.97	2.12	7.59	2.77
General government health expenditure per capita, PPP ($), 2017	$243.72	$260.29	$2,323.90	$1,373.42
Population ages 65 and above as a percentage of population, 2019	5.83	3.85	15.07	6.41
$PM_{2.5}$ air pollution, population exposed to levels exceeding WHO guideline value (% of total), 2017	97.70	11.95	72.34	38.23
COVID-19 pandemic lockdowns (days)	55.26	51.22	96.71	85.79

Note: M= arithmetic mean; SD= Standard Deviation.

Table 1 shows that fatality rate is lower (1.68%) in richer countries that have an average GDP per capita of more than $46,000 per capita, a higher health expenditure (% of GDP) of roughly 7.6%, higher government health expenditure per capita of about $2,300, a lower exposure of population to levels exceeding $PM_{2.5}$ air pollution according to WHO guidelines and longer period of lockdown, regardless a higher percentage of population aged more than 65 years and higher incidence of confirmed cases on population in these countries (cf., Figure 1 and Table 2).

Table 2. Group statistics

Variables	Groups	Mean	Std. Deviation
Cases/population, 2020	GDP Lower than Mean $22794	0.008	0.011
	GDP Higher than Mean $22794	0.024	0.017
Fatality rate, 2020	GDP Lower than Mean $22794	0.023	0.016
	GDP Higher than Mean $22794	0.017	0.009
GDP per capita PPP ($), 2019	GDP Lower than Mean $22794	$8,538.846	$6,035.578
	GDP Higher than Mean $22794	$46,634.607	$20,215.075
Health expenditure (% of GDP), 2017	GDP Lower than Mean $22794	5.967	2.120
	GDP Higher than Mean $22794	7.594	2.766
General government health expenditure per capita, PPP ($), 2017	GDP Lower than Mean $22794	$243.716	$260.293
	GDP Higher than Mean $22794	$2,323.896	1,373.424
Population ages 65 and above as a percentage of population, 2019	GDP Lower than Mean $22794	5.830	3.852
	GDP Higher than Mean $22794	15.075	6.406
Log $PM_{2.5}$ air pollution, population exposed to levels exceeding WHO guideline value (% of total), 2017	GDP Lower than Mean $22794	4.589	0.091
	GDP Higher than Mean $22794	4.071	1.179
Log COVID-19 lockdowns (days)	GDP Lower than Mean $22794	3.707	0.776
	GDP Higher than Mean $22794	4.140	1.028

Note: Log scale is to normalize the distribution of some variables.

Table 3. Independent Samples Test

		Levene's Test for equality of variances		*t*-test for equality of Means				
		F	Sig.	*t*	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
ses/population, 20	Equal variances assumed	17.462	0.001	-7.079	153.000	0.001	-0.016	0.002
	Equal variances not assumed			-6.431	88.151	0.001	-0.016	0.002
ality rate, 2020	Equal variances assumed	7.842	0.006	2.671	154.000	0.008	0.006	0.002
	Equal variances not assumed			3.057	153.670	0.003	0.006	0.002
P per capita P, 2019	Equal variances assumed	46.016	0.001	-17.345	153.000	0.000	-38095.761	2196.380
	Equal variances not assumed			-13.984	63.132	0.001	-38095.761	2724.193
alth expenditure of GDP), 2017	Equal variances assumed	4.929	0.028	-4.127	154.000	0.001	-1.627	0.394
	Equal variances not assumed			-3.859	96.660	0.001	-1.627	0.422
neral government alth expenditure capita, PPP ($), 17	Equal variances assumed	163.442	0.001	-14.446	152.000	0.001	-2080.181	143.998
	Equal variances not assumed			-11.412	59.484	0.001	-2080.181	182.286
pulation ages 65 d above as a rcentage of pulation, 2019	Equal variances assumed	21.540	0.001	-11.266	154.000	0.001	-9.244	0.821
	Equal variances not assumed			-9.975	81.803	0.001	-9.244	0.927
g PM$_{2.5}$ air lution, pulation exposed evels exceeding IO guideline ue (% of total), 17	Equal variances assumed	59.944	0.001	4.311	148.000	0.001	0.518	0.120
	Equal variances not assumed			3.190	52.335	0.002	0.518	0.162
g COVID-19	Equal	3.749	0.057	-2.030	70.000	0.046	-0.433	0.213

kdowns (days), 20	variances assumed					
	Equal variances not assumed	-1.999	61.106	0.050	-0.433	0.217

In order to assess the significance of the difference of arithmetic mean between groups of countries under study (table 2), the Independent Samples *t* Test is performed. The *p*-value of Levene's test is significant, and we have to reject the null of Levene's test and conclude that the variance in the groups under study is significantly different (i.e., Equal variances not assumed), except COVID-19 pandemic lockdown that has *p*-value<.06 and Equal variances assumed.

