Preparedness of countries to face COVID-19 pandemic crisis: Strategic positioning and factors supporting effective strategies of prevention of pandemic threats

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A B S T R A C T

The Coronavirus Disease 2019 (COVID-19) continues to generate a constant pandemic threat with new mutations of the viral agent (SARS-CoV-2) that create socioeconomic issues. One of the fundamental problems is the evaluation of the preparedness of countries to cope with COVID-19 pandemic crisis to detect and support factors associated with the reduction of mortality and the growth of vaccinations in society. The study here confronts this problem by developing two basic indexes, which measure the performance of countries to face pandemic threats. In particular, the Index *r* (as *resilience*) detects the countries having the best performance in the reduction of the negative impact of mortality related to COVID-19 pandemic and the Index *p* (as *preparedness* and *prevention*) assesses best-performer countries to support COVID-19 vaccinations in order to constrain future pandemic threats and support the recovery of socioeconomic systems. Index of *resilience* is a composite measure based on three indicators associated with COVID-19, given by average mortality, hospital occupancy and Intensive Care Units occupancy per 100 000 people, producing an overall score; Index of *preparedness/prevention* is a composite measure of two indicators related to COVID-19 vaccinations (i.e., doses of vaccines administered and total vaccinates per 100 000 people), producing also an overall score of performance. The application of these indexes on a case study of European countries, having a homogenous socioeconomic area, shows the strategic positioning of countries to cope with a major pandemic threat. Findings reveal that all countries have some weaknesses and no country has a high preparedness to cope with a major epidemic or pandemic. Moreover, results suggest that best-performer countries to cope with COVID-19 pandemic crisis have a smaller size of population and/or better public governance, associated with high expenditures in health system. These indexes can help policymakers for designing effective strategies to improve preparedness and prevention of countries to face future pandemic threats.

1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the novel Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which appeared in late 2019 (Coccia, 2020, 2020a). COVID-19 is still circulating in 2021 with mutations of the novel coronavirus (e.g., Delta and Kappa variants) that continue to generate a constant pandemic threat for upcoming seasons in manifold countries (Johns Hopkins Center for System Science and Engineering, 2021; World Health Organization, 2021). One of the fundamental problems in COVID-19 pandemic crisis is the measurement of preparedness of countries to cope with pandemic threats. In this context, scholars and institutions endeavor to analyze, categorize and assess the reaction capability of

countries considering a variety of measures to face pandemic threats (Coccia, 2020a, 2020b; Coccia, 2021, 2021a, Coccia, 2021a,b,g,h; Hale et al., 2021; Lowy Institute, 2021). Although manifold studies, how measure the preparedness of countries and how explain critical factors affecting their performance to cope with COVID-19 pandemic crisis and similar infectious diseases in society are aspects hardly known. This study has the principal goal to propose two indexes for a comparative evaluation system that detects the best and worst performer countries to face COVID-19 pandemic threat for digging driving factors of better preparedness. In particular, the first index quantifies and assesses the countries with the best performance to reduce the negative impact of COVID-19 pandemic in terms of mortality; the second index measures the performance of countries to prevent the diffusion of future epidemics

of the COVID-19 with vaccinations in society. This study focuses on data of European countries having a homogeneous socioeconomic area. Results here show the strategic positioning of countries in the handling of the COVID-19 pandemic crisis in order to determine, whenever possible, structural factors associated with a better preparedness to support policy responses for constraining negative effects given by higher mortality of the COVID-19 and similar infectious diseases in society.

The crux of the study here is rooted in the concept of performance and comparative evaluation system and some brief backgrounds are useful to understand and clarify these topics. Coccia and Benati (2018) argue that an evaluation system is a systematic process for data collection, measurement, and analysis of the characteristics of different entities to generate a final rating that supports decision making processes of stakeholders for specific goals (Coccia and Benati, 2018). In addition, an evaluation system is based on a stable set of tools to compare different units (organizations, countries, etc.) over time and space. In particular, a comparative performance system is a set of elements and processes to assess the capability of individuals, organizations, and other subjects to achieve strategic goals using, as benchmark, the performance of similar subjects and/or the previous performance of the unit itself. A comparative performance system supports decision-making of managers and policymakers directed to accomplish strategic targets (Benati and Coccia, 2019). These concepts provide a theoretical framework for creating new indexes to measure the preparedness of countries and ranking their performance to cope with pandemic threats, such as COVID-19.

