Effective Strategies to cope with Next Pandemics: Lessons Learned from COVID-19 to Improve Outlook of Next Crisis Management

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Abstract

Countries are still dealing with the tail of the COVID-19 pandemic, and scholars and experts are already guessing that future pandemics and/or epidemics are almost inevitable events. In the context of climate, environmental and social change, one of the problems is not whether a new pandemic will happen, but when the next health emergency will emerge. The goal of this study is to analyze anthropogenic activities that may trigger factors determining pandemic threats and how nations can act to prevent and/or improve the preparedness to cope with the next pandemic crises. Results and discussion suggest that the next infectious disease similar to COVID-19 is the effects of main factors associated with high population growth worldwide, polluting industrialization, energy crisis, land use change, ecological and climate change, environmental pollution and in particular the change of the interrelationship between humans, fauna and plant life. In this context, large cities and conurbations can be the epicenter to amplify pandemic waves because of the high density of people, high air pollution, accelerated mobility and intensive trade at national and international levels. In fact, the globalization of economies and the high interaction of people within and between nations are critical factors for the diffusion of new viral agents around the world. To solve these urgent issues and improve forecasting, prevention and preparedness to cope with the next pandemic crisis, this study suggests strategic

actions of surveillance that governments should implement for a reduction and/or removal of complex factors determining pandemics and new diseases that threaten national and global health. Hence, like MERS, COVID-19, etc., the next pandemic threats are the effects of a deterioration of the total environment and anthropogenic activities in a world based on different economic competitions. Discussions here suggest how nations should design appropriate strategies to be prepared to implement appropriate policy responses when the next pandemic impact occurs to mitigate socioeconomic and health negative impacts.

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1. Introduction

In 2022 we are still in the throes of the negative effects of the Coronavirus Disease 2019 (COVID-19) pandemic, an infectious illness emerged with the Severe Acute Respiratory Syndrome Coronavirus 2 or SARS-CoV-2 virus (Chowdhury et al., 2022; Coccia, 2020, 2022, 2022a, 2022b; Bontempi et al., 2021; Bontempi and Coccia, 2021; Johns Hopkins Center for System Science and Engineering, 2022; Núñez-Delgado et al., 2021).

A vital aspect of public health and security of nations is predicting the next pandemic to design appropriate strategies of crisis management based on policy responses, pharmaceutical and non-pharmaceutical interventions to stop and/or mitigate, whenever possible, that a new virus emerges, spreads and infects a lot of people (Coccia, 2022a, 2022b). The prediction of the next pandemics involves different aspects, such as understanding how new viral agents emerge, behave and mute to design and implement effective policy responses for reducing socioeconomic impact (Coccia, 2021a). In this context, governments largely relied on epidemiological models of predicted COVID-19 cases and/or deaths to guide the application of effective and timely containment policies and vast vaccination campaigns (Alsobhi, 2023; Keshavamurthy et al., 2022; Magazzino et al., 2022). However, epidemiologic models for the prediction of COVID-19 have shown many limitations because of the unpredictable dynamics of SARS-CoV-2 in the environment and society (Rosenfeld and Tibshirani, 2021). In the presence of manifold limitations of epidemiologic models of pandemic prediction for SARS-CoV-2

and its mutations, one of the critical activities of nations and their institutions is to examine sources and driving factors of new infectious diseases having potential elements to generate a pandemic. The impact of human activities on the development of COVID-19 plays a vital role in preventing, whenever possible, new hazardous viral agents and prepare optimal strategies of crisis management to guide effective and timely processes of decision-making for stopping transmission dynamics in society (Coccia, 2021, 2021a, 2022c; Khandia et al., 2022). In fact, appropriate strategies of crisis management should deal with pandemic threats before the emergence and diffusion of new viral agents that can generate main negative effects in society (cf., Groh, 2014).

Hence, since the forecasting of pandemics in the short and long run using current epidemiologic models, as all human activity of prediction, has manifold shortcomings and can provide misleading results, the main goals of this study are twofold: first, the analysis of anthropogenic activities and factors that may trigger pandemic threats; second, suggest planning strategies before pandemic threat emerges and/or in the initial phase to reduce hazards and risks that the emergence and diffusion of new viruses can generate on public health, environment and socioeconomic systems. In particular, the investigation and understanding of sources and driving factors concerning the emergence and diffusion of new pandemics have critical aspects for strategic actions of forecasting, prevention, preparedness and planning of effective policy responses to cope with crises and health emergencies (Coccia, 2022c; Dai et al., 2022; Krechetov et al., 2022; Kuvvetli et al., 2021; Liu et al., 2022; Šušteršič et al., 2021). Hence, this study endeavors, whenever possible, to clarify these problems to increase the knowledge of the sources and factors determining the emergence of new viral agents and designing optimal response policies of crisis management to cope with pandemics similar to COVID-19 (Farazmand, 2001, 2014).

2. Study Design

The method of inquiry is based on a research process to search in the existing scientific literature for the factors determining pandemic threat and its diffusion for planning and preventing next pandemic crises and systematically designing and implementing optimal policy responses to cope with health emergencies.

The systematic review here is based on a search strategy with the goal of determining drivers of pandemic threats by identifying, appraising, and synthesizing all relevant studies on these topics (Uman, 2011). In this perspective, the systematic review here focuses on a method of logical selection of specific literature aimed at minimizing bias in order to produce robust findings to clarify sources of new viral agents and design strategic actions for supporting the decision-making of policymakers to cope with pandemics (Clarke, 2011).

In addition, the systematic review here also includes a meta-analysis to show quantitative values, data and information from some studies related to these topics (Petticrew and Roberts, 2006). In particular, examining the studies about lab accidents, the reported occurrence of accidents in different labs dealing with biological experiments is reported and discussed. Systematic reviews differ from narrative reviews that are mainly descriptive and focus on a subset of studies also generating elements of bias (Clarke, 2011; Uman, 2011). In short, systematic review here endeavors to identify,

appraise and synthesize selected literature to provide main evidence and information to clarify the specific problem of detecting sources of new viral agents and predicting risk factors of pandemic threats for planning optimal strategies of prevention to improve the preparedness of nations to cope with health crises and emergencies.

3. Results

The assessment and prediction of pandemic threats, similar to COVID-19, have vital aspects for the prevention and preparedness of nations. In this perspective, the reduction of the risks and hazards for the emergence and diffusion of new viral agents and consequential pandemics has to focus pre-emptively on the following measures of control.