Table 3 shows main results about a statistically significant difference of arithmetic mean between groups as indicated in table 1 and 2. In particular, table 3 substantiates that:

- There was a significant difference in mean cases/population between countries with GDP Lower than $22,794   and GDP Higher than $22,794 ($t_{88.15} = -6.43$, $p < .001$).
- There was a significant difference in mean fatality rate between countries with GDP Lower than $22,794 and GDP Higher than $22,794 (*153.67* = 3.06, $p < .01$).
- There was a significant difference in mean GDP per capita between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{63.13} = -13.98$, $p < .001$).
- There was a significant difference in mean health expenditure (% of GDP) between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{96.66} = -3.86$, $p < .001$).
- There was a significant difference in mean general government health expenditure per capita between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{59.48} = -11.41$, $p < .001$).
- There was a significant difference in mean population aged 65 and above as a percentage of total population between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{81.80} = -9.98$, $p < .001$).
- There was a significant difference in mean $PM_{2.5}$ air pollution, population exposed to levels exceeding WHO guideline value (% of total) between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{52.34} = 3.19$, $p < .01$).
- There was a significant difference in mean COVID-19 pandemic lockdowns between countries with GDP Lower than $22,794 and GDP Higher than $22,794 ($t_{70.00} = -2.03$, $p < .05$).

Hence, findings suggest that fatality rate in richer countries (1.7%) is lower than medium-low income per capita countries (2.3%). Factors determining the mitigation of the fatality of COVID-19 in society can be due to a higher health expenditure (% of GDP) of roughly 7.6%, higher government health expenditure per capita of about $2,300, a lower exposure of population to levels exceeding $PM_{2.5}$ air pollution according to WHO guidelines and longer lockdown, though these countries have a higher percentage of population aged more than 65 years and higher incidence of confirmed cases on population.

These analyses provide important, very important results to constrain the effects of COVID-19 pandemic and future epidemics similar to COVID-19; in particular, an effective strategy has to be based on health policy with higher healthcare expenditure as percentage of GDP, environmental policies based on reduction of exposure of population to air pollution and finally a timely policy response based on lockdown of a long duration, in a context of general development of nations (Coccia, 2019).

Discussion, Policy Implications And Concluding Observations

One of the problems in the presence of COVID-19 pandemic crisis is to mitigate the mortality in society. Previous studies suggest that measures of containment can constraint the human-to-human transmission dynamics of infectious diseases and negative effects in society (Atalan, 2020; Prem et al., 2020; Tobías, 2020). However, w*hat this study adds to current studies* on the COVID-19 global pandemic crisis is that a comprehensive strategy to reduce fatality rates of COVID-19 in society is associated with critical factors as schematically summarized in the figure 2.

The main aspects to mitigate fatality rates are focused on appropriate previous health and environmental policies and current policy responses to cope with COVID-19 pandemic crisis. In particular,

- *Health Policy*

This study reveals that countries with a lower fatality rates have a high health expenditure (% of GDP) of roughly 7.6% and government health expenditure per capita of about $2,300, whereas countries with a higher fatality rates have a health expenditure (% of GDP) of roughly 6% and government health expenditure per capita of about $243 that indicate a weak healthcare sector to cope with pandemics and also other diseases. This main result is confirmed by other scholars, such as Kapitsinis (2020) that argues how health investments over time are a critical health policy to mitigate mortality rate of COVID-19.