In fact, the measurement of performance by countries in the presence of COVID-19 outbreaks is a basic aspect to support best practices of prevention of future pandemic threats. The University of Oxford suggests the Stringency Index, which assesses the strictness of 'lockdown' policies (with a range from 0 to 100, 100 = strictest) based on different measures of restriction (e.g., school closures, social distancing, travel bans, etc.; cf., Hale et al., 2021). On July 2021, some countries have very high values of stringency, such as Italy, Portugal, Spain, Germany, etc. In this context, another measure is the Global Health Security Index that categorizes the preparedness of countries to face a biological threat on a variety of indicators (Cameron et al., 2019). The United States of America and the UK were ranked in 2019 at the first and second position in the Global Health Security Index suggesting a strong capability of these countries to face a major biological threat, such as a pandemic (Stribling et al., 2020). Lowy Institute (2021) also suggests rankings of the relative performance of countries at different phases of the evolution of COVID-19 pandemic considering a variety of indicators. Anttiroiko (2021) analyzes how socioeconomic context, institutional arrangement, culture, and technology level can affect policy responses to the COVID-19 pandemic in Eastern and Western countries (Coccia, 2018, 2019a, 2019). The study reveals that Asian countries reflect proactivity of interventions, whereas Western countries provide reactive policy responses (cf., Coccia, 2021b). In general, crisis management of COVID-19 pandemic is based on an effective multi-level governance, combining both national, regional and urban institutions to provide timely policy responses in society (Anttiroiko, 2021; Stribling et al., 2020; Coccia, 2021). Studies also show that in average, policy responses in Europe tend to be less stringent than countries in East Asia (Ritchie et al., 2020). Abuza (2020) argues that the effectiveness of policies in the presence of biological threats is based on leadership and competence, rather than political systems of countries. Moreover, Anttiroiko (2021) highlights that Asian countries have applied with determination policy responses to face COVID-19 crisis because of the early diffusion of pandemic in their regions that has induced learning processes for improving capabilities of crisis management. In fact, successful policy responses among Asian countries are due to early travel restrictions, quarantine arrangements, effective social distancing, associated with efficient healthcare systems. Instead, European countries have different culture, institutions, political systems and approaches to cope with crises, and they have also to face with privacy and human rights issues, protests against governments for businesses closures and other restrictions,

vaccine hesitancy in population, etc.; all these factors slow down the implementation and effectiveness of policies to reduce negative effects of COVID-19 crisis and similar pandemic threats (Anttiroiko, 2021; Coccia, 2021c). Bontempi (2020a,b) argues that in the presence of COVID-19 crisis, it is important to promote interdisciplinary research studies that are able to analyze the problem from different perspectives (cf., Anand et al., 2021). Bontempi (2020a, p. 2) also suggests that a more exhaustive and comprehensive approach to the analysis of the COVID-19 can be achieved by considering different parameters that may be not strictly related to healthcare sector (cf., Bontempi et al., 2020). In fact, factors associated with governance of countries play a vital role for the management of policy responses and rollout of vaccines (Glatman-Freedman et al., 2010). Kjar (2004, p.10-11) argues that: "governance is the capacity of government to make and implement policy, in other words, to steer society". Worldwide Governance Indicators (2021) states that: "Governance consists of the traditions and institutions by which authority in a country is exercised. This includes … the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them". The role of public governance is shared between government, public administration, and other economic and institutional organizations and plays a basic role for crisis management (Coccia, 2021b; Glatman-Freedman and Nichols, 2012).

Hence, the pandemic of COVID-19 and future epidemics/pandemics of similar viral agents challenge global societies that are susceptible to infectious diseases. In a more and more global environment of the world, it important to design composite measures based on simple indicators to assess performance of countries that can help the decisionmaking of policymakers in the presence of biological threats in order to analyze the sources of better preparedness to support effective policy responses that contain and/or prevent negative effects of future pandemics on health of people and operation of socioeconomic systems.

2. Methods and materials

2.1. Case study

The novel Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is the viral agent causative the Coronavirus Disease 2019 (COVID-19) that has generated a pandemic crisis worldwide (Coccia, 2020, 2021a).

2.2. Proposed metrics for assessing resilience and preparedness/ prevention of countries to cope with pandemic threats

The principal indicators associated with COVID-19 pandemic are assumed to be:

☐ *Indicator* 1: Average mortality rate is given by (number of deaths divided by population of country) × 100 000 inhabitants from February 2020 to February 2021. Lau et al. (2021) argue that the level of mortality related to COVID-19 can be a precise indicator of the negative impact in society, reducing whenever possible under reporting and/or under detection of COVID-19 cases. Source of data: Johns Hopkins Center for System Science and Engineering (2021).

☐ *Indicator* 2: Daily hospital occupancy × 100 000 inhabitants, using average daily data of country from February 2020 to February 2021. Daily hospital occupancy indicates the number of COVID-19 patients in hospitals on a given day (including patients with different COVID-19 symptoms). This indicator provides main information about the impact of infectious disease on health systems and as a consequence in society (Faes et al., 2020). Source: European Centre for Disease Prevention and Control (2021).

☐ *Indicator* 3: Intensive Care Units (ICUs) occupancy × 100 000 inhabitants, using average daily ICU data of country from February 2020 to February 2021. Daily ICU occupancy is the number of COVID-19

patients in ICUs on a given day. This indicator also provides main information about the impact of pandemic on health systems of countries. Source: European Centre for Disease Prevention and Control (2021).