3.1. Factors determining a high risk for the emergence of new viral agents

- *Surveillance of wildlife to avoid pandemic emergence and diffusion*
  Daszak et al. (2020) argue some risk factors determining the emergence of pandemic threats, such as the interaction between humans and wildlife that can foster the transmission of dangerous pathogens and spillover effects; moreover, wildlife trade in domestic and international markets, with poor measures of control, can reduce biosecurity and increase the emergence of new viral agents. A large literature discusses the conditions leading to the emergence of an epidemic and/or pandemic (Anderson and May, 1991; Dobson and Carper, 1996). For instance, poor surveillance of wildlife can trigger evolutionary stages in the transformation of an animal pathogen into a specialized pathogen for humans. These aspects can generate compounding and cascading events because each infected human introduced into a large population of susceptible individuals can infect other individuals and trigger a widespread transmission. Moreover, the persistence of infection depends on manifold factors that deserve to be analyzed, such as the duration of a host's infectivity; the rate of infection of new hosts; the rate of development of host protective immunity; host population density; size and structure permitting the pathogen's regional persistence despite local extinctions (Wolfe et al., 2007).
- *Biosafety lab risk assessment and protocols to reduce accidents for the emergence and diffusion of new viral agents*
  Manifold studies show that there have been several high-profile accidents in research laboratories of biology, chemistry and related disciplines of life sciences (Ménard and Trant, 2020). Hellman et al. (1986), examining almost six hundred accidents between 1966 and 1984, found that 13% of accidents occurred in research labs and 2% in fabrication rooms. Van Noorden (2013), with a survey of about 2,500 scientists, reveals that 30% of interviewed reported having witnessed a severe lab injury. Another study in Canadian chemistry and biology labs reports that 15% of scholars surveyed had at least one injury (Ayi and Hon, 2018). Simmons et al. (2018) found that accidents in the laboratory represented 18.4% of the total incidents reported at Iowa State University in the U.S.A.
  Kou et al. (2021) argue that major accidents of lab that involve personal injuries or main property damages have to be reported by law, but a lot of minor lab incidents or near misses concerning academic research tend to be not often reported. This study at the Departments of Chemistry and Chemical Engineering & Materials Science at the University of Minnesota (USA) during the 2014-2019 period (based on a platform of self-report safety stories occurring within departments by researchers that were either directly involved with or witnessed a safety-related incident) reveals that

the most frequently occurring hazards are due to spill, fire, and equipment failures (Kou et al., 2021). Ménard and Trant (2020, p. 18) maintain that factors determining accidents in the laboratory can be due to: "risks associated with the materials or equipment being used, risks related to the skills, knowledge and choices of the research personnel doing the study, characteristics or qualities of the PI and the research lab in which the research is occurring and risk factors arising from the departmental or institutional level". Results of these studies suggest that the escape and diffusion of new viral agents associated with an accident of lab have a vital role in the emergence of epidemics and pandemics and need accurate monitoring to improve the prediction, prevention and preparedness of nations (Coccia, 2022). In particular, the reduction of pandemic threats is associated with effective control and implementation of biosafety protocols in public and private laboratories of virology that analyze pathogens, novel viral agents and biological elements to minimize the possibility of accidental diffusion in the environment and society with consequential socioeconomic issues. Li Na et al. (2019) argue that risk assessment in biosafety labs can be performed with different methods, such as scenario analysis, pre-hazard analysis, hazard and operability analysis, fault tree analysis, event tree analysis, matrix analysis, risk mapping, etc. However, source and control measures of risks cannot be general for all labs worldwide and biological risk management system has no fixed modes generalizable for all nations and has to be adapted to the specificity of labs and countries. In general, effective R&D management can complement laboratory safety and protect personnel, public health, and environmental safety (Coccia, 2022, 2021a). For the prevention of epidemics and pandemics, information on lab safety and accidents should be linked to a national and international surveillance system, which can better coordinate targeted investigations and interventions to improve the safety of labs in the presence of specific needs, threats and global risk for new infectious disease outbreaks (Jia and Yang, 2020). Hence, laboratory biosafety risk assessments are a critical activity to be conducted regularly in order to ensure the safe operation of the laboratory and the evaluation of pathogenic microbial hazards, aerosol exposure risk of personnel, etc. to prevent the escape of hazardous viral agents and the emergence of epidemic and pandemic diseases (Li Na et al., 2019).

- *High air and environmental pollution, and (un) sustainable environment can support pandemic emergence and spread*

  Studies have found that (un) a sustainable environment plays a vital role in increasing risk factors of emergence and diffusion of epidemics and pandemics similar to COVID-19 with a consequential negative impact on the socioeconomic system (Akan and Coccia, 2022; Coccia, 2020, 2020a, 2020b, 2020c; 2022g). In general, countries with 72% of the population exposed to levels exceeding the WHO guideline value of air pollution have lower fatality rates of COVID-19 than countries with 98% population exposed to similar levels of air pollution (Coccia, 2021b). Studies also suggest that the concentration of atmospheric pollutants is a main factor affecting the spread of SARS-CoV-2 (Coccia, 2020), but a high wind speed sustains clean days from air pollution including viral agents, reducing whenever possible the ambient concentration of the SARS-CoV-2 and as a consequence the spread of COVID-19 in society (cf., Coccia, 2020; Rosario Denes et al., 2020). Hence, geo-economic regions have to, more and more, apply long-run environmental policies and sustainable strategies to reduce the level of particulate compounds emissions that can mix with viral agents generating mutations and resistance of viral agents that increase their transmissibility and infectivity with main issues on health of people and socioeconomic systems (Jones and Harrison, 2004; Wei et al., 2018; Zhong et al., 2020; Coccia, 2021b; 2021c, 2021d).

3.2. Pre-emptively measures of control for the widespread diffusion of new viral agents

- *Strengthening the early warning system with an effective contract tracing system*
  In the presence of a local epidemic outbreak, rapid contact tracing is a basic strategy within the epicenter to limit human-to-human transmission outside of outbreak areas, also applying appropriate isolation of cases (Wells et al., 2020). Contact tracing system achieves the early detection and isolation of secondary cases, which play an important role in diffusion because the peak in infectiousness can occur during the pre-symptomatic phase (Coccia, 2020). Moreover, the early detection achieved by effective contact tracing accelerates the rate at which infected individuals receive medical care to improve their chance of recovery. In short, a functional and effective contact tracing system is a vital strategy for controlling infectious diseases in the initial stage, such as COVID-19 and similar infectious diseases, when appropriate drugs and therapies are lacking. A lot of protocols apply “forward-trace” to notify people who were recently exposed, but Bradshaw et al. (2021) found that “bidirectional” tracing to identify infector individuals and their other infected robustly improves outbreak control and reduces/stops rapid diffusion. Yalaman et al. (2021) suggest that comprehensive contact tracing is an instrumental approach not only for curtailing transmission but also to reduce case fatality rates.
- *Effective governance improves prevention and preparedness to face pandemic threats.*
  Effective governance, associated with economic development[1], can support prevention and preparedness for pandemic threats with constant investments to reinforce: surveillance of the interaction of human society with wildlife, protocols for biosafety laboratory risk assessment, health system human resources and management, new technology that reduces human exposure to new vital agents and opportunities for a pandemic virus to emerge, effective early warning system and rapid containment actions to stop rapid diffusion of viral agents[2]. In short, good governance in countries plays a critical role in predicting, preventing and preparing for the emergence of a pandemic virus as well as in supporting a resilient response of the health system in the presence of a pandemic crisis similar to COVID-19 (Coccia, 2021a, 2022b). Sagan et al. (2020) consider a broad concept of governance, not limited to the health system alone, that creates the institutional background to support the government to work properly to prevent and/or cope with pandemic threats and crises. In fact, Sagan et al. (2020) pinpoint that the prevention of pandemic threats is based on: (1) appropriate and effective governance of institutions and (2) skilled human capital with interdisciplinary technical capacity of crisis management and appropriate incentives to respond in a short period of time (Coccia, 2019; Coccia and Benati, 2018). Benati and Coccia (2022) show that some Italian regions have managed the COVID-19 pandemic crisis with appropriate policy responses using: a) timely and widespread testing of individuals, b) effective task force of epidemiological investigation in a pervasive contact-tracing systems to detect and isolate all infected people. This health policy has reduced total deaths and negative effects of COVID-19 on people's health during the first pandemic wave when pharmaceutical interventions were not available. Benati and Coccia (2022a) also show the positive effects of good governance for supporting optimal policy responses towards the COVID-19 pandemic with a timely vaccination directed to reduce the negative pandemic impact on society (Magazzino et al., 2022).