- *Environmental policy*

This study shows that environment plays a vital role for impact of COVID-19 in society; in particular, a low rate of fatality is associated with a low impact of air pollution on population: considering $PM_{2.5}$ air pollution, population exposed to levels exceeding WHO guideline value (% of total) is 72% in countries with a lower fatality rate, whereas in countries with a higher incidence of mortality of COVID-19 is almost 98%! Coccia (2020, 2020a, 2020b, 2020c) finds out that number of infected people was higher in Italian cities with >100 days per year exceeding limits set for PM_{10} or ozone, cities located in hinterland zones (i.e. away from the coast), cities having a low average wind speed and cities with a lower temperature. In fact, diffusion of the COVID-19 is higher in cities with low wind speed that prevents the dispersion of air pollutants and bio aerosols that can include bacteria and viruses, such as SARS-CoV-2 (Coccia, 2020). Guo et al. (2019) argue that in recent years, haze pollution is a serious environmental problem affecting cities, proposing policies for urban planning that improve respiratory health of population. In fact, improvements in air quality have been accompanied by demonstrable benefits to human health. In this perspective, countries should introduce organizational, product and process innovations directed to a sustainable economic development and sustainable technologies for the improvement of environment, atmosphere, air quality and especially public health to cope with epidemics similar to COVID-19. In this context, countries should also support the expansion of hospital capacity and testing capabilities to reduce diagnostic delays, the application of artificial intelligence and new ICT technologies for improving diagnostics, the development of effective vaccines, antivirals and other innovative drugs that can counteract future global public health threat in the presence of new epidemics similar to COVID-19, etc. (Coccia, 2005, 2015, 2017, 2017a, 2017b, 2018, 2019, 2019a, 2019b; Coccia, 2020e; Coccia and Watts, 2020).

- *Policy responses based on containment measure of lockdown*

This study also shows that mortality of COVID-19 is lower in the presence of longer lockdowns. The model by Balmford et al. (2020) reveals that countries with an immediate application of lockdown reduced deaths compared to countries that delayed the application of this strong containment measure. Gatto et al. (2020) maintain that restriction to mobility and human interactions can reduce transmission dynamics of the COVID-19 by about 45%. Janssen and van der Voort (2020) show the utility of “smart lockdown” as policy responses based on suggested and not mandated mitigation measures focused on responsibility of individuals in the presence of specific local conditions. In this context, new studies show that specific places have a high risk to be COVID-19 outbreaks (e.g., restaurants, gyms, stadium, discotheques, etc.), generating a lot of infections (Chang et al., 2020); as a consequence, selected measures of containment, such as restricting maximum occupancy of these specific places, are more effective interventions than policies based on uniformly reducing mobility of people (Chang et al., 2020; cf., Renardy et al., 2020).

- *Policy and theoretical implications*

Overall, then, one of the most important findings here is that an appropriate health policy that supports healthcare sector, a sustainable environmental policy that reduces the exposure of population to air pollution and a timely policy response of lockdown can induce a reduction of COVID-19 fatality rates, regardless a higher incidence of confirmed cases and a higher percentage of elderly on total population in countries. In general, the COVID-19 pandemic crisis needs high investments in health sector, sustainable policies and policy responses based on agility and adaptive governance. Evans and Bahrami (2020) pinpoint that super-flexibility can be an appropriate approach to cope with environmental threats of current COVID-19 in which decision making should be oriented to versatility, agility, and resilience. In short, to reiterate, this study suggests that in order to constrain the impact in society of new pandemic waves of COVID-19 and future epidemics similar to the COVID-19, regions and nations have to apply critical policies directed to increase investments in healthcare sectors and reduce the sources of air pollution to improve air quality (Coccia, 2019; Coccia, 2020f, 2020g).

- *Limitations and concluding observations*

This statistical analysis here suggests mainly association between the variables under study because of manifold confounding factors that influence variables (Sabat et al., 2020, p. 917). The positive side of this study is a large dataset for a global analysis of countries that have been categorized in two sub-samples to have homogenous groups to perform a comparative analysis. However, future studies have to reinforce the generalization of these main findings with additional statistical analyses over time and space. To conclude, an effective strategy to reduce the negative impact of future epidemics similar to COVID-19 has to be based on preventive high investments in healthcare sector to have a prearranged efficient organization, in a sustainable environment, to cope with pandemics of new viral agents to be able to minimize fatality rates of new waves of COVID-19 pandemic and similar viral agents in future.

Declarations

Declaration of competing interest. The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding was received for this study.