☐ *Indicator* 4: Doses of vaccines administered × 100 000 inhabitants at February-March 2021 between countries. Vaccinations refer to the total number of vaccine doses, considering that an additional dose may be obtained from each vial (e.g. six doses for Pfizer BioNTech® Comirnaty), whereas number of doses administered refers to any individual receiving any dose of the COVID-19 vaccines (cf., Freed, 2021; Oliver et al., 2020). Source: Our World in Data (2021).

☐ *Indicator* 5: Total vaccinates × 100 000 inhabitants at February–March 2021 between countries (cf., Dooling et al., 2020; Cylus et al., 2021; GOV.UK, 2021; NHS, 2021). Sources: Lab 24 (2021), Our World in Data (2021).

The five indicators just mentioned create the structure of two suggested indexes: Index *r* (as *resilience*) and Index *p* (as *preparedness* and *prevention*) of countries.

2.3. Index r (as resilience) of countries to pandemic threat

☐ Index *r* measures the capacity of reaction of health system and in general of a country to minimize the negative impact of infectious disease in society in terms of mortality rate.

Let Indicator i ($i = 1, 2, 3$), just mentioned, observed per j units with $j = 1, …, n$ countries.

In particular, F1j = Average daily mortality rate × 100 000 inhabitants in country j

F2j = Average daily hospital occupancy × 100 000 inhabitants in country j

F3j = Average daily Intensive Care Units (ICUIs) occupancy × 100 000 inhabitants in country j

$j = 1, …, n$ countries

Let

$$I_{1j} = \frac{F1j}{100\ 000}\ with\ 0 < I_{1j} < 1$$

$$I_{2j} = \frac{F2j}{100\ 000}\ with\ 0 < I_{2j} < 1$$

$$I_{3j} = \frac{F3j}{100\ 000}\ with\ 0 < I_{3j} < 1$$

Remark. As indicators F i,j are per 100 000 inhabitants for a comparative analysis between countries, to have normalized indicators Ii,j that vary in the range [0, 1], they are divided by the natural number 100 000.

For country j, in the period t

$$Index\ r\ (resilience)j = \sum_{i=1}^{3} \frac{Iij}{3}\ with\ 0 < Index\ r, j < 1;\ j = 1, …, n\ countries$$

(1)

The ranking of the Index *r* for *j* countries is in increasing order and indicates the performance of health system of countries, in the presence of an unforeseen pandemic threat, to minimize the mortality; this composite measure (Index *r*) of three indicators *I 1,2,3* ranging between 0 and 1 has the same range of values given by [0,1]; in particular:

- Index *r, j* = 0 indicates the best performer country *j* in terms of resilience, minimizing the mortality of COVID-19.
- Index *r, j* = 1 indicates the worst performer country *j* in terms of resilience, not minimizing the mortality of COVID-19.

The arithmetic mean of the index of resilience in the sample is used to categorize countries in two groups:

☐ *Best resilient countries* have a high capability (performance) to adapt in the presence of pandemic threat to reduce negative effects in society (e.g., reduce the mortality rate). These countries have performance higher than arithmetic mean of the sample.

☐ *Worst resilient countries* have a low capability (performance) to adapt in the presence of pandemic threat and do not constrain negative effects in society (e.g., having high levels of mortality rate). Countries have performance lower than arithmetic mean of the sample.

2.4. Index p (as preparedness and prevention) of countries to pandemic threat

Index *p* measures the capability of countries to stop and/or reduce the impact of future outbreaks of infectious diseases by maximizing the vaccinations directed to support rapidly a normal operation of economic system to satisfy population needs.

Let Indicator i ($i = 4, 5$), mentioned above, observed per j units with $j = 1, …, n$ countries. In particular, here:
F4j = Average daily doses of vaccines administered × 100 000 inhabitants in country j
F5j = Average daily vaccinates × 100 000 inhabitants in country j

Iij is composed by:

$$I_{4j} = \frac{F4j}{100\ 000}\ with\ 0 < I_{4j} < 1$$

$$I_{5j} = \frac{F5j}{100\ 000}\ with\ 0 < I_{5j} < 1$$

Remark. As indicators Fi,j also here are per 100 000 inhabitants for a comparative analysis between countries, to have normalized indicators Ii,j that vary in the range [0, 1], they are divided by the natural number 100 000.

For country j, in the period t,

$$Index\ p\ (prevention)j = \sum_{i=4}^{5} \frac{Iij}{2}\ with\ 0 < Index\ p, j < 1;\ j = 1, …, n\ countries$$

(2)

As the goal is the maximization of vaccinations, the ranking of the Index *p* for *j* countries is in decreasing order and indicates the performance of countries to stop and/or reduce the impact of future pandemic threats, supporting a vast diffusion of vaccinations for leading rapidly to a normal operation of socioeconomic system. In addition, this composite measure *p* based on two indicators, ranging between 0 and 1, has the same range of variation given by [0,1]. In this case,

- Index *p, j* = 1 indicates the best performer country *j* with a high proactive capability to stop future epidemics by effective vaccination plan directed to support a recovery of socioeconomic system.
- Index *p, j* = 0 indicates the worst performer country *j* with a low capacity of reaction and adaptation to stop negative effects and/or prevent future pandemic threats with effective vaccination campaign, generating consequential damages for socioeconomic systems.

