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EFFECTIVE HEALTH SYSTEMS FACING PANDEMIC CRISIS: LESSONS FROM COVID-19 IN EUROPE FOR NEXT EMERGENCIES

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Abstract:

Purpose: The investigation goal is the relation between healthcare expenditures and resources, and COVID-19 fatality rates among European countries to design effective health policies for crisis management.

Design/methodology/approach: Research methodology is based on descriptive statistics and various parametric methods, also including a linear model of regression to analyze basic relationships.

Findings: Results show that a lower COVID-19 fatality rate is associated with higher levels of health expenditure (% GDP), healthcare expenditure per capita, health expenditure in preventive care (% GDP), hospitals per million inhabitants, physicians, nurses, hospital beds and curative acute care beds per 1000 inhabitants. Regression analysis also shows that a 1% increase in healthcare expenditures per capita of countries, it reduces the level of COVID-19 fatality rate by 0.74%. In fact, many countries in Eastern Europe with low healthcare expenditures per capita in 2019 (e.g., Bulgaria, Romania, Hungary, Poland, Latvia, Slovakia, Lithuania, etc.), they have experienced high COVID-19 fatality rates. Instead, a lot of countries in Western Europe, with high healthcare expenditures per capita, such as Germany, Denmark, Austria, and the Netherlands, they had a resilient health systems and lower COVID-19 fatality rates.

Policy and Practical implications: These findings suggest strategies of systematic and continuous investments in healthcare, medical technologies, and ICT infrastructures to support effective health policy of crisis management in countries to face future pandemic crisis and other health emergencies in society.

Originality/value: The explanation of critical role of high health expenditure (% GDP) and healthcare expenditure per capita to support robust health systems that bolster the resilience in nations to face health emergencies.

Keywords: COVID-19 pandemic, Health systems, Health investments, Health policy, Public health, Governance, Resilience, Pandemic crisis, Health emergencies.

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1. Introduction and investigation goal

The COVID-19 pandemic (Coronavirus Disease 2019 caused by novel coronavirus SARS-CoV-2) has affected the whole world since the first months of 2020, driven by manifold environmental factors, causing high numbers of deaths and negative economic, health and social consequences (Amarlou and Coccia, 2023; Abel and Gietel-Basten, 2020; Bontempi et al., 2021; Bontempi and Coccia M., 2021; Chowdhury et al., 2022; Coccia, 2020, 2020c, 2020d, 2021, 2021a, 2021h, 2021g, 2021l, 2021m; Coccia, 2022, 2022g; Kargi et al., 2023, 2023a, 2023b, 2024; Núñez-Delgado et al., 2021; Tisdell, 2020; Uçkaç et al., 2023; Verma and Prakash, 2020). The negative effects of the novel coronavirus were initially countered by countries through a variety of non-pharmaceutical measures of control (e.g., lockdown, social distance, facemask wearing, etc.; cf., Akan and Coccia, 2022, 2023; Coccia, 2021b, c, d; Coccia, 2022) and basic health interventions and policies based on testing, monitoring and COVID-19 treatment guidelines considering the lack in 2020 of effective drugs and other treatments (Benati and Coccia, 2022). From the initial pandemic wave of COVID-19 in 2020 to 2023, there are differences in COVID-19 deaths and related infections between countries worldwide and also between European countries having similar health and inter-related socioeconomic systems (JHU, 2023; cf., Banik et al., 2020). Some countries in the presence of the COVID-19 pandemic have had lower deaths, though high numbers of related infections (Zhang et al, 2021; Soltesz et al., 2020; Brauner et al, 2020; Bo et al., 2021). However, many countries have experienced during initial waves of the COVID-19 pandemic, although containment and/or mitigation policies, high numbers of deaths, such as Italy, etc. (Coccia, 2023). In Europe, policy responses for COVID-19 in terms of mitigation and containment interventions, and medical treatment guidelines have been progressive homogenized to mitigate negative impact in society (Benati and Coccia, 2022a; Flaxman et al., 2020; Kluge et al., 2020; Sagan et al., 2021). In the year 2024, COVID-19 generates, in some countries, deaths with an annual mortality burden higher than a bad influenza season. In addition, many people continue to face severe short- or long-term consequences of COVID-19, and the threat of the evolution of a new variant of SARS-CoV-2 or similar vital agents, one that can evade vaccines and antivirals, remains very real in future (El-Sadr et al., 2023).

In this context, one of the fundamental problems is to explain why Case Fatality Rate (in short CFR[1] or fatality) of COVID-19 in some countries has had higher levels than other ones (Our World in Data, 2023). The literature examines several factors that can contribute to these differences in COVID-19 fatality rates across different regions and/or nations (Shakor et al., 2021; Sorci et al., 2020; Khan et al, 2020). The determinants of variability in fatality can be the structure of population, like size and age composition, income per capita and health status of people (Dowd et al., 2020; Sanyaolu et al., 2020; Cao et al, 2020), but also healthcare expenditure and capacity in countries (Khan et al, 2020; Upadhyay and Shukla, 2021). Cao et al. (2020) show that the size of a country's population and the density in cities are associated with an increased case fatality rate (CFR) of COVID-19. Age composition, of course, is also a relevant factor that affects the impact of COVID-19 in society (Coccia, 2020a). Older individuals with a lot of comorbidities are at high risk of developing severe COVID-19 consequences and of dying from this infectious disease (Elo et al., 2022; Kim et al., 2022). Levin (2020) maintains that the fatality rate for COVID-19 is very low for children and younger adults, but it increases progressively with age associated with a weak immune system. Wolff et al. (2020) pinpoint that age and comorbidities, such as obesity, diabetes, and hypertension are risk factors for severe and fatal COVID-19 (cf., Galvão et al., 2021; Sorci et al., 2020). Khan et al. (2020) show that an improved healthcare capacity is associated with a lower-case fatality rate for COVID-19. Coccia and Benati (2022a) suggest that the effective preparedness of countries is due to good governance that can foster a rapid rollout of vaccinations to cope with negative effects of pandemic impact (cf., Magazzino et al., 2022; Coccia, 2022c, d, e, 2023b). To put it differently, countries with good governance, better

[1] CFR (Case Fatality Rate) is simply the number of confirmed deaths divided by the number of confirmed cases.

healthcare system and a greater access of people to medical devices, such as medical ventilators and personal protective equipment (Coccia, 2023), are better equipped for crisis management of new airborne diseases, such as COVID-19, in order to reduce, whenever possible fatality rate (Coccia, 2023a).