Figure 1 shows critical risk factors for the emergence and diffusion of future pandemics.

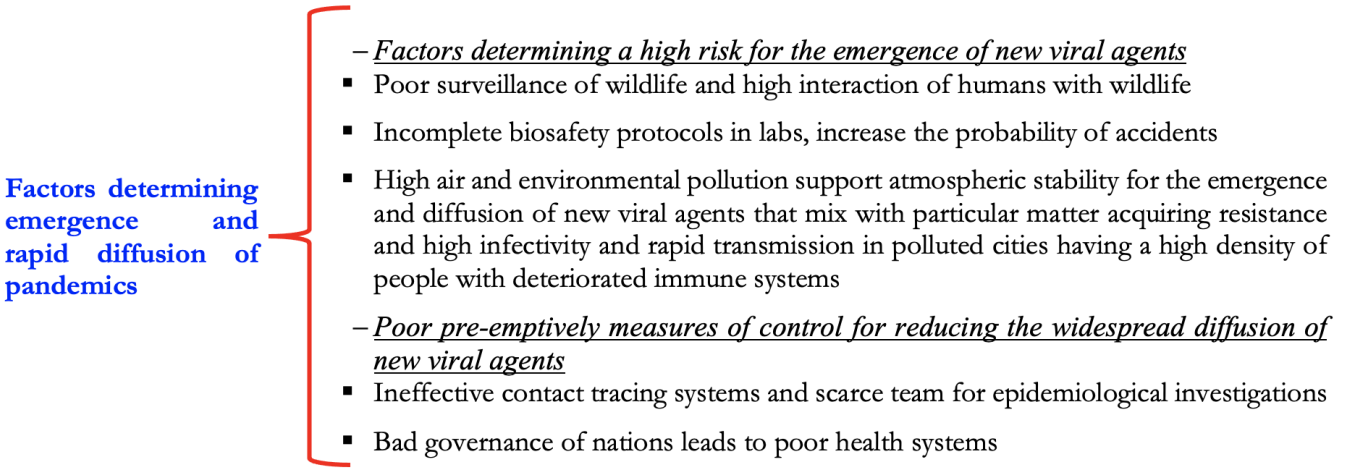

Figure 1. Factors that increase the opportunities for a pandemic virus to emerge and spread

4. Policy Implications: Limits of Covid-19 Prediction Models and Strategic Actions for Forecasting and Preventing Pandemic Threats

Epidemic forecasting plays a vital role in improving the surveillance for pandemic risks, protecting public health and coping with future pandemic threats (Johansson et al., 2019; Ajelli et al., 2018). In the presence of COVID-19, scholars suggest different models for epidemic tracking and forecasting (Rosenfeld and Tibshirani, 2021). Reinhart et al. (2021) have made many efforts in the construction and maintenance of an open repository of real-time and geographically detailed COVID-19 indicators in the United States. This repository provides the main information about COVID-19, such as confirmed cases, hospitalizations, deaths, fatality rates, etc. McDonald et al. (2021) endeavor to explain if a set of indicators can improve the accuracy of COVID-19 short-term forecasting and hot spot detection models in spatial regions. However, pandemic tracking and forecasting models have also some problematic points, such as the data generation process being a critical aspect for downstream applications, in addition, human behavior and its impact on the progression of epidemics are hard to measure and model. Moreover, COVID-19 diffusion has shown rapid peaks and then infections abruptly fall, regardless of measures of control. In fact, unlike predictions of different epidemiologic models, the reduction of control measures for COVID-19 did not generate a rapid take-off of infections (Wieland, 2020). One of the main problems of epidemiologic models applied for COVID-19 is the high overestimation of deaths (Allen, 2022; Briggs and Littlejohn, 2021; Korolev, 2021). This limitation of current models for pandemic prediction is the assumption of a constant reproductive number, whereas in real contexts it changes over the course of time (Korolev, 2021). Additionally, a lot of models do not consider that the deaths of COVID-19 have a skewed distribution towards elderly and susceptible people with comorbidities (Chen et al., 2022). Appropriate prediction models of infectious diseases, like COVID-19, should be age-dependent. Another critical limitation of the epidemiological model applied to COVID-19 is the reductionism approach which did not consider the behavioral change of people in the presence of a pandemic (Mohammadi et al., 2022). In fact, many epidemiologic models do not consider that people, with the fear of being infected and/or of dying from new infections, can adapt their behaviour to new situations taking provident actions to protect themselves and survive (Stangier

et al., 2022). For instance, in the US economy, the reduction of consumer mobility is due mainly to private responses rather than public obligations (Goolsbee and Syverson, 2021). Finally, susceptible-infectious-removed (SIR), Susceptible-Exposed-Infected-Recovered-Dead (SEIRD) and other epidemiologic models focus mainly on stable and short-run variables, whereas factors driving the pandemic have dynamic change over time. As a consequence, in general, epidemiologic models cannot provide reliable long-run forecasting of the pandemic which is an ideal goal for all forecasting activities, because limits are due to the interaction of manifold and complex factors.

The improvement of pandemic forecasting can be done by focusing on key components described in Table 1.

Table 1. Elements for improving pandemic forecasting and tracking

▪ Electronic Medical Records (EMR)
Accurate analytics and forecasting depend on the availability of rich, real-time data sources.*Electronic Medical Records* (EMR) have a high potential for real-time surveillance streams of infections and deaths related to the pandemic of new viral agents similar to SARS-CoV-2
▪ Different phases of epidemic surveillance need different analytic techniques and approaches.
In the inter-pandemic phase, the main activity is monitoring data streams and events worldwide to avoid compounding and cascading events, such as species jumping or point mutations. *In the containment phase*, a threat of a new viral agent has to be intensely monitored, assessed, and contained. Real-time estimation of critical epidemiological parameters (e.g., R_0, fatality rates, etc.) is a basic activity.