The arithmetic mean of the index of *preparedness* and *prevention* in the sample under study is used to categorize countries in two groups:

☐ Countries with *best preparedness* have a prompt reaction to cope with future pandemic threats by appropriate strategies directed to support vaccinations. Countries have a performance higher than arithmetic mean of the sample.

□ Countries with *worst preparedness* have a delayed reaction to cope with pandemic threats by not implementing effective strategies of vaccination directed to reduce negative effects in society. Countries have a performance lower than arithmetic mean of the sample.

Properties of the indexes *r* and *p*

- *Range of variation*. Indexes have a range of variability in the set of real numbers given by [0, 1]
- *Transitive property*. If $F_{i, j} \leq F_{i, j+1} \Rightarrow$ indexes $_{i, j} \leq$ indexes $_{i, j+1}$
- *Symmetry property*. If $F_{i,j} = F_{i,j+1} \Rightarrow$ indexes $_{i,j} =$ indexes $_{i,j+1}$
- *Substitution property*. If $F_{i,j} = F_{i,j+1} \Rightarrow F_{i,j}$ can be substituted in for $F_{i,j+1}$ in any formula of indexes $_{i, j}$ and vice versa, generating the same score/result.

for *i* = 1, …, *m* indicators, *j* = 1, …, *n* countries.

Suggested indexes are used to classify the *j*-th units (countries) from 1st to *n-th rank* according to their score of performance. In particular, a rank close to the 1st position indicates a best performer country for proposed index, a rank close to *n* (*last position*) suggests a worst performer country in terms of resilience and prevention of pandemic threat.

In addition, suggested indexes, having a complementary perspective of analysis of performance, are combined in a map with the index of resilience on *x*-axis and the index of preparedness/prevention on *y*-axis to show strategic positioning of countries in terms of pandemic security weaknesses and strengths to cope with major pandemic/environmental threats. In particular:

❑ *Top-right corner* shows the positioning of countries having high resilience and high preparedness to cope with pandemic threats. The best countries with high performance in both dimensions.
❑ *Bottom-right corner* shows the positioning of countries having high resilience and low preparedness to cope with pandemic threats. These countries have a weakness to react with the rollout of vaccinations.
❑ *Top-left corner* indicates the positioning of countries having low resilience and high preparedness to cope with pandemic threats. These countries have a prompt capability to rollout of vaccinations but healthcare system has not a capability for a considerably reduction of mortality for manifold factors and for the accelerated diffusion of COVID-19 or similar infectious diseases.
❑ *Bottom-left corner* indicates the positioning of countries having low resilience and low preparedness to cope with pandemic threats. These countries have several weaknesses both in reducing mortality and in a timely rollout of vaccinations. These countries have to improve the preparedness and capability of health and institutional system to cope with a major pandemic/environmental threat.

This novel tool for measuring the performance of countries to cope with pandemic threat can provide important findings because the ranking presentation and strategic positioning map including countries make it easy for the human mind to grasp many of the essential aspects of general performance of countries in the presence of biological/pandemic/environmental threat.

Finally, the arithmetic mean of following indicators is used to analyze the structural differences between the set of best and worst performer countries detected with proposed indexes *r* and *p*.

□ Population in Europe, 2019. The number of persons having their usual residence in a country on 1 January of the year 2020. When usually resident population is not available, countries may report legal or registered residents. Source: Eurostat (2021).

□ Health expenditure (% of GDP) over 2018 (last year available) is a proxy of the efficiency of health system. Level of current health expenditure expressed as a percentage of GDP includes 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: World Bank (2021).

□ Lockdown is a temporary condition imposed by governmental authorities during the outbreak of an epidemic disease to people or communities requiring to stay in their homes and refrain from or limit activities outside the home involving public contacts to reduce transmission dynamics of infectious disease (Coccia, 2021c, 2021d; Warren et al., 2021). This containment policy is measured by the sum of days from starting of COVID-19 pandemic in 2020.

Measures of public governance are given by:

□ Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Source: Worldwide Governance Indicators (2021).

□ Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Source: Worldwide Governance Indicators (2021).

□ Rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Source: Worldwide Governance Indicators (2021).

2.5. Research setting of application

The proposed indexes are applied in a specific analysis of European countries (having a homogenous socioeconomic area) during COVID-19 pandemic crisis.

The sample of 31 countries is given by: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Period under study is from February 2020 to March 2021, when all data of indicators are available for a comparative analysis between countries.