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Figures

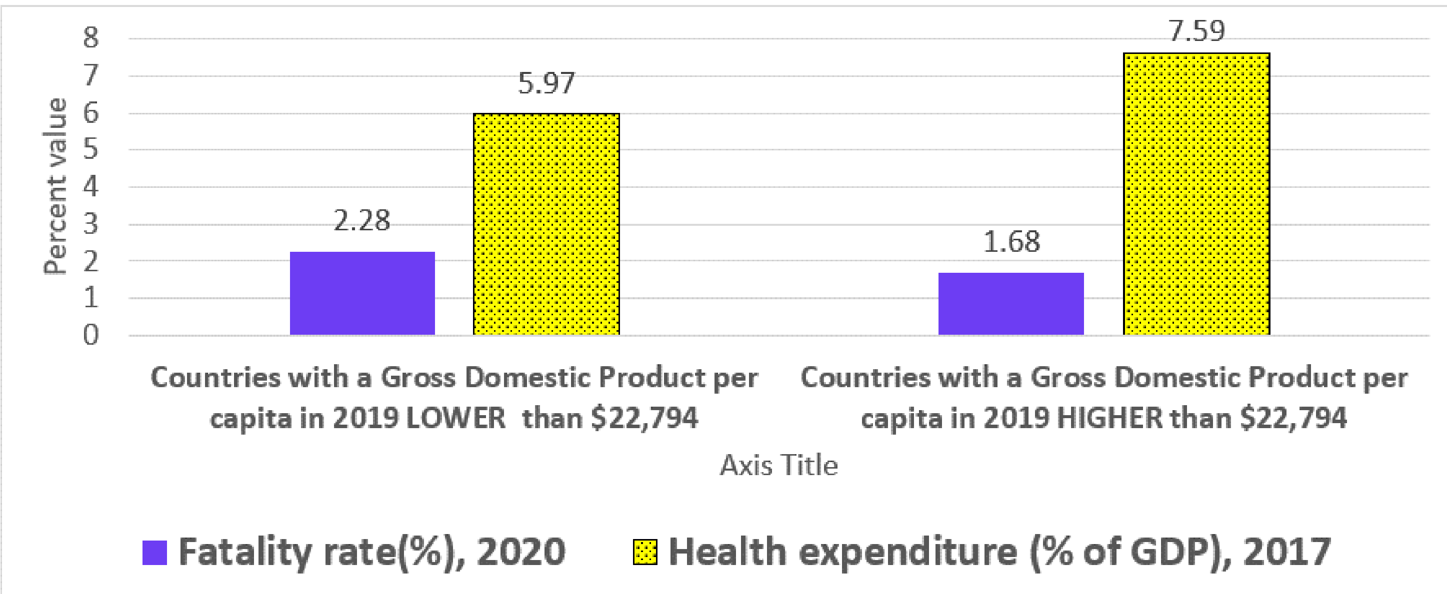

Figure 1

Fatality of COVID-19 and Health Expenditure in 155 countries with higher/lower GDP per capita than $22,794 (arithmetic mean of the sample).

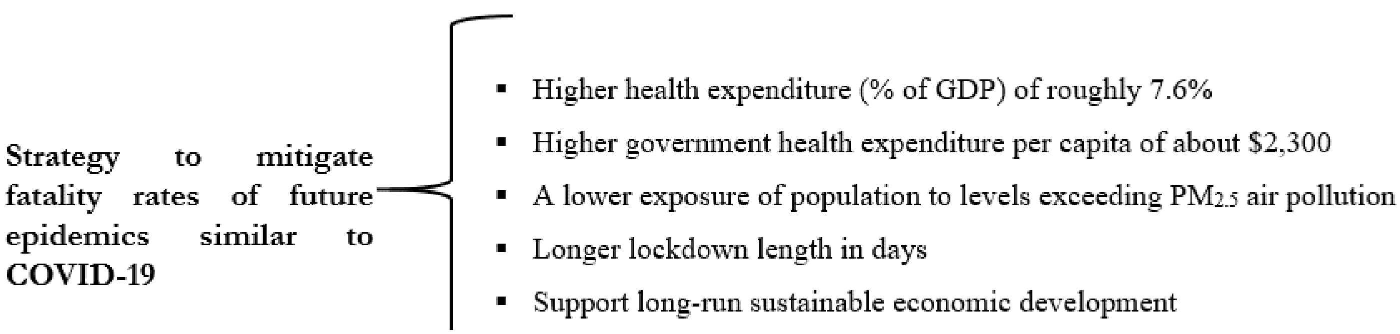

Figure 2

Factors determining a mitigation of fatality rates of COVID-19 to design future strategies to constrain pandemic crises of novel viral agents similar to Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that is the strain of coronavirus that causes coronavirus disease 2019 (COVID-19).