However, the effective role of healthcare expenditures and other structural factors of health systems on the impact of COVID-19 in society are hardly known (Coccia and Benati, 2024; Rađenović et al, 2022).

In order to cover this gap and clarify this scientific problem, the study here examines the relationship between healthcare expenditures and COVID-19 case fatality rate in countries. Healthcare expenditures are basic factors of health systems because they represent the total amount of money spent in healthcare goods and services by organizations and governments (OECD, 2023). These healthcare expenditures include costs associated with medical services (such as doctor's visits, hospital stays, and diagnostic tests), prescription drugs, medical devices, public health programs of prevention, and health insurance (WHO, 2023a). Instead, healthcare capacity refers to the ability of the health system to provide medical care to individuals by healthcare facilities, such as hospitals, medical equipment, and related high-skill human resources (e.g., doctors, nurses, and other healthcare professionals; Roche, 2023). In this context, the capacity of a health system can be measured by the number of hospital beds, the number of medical professionals, the amount of medical equipment and supplies, etc. (OECD, 2023a-f).

This study focuses on European countries because they have homogenous and inter-related socioeconomic systems and stable structural indicators for robust and reliable statistical inquiries for appropriate comparative analyses of the relation between elements of the health system and COVID-19 impact in countries. The contribution here endeavors to explain whether and how health expenditures and capacity affect health management of COVID-19 pandemic crisis in terms of reduction of fatality. In particular, this study clarifies the following research questions:

- *Do* higher health expenditures reduce, associated with other factors, COVID-19 fatality rate at the beginning and during the COVID-19 pandemic crisis?
- *What* are the countries that have shown a better preparation and resilience to face COVID-19 pandemic crisis and minimize fatality rates, at the beginning when effective drugs and treatments lack?

Next section describes methods and data for quantitative analyses that clarify the relationship just mentioned.

2. Methods of inquiry

The principal goal of the present study is to see whether statistical evidence supports the working hypothesis that the level of COVID-19 fatality rate in 2022 (when pandemic crisis is almost over) between European countries can be explained by the levels of health expenditure until 2019, that can reinforce health systems and their resilience for crisis management. The research philosophy of the study is underpinned in literature of good governance that should support effective socioeconomic systems and also their resilience in the presence of crisis (Benati and Coccia, 2022; Coccia and Benati I.,2018; Kluge et al., 2020; Sagan et al., 2021).

2.1 Study design

- Sample and sources of data

The sample under study is 27 countries from the European Union. The choice of this sample is motivated by the need to consider countries that have a similar socioeconomic structure to build a homogenous sample for robust statistical analyses and reliable predictions. In particular, the sample includes the following European countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

- Measures of variables

This study analyzes variables concerning resources of the health system in European countries in specific years (2009 and 2019) to assess the level and change before the COVID-19 pandemic crisis (started in February 2020) and the relationship of these resources with case fatality rate of the COVID-19 (Our World in Data, 2023) in the years 2020 and 2022 (i.e., at the beginning and the end of pandemic crisis). The idea is to assess the effectiveness and resilience of health systems in countries to face pandemic crisis. The investment in the health system is measured with following variables: health expenditure as a share of GDP, total health care expenditures per capita and health expenditure in preventive care as a share of GDP. Instead, the health system capacity of countries under study is measured with following normalized variables: physicians, nurses, total hospital beds and curative (acute) care beds per 1,000 inhabitants, whereas data of hospitals are per million inhabitants. In table 1, the variables under study are described in detail, also pointing out the sources. Although some limitations in data, currently the selected variable are the best option to analyze effectiveness and functionality of health systems.

Table 1. Variables and sources

Variable, Acronym, source	Description
Health expenditure as a share of GDP, 2009 and 2019. OECD (2023)	Current expenditure on health (all functions), from all providers and financing schemes (Government and Voluntary)
Total health care expenditures per capita in current US$, 2009 and 2019. WHO (2023)	Per capita total expenditure on health, expressed in current US$.
Physicians per 1,000 inhabitants, 2009 and 2019. OECD (2023a)	Practicing physicians that provide services for individual patients. It includes: Practicing physicians who have completed studies in medicine at university level (granted by adequate diploma) and who are licensed to practice - Interns and resident physicians (with adequate diploma and providing services under supervision of other medical doctors during their postgraduate internship or residency in a health care facility)- Salaried and self-employed physicians delivering services irrespectively of the place of service provision - Foreign physicians licensed to practice and actively practicing in the country - All physicians providing services for patients, including radiology, pathology, microbiology, hematology, hygiene.
Nurses per 1,000 people, 2009 and 2019. OECD (2023b)	Practicing nurses that provide services directly to patients. It includes - Professional nurses, associate professional nurses, foreign nurses licensed to practice and actively practicing in the country
Total hospital beds per 1,000 inhabitants, 2009 and 2019. OECD (2023c)	Total hospital beds are all hospital beds which are regularly maintained and staffed and immediately available for the care of admitted patients. They are the sum of the following categories: a) Beds in publicly owned hospitals; b) Beds in not-for-profit privately owned hospitals; and c) Beds in for-profit privately owned hospitals.
Health expenditure in preventive care as a share of GDP, 2009 and 2019. OECD (2023d)	Current expenditure on health (all functions), from all providers and financing schemes (Government and Voluntary)
Hospitals per million inhabitants, 2009 and 2019. OECD (2023e)	Hospitals comprise licensed establishments primarily engaged in providing medical, diagnostic and treatment services that include physician, nursing, and other health services to inpatients and the specialized accommodation services required by inpatients. It includes: Inclusion - General hospitals - Mental health hospitals. Specialized hospitals (other than mental health hospitals).