3. Results and discussion

Table 1 shows in the top of ranking, countries having a higher capability of resilience to cope with COVID-19 pandemic crisis, reducing mortality rates, such as Iceland, Norway, Finland, Cyprus, Denmark, etc. Instead, Table 3 shows in the top of ranking, countries having a higher capability of reaction to prevent future pandemic threats, supporting a higher administration of vaccinations directed to immunization of overall population, such as United Kingdom, Malta, Hungary, Denmark, Norway, Poland, Switzerland, etc. The categorization of countries in best and worst performers, according to the score of performance is higher/lower than arithmetic mean of proposed indexes in sample, it suggests main characteristics of countries associated with a higher preparedness to face pandemic crisis that can be used to support decisionmaking for improving socioeconomic structures, institutions and policies of crisis management to cope with pandemic threats. In particular, Table 5 synthetizes results of Table 2 and Table 4 to show basic characteristics of countries with higher performances to cope with COVID-19 pandemic crisis.

In average, best performer countries with both indexes have a population lower than 14 million of people, average health expenditure (% of GDP) of about 8.6% and higher levels of the indexes of public governance. Instead, countries with a lower performance in the sample under study have in average a population of about 19–22 million and lower levels of health expenditures associated with lower levels of the indicators of public governance (cf., Coccia, 2021b; Coccia, 2021e). In brief, results here seem to suggest that better preparedness to cope with COVID-19 pandemic crisis is in countries having a smaller size of

Table 1

Index *r* of *resilience* (*Ir*) of European countries to cope with COVID-19 pandemic crisis.

Countries	Ir(‰)	
Iceland	0.043	Best performer
Norway	0.045	
Finland	0.053	
Cyprus	0.110	
Denmark	0.151	
Estonia	0.180	
Greece	0.238	
Ireland	0.325	
Netherlands	0.330	
Latvia	0.332	
Germany	0.335	
Austria	0.367	
Switzerland	0.399	
Luxembourg	0.402	
Average of high performers	**0.236**	
Romania	0.424	Worst performer
Malta	0.449	
Sweden	0.463	
Poland	0.467	
Slovakia	0.512	
France	0.517	
Croatia	0.531	
Portugal	0.591	
Bulgaria	0.591	
Lithuania	0.601	
Hungary	0.608	
Spain	0.616	
Italy	0.636	
United Kingdom	0.683	
Slovenia	0.692	
Belgium	0.717	
Czechia	0.721	
Average of low performers	**0.578**	

Note: the categorization of countries in high or low performers is based on countries having a final score higher or lower than arithmetic mean of the Index of resilience (I*r*) in sample under study.

Table 3

Index *p* of preparedness and prevention (*Ip*) of European countries to prevent/control future pandemic threats.

Countries	Ip(‰)	
United Kingdom	183.49	Best performer
Malta	129.99	
Hungary	81.68	
Denmark	79.73	
Iceland	73.47	
Norway	73.09	
Estonia	71.46	
Poland	70.79	
Switzerland	69.16	
Lithuania	68.32	
Greece	67.98	
Average of high performers	**88.11**	
Ireland	65.40	Worst performer
Slovenia	64.92	
Slovakia	64.41	
Portugal	64.28	
Romania	62.51	
Spain	61.93	
Italy	60.89	
Finland	58.92	
Germany	58.64	
Austria	57.73	
France	56.67	
Belgium	56.44	
Cyprus	56.36	
Sweden	52.55	
Czech Republic	51.27	
Netherlands	48.26	
Luxembourg	46.93	
Croatia	37.04	
Bulgaria	24.19	
Latvia	21.82	
Average of low performers	**53.56**	

Note: the categorization of countries in high or low performers is based on countries having a final score higher or lower than arithmetic mean of the Index of prevention (I*p*) in sample under study.

population and/or better public governance that can support effective strategies of crisis management to cope with pandemic threats (cf., Coccia, 2021b). Shi et al. (2021) argue that many diseases exhibit population-specific causal effect sizes with trans-ethnic genetic correlations. Milner and Weyman–Jones (2003) maintain that there is some evidence of a country size constraint on efficiency when other influences are controlled for. Mulino (2005) shows that when population grows beyond the minimum level of welfare, the overall economy becomes more dynamically inefficient. Frankel (2012) argues that various great powers can be models of economic and social development but small countries can set new institutions and timely formulate and implement new policies with positive socioeconomic effects, though no one size fits all (cf., Coccia, 2018; 2019, 2019a).

In fact, Table 1 shows that the United Kingdom is in the group of low performers to minimize the mortality in the initial phase of diffusion of the COVID-19 pandemic, whereas it is in the group of high performers in

Table 3 for the rollout of vaccinations to prevent future epidemic outbreaks. Stribling et al. (2020) examine this UK COVID-19 paradox because the country has an advanced healthcare system and a relatively high expenditure on health, and as a consequence it should have had a better performance to cope with COVID-19 pandemic, minimizing mortality in society. Moreover, the Global Health Security Index that assesses preparedness of countries to face a biological threat has ranked the United Kingdom at 2nd position in ranking, after the United States of America, as one of the most prepared country in 2019 (Coccia, 2019c). The proposed indexes here, based on a variety of measures, show the weaknesses of the UK to react in the short run with timely containment policies but the advanced national system of innovation with high levels of R&D investement has supported one of the first COVID-19 vaccines and government has showed an effective rollout of vaccinations in society, achieving the best performance among advanced Western countries. Lesson learned from this study is that all countries, also advanced

Table 2

Characteristics of countries having high or low performance of the Index *r* of resilience (*Ir*) to cope with COVID-19 pandemic crisis.