In general, since pandemic forecasting, in the long run, provides uncertain results, countries can direct their efforts on pre-emptively strategic actions to increase R&D investments in new technology, organized infrastructures in health sector, equipment, and education of human resources for improving activities of prevention and preparedness in crisis management to react quickly in the presence of inevitable pandemics, also reinforcing international collaboration, to reduce main problems on health of people and socioeconomic systems (Coccia, 2021; U.S. Department of Health & Human Services, 2021).

In general, strategies of countries for unforeseen pandemic crises should be preventive and based on planned interventions directed to the reduction of risk factors associated with the emergence and diffusion of new pandemic viruses (Bundy et al., 2017; Seeger et al., 1998); and government should design ex-ante effective solutions for problems generated by new viral agents, preparing rapid strategic actions to stop and/or reduce negative effects on public health and overall society (cf., Mahmoudi and Xiong, 2022).

In particular, strategies for pandemic forecasting and prevention can focus on the following vital aspects of a specific task force:

- Analysis of the potential hazards, risk factors and causes of pandemic threat (problem) in society, and possible

solutions to reduce occurrences of new viral agents.

- Analysis of a limited number of variables associated with different solutions for achieving and sustaining specific goals to forecast, prevent and/or cope with pandemic threats, evaluating pros and cons.
- Choice of the satisfying solutions in the context of a turbulent environment.
- Application of critical decisions for achieving the goals of prediction and/or prevention, evaluating expected results in a short period of time to refine and improve the decision-making process with continuous cumulative learning.

This general strategy in practice has to design and implement three main strategic actions.

Firstly, the reduction of interaction with wildlife and/or appropriate protections in hazardous environments (e.g., mines) for reducing human exposure of people to animals inducing a pandemic virus to emerge (e.g., spillover from wildlife).

Secondly, it has to be directed to improve the early warning system and timely containment operations in the initial phase of an outbreak that could prevent chains of transmission. Effective early warning systems in the international community can ensure the timely detection of suspected cases in humans with reliable international laboratories that receive all the data and clinical specimens needed for an accurate evaluation of pandemic risk. Moreover, rapid containment policies can prevent the spread of novel viral agents in human society. New studies show that selected restrictions in specific places are better policy responses than full lockdown (Coccia, 2021e; Tsiotas et al., 2020; Warren et al., 2021). International institutions should verify that all countries have designed and tested pandemic response plans and should provide clear guidelines to coordinate nations during a pandemic crisis. Developing countries with limited economic resources have to be supported in the development of pandemic plans to reduce gaps in basic capacities and to improve a coordinated global response to a pandemic threat or crisis.

Thirdly, prevention and preparedness activities for pandemic threats should reinforce the coordination of global science and research to accelerate the R&D and diffusion, on a vast scale, of effective pandemic vaccines and innovative antiviral drugs to minimize socioeconomic issues (Coccia, 2021, 2021a). In fact, nations should jointly invest and coordinate global R&D to produce pandemic vaccines and antiviral drugs in health emergencies that are rapidly and widely available and that ensure equitable access across all nations as soon as a pandemic emerges and/or the diffusion of the novel virus takes off. Additionally, it is also important to gather and analyze a lot of data on the use of established and new anti-viral drugs and vaccines for the safe administration of treatment and prophylaxis in the population (Benati and Coccia, 2022, 2022a; Crow et al., 2018; Coccia, 2021a; 2022e, 2022f). R&D investments have to be directed to new vaccines that have the property of conferring long-lasting protection against novel viruses and their mutations for broad-spectrum protection against pandemics across populations worldwide. (Coccia, 2022a, 2022b, 2022d).. According to Kapitsinis (2020), investments in the health sector and other institutions can support strategies to forecast and/or prevent novel infectious diseases and to foster scientific and technological advances directed to new vaccines, antivirals and other innovative drugs that can avoid and/or control future pandemic crisis (Coccia, 2020; 2022a, 2022d, 2022e; Williams et al. 2020).

Overall, then, the success or failure of strategies to forecast and/or prevent pandemic threats and crises depends on effective decision-making in the presence of uncertainty, turbulent environment and highly restricted time (Coccia, 2021). Studies show that the general guidelines for an effective strategy to cope with pandemic threats have to increase health

expenditures, R&D investments and good governance for reducing opportunities for human exposure to hazardous situations and risk factors that a pandemic virus to emerge, strengthening the early warning systems and effective policy responses that decrease/stop transmissibility among humans and/or delay its international spread (Coccia, 2020, 2021, 2022c).

5. Concluding Remarks

The experience of COVID-19 suggests that future infectious diseases of novel viruses can generate crisis and socioeconomic issues for public health and economies of countries (Sirois and Owens, 2021; Newby et al., 2020). Strategies of crisis management to forecast and prevent the pandemic similar to COVID-19 are based on effective multi-level governance and institutions to design actions and timely policy responses for improving health safety in society (Whittaker et al., 2021). Nations have to design a crisis management structure for managing strenuous situations given by pandemic threats and for making timely critical decisions to resolve them (Coccia, 2021). This crisis management structure understands the specificity of the pandemic threat and is thoroughly prepared to solve all problems and problematic situations. New pandemics, similar to COVID-19, can emerge and spread rapidly and it is important to ensure timely gathering and sharing of information and samples of novel viral agents for appropriate interventions to stop the emergence of epidemics/pandemics. Scientific collaboration among international laboratories plays a critical role in supporting the sharing of vital data and information for helping policymakers to apply rapid plans directed to prevent/reduce the hazardous and risk factors of pandemic threats that can create socioeconomic problems worldwide (Coccia, 2020).

Hence, strategies for forecasting and preventing pandemic threats have to be, more and more, based on efficiency, flexibility, responsiveness and resiliency for reducing opportunities for a pandemic virus to emerge and for mitigating the vast diffusion of infectious diseases in society. In short, capacities of global prediction and prevention of pandemic threats can collectively improve the world's ability to defend itself against many emerging and epidemic-prone diseases. International experience with the COVID-19 pandemic crisis has shown that well-planned public policies, and scientific and economic coordination policies can support effective strategic actions for reducing high-risk factors before and during an outbreak (Coccia, 2021a; Benati and Coccia, 2022, 2022a).