(to be continued)

Table 1. Variables and sources (continue)

Variable, Acronym, source	Description
Curative (acute) care beds per 1,000 inhabitants, 2009 and 2019. OECD (2023f)	Curative care (acute care) beds in hospitals are hospital beds that are available for curative care. It includes: Beds accommodating patients where the principal clinical intent is to do one or more of the following: manage labor (obstetrics), cure illness or provide definitive treatment of injury, perform surgery, relieve symptoms of illness or injury (excluding palliative care), reduce severity of illness or injury, protect against exacerbation and/or complication of illness and/or injury which could threaten life or normal functions, perform diagnostic or therapeutic procedures - Beds for somatic curative (acute) care and psychiatric curative (acute) care (with a breakdown between these two categories) - Beds in all hospitals, including general hospitals, mental health hospitals and other specialized hospitals
Case fatality rate on 30 December 2020, JHU (2023)	The number of deaths in COVID-19 cases divided by the total number of people infected by COVID-19. The case fatality rate (CFR) is simply the number of confirmed deaths divided by the number of confirmed cases (Our World in Data, 2023)
Case fatality rate on 25 December 2022, JHU (2023)	The number of deaths in COVID-19 cases divided by the total number of people infected by COVID-19. The case fatality rate (CFR) is simply the number of confirmed deaths divided by the number of confirmed cases (Our World in Data, 2023)

- Statistical analysis procedure of the scientific experiment

Firstly, the variables in Table 1 are analyzed with descriptive statistics given by arithmetic mean, standard deviation, skewness and kurtosis to assess the distributions and their normality. Variables with distortions having high standard deviation are removed to have robust statistical analyses (Table 1A and 2A in Appendix).

Secondly, the average value of COVID-19 fatality rate in 2020 between European countries under study, when COVID-19 pandemic crisis started, is used to categorize the sample of countries in two groups (Coccia and Benati, 2018):

- Group 1: Countries with lower COVID-19 fatality rates in 2020 than sample arithmetic mean
- Group 2: Countries with higher COVID-19 fatality rates in 2020 than sample arithmetic mean

In addition, it is calculated, for variables of health system in Table 1, the arithmetic mean and rate of change from 2009 to 2019 to assess the dynamics of these factors in groups 1 and 2, before the emergence of COVID-19 pandemic crisis. The rate of change for variable *x* is given by:

$$\Delta change\ of\ variable\ x = \frac{(x\ in\ 2019 - x\ in\ 2009)}{x\ in\ 2009}$$

After that, the arithmetic mean of variables in groups 1 and 2 is calculated to assess differences inter-groups. The significance of differences in arithmetic mean between groups 1 and 2 is analyzed by using the Independent Samples *t*-Test. In order to analyze the assumption of homoscedasticity and how this might affect the results in terms of transparency and effectiveness, Levene's test is used to check the underlying assumption of homogeneity in variance (i.e., that both groups have the same variance), based on the following statistical hypotheses:

H_0: $\sigma_1^2 - \sigma_2^2 = 0$ (the population variances in groups 1 and 2 are equal)

H_1: $\sigma_1^2 - \sigma_2^2 \neq 0$ (the population variances in groups 1 and 2 are not equal)

If the results of Levene's test leads to a rejection of the null hypothesis, the conclusion is that the variances of two groups are not equal, and the assumption of homoscedasticity is violated.

The analysis of the assumption of homoscedasticity is follow-up by Independent Samples *t*-Test based on following statistical hypothesis:

H'_0: $\mu_1 = \mu_2$, the two-population means of group 1 and 2 are equal

H'_1: $\mu_1 \neq \mu_2$, the two-population means of group 1 and 2 are not equal

Finally, the relationship between a basic and comprehensive health factor (Total health care expenditures per capita) and COVID-19 case fatality rate between countries is analyzed with a simple regression analysis. Variables are expressed in natural logarithm (*ln*, logarithm with base *e* = 2.718281828) to reduce the variability of data for robust statistical analyses, clear interpretation of results in percent values and a better prediction model. The linear *ln*-*ln* model of regression analysis is:

$$y_i = \alpha_i + \beta x_i + u_i \quad [1]$$

y = *ln* COVID-19 case fatality rate in December 2022, when the pandemic is approaching to end
x = *ln* Total health care expenditures per capita in current US$ in 2019
u = error term
α = constant
β = coefficient of regression
ln= logarithm with base *e* = 2.718281828
i=countries

This *ln*-*ln* model has the goal to estimate the unknown parameters (α and β) and describe the relationship and how the predictor variable of healthcare expenditure per capita can explain the response variable of COVID-19 case fatality rate in December in 2022. The coefficient of regression β in ln-ln model is the estimated change in percent value of the dependent variable (y) for a one-unit change (1%) in a predictor variable (x), while holding all other predictors constant. This statistical analysis, with visual representation of regression line and scatter of data, can also show the level of vulnerability, preparedness and resilience of European countries to face COVID-19 pandemic and similar crises in future.

3. Results of statistical analyses

First of all, arithmetic mean (M) of case fatality rate on 30 December 2020, in the year when COVID-19 pandemic crisis starts is M= 1.98% (Standard Deviation, SD=0.86%). This average mean is used to categorize European countries in two groups as explained in research methodology:

- Group 1: Countries with ~~a~~ lower COVID-19 fatality rates in 2020 than sample arithmetic mean, M= 1.98%
- Group 2: Countries with ~~a~~ higher COVID-19 fatality rates in 2020 than sample arithmetic mean, M= 1.98%

The categorization shows the initial preparedness of European countries to face the pandemic crisis by reducing COVID-19 case fatality rate. Table 2 shows arithmetic mean of variables and rate of change of the two groups just mentioned. Statistical significance of the differences in arithmetic mean between groups 1 and 2 in Table 2 is analyzed by using the Independent Samples *t*-Test (and Levene's test). Results are in tables 3A and 4A (Appendix). Results of table 2 reveal that COVID-19 case fatality rate in group 1 is lower both in 2020 (1.40%) and 2022 (0.57%) than group 2 with an overall reduction from 2020 to 2022 by 59.29% compared to –57.24 of group 2 (that had 2.83% in 2020 and 1.21% in 2022). Group 1 with a lower COVID-19 case fatality rate has in the year 2019 higher levels of health expenditure % GDP, healthcare expenditure per capita, physicians per 1,000 inhabitants, nurses per 1,000 people, hospital beds per 1,000 inhabitants, health expenditure in preventive care (% GDP), hospitals per million inhabitants, and curative acute care beds per 1,000 inhabitants.