	High performer countries		Low performer countries	
	Mean	SEM	Mean	SEM
Population, 2020	11 076 950.07	5 675 712.46	21 896 822.65	5 771 943.33
Health Expenditure % GDP, 2018	8.64	0.55	8.27	0.42
Health Expenditure (PPS) per inhabitant, € 2018	3 284.75	325.67	2 289.30	215.05
Government Effectiveness Index, 2020	1.48	0.12	0.85	0.12
Regulatory Quality Index, 2020	1.49	0.10	1.04	0.09
Rule of Law Index, 2020	1.52	0.14	0.89	0.13
Days of lockdown, 2020–2021	51.36	13.23	68.41	14.64

Note: Expenditure Purchasing Power Standard (PPS) per inhabitant 2018; SEM = St. Error of Mean.

Table 4

Characteristics of countries having high or low performance of the Index *p* of prevention (Ip) to prevent pandemic threats.

	High performer countries		Low performer countries	
	Mean	SEM	Mean	SEM
Population, 2020	13 615 059.36	6 179 342.81	18 877 881.65	5 483 618.19
Health Expenditure % GDP, 2018	8.50	0.56	8.40	0.43
Health Expenditure (PPS) per inhabitant, € 2018	2 788.46	393.83	2 711.59	242.72
Government Effectiveness Index, 2020	1.21	0.17	1.09	0.13
Regulatory Quality Index, 2020	1.26	0.13	1.24	0.10
Rule of Law Index, 2020	1.23	0.20	1.14	0.13
Days of lockdown, 2020–2021	67.73	22.98	56.85	9.38

Note: Expenditure Purchasing Power Standard (PPS) per inhabitant 2018; SEM = St. Error of Mean.

Table 5

Structural characteristics of countries having higher performance to cope with COVID-19 pandemic crisis, minimizing mortality and maximizing vaccinations.

Characteristics associated with high performer countries
o *Lower* Population
o *Higher* Health Expenditure as % GDP
o *Higher* Health Expenditure per inhabitant
o *Higher* Government Effectiveness
o *Higher* Regulatory Quality
o *Higher* Rule of Law

nations with an organized healthcare system, have some biological and environmental security weaknesses, in particular in a global world with high mobility of people and high levels of international trade, and as a consequence no country is completely prepared for an unforeseen epidemic or pandemic threat of novel viral agents (Bontempi and Coccia, 2021; Bontempi et al., 2021; Stribling et al., 2020).

Fig. 1 shows the strategic positioning of countries to face a pandemic crisis, considering proposed indexes of resilience and preparedness/prevention that have a complementary perspective to assess performance to cope with pandemic threats. The visualization shows that none countries is in the top-right corner (with high resilience and high preparedness/prevention capability). Some countries have shown a higher level of resilience (bottom-right corner) but very few countries have showed a high level of preparedness to prevent future epidemic outbreaks, such as the UK has supported the discovery of one of the first COVID-19 vaccines with advanced R&D of a premier biopharmaceutical company (AstraZeneca) that has timely funded scientific research for this global health issue (i.e., COVID-19), generating a technological breakthrough to treat this new infectious disease (Coccia, 2017, 2019a, c). Fig. 1 also shows that a lot of advanced countries in Europe have a low capability of resilience and preparedness, such as Belgium, Italy, Spain, France, etc. These and other countries should support strategies of dissolution (i.e., it means to redesign either the institution/governance that has the problems or the environment in order to eliminate the sources of problems, thus enabling the country to do better in the future than the best it can do today; cf., Ackoff and Rovin, 2003; Coccia, 2021b).