Overall, then, a comprehensive strategy of crisis management for forecasting and preventing pandemic threats has to be based on manifold factors and new technology, and not only on parameters related to medicine, to help policymakers evaluate different aspects that reduce institutional and social vulnerabilities to epidemics and support the design of appropriate short- and long-run plans to prevent and/or contain rapid diffusion and the negative impact of future infectious diseases on public health, economy and society (Ackoff and Rovin, 2003; Gigerenzer and Todd, 1999; Janssen and van der Voort, 2020; Kahneman et al., 1982; Weible et al., 2020).

Although this study has provided interesting results, that are of course tentative, it has several limitations. One of the problems is the difficulty of an accurate prediction of the numbers of reported and unreported cases for the COVID-19

pandemic, and similar pandemics for different classes of age (cf., Liu et al., 2021a). A lot of confounding and situational factors should be considered for accurate forecasting and prevention of the next pandemic, especially with environmental turbulence. In short, there is a need for much more detailed research on these topics and this study encourages further investigations that should be collaborative between scholars of different disciplines and nations to have access to relevant information that can help to forecast and clarify unknown sources of new viral agents and prevent a pandemic similar to COVID-19. In this context, science plays an increasingly significant role in predicting, preventing and explaining sources of new viral agents to support the preparedness of nations to cope with future pandemics. However, a basic aspect is to invest ex-ante in biosafety, health sector, vaccine development, etc., to create the bedrock for effective crisis management of pandemic threats. To conclude, the emergence of new viral agents and related pandemics is a problem of hot discussion and debate in science and society. Scientific investigation has powerful tools, but it is not enough to clarify the problem under study here because available data and information can provide only probable, not certain results for supporting a global prediction and prevention about the sources and diffusion of new viral agents in society.

Compliance with Ethical Standards

- Conflict of Interest: none
- Informed consent: none
- Funding information: none
- Ethical approval: none

Footnotes

[1] For factors of economic growth see, Coccia, 2017; Coccia 2018.

[2] For role of science and technologies in society, see Coccia, 2017a, 2018a, 2019, 2020d; Coccia and Bellitto, 2018; Mosleh et al., 2022.

Bibliography

- Ackoff RL, Rovin S. 2003. Redesigning Society. Stanford University Press, Stanford
- Ajelli M., et al. 2018. The RAPIDD Ebola forecasting challenge: Model description and synthetic data generation. Epidemics 22, 3–12
- Akan A. P., Coccia M. 2022. COVID-19 lockdown impact on air pollution: a global comparative analysis, Applied Sciences, preprints-63935, DOI: 10.20944/preprints202210.0425.v1
- Alsobh, A. 2023Prediction of COVID-19 Disease by ARIMA Model and Tuning Hyperparameter Through GridSearchCV. Lecture Notes in Networks and Systems 490, pp. 543-551
- Amarlou, A., & Coccia, M. (2023). Estimation of diffusion modelling of unhealthy nanoparticles by using natural and

safe microparticles. Nanochemistry Research, 8(2), 117-121. doi: 10.22036/ncr.2023.02.004

- Anderson, R. M. & May, R. M. 1991. Infectious Diseases of Humans: Dynamics and Control (Oxford Univ. Press, Oxford, UK, 1991).
- Ayi, H.-R., Hon, C.-Y. 2018. Safety culture and safety compliance in academic laboratories: A Canadian perspective. J. Chem. Health Saf. 25, 6–12.
- Benati I., Coccia M. 2022a. Global analysis of timely COVID-19 vaccinations: Improving governance to reinforce response policies for pandemic crises. International Journal of Health Governance. https://doi.org/10.1108/IJHG-07-2021-0072
- Benati I.,Coccia M. 2022. Effective Contact Tracing System Minimizes COVID-19 Related Infections and Deaths: Policy Lessons to Reduce the Impact of Future Pandemic Diseases. Journal of Public Administration and Governance, vol. 12, n. 3, pp. 19-33. DOI: https://doi.org/10.5296/jpag.v12i3.19834
- Biggs, A. T. and Littlejohn, L. F., 2021. Revisiting the initial COVID-19 pandemic projections. The Lancet Microbe, 2(3): E91-E92.
- Bontempi E., Coccia M., 2021. International trade as critical parameter of COVID-19 spread that outclasses demographic, economic, environmental, and pollution factors, Environmental Research, vol. 201, Article number 111514, https://doi.org/10.1016/j.envres.2021.111514
- Bontempi E., Coccia M., Vergalli S., Zanoletti A. 2021. Can commercial trade represent the main indicator of the COVID-19 diffusion due to human-to-human interactions? A comparative analysis between Italy, France, and Spain, Environmental Research, vol. 201, Article number 111529, https://doi.org/10.1016/j.envres.2021.111529
- Bradshaw, W.J., Alley, E.C., Huggins, J.H., Lloyd, A.L., Esvelt, K.M. 2021. Bidirectional contact tracing could dramatically improve COVID-19 control. Nature Communications 12(1),232
- Bundy J., Pfarrer M. D., Short C. E., Coombs W. T. 2017. Crises and Crisis Management: Integration, Interpretation, and Research Development. Journal of Management, 43 (6): 1661–1692. doi:10.1177/0149206316680030.
- Chen, C., So, M., & Liu, F. C. (2022). Assessing government policies' impact on the COVID-19 pandemic and elderly deaths in East Asia. Epidemiology and infection, 150, e161. https://doi.org/10.1017/S0950268822001388
- Chowdhury T., Chowdhury H., Bontempi E., Coccia M., Masrur H., Sait S. M., Senjyu T. 2022. Are mega-events super spreaders of infectious diseases similar to COVID-19? A look into Tokyo 2020 Olympics and Paralympics to improve preparedness of next international events. Environmental Science and Pollution Research, https://doi.org/10.1007/s11356-022-22660-2
- Clarke J. 2011. What is a systematic review? Evidence-Based Nursing 2011;14:64.
- Coccia M. 2010. Foresight of technological determinants and primary energy resources of future economic long waves. International Journal of Foresight and Innovation Policy, vol. 6, n. 4, pp. 225–232, https://doi.org/10.1504/IJFIP.2010.037468
- Coccia M. 2017. New directions in measurement of economic growth, development and under development, Journal of Economics and Political Economy, vol. 4, n. 4, pp. 382-395, http://dx.doi.org/10.1453/jepe.v4i4.1533
- Coccia M. 2017a. A new classification of technologies, Working Paper CocciaLab n. 26/2, Arizona State University (USA), Available at permanent arXiv eLibrary: http://arxiv.org/abs/1712.07711