Table 2. Descriptive statistics per groups

	Countries with LOWER COVID-19 Fatality in 2020		Countries with HIGHER COVID-19 Fatality in 2020	
Variables	Mean	SD	Mean	SD
COVID-19 Case Fatality Rates 2020 %	1.40	0.44	2.83	0.54
COVID-19 Case Fatality Rates 2022 %	0.57	0.32	1.21	0.89
Difference COVID-19 Fatality 2022-2020	-0.84	0.42	-1.62	0.93
Health expenditure % GDP 2019	8.46	1.89	8.05	1.78
Healthcare Exp Per Capita $ 2019	$3,376.29	$2,014.03	$2,530.77	$1,749.05
Physicians per 1,000 inhabitants 2019	4.15	0.62	3.52	0.46
Nurses per 1,000 people 2019	8.98	2.45	6.47	2.48
Hospital beds per 1,000 inhabitants 2019	4.81	1.87	4.68	1.51
Health Exp in preventive care % GDP 2019	0.22	0.10	0.20	0.09
Hospitals per million inhabitants 2019	28.88	7.71	22.09	10.36
Curative acute care beds per1,000 inhabitants 2019	4.13	1.25	3.57	1.00
Δ change from 2009 to 2019	Mean	SD	Mean	SD
Δ Health expenditure % GDP	0.004	0.12	-0.05	0.13
Δ Healthcare Exp per Capita $	0.19	0.30	0.09	0.31
Δ Physicians per 1,000 inhabitants	-0.44	0.14	-0.49	0.30
Δ Nurses per 1,000 people	0.11	0.22	0.14	0.11
Δ Hospital beds per 1,000 inhabitants	-0.17	0.13	-0.08	0.06
Δ Health Exp in preventive care %GDP	0.12	0.54	-0.14	0.34
Δ Hospitals per million inhabitants	-0.09	0.21	-0.04	0.18
Δ Curative acute care beds per 1,000 inhabitants	-0.12	0.09	-0.06	0.07

Note: SD= Standard Deviation; Δ= variation from 2009 to 2019 to assess the change and dynamics of the health sector before the emergence of COVID-19 pandemic crisis.

The statistical analysis shows, *ictu oculi*, that countries with lower fatality rates had higher health expenditures across various indicators in 2019. In addition, the rate of change from 2009 to 2019 further supports this result, since group 1, with lower COVID-19 case fatality rate in 2020 has, compared to group 2 (with high COVID-19 fatality), a higher growth of health expenditure as % GDP, healthcare expenditure per capita and health expenditure in preventive care as % GDP, as well as group 1 presents a lower reduction of physicians per 1,000 inhabitants a main human resource in health system. In addition, Group 1 has also a lower growth of nurses per 1,000 people, and a higher reduction of hospital beds per 1,000 inhabitants, hospitals per million inhabitants and curative acute care beds per1,000 inhabitants. Hence, the empirical evidence, based on European countries, seems to support the working hypothesis that increased healthcare spending and investment in health sector are associated with a higher resilience, better pandemic response and lower fatality rates.

These results provide main information about the structure and operation of health system in European countries to face pandemic crisis. Policy implications are that countries with a lower COVID-19 case fatality rate, though a reduction of physical infrastructure given by hospitals and hospital beds, have increased health expenditure as % GDP and per capita, and expenditure in preventive care as % of GDP. The growth of these factors in health system suggests a higher level of investment in technologies and services that improve the preparedness and resilience to face health emergencies, such as COVID-19 pandemic crisis.

Table 3. Parametric estimates of the relationship, *ln*-*ln* model

Dependent variable	Constant α	Coefficient β_1	Standardized Coefficient Beta	R^2	F
Ln (COVID-19 case fatality rate December 2022, *N*=26)	5.35***	–0.74***		.54	28.96***

Note: *** p<0.001; Explanatory variable: Ln (Healthcare expenditures per capita in current US$ in 2019). Variable in natural logarithm, *ln* with base *e*.

