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Globalization and global risk: How risk analysis needs to be enhanced to be effective in confronting current threats

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ABSTRACT

In the last 20-30 years, technological innovation has enabled the advancement of industry at a global scale, giving rise to a truly global society, resting on an interdependent web of transnational technical, economic and social systems. These systems are exposed to scenarios of cascading outbreaks, whose impacts can ripple to very large scales through their strong interdependencies, as recently shown by the pandemic spreading of the Coronavirus. Considerable work has been conducted in recent years to develop frameworks to support the assessment, communication, management and governance of this type of risk, building on concepts like systemic risks, complexity theory, deep uncertainties, resilience engineering, adaptive management and black swans. Yet contemporary risk analysis struggles to provide authoritative societal guidance for adequately handling these types of risks, as clearly illustrated by the Coronavirus case. In this paper, we reflect on this situation. We aim to identify critical challenges in current frameworks of risk assessment and management and point to ways to strengthen these, to be better able to confront threats like the Coronavirus in the future. A set of principles and theses are established, which have the potential to support a common foundation for the many different scientific perspectives and ‘schools’ currently dealing with risk handling issues.

1. Introduction

Currently the world is suffering as a result of the Coronavirus, which among other catastrophic consequences has also led to the implementation of different forms of social isolation as measures of mitigation. This is affecting directly the fundamental element exposed to the health risk, which is also the principal actor in the globalized industrial, economic and social world: people. As a result of people’s isolation, many industrial, social and cultural systems have suspended or significantly reduced their production and services, with future effects still to be seen. The Coronavirus case demonstrates that the development of disastrous events has dramatically changed during recent years, because of globalization, pushed by technological innovation and strong industrialization. Our society now relies on an interdependent web of transnational technical, economic and social systems, which has allowed the massive and wide transportation and distribution of people, materials, products, services, for an unprecedented improvement of welfare in most regions of the world. At the same time, however, the interconnected systems are inevitably exposed to potential scenarios of cascading outbreaks, whose effects can ripple to very large scales through their strong interdependencies. The vulnerabilities are massive and disturbing. The underlying systems have complex features, interactions among the system elements lead to complex dynamics, and surprises occur [19,36,37,49]. Classical risk assessments do not work in these situations, as a potential disaster in such complex systems cannot be foreseen by looking at the chain of events that may occur [30]. The global financial crisis of a few years ago is an example: one bank, Lehman Brothers, filed for bankruptcy in 2008 [38], with losses that extended far beyond its own financial value or its thousands of employees who lost their jobs; the effects rippled throughout the global financial system, bringing it to its knees and spreading to other major sectors like the car industry. The main lifeline systems today are all tightly connected in large and intricate networks of dependency and with interdependent links to other sectors and across national borders.

With respect to the above, a major issue for risk analysts and managers is how to deal with hazards and threats with a potential for extreme consequences and large uncertainties. We know that in these cases, accurate predictions of what is coming cannot be made and, in fact, the Coronavirus case has shown that the world’s risk management and governance systems are not working as intended. We have not been
effective in protecting people from this virus. As risk scientists, it is necessary to reflect on this – is the reason mainly about unfortunate circumstances or poor risk handling by authorities and agencies? Do we, as a risk science community, also bear a responsibility for this failure? Have we provided the proper concepts, principles, approaches, methods and models for adequately assessing, communicating, managing and governing the risk?

In recent years, various perspectives and approaches have been proposed in the literature, to try to meet the challenges of assessing and handling risk in relation to such extreme situations and complex systems. These perspectives and approaches, which to a large extent can be viewed as scientific schools, include what we will refer to as ‘safety science’ (highlighting sociotechnical aspects, complexity theory, and resilience analysis), ‘risk governance and systemic risk frameworks’, ‘post-normal science’, quality management and ‘risk science’ (highlighting ‘broad’ perspectives on risk with an emphasis on uncertainties, knowledge and potential surprises (black swans)). These perspectives and approaches all produce knowledge relevant to the proper assessment, communication and handling of risks subject to large uncertainties. But is the message the same? Is the separation between these schools – as reflected by differences in scientific pillars and preferred journals, conferences, societies, etc. - hampering the development of authoritative guidance to help policy-makers, managers and decision-makers to properly assess, communicate and handle risk? Is there a potential for joining forces, to build a new generation of risk, safety and resilience frameworks for the benefit of society and us all?