Williams et al. (2020) argue that effective responses to public health emergencies should rely on timely evidence-informed policy and practice directed to transfer rapidly new scientific results and innovations in society (Coccia, 2019a–c). Results here also reveal that resilient countries to pandemic/environmental shocks have to be based on good governance associated with adequate and effective leadership that engages with communities and adapts to population needs, such as in the UK, Hungary, etc. (cf., Coccia, 2021f). Efficient public governance can support health system preparedness in the presence of a turbulent environment given by pandemic crisis. Results also show that countries with constant investments in health sector can reduce mortality and morbidity among population, as well as can promote timely public policy directed to socioeconomic recovery after a pandemic crisis (Kluge et al., 2020; Coccia, 2021b). Sagan et al. (2020) confirm that among European health system functions, effective governance is a critical factor to a resilient response in the presence of pandemic crisis. In particular, good governance is more and more a necessary condition for effective policy responses to improve performance of crisis management directed to cope with pandemic and in general environmental threats.
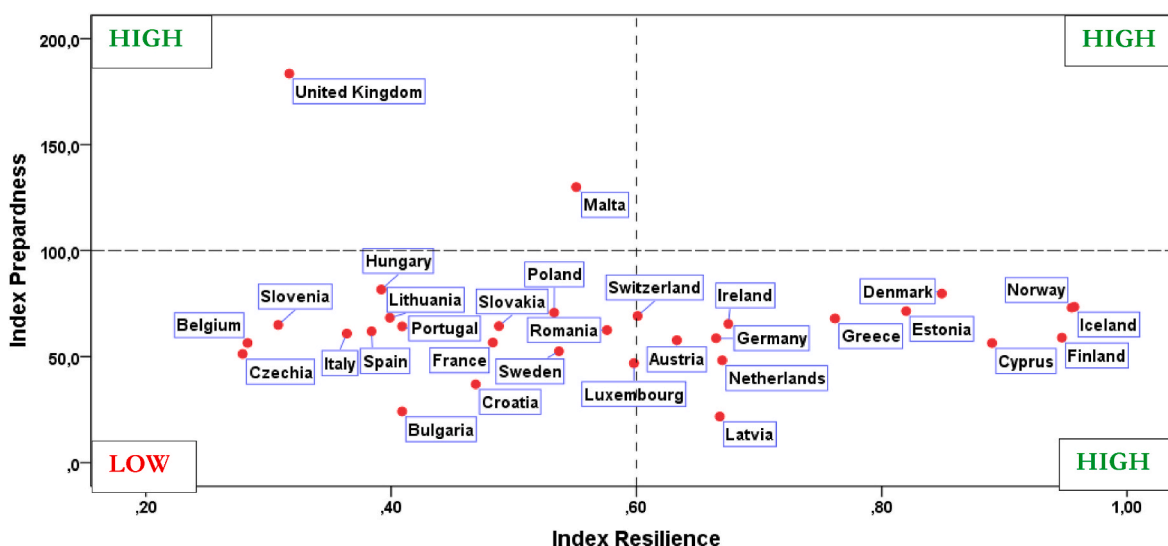

Fig. 1. Strategic positioning of countries to face a pandemic threat considering indexes of resilience and preparedness/prevention, showing countries with vulnerabilities in the bottom-left corner.

Sagan et al. (2020) consider a broad concept of governance, which is not limited to health system alone, but a complex system that creates the institutional background to support government and other functions of nation to work properly for strengthen health, economic and social systems. In fact, results here reveal that countries with effective vaccination plans have higher levels of governance indicators (Government Effectiveness, Regulatory Quality and Rule of Law) than countries with less effectively rollout of vaccinations. In general, novel influenza viruses continue to be a constant pandemic threat worldwide, and the health sector is just one element of a comprehensive system and strategy of crisis management; governments have to reinforce different socioeconomic and institutional factors for supporting effective policy responses to cope with pandemic threat and prevent future social and health issues (Mendonça and Fiedrich, 2006).

This study suggests that in the next years, countries have to increase R&D investments in equipment, infrastructures and education of human resources in health sector and support the public governance for improving preparedness to timely react in the presence of inevitable pandemics, also reinforcing international collaboration with key subjects, and for reducing negative effects on health of people and overall socioeconomic systems (U.S. Department of Health & Human Services, 2021). In particular, high levels of investments and expenditures have to reinforce health sector and R&D for new vaccines, conferring to population long-lasting protection against novel viruses and their mutations. Overall, then, the COVID-19 pandemic crisis needs rapid policy responses based on good governance, effective health systems, development of innovative drugs, and new vaccines with consequential manufacturing, distribution, allocation, and administration (Coccia, 2020; 2021a; National Academy of Medicine, 2021a; 2021b). In addition, results here reveal that the management of vaccination plans plays a vital role to improve performance of countries by reducing negative effects of COVID 19 pandemic and similar infectious diseases in society (DeRooSchaffer et al., 2020; Frederiksen et al., 2020; Harrison and Wu, 2020). The effectiveness of vaccination plans is associated with manifold economic, socio-cultural and institutional factors, such as good governance, effective public investments and overall management of administration of doses on vast populations (Ethgen et al., 2018; cf., GOV.UK, 2021; NHS, 2021). Therefore, the characteristics of best performance countries to cope with pandemic crisis, detected with proposed indexes here, can support effective strategic actions to achieve and sustain the main goal of reducing hazards and risk factors of pandemic threats and, in the presence of pandemics, provide a vast immunological protection of people before they are exposed to novel viral agents.