- Coccia M. 2018. An introduction to the theories of national and regional economic development, Turkish Economic Review, vol. 5, n. 4, pp. 350-358, http://dx.doi.org/10.1453/ter.v5i4.1794
- Coccia M. 2018. Classification of innovation considering technological interaction, Journal of Economics Bibliography, vol. 5, n. 2, pp. 76-93, http://dx.doi.org/10.1453/jeb.v5i2.1650
- Coccia M. 2018a. General properties of the evolution of research fields: a scientometric study of human microbiome, evolutionary robotics and astrobiology, Scientometrics, vol. 117, n. 2, pp. 1265-1283, https://doi.org/10.1007/s11192-018-2902-8
- Coccia M. 2019. Comparative Institutional Changes. A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance, Springer Nature, https://doi.org/10.1007/978-3-319-31816-5_1277-1
- Coccia M. 2019. Intrinsic and extrinsic incentives to support motivation and performance of public organizations, Journal of Economics Bibliography, vol. 6, no. 1, pp. 20-29, http://dx.doi.org/10.1453/jeb.v6i1.1795
- Coccia M. 2019. The Role of Superpowers in Conflict Development and Resolutions. A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance, Springer, https://doi.org/10.1007/978-3-319-31816-5_3709-1
- Coccia M. 2019. Theories of Development. A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance, Springer Nature, https://doi.org/10.1007/978-3-319-31816-5_939-1
- Coccia M. 2020. An index to quantify environmental risk of exposure to future epidemics of the COVID-19 and similar viral agents: Theory and Practice. Environmental Research, volume 191, number 110155, https://doi.org/10.1016/j.envres.2020.110155
- Coccia M. 2020. Asymmetry of the technological cycle of disruptive innovations. Technology Analysis & Strategic Management, vol. 32, n. 12, p. 1462-1477. https://doi.org/10.1080/09537325.2020.1785415
- Coccia M. 2020. Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. Science of The Total Environment, vol. 729, n.138474, https://doi.org/10.1016/j.scitotenv.2020.138474.
- Coccia M. 2020a. How (Un) sustainable Environments are Related to the Diffusion of COVID-19: The Relation between Coronavirus Disease 2019, Air Pollution, Wind Resource and Energy. Sustainability, 12, 9709; doi:10.3390/su12229709
- Coccia M. 2020b. Effects of Air Pollution on COVID-19 and Public Health, Research Article-Environmental Economics-Environmental Policy, ResearchSquare, DOI:10.21203/rs.3.rs-41354/v1
- Coccia M. 2020d. The evolution of scientific disciplines in applied sciences: dynamics and empirical properties of experimental physics, Scientometrics, n. 124, pp. 451-487. https://doi.org/10.1007/s11192-020-03464-y
- Coccia M. 2021. Comparative Critical Decisions in Management. In: Farazmand A. (eds), Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham. https://doi.org/10.1007/978-3-319-31816-5_3969-1
- Coccia M. 2021. Recurring waves of Covid-19 pandemic with different effects in public health, Journal of Economics Bibliography, vol. 8, n. 1, pp. 28-45. http://dx.doi.org/10.1453/jeb.v8i1.2184
- Coccia M. 2021a. Pandemic Prevention: Lessons from COVID-19. Encyclopedia, vol. 1, n. 2, pp. 433-444. doi:

10.3390/encyclopedia1020036

- Coccia M. 2021b. High health expenditures and low exposure of population to air pollution as critical factors that can reduce fatality rate in COVID-19 pandemic crisis: a global analysis Environmental Research, vol. 199, Article number 111339, https://doi.org/10.1016/j.envres.2021.111339
- Coccia M. 2021c. Effects of the spread of COVID-19 on public health of polluted cities: results of the first wave for explaining the *dejà vu* in the second wave of COVID-19 pandemic and epidemics of future vital agents. Environmental Science and Pollution Research 28(15), 19147-19154. https://doi.org/10.1007/s11356-020-11662-7
- Coccia M. 2021d. The effects of atmospheric stability with low wind speed and of air pollution on the accelerated transmission dynamics of COVID-19. International Journal of Environmental Studies, vol. 78, n. 1, pp. 1-27, https://doi.org/10.1080/00207233.2020.1802937
- Coccia M. 2021e. The relation between length of lockdown, numbers of infected people and deaths of COVID-19, and economic growth of countries: Lessons learned to cope with future pandemics similar to COVID-19. Science of The Total Environment, vol. 775, number 145801, https://doi.org/10.1016/j.scitotenv.2021.145801
- Coccia M. 2022. Meta-analysis to explain unknown causes of the origins of SARS-COV-2. Environmental Research, vol. 111, Article n. 113062. https://doi.org/10.1016/j.envres.2022.113062
- Coccia M. 2022a. Effects of strict containment policies on COVID-19 pandemic crisis: lessons to cope with next pandemic impacts. Environmental Science and Pollution Research, DOI: 10.1007/s11356-022-22024-w, https://doi.org/10.1007/s11356-022-22024-w
- Coccia M. 2022b. Improving preparedness for next pandemics: Max level of COVID-19 vaccinations without social impositions to design effective health policy and avoid flawed democracies. Available online 31 May 2022, n. 113566. https://doi.org/10.1016/j.envres.2022.113566
- Coccia M. 2022c. Preparedness of countries to face COVID-19 pandemic crisis: Strategic positioning and underlying structural factors to support strategies of prevention of pandemic threats. Environmental Research, Volume 203, n. 111678, https://doi.org/10.1016/j.envres.2021.111678.
- Coccia M. 2022d. COVID-19 Vaccination is not a Sufficient Public Policy to face Crisis Management of next Pandemic Threats. Public Organization Review, https://doi.org/10.1007/s11115-022-00661-6
- Coccia M. 2022e. Optimal levels of vaccination to reduce COVID-19 infected individuals and deaths: A global analysis. Environmental Research, vol. 204, Part C, March 2022, Article number 112314, https://doi.org/10.1016/j.envres.2021.112314
- Coccia M. 2022f. COVID-19 pandemic over 2020 (with lockdowns) and 2021 (with vaccinations): similar effects for seasonality and environmental factors. Environmental Research, Volume 208, n. 112711. https://doi.org/10.1016/j.envres.2022.112711
- Coccia M. 2022g. The Spread of the Novel Coronavirus Disease-2019 in Polluted Cities: Environmental and Demographic Factors to Control for the Prevention of Future Pandemic Diseases. In: Faghih, N., Forouharfar, A. (eds) Socioeconomic Dynamics of the COVID-19 Crisis. Contributions to Economics: 351-369. Springer, Cham. https://doi.org/10.1007/978-3-030-89996-7_16
- Coccia M. 2023. High potential of technology to face new respiratory viruses: mechanical ventilation devices for

effective healthcare to next pandemic emergencies, Technology in Society, vol. 73, May 2023, n. 102233, https://doi.org/10.1016/j.techsoc.2023.102233