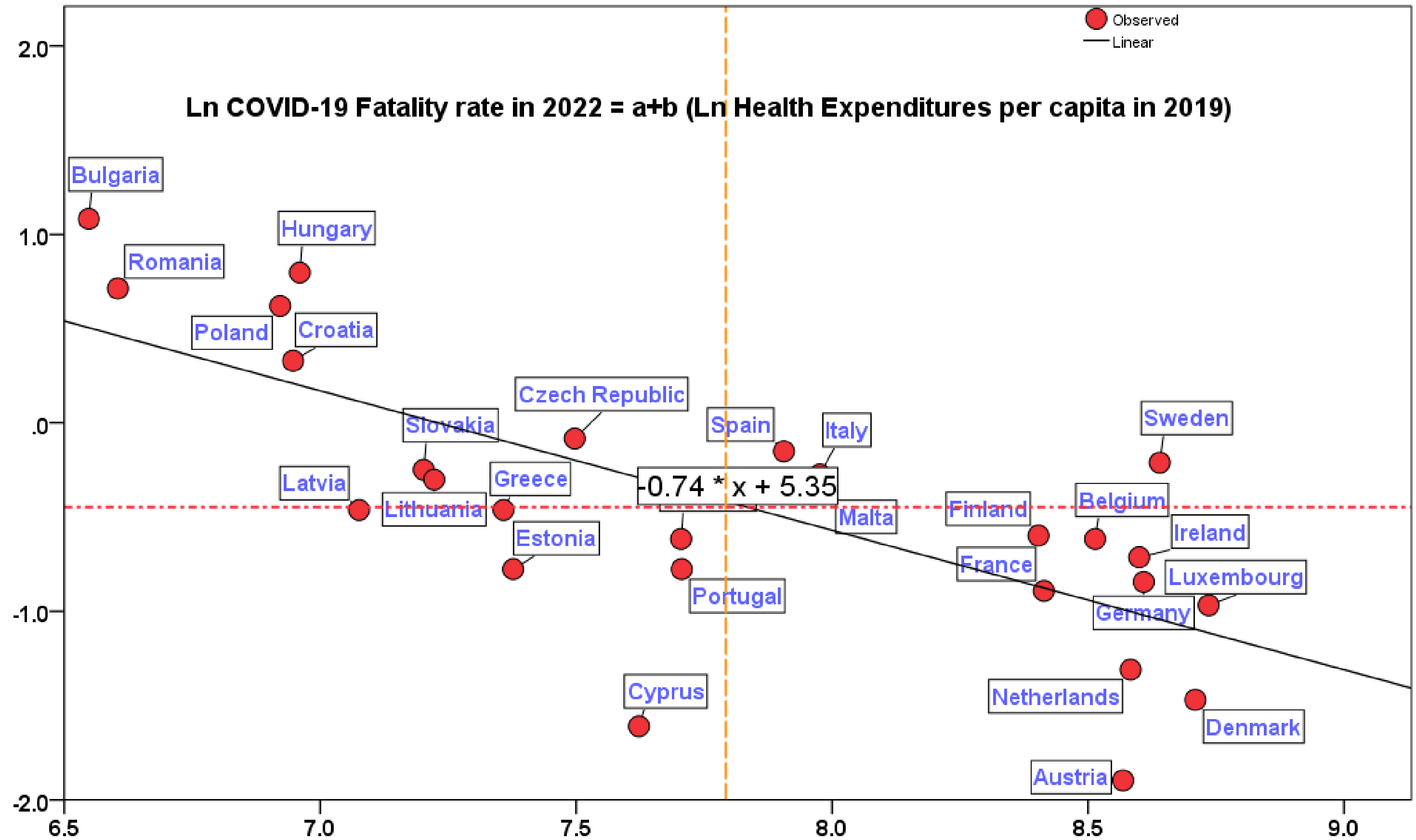

Figure 1. Regression line of *ln* COVID-19 case fatality rate in 2022 on *ln* healthcare expenditures per capita in current US$ in 2019. Variable in natural logarithm, *ln* with base *e*.

Regression analysis further confirms a significant inverse relationship between healthcare expenditures per capita in 2019 and COVID-19 fatality rates in 2022. Especially, the *ln-ln* model in table 3 considers the COVID-19 case fatality rate in 2022 between European countries as dependent variable and healthcare expenditures per capita in 2019 as predictor. The other variables of health system are not inserted in the model to avoid the statistical problem of multicollinearity. The estimated relationship provides robust and significant statistical results (table 3): a 1% increase of the healthcare expenditures per capita, it reduces the level of COVID-19 fatality rate by 0.74%. The coefficient R^2 is high and explains about 54% of variance in the data. The *F* value equal to

28.96 is significant (*p*-value<0.001), then independent variable (healthcare expenditures per capita) reliably predicts dependent variable (i.e., COVID-19 Fatality rate reduction %).

Figure 1, based on estimated relationship in Table 3, shows distinct patterns between Eastern and Western European countries:

- *LOW intensity in health expenditures* is mainly in countries of Eastern Europe (e.g., Bulgaria, Romania, Hungary, Poland, Latvia, Slovakia, Lithuania, etc.); they have lower healthcare expenditures per capita in 2019, before that COVID-19 pandemic crisis starts and have experienced very high COVID-19 fatality rate in 2022.

- *HIGH intensity in health expenditure* is in countries of Western Europe, such as Germany, Denmark, Austria, the Netherlands; they have higher levels in healthcare expenditures per capita in 2019 and lower COVID-19 case fatality rate.

This result suggests main health policy implications: a strategy of high levels of healthcare expenditures per capita and of course of investments in health system play a main role to support preparedness and resilience of countries to cope with unforeseen pandemic and minimize case fatality rates. Hence, the critical role of pre-pandemic investments in healthcare infrastructure and expenditures enhance preparedness and resilience to unforeseen health emergencies.

4. Discussion and policy implications of results

The dynamics and effects of COVID-19 pandemic in society are due to a variety of factors associated with environmental pollution, climate, public governance, institutions, healthcare system, national system of innovation, etc. (Allen Douglas, 2022; Angelopoulos et al., 2020; Ardito et al., 2021; Ball, 2021; Barro, 2020; Coccia, 2014, 2019; Goolsbee and Syverson, 2021; Haghighi and Takian, 2024; Homburg, 2020; Miranda et al., 2024; Sigh, 2024; Wieland, 2020). The group of Global Burden of Disease (2023) showed that COVID-19 pandemic highlighted gaps in health surveillance systems, disease prevention, technologies and treatment globally. Among the many factors that might have led to these gaps is the issue of the appropriate financing in national health systems. In 2019, at the onset of the COVID-19 pandemic, US$9·2 trillion was spent on health worldwide. However, there are great disparities in the amount of resources devoted to health sector, with high-income countries spending $7·3 trillion in 2019; 293·7 times the $24·8 billion spent by low-income countries in 2019 (cf., Ahmed et al., 2024). Projected spending estimates suggest that between 2022 and 2026, governments in 17 of the 137 low-medium income countries will observe an increase in national government health spending equivalent to an addition of 1% of GDP. Jacques et al. (2023) show that public health systems have been center stage during the COVID-19 pandemic, but governments have invested relatively little in public health in recent years also because of fiscal austerity applied in modern economic systems to slow public deficit and debts.