4. Conclusions, limitations and prospects

COVID-19 and future epidemics of novel influenza viruses pose, more and more, serious threats to national security and public health of countries. An influenza pandemic can occur at any time with little warning and any delay in detecting a novel influenza strain; sharing of influenza virus samples; and in developing, producing, distributing, or administering innovative drugs or vaccines could result in a significant additional morbidity and mortality, and deterioration of socioeconomic systems in the long run. In the presence of COVID-19 pandemic crisis, it is more and more important to measure resilience and preparedness of countries to face pandemic threats and explain critical characteristics that can support better policy responses to contain and/or prevent negative effects of future pandemic crisis on health of people and economic systems. In this paper, two complementary indexes are proposed as a new method that quantifies the capability of countries to cope with and/or prevent new pandemic threats assessing, whenever possible, resilient countries that minimize mortality and support effective policy responses that maximize vaccinations. The idea here is to synthetize the results of multivariate indicators of countries in a composite index to grasp intuitively the general capability of resilience and preparedness to cope with pandemic threats, also visualizing the performance in a graph

of strategic positioning. The proposed indexes of resilience and preparedness/prevention can help policymakers to support an institutional change and appropriate strategies to constrain pandemic threats (Coccia, 2021d,f). The best performance of countries, such as rapid rollout of vaccinations for COVID-19 on vast population, is also associated with good governance, a high level of expenditures on health system, etc. However, these are necessary but not sufficient conditions to reduce the risk and negative impact of pandemic crisis because results here suggest that all countries have some weaknesses and that no country is fully prepared for an unforeseen pandemic. Other complex factors have to be considered for measuring and improving capabilities of resilience and preparedness of countries to face a major pandemic threat. For instance, one of the factors to investigate in future is vaccine hesitancy of people because can affect the performance of nations (cf., Verger and Peretti-Watel, 2021). Murphy et al. (2021) found that general adult populations of Ireland and the United Kingdom had vaccine hesitancy/resistance for 35% and 31% respectively. Schwarzinger et al. (2021) analyze the determinants of COVID-19 vaccine acceptance or refusal and suggest that highlighting the benefits in terms of herd immunity can reduce hesitation of people about COVID-19 vaccines and support better performance of countries (cf., Echoru et al., 2021; Kanyike et al., 2021). In fact, performance of nations for COVID-19 vaccinations is also associated with levels of public trust that has to be built and reinforced for crisis management of pandemic threat (cf., Soveri et al., 2021). Although the study here provides main findings to measure the preparedness of countries to cope with pandemic threat, other confounding factors that influence variables under study can be considered for more comprehensive analyses and policy responses of countries, such as ethnicity, age, sex, risk perception, comorbidities, exposure to different media for COVID-19 news, confidence in scientists, communities concerns in the presence of emergencies and environmental threats, etc. (Elhadi et al., 2021; Seale et al., 2021; Syed Alwi et al., 2021; Viswanath et al., 2021). Other limitations of the method here is that there can be a bias between countries for detecting and reporting all COVID-19 deaths because of different approaches for counting deaths. In fact, variations in data may be also due to dissimilar quality of healthcare systems and/or to public interventions applied at different stages of the illness between countries, making comparative analysis in some cases problematic (Angelopoulos et al., 2020; Antony et al., 2020; Lau et al., 2021).

Overall, then, the proposed indexes here provide main information in terms of performance of countries to cope with COVID-19 pandemic crisis and support effective plans of vaccination. The suggested indexes can be applied in a general strategy directed to help policymakers to know points of strength but also elements of vulnerability for the success of public policy of crisis management to prevent future outbreaks of new viral agents. These conclusions, of course, are tentative. The challenge is the design of simple but effective metrics to support timely strategies of prevention that meet needs of countries shortly after the emergence of a pandemic, in order to constrain negative effects in society. In addition, new comparative performance systems for pandemic threats should be direct to sustain public policies that are highly responsive, flexible, resilient and scalable for reducing the negative impact of pandemic viruses (Ardito et al., 2021; Evans and Bahrami, 2020; U.S. Department of Health & Human Services, 2021). In brief, these new approaches should support the decision making of policymakers to design policy responses based on versatility, agility and resilience in order to improve the performance of countries to cope with COVID-19 and future epidemics/pandemics similar to COVID-19 (Chang et al., 2020; Janssen and van der Voort, 2020; Renardy et al., 2020).

To conclude, this study encourages further investigations for developing composite indexes of performance for crisis management in the presence of pandemic threat also based on environmental and socioeconomic factors, and not only on parameters related to medicine. In particular, these new tools can help policymakers to evaluate manifold factors to reduce biological security weaknesses and improve

preparedness of crisis management of countries through the design of appropriate short-run and long-run strategies to prevent future epidemics or pandemics and in general to contain the negative impact of novel infectious diseases on health of people, economy and society.

Credit author statement

Author's contributions: Single author, Mario Coccia (Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Visualization, Writing - original draft, Writing - review & editing, Funding acquisition, Project administration, Resources, Software, Supervision, Validation). Mario Coccia thanks Mr. Diego Margon for helpful research assistance.

Declaration of competing interest

The author COCCIA MARIO declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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