- Coccia M. 2023. Sources, diffusion and prediction in COVID-19 pandemic: lessons learned to face next health emergency[J]. AIMS Public Health, 2023, 10(1): 145-168. doi: 10.3934/publichealth.2023012
- Coccia M., Bellitto M. 2018. A critique of human progress: a new definition and inconsistencies in society, Quaderni IRCrES-CNR, 4(3), 51-67. http://dx.doi.org/10.23760/2499-6661.2018.017
- Coccia M., Benati I. 2018. Rewards in public administration: A proposed classification, Journal of Social and Administrative Sciences, vol. 5, n. 2, pp. 68-80, http://dx.doi.org/10.1453/jsas.v5i2.1648
- Coccia M., Bontempi E. 2023. New trajectories of technologies for the removal of pollutants and emerging contaminants in the environment. Environmental Research, vol. 229, n. 115938, https://doi.org/10.1016/j.envres.2023.115938
- Crow D. A., Albright E. A., Ely T., Koebel, E., Lawhon L. 2018. Do disasters lead to learning? Financial policy change in local government. Review of Policy Research, 35(4), 564–589.
- Dai, H., Cao, W., Tong, X. et al. 2022. Global prediction model for COVID-19 pandemic with the characteristics of the multiple peaks and local fluctuations. BMC Med Res Methodol 22, 137 (2022). https://doi.org/10.1186/s12874-022-01604-x
- Daszak P., Olival K. J., Li H. 2020. A strategy to prevent future epidemics similar to the 2019-nCoV outbreak, Biosafety and Health, http://dx.doi.org/10.1016/j.bsheal.2020.01.003
- Dobson, A. P., Carper, E. R. 1996. Infectious diseases and human population history. Bioscience 46, 115–126 (1996).
- Douglas W. Allen (2022) Covid-19 Lockdown Cost/Benefits: A Critical Assessment of the Literature, International Journal of the Economics of Business, 29:1, 1-32, DOI: 10.1080/13571516.2021.1976051
- Farazmand A. (ed.) 2001. Handbook of crisis and emergency management. Marcel Dekker, New York.
- Farazmand A. (ed.) 2014. Crisis and Emergency Management. Theory and Practice, Second Edition. Routledge.
- Gigerenzer G., Todd P. M. 1999. Ecological rationality: the normative study of heuristics. In Gigerenzer Gerd; Todd Peter M. The ABC Research Group (eds.). Ecological Rationality: Intelligence in the World. New York: Oxford University Press. pp. 487–497.
- Goolsbee, A. and Syverson, C., 2021. Fear, lockdown, and diversion: Comparing drivers of pandemic economic decline 2020. Journal of Public Economics, 193:104311.
- Groh M. 2014. Strategic Management in Times of Crisis. American Journal of Economics and Business Administration. 6 (2): 49–57.
- Hellman, M. A., Savage, E. P. & Keefe, T. J. 1986. Epidemiology of accidents in academic chemistry laboratories. Part 1. Accident data survey. J. Chem. Educ. 63, A267.
- Janssen M., van der Voort H. 2020. Agile and adaptive governance in crisis response: Lessons from the COVID-19 pandemic. International Journal of Information Management, vol. 55, Article number 102180
- Jia, Peng, Yang, Shujuan, 2020. China needs a national intelligent syndromic surveillance system. Nature Med. 26, 990. https://doi.org/10.1038/s41591-020-0921-5.
- Johansson M. A., et al. 2019. An open challenge to advance probabilistic forecasting for dengue epidemics. Proc. Natl.

Acad. Sci. U.S.A. 116, 24268–24274.

- Johns Hopkins Center for System Science and Engineering, 2022. Coronavirus COVID-19 Global Cases, https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6 (accessed on 4 October 2022).
- Jones, A.M., Harrison, R.M., 2004. The effects of meteorological factors on atmospheric bio aerosol concentrations-a review. Sci. Total Environ. 326, 151e180.
- Kahneman D., Slovic P., Tversky A. 1982. Judgment Under Uncertainty: Heuristics and Biases. Cambridge University Press.
- Kapitsinis N. 2020. The underlying factors of the COVID-19 spatially uneven spread. Initial evidence from regions in nine EU countries. Regional Science Policy and Practice, 12(6), pp. 1027-1045
- Keshavamurthy, R., Dixon, S., Pazdernik, K.T., Charles, L.E. 2022. Predicting infectious disease for biopreparedness and response: A systematic review of machine learning and deep learning approaches. One Health15,100439
- Khandia, R., Singhal, S., Alqahtani, T., Kamal, M. A., El-Shall, N. A., Nainu, F., Desingu, P. A., & Dhama, K. 2022. Emergence of SARS-CoV-2 Omicron (B.1.1.529) variant, salient features, high global health concerns and strategies to counter it amid ongoing COVID-19 pandemic. Environmental research, 209, 112816. https://doi.org/10.1016/j.envres.2022.112816
- Korolev, I., 2021. Identification and estimation of the SEIRD epidemic model for COVID-19. J. Econometrics, 220(1): 63-85.
- Krechetov, M., Esmaieeli Sikaroudi, A.M., Efrat, A. et al. 2022. Prediction and prevention of pandemics via graphical model inference and convex programming. Sci Rep 12, 7599 (2022). https://doi.org/10.1038/s41598-022-11705-8
- Kuvvetli Y., Deveci M., Paksoy T., Garg H., 2021. A predictive analytics model for COVID-19 pandemic using artificial neural networks. Decision Analytics Journal, vol. 1, n. 100007, https://doi.org/10.1016/j.dajour.2021.100007.
- Li Na, Hu Lingfei, Jin Aijun, Li Jinsong 2019. Biosafety laboratory risk assessment,Journal of Biosafety and Biosecurity, vol. 1, n. 2, pp. 90-92. https://doi.org/10.1016/j.jobb.2019.01.011
- Liu Z., Magal P., Webb G. 2021a. Predicting the number of reported and unreported cases for the COVID-19 epidemics in China, South Korea, Italy, France, Germany and United Kingdom. Journal of theoretical biology, 509, 110501. https://doi.org/10.1016/j.jtbi.2020.110501
- Liu, X. X., Fong, S. J., Dey, N., Crespo, R. G., & Herrera-Viedma, E. (2021). A new SEAIRD pandemic prediction model with clinical and epidemiological data analysis on COVID-19 outbreak. Applied intelligence (Dordrecht, Netherlands), 51(7), 4162–4198. https://doi.org/10.1007/s10489-020-01938-3
- Magazzino C., Mele M., Coccia M. 2022. A machine learning algorithm to analyze the effects of vaccination on COVID-19 mortality. Epidemiology and infection, 1–24. Advance online publication. https://doi.org/10.1017/S0950268822001418
- Mahmoudi, J., Xiong, C. 2022. How social distancing, mobility, and preventive policies affect COVID-19 outcomes: Big data-driven evidence from the District of Columbia-Maryland-Virginia (DMV) megaregion. PloS one, 17(2), e0263820. https://doi.org/10.1371/journal.pone.0263820
- McDonald D. J. et al., 2021. Can auxiliary indicators improve COVID-19 forecasting and hotspot prediction? Proc. Natl.

Acad. Sci. U.S.A. 118, e2111453118 (2021).