The analysis of the data here reveals, between European countries, that high investments in health system have vital role in the preparedness to face pandemic crises and in general emergencies (Coccia, 2020, 2022e). In particular, countries having *HIGH intensity in health expenditures* support a better resilience of health systems and effectiveness for crisis management. In fact, countries with higher health expenditures generally have better-equipped healthcare systems, which allow for earlier and more accurate diagnoses, more effective treatments, and a better health management in the presence of health emergencies that mitigates the fatality (Coccia, 2021, 2021a,b). In fact, results show that countries with a lower COVID-19 fatality rate have higher levels of health expenditure (% GDP) and healthcare expenditure per capita (including physicians, nurses, hospital beds, preventive care and curative acute care). These factors reinforce the health system and governance that lay the foundations for a greater preparedness and resilience to face emergencies (Haldane et al, 2019).

- Explanations of results with reference to previous research

Almeida (2024) suggests the existence of a trade-off between health system efficiency and health system resilience during the COVID-19 pandemic. Instead, supported by literature, empirical evidence here suggests that a good governance supports, associated with appropriate expenditures and investments, efficient and effective health infrastructure, disease surveillance systems and health policy responses that improve the prevention and management of outbreaks and related treatment patients (Coccia and Benati, 2024; Kluge et al., 2020; Sagan et al., 2020). Benati and Coccia (2022a) analyzed the relationship between public governance and COVID-19 vaccination policies during early 2021 and showed that the improvement of preparedness in countries, through good governance, can foster a rapid rollout of vaccinations to cope with pandemic threats and reduce negative socio-economic and health effects. Coccia (2023) shows that countries with better equipment in healthcare systems and a greater access of people to medical devices, such as high-tech ventilators or breathing devices (e.g., 26.76 units per 100,000 inhabitants), they have reduced COVID-19 case fatality rates. Moreover, countries with good governance have also implemented effective public health contact tracing systems, which can reduce, associated with other interventions, the spread of novel viral agents and protect vulnerable populations in the initial phase of pandemic wave (Benati and Coccia, 2022, Coccia, 2022a). Coccia and Benati (2024) maintain that high levels of public debt in countries trigger budget constraints that limit their ability to allocate resources to healthcare systems (e.g., health expenditures and investments), weakening health system performance and causing systemic vulnerability and lower preparedness during emergencies, such as with the COVID-19 pandemic. In this context, the group of Global Burden of Disease (2023) suggests that there is a unique opportunity to increase and sustain funding for crucial health functions, also including aspects for pandemic preparedness. In line with the results of this study, historical patterns of underfunding in health sector suggest that deliberate effort must be made to ensure that health funding is supported to improve preparedness to face next pandemics. The perspective of higher funding in health sector is directed at building resilient health systems for many European countries (Kluge et al., 2020). COVID-19 has shown us main lessons: we need substantial economic resources for health systems and national and subnational strategies to reinvigorate health systems with new investments to prevent negative effects of pandemics similar to COVID-19. Sagan et al. (2020) maintain that enhancing health system resilience is based on reinforcing expenditures for health systems functions and effective governance , not limited at the health sector, which is the adhesive factor to support overall effectiveness of public policies and related responses.

- Policy implications

Overall, the relationship between health expenditure and case fatality rate of COVID-19 highlights the importance of investing in healthcare systems and public health infrastructure, supported by good governance, for improving preparedness in crisis management and protecting population from the impact of new infectious diseases similar to COVID-19 (Benati and Coccia, 2022, 2022a; Coccia, 2022b, c, d). This evidence here also suggests that effective health system may not be solely determined by healthcare spending but from overall structure and governance of institutions (Coccia, 2018a, 2019; 2019c, 2021i). Therefore, investing in healthcare infrastructure and increasing health expenditures may be necessary but not sufficient conditions for a generalized improvement in health outcomes and preparedness to emergencies, because of other situational factors such as population density, age distribution, rate of insurance in some countries, etc. (Galvani et al., 2022; Fisman, 2022; Elo et al., 2023). In short, strong healthcare systems and high health expenditures are essential factors for protecting populations from infectious diseases like COVID-19, but these factors have to be put in a context of good governance to improve overall preparedness to face pandemic crises and lower fatality rates (Benati and Coccia, 2022; Sagan et al., 2020; Kluge et al., 2020). Benach et al. (2022) argue that to ensure preparedness for future crises, it is also important investments for reducing health inequalities between and within countries (cf., Smith et al., 2023).

Overall, then, higher health expenditures support the health system resilience that nowadays has expanded the function to also consider how to minimize exposure to shocks (i.e., managing risks) and to identify measures that address more predictable and enduring system strains or stresses, such as epidemics. Of course, a higher level of health investment and improvement of governance have to go beyond the governance of the health system alone but involve different institutions and structures of government. Investments in health system should be also directed to organizational aspects, such as strengthening coordination channels and plans drawn (and kept up to date) to ensure an effective response to emergencies. In addition to reinforcing expenditures and investments at national level, also overall European Union has to increase investment to reinforce common surveillance systems, joint procurement initiatives, and targeted funding in health sector (Legido-Quigley et al., 2020). European countries, operating in a homogenous economic context can benefit, in the presence of crises, from better global surveillance and notification systems; more cooperation in procurement; stronger cooperation in medical research and technologies (for example, for vaccine development and diffusion); sharing of best practices (with European professional societies and the WHO having a role); and better common governance (Coccia, 2018).

5. Concluding remarks

In the presence of pandemic crises, one of the goals of nations is to mitigate mortality and support the socioeconomic system (Coccia, 2021). Studies analyze different public policies to cope with the spread of COVID-19 but the role of previous level in health expenditures to explain negative effects, given by deaths, is hardly known.

Results of the study here suggest a clear policy imperative to effectively cope with pandemics:

- Prioritize a strategy of continuous and substantial investments in healthcare infrastructure, including technologies, staffing, and training of human resources that can contribute to increased preparedness and resilience.
- Design appropriate and effective governance for crisis management
- A systematic planning directed not only in addressing immediate healthcare needs but also considering long-term investments to enhance a nation's ability to respond to unforeseen emergencies.
- Between European countries, 1% increase of the healthcare expenditures per capita can reduce the level of fatality rate by 0.74%, improving the resilience of countries to face pandemic crises similar to COVID-19.