- Ménard, A. D., Trant, J. F. (2020). A review and critique of academic lab safety research. Nature chemistry, 12(1), 17–25. https://doi.org/10.1038/s41557-019-0375-x
- Mohammadi, Z., Cojocaru, M.G., Thommes, E.W. 2022. Human behaviour, NPI and mobility reduction effects on COVID-19 transmission in different countries of the world. BMC Public Health, 22(1),1594
- Mosleh M., Roshani S., Coccia M. 2022. Scientific laws of research funding to support citations and diffusion of knowledge in life science. Scientometrics 127, 1931–1951. https://doi.org/10.1007/s11192-022-04300-1
- Newby J. M., O'Moore K., Tang S., Christensen H., Faasse K. 2020. Acute mental health responses during the COVID-19 pandemic in Australia. PloS one, 15(7), e0236562. https://doi.org/10.1371/journal.pone.0236562
- Núñez-Delgado A., Bontempi E., Coccia M., Kumar M., Farkas K., Domingo, J. L. 2021. SARS-CoV-2 and other pathogenic microorganisms in the environment, Environmental Research, Volume 201, n. 111606, https://doi.org/10.1016/j.envres.2021.111606.
- Núñez-Delgado, Avelino, Zhien Zhang, Elza Bontempi, Mario Coccia, Marco Race, and Yaoyu Zhou. 2023. Editorial on the Topic “New Research on Detection and Removal of Emerging Pollutants” Materials, vol. 16, no. 2: 725. https://doi.org/10.3390/ma16020725
- Petticrew, M., Roberts, H. (2005). Systematic reviews in the social sciences: A practical guide. Malden, MA: Blackwell Publishing.
- PStangier, U., Kananian, S., Schüller, J. 2022. Perceived vulnerability to disease, knowledge about COVID-19, and changes in preventive behavior during lockdown in a German convenience sample. Current Psychology41(10), pp. 7362-7370
- Reinhart A. et al., 20221. An open repository of real-time COVID-19 indicators. Proc. Natl. Acad. Sci. U.S.A. 118, e2111452118.
- Rosario Denes K.A., Mutz Yhan S., Bernardes Patricia C., Conte-Junior Carlos A., 2020. Relationship between COVID-19 and weather: Case study in a tropical country. International Journal of Hygiene and Environmental Health 229, 113587
- Rosenfeld, R., & Tibshirani, R. J. (2021). Epidemic tracking and forecasting: Lessons learned from a tumultuous year. Proceedings of the National Academy of Sciences of the United States of America, 118(51), e2111456118. https://doi.org/10.1073/pnas.2111456118
- Sagan A., Thomas S., McKee M., Karanikolos M., Azzopardi-Muscat N., de la Mata I., Figueras J. 2020. COVID-19 and health systems resilience: lessons going forwards, Eurohealth 2020; 26(2).
- Seeger M. W., Sellno T. L., Ulmer R. R. 1998. Communication, organization and crisis. Communication Yearbook. 21: 231–275.
- Simmons, H. E., Matos, B. & Simpson, S. A. 2017. Analysis of injury data to improve safety and training. J. Chem. Health Saf. 24, 21–28.
- Sirois, F. M., & Owens, J. 2021. Factors Associated With Psychological Distress in Health-Care Workers During an Infectious Disease Outbreak: A Rapid Systematic Review of the Evidence. Frontiers in psychiatry, 11, 589545. https://doi.org/10.3389/fpsyt.2020.589545

- Šušteršič T, Blagojević A, Cvetković D, Cvetković A, Lorencin I, Šegota SB, Milovanović D, Baskić D, Car Z and Filipović N (2021) Epidemiological Predictive Modeling of COVID-19 Infection: Development, Testing, and Implementation on the Population of the Benelux Union. Front. Public Health 9:727274. doi: 10.3389/fpubh.2021.727274
- Tsiotas, D.; Magafas, Lykourgos. 2020. The Effect of Anti-COVID-19 Policies on the Evolution of the Disease: A Complex Network Analysis of the Successful Case of Greece. Physics 2, no. 2: 325-339. https://doi.org/10.3390/physics2020017
- U.S. Department of Health & Human Services, 2021. Public health Emergency-Executive Summary, https://www.phe.gov/Preparedness/planning/nivms/Pages/executive-summary.aspx (accessed March 2021).
- Uman L. S. (2011). Systematic reviews and meta-analyses. Journal of the Canadian Academy of Child and Adolescent Psychiatry. Journal de l'Academie canadienne de psychiatrie de l'enfant et de l'adolescent, 20(1), 57–59.
- Van Noorden, R. 2013. Safety survey reveals lab risks. Nature 493, 9–10 (2013).
- Warren G. W., Lofstedt R., Wardman J. K. 2021.COVID-19: the winter lockdown strategy in five European nations Journal of Risk Research 0:0, pages 1-27.
- Wei, M., Liu, Houfeng, Chen, Jianmin, Caihong, Xu, Li, Jie, Pengju, Xu, Sun, Ziwen, 2020. Effects of aerosol pollution on PM2.5-associated bacteria in typical inland and coastal cities of northern China during the winter heating season. Environ. Pollut. 262 (2020), 114188. https://doi.org/10.1016/j.envpol.2020.114188.
- Weible C.M., Nohrstedt D., Cairney P. et al. 2020. COVID-19 and the policy sciences: initial reactions and perspectives. Policy Sci 53, 225–241.
- Whittaker C., Kamaura L. T., Takecian P. L., da Silva Peixoto P., Oikawa M. K., Nishiya A. S., … Sabino E. C. 2021. Three-quarters attack rate of SARS-CoV-2 in the Brazilian Amazon during a largely unmitigated epidemic. Science (New York, N.Y.), 371(6526), 288–292. https://doi.org/10.1126/science.abe9728
- Wieland, T., 2020. A phenomenological approach to assessing the effectiveness of COVID-19 related nonpharmaceutical interventions in Germany. Safety Science, 131:104924.
- Williams G. A., Ulla Díez S. M., Figueras J., Lessof S. 2020. Translating evidence into policy during the COVID-19 pandemic: bridging science and policy (and politics). Eurohealth 2020; 26(2).
- Wolfe, N., Dunavan, C. & Diamond, J. 2007. Origins of major human infectious diseases. Nature 447, 279–283 (2007). https://doi.org/10.1038/nature05775
- Yuan, D., Gao, W., Liang, S., Yang, S., & Jia, P. (2020). Biosafety threats of the rapidly established labs for SARS-CoV-2 tests in China. Environment international, 143, 105964. https://doi.org/10.1016/j.envint.2020.105964
- Zhong, J., Zhang, X., Dong, Y., Wang, Y., Wang, J., Zhang, Y., et al., 2018. Feedback effects of boundary-layer meteorological factors on explosive growth of PM2.5 during winter heavy pollution episodes in Beijing from 2013 to 2016. Atmos. Chem. Phys. 18, 247e258.