In general, the strategy for improving the preparedness and resilience of nations to face new pandemic crisis should be based on a systemic approach, going beyond strengthening national health systems, and incorporating common best practices of good governance that can reduce the variability of COVID-19 fatality rates between European countries (Coccia, 2019a, 2019b; Penkler et al., 2020). This systemic approach is important since Europe is a based on interconnected and inter-related socioeconomic systems, of which the health system is just one. In short, strategies directed to increase expenditures and investments in health sectors have not to be isolated public policy, but they have to be part of broader and systemic multi-sectorial approaches to effectively enhance the overall health system resilience of countries and overall European area (McKee, 2020; Sagan et al., 2020; cf., Coccia, 2023, 2023a). To put it differently, the preparedness of countries for next pandemic crises should be oriented to strengthening health system with higher expenditures and incentive systems, to cope with future emergencies, especially when effective drugs to treat patients with new respiratory illness are missing (Coccia, 2019b, 2021b; Kluge et al., 2020; Kapitsinis, 2020). Hence, considering results of the study here, a basic aspect to cope with pandemics is a systematic planning, which should consider continuous investments in health sector to support infrastructure, equipment and human resources. Overall, then, results of this analysis here seem to suggest that in the first pandemic wave of COVID-19, countries with a high investment in health sector and high healthcare expenditure per capita experienced a lower-case fatality rate of COVID-19. The findings here suggest a general strategy of crisis management for future pandemic threats based on high levels of investments in healthcare sector also focused on widespread implementation of new technologies (such as high-tech medical ventilators) for improving national performance in health emergencies and supporting the overall preparedness of countries to cope with negative effects of pandemic impact on health of people and socioeconomic system (Coccia, 2016, 2020b; 2021, 2021a, b, c). In this context, Götz et al. (2024) show the importance of including supply chain strategies as part of the preparedness and response policies to contribute to health system resilience.

- Limitations and future research

These conclusions are, of course, tentative. Although this study has provided some interesting, albeit preliminary results, it has limitations. First, potential data limitations may concern data quality and reliability. The accuracy and completeness of COVID-19 reporting may vary between countries, affecting the reliability of fatality rates utilized in the analysis. Second limitation is the diversity in Healthcare Systems: different healthcare financing structures, accessibility, and efficiency across European countries may not be fully captured by expenditure data alone, which can influence the study's outcomes. Third, the aggregate health expenditure might not reflect the specific allocation of funds, such as the amount spent on critical care, public health measures, or emergency preparedness, which could be more directly related to COVID-19 outcomes. Fouth, sources understudy may only capture certain aspects of the ongoing dynamics in health system over time. Finally, there are multiple confounding factors that could have an important role in the dynamics of health systems to be further investigated, such as level of public debt, administrative governance of health systems, coordination between local and national competencies in health systems, etc.

Hence, in the presence of rapid changes, there is need for much more research on these topics because not all the confounding factors that affect the relationship between COVID-19 fatality rates and level of health expenditures and capacity are analyzed and discussed. The follow-up investigation can be based on new factors of health system and methods of inquiry to clarify the factors determining lower health expenditures in some European countries that increase vulnerability to unforeseen emergencies. To conclude, the finding here can be the starting point for designing a general and long-run strategy of crisis management to support preparedness and resilience of nations to face health emergencies and reduce negative effects of next pandemic crises similar to COVID-19.

APPENDIX

Table 1A. Descriptive statistics (Mean, Std. Deviation, Skewness and Kurtosis) in European countries

	Mean	**Std. Deviation**	**Skewness**	**Kurtosis**
Case Fatality Rate % 2020	1.98	0.86	0.37	-0.51
Case Fatality Rate % 2022	0.83	0.68	1.81	2.91
Health expenditure as a % of GDP 2019	8.29	1.82	0.27	-1.21
Health expenditure as a % of GDP 2009	8.47	1.71	0.01	-1.12
Healthcare Expenditure per capita $ 2019	3,031.82	1,922.50	0.41	-1.52
Healthcare Expenditure per capita $ 2009	2,911.75	2,030.88	0.57	-0.68
Physicians per 1,000 inhabitants 2019	3.85	0.62	0.73	-0.01
Physicians per 1,000 inhabitants 2009	7.59	2.55	0.20	-1.09
Nurses per 1,000 people 2019	8.08	2.67	-0.28	-1.22
Nurses per 1,000 people 2009	7.59	2.55	0.20	-1.09
Total hospital beds per 1,000 inhabitants 2019	4.76	1.69	0.17	-1.17
Total hospital beds per 1,000 inhabitants 2009	5.47	1.71	-0.23	-1.31
Health expenditure in preventive care as % of GDP 2019	0.21	0.09	0.64	-0.07
Health expenditure in preventive care as % of GDP 2009	0.22	0.13	-0.07	-0.43
Hospitals per million inhabitants 2019	25.83	9.40	0.54	-0.66
Hospitals per million inhabitants 2009	28.36	10.65	1.02	0.78
Curative acute care beds per 1,000 inhabitants 2019	3.88	1.15	0.26	-1.26
Curative acute care beds per 1,000 inhabitants 2009	4.49	1.44	-0.12	-1.77

Table 2A. Descriptive statistics (mean, Std. Deviation, Skewness and kurtosis) in European countries of group 1 and group 2

Countries with Lower case fatality rate	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
Case Fatality Rate % 2020	1.40	0.44	-0.58	-0.94
Case Fatality Rate % 2022	0.57	0.32	0.98	1.45
Health expenditure as a % of GDP 2019	8.46	1.89	0.15	-1.34
Health expenditure as a % of GDP 2009	8.43	1.64	0.27	-1.25
Healthcare Expenditure per capita $ 2019	3376.29	2014.03	0.24	-1.89
Healthcare Expenditure per capita $ 2009	3119.79	2192.71	0.65	-0.78
Physicians per 1,000 inhabitants 2019	4.15	0.62	0.42	0.55
Physicians per 1,000 inhabitants 2009	8.65	2.40	-0.15	-1.34
Nurses per 1,000 people 2019	8.98	2.45	-0.88	-0.18
Nurses per 1,000 people 2009	8.65	2.40	-0.15	-1.34
Total hospital beds per 1,000 inhabitants 2019	4.81	1.87	0.16	-1.22
Total hospital beds per 1,000 inhabitants 2009	5.73	1.78	-0.40	-1.14
Health expenditure in preventive care as % of GDP 2019	0.22	0.10	0.31	-0.67
Health expenditure in preventive care as % of GDP 2009	0.21	0.14	0.05	-0.78
Hospitals per million inhabitants 2019	28.88	7.71	0.23	-0.15
Hospitals per million inhabitants 2009	32.93	10.27	1.13	1.10
Curative acute care beds per 1,000 inhabitants 2019	4.13	1.25	0.08	-1.63
Curative acute care beds per 1,000 inhabitants 2009	5.11	1.28	-0.77	-1.35

Countries with Higher case fatality rate	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
Case Fatality Rate % 2020	2.83	0.54	0.49	-1.20
Case Fatality Rate % 2022	1.21	0.89	0.94	-0.58
Health expenditure as a % of GDP 2019	8.05	1.78	0.49	-0.82
Health expenditure as a % of GDP 2009	8.53	1.89	-0.28	-0.92
Healthcare Expenditure per capita $ 2019	2530.77	1749.05	0.63	-1.13
Healthcare Expenditure per capita $ 2009	2609.13	1828.01	0.23	-1.37
Physicians per 1,000 inhabitants 2019	3.52	0.46	1.41	0.75
Physicians per 1,000 inhabitants 2009	6.07	2.04	0.63	-0.11
Nurses per 1,000 people 2019	6.47	2.48	0.71	2.06
Nurses per 1,000 people 2009	6.07	2.04	0.63	-0.11
Total hospital beds per 1,000 inhabitants 2019	4.68	1.51	0.10	-1.61
Total hospital beds per 1,000 inhabitants 2009	5.09	1.63	-0.15	-1.74
Health expenditure in preventive care as % of GDP 2019	0.20	0.09	1.41	3.22
Health expenditure in preventive care as % of GDP 2009	0.22	0.11	-0.30	1.31
Hospitals per million inhabitants 2019	22.09	10.36	1.61	1.99
Hospitals per million inhabitants 2009	22.78	8.59	1.78	3.67
Curative acute care beds per 1,000 inhabitants 2019	3.57	1.00	0.19	-1.81
Curative acute care beds per 1,000 inhabitants 2009	3.63	1.30	0.85	-1.25

Table 3A. Independent Samples Test based on average mean of variables in European countries of group 1 and group 2

Variables		Levene's Test for Equality of Variances		t-test for Equality of Means		
	Equal variances	***F***	**Sig.**	**t**	**df**	**Sig.(2-tailed)**
Health expenditure % GDP 2019 in countries of group 1 and group 2	assumed	0.548	0.466	0.573	25	0.572
	not assumed			0.579	22.461	0.568
Healthcare Exp Per Capita $ 2019 in countries of group 1 and group 2	assumed	2.095	0.16	1.129	25	0.270
	not assumed			1.16	23.515	0.258
Physicians per 1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	0.401	0.536	2.384	15	0.031
	not assumed			2.427	14.602	0.029
Nurses per 1,000 people 2019 in countries of group 1 and group 2	assumed	0.273	0.611	1.833	12	0.092
	not assumed			1.828	8.317	0.104
Hospital beds per 1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	0.821	0.376	0.179	20	0.860
	not assumed			0.186	19.428	0.854
Health Exp in preventive care % GDP 2019 in countries of group 1 and group 2	assumed	0.806	0.378	0.509	25	0.615
	not assumed			0.523	23.53	0.606
Hospitals per million inhabitants 2019 in countries of group 1 and group 2	assumed	0.621	0.441	1.683	18	0.110
	not assumed			1.632	14.508	0.124
Curative acute care beds per1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	0.882	0.364	0.967	14	0.350
	not assumed			0.996	13.973	0.336

Note: Group 1 is Countries with LOWER COVID-19 case fatality rate in 2020; Group 2 is Countries with HIGHER COVID-19 case fatality rate in 2020. Significance of results does not change with Bonferroni correction that is most appropriate one-way ANOVA and three groups. df= degrees of freedom

Table 4A. Independent Samples Test based on average mean of change of variables from 2009 to 2019 in European countries of group 1 and group 2

Δ= the rate of change from 2009 to 2019		Levene's Test for Equality of Variances		t-test for Equality of Means		
	Equal variances	***F***	**Sig.**	**t**	**df**	**Sig.(2-tailed)**
Health expenditure % GDP 2019 in countries of group 1 and group 2	assumed	0.003	0.958	1.049	25	0.304
	not assumed			1.031	20.271	0.315
Healthcare Exp per Capita $ 2019 in countries of group 1 and group 2	assumed	0.214	0.648	0.828	25	0.416
	not assumed			0.826	21.541	0.418
Physicians per 1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	3.165	0.099	0.373	13	0.715
	not assumed			0.357	8.364	0.730
Nurses per 1,000 people 2019 in countries of group 1 and group 2	assumed	0.789	0.394	-0.332	11	0.746
	not assumed			-0.386	10.705	0.707
Hospital beds per 1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	4.21	0.054	-1.966	20	0.063
	not assumed			-2.24	17.443	0.038
Health Exp in preventive care % GDP 2019 in countries of group 1 and group 2	assumed	1.58	0.222	1.326	22	0.199
	not assumed			1.43	21.728	0.167
Hospitals per million inhabitants 2019 in countries of group 1 and group 2	assumed	0.19	0.668	-0.562	18	0.581
	not assumed			-0.573	17.986	0.574
Curative acute care beds per1,000 inhabitants 2019 in countries of group 1 and group 2	assumed	0.31	0.59	-1.442	10	0.180
	not assumed			-1.487	9.611	0.169

Note: Group 1 is Countries with LOWER COVID-19 case fatality rate in 2020; Group 2 is Countries with HIGHER COVID-19 case fatality rate in 2020. Significance of results does not change with Bonferroni correction that is most appropriate one-way ANOVA and three groups. df= degrees of freedom

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