The present paper discusses all these issues, motivated by the pandemic outbreak that the whole world is experiencing and the consequences that it is suffering because of the Coronavirus, COVID-19. The main aim of the paper is to provide new reflections and knowledge on the proper assessment and handling of risk of the types addressed above, by critically reviewing current perspectives and approaches, and pointing to areas with the potential for enhancements, so that we can be better able to confront global, highly uncertain and large consequence threats like the Coronavirus in the future. A key topic discussed is the tension between using scientific methods and models, on the one hand, and applying the precautionary principle, on the other, as we have seen also in the context of the scientific and political debates for the Coronavirus. In fact, in relation to the Coronavirus case, politicians have to a large extent referred to the precautionary principle (and still are), to justify the implementation of many specific measures. In this respect, we seek to bring new insights about this principle and associated ideas of risk handling, by relating it to the particular case of the global risk of Coronavirus and the perspectives of the different scientific schools of risk assessment, management and governance mentioned above.

The reminder of this paper is structured in the following way. First, in Section 2, we discuss the general issues involved in preparing for and managing disasters. Then, in Section 3, we describe the Coronavirus case as a risk assessment and management perspective, addressing relevant specific features and challenges. In Section 4, we summarize and reflect on current perspectives and approaches (schools) for assessing and handling risks of this type, using the classification referred to above. From this basis, in Section 5, we discuss what we can do to improve the way we assess, communicate and handle risks like those of the Coronavirus type. Finally, Section 5 provides some conclusions.

2. The need to prepare for face-to-face disasters and to manage crises in a globalized world

In general terms, a disaster is any occurrence that causes damage, destruction, ecological disruption, loss of human life, human suffering, or the deterioration of health and health services on a scale sufficient to warrant an extraordinary response from outside the affected community or area [53]. Such situations may include natural disasters, such as droughts, earthquakes, floods or storms, and epidemics; or industrial accidents, such as nuclear or chemical ones ([29,32], and [55]). The former are addressed within the concept of disaster management [1], but studies of epidemic disaster management are quite rare, compared to those of earthquakes, floods and other disasters, and are mostly focused on predicting the impact of an epidemic if one were to start. The latter (industrial disasters) are typically dealt with by formalized frameworks of technical risk assessment and management, to inform decisions on the design and operation of adequate preventive and mitigative barriers.

The physical setting in which disasters may occur has dramatically changed over recent years, because of globalization pushed by technological innovation and strong industrialization. New factors are driving the occurrence and the consequences of disasters, among which population density, urbanization, globalization and climate change are perhaps the most evident. These factors are proving catalysts for the acceleration of pandemic disasters. For example, climate change might play a role in the birth and transmission of specific diseases; the huge trend of urbanization of the world’s population, along with the substantial growth in population itself, is a factor that can accelerate epidemic outbreaks into pandemic disasters, through social globalization. All this renders our socio-technical-economic systems vulnerable to a pandemic like the one we are facing today, and more difficult the risk management of disasters and crises in general.

Disaster management comprises, in general, a set of activities that are performed before, during and after a disaster, with the goal of preventing loss of human life, reducing the impact of the disaster on the economy and re-establishing a normal, or even improved, state of affairs [4]. Disaster risk management seeks to identify and adopt adequate measures of prevention, mitigation, preparedness, emergency response and recovery [40]. Various studies have shown that risk management of disasters can save lives and offer relief to those hit by the disaster [1,40].

The objectives of disaster preparedness for control and containment of an outbreak of an epidemic or pandemic relate, then, to reducing the rate at which vulnerable individuals become infected, reducing the mortality rate for those already infected and increasing the immunization capacity of the population. The preparation measures for control and containment must build the capabilities to launch quarantine programs over entire geographic regions, where possible. They must provide medical supplies and life commodities. They can be adopted both for prevention of the spread after the initiation of an infectious disease (pre-event measures) or for control and containment of a confirmed outbreak (post-event measures). In the former case, a predetermined amount of medical supplies should be kept in stock and ready to be used at the outbreak of the epidemic. For the specific case of the Coronavirus, the European Union (EU) has created a stockpile of medical equipment (such as ventilators and protective masks) to help EU countries fight the COVID-19 pandemic. The stockpile includes medical items, such as intensive care medical equipment, for example ventilators, and personal protective equipment, such as reusable masks, and laboratory supplies; its current main aim is to help those EU states that face shortages of the equipment needed to treat infected patients and to protect health care workers (https://ec.europa.eu/commission/presscorner/detail/en/ip _20.476).

In general, the management of the risk of disasters, such as epidemic/pandemic outbreaks, calls for preparedness and a prompt response to control them. Certain protocols should be prepared and, then, followed; supplies and human resources (medical and other personnel, particularly in the case of epidemics and pandemics) should be adequately prepared and effectively made available and utilized, for the containment effort to be successful. For example, if a smallpox attack happens, vaccination of the affected population should take place within four days, while, in the case of an anthrax outbreak, the distribution of antibiotics should take place within two days of the event [28]. This calls for an emergency supply chain (sometimes also called a humanitarian supply chain) that is properly designed, managed and operated, to successfully handle the many logistics issues that arise. This entails that financial resource allocation, vital commodities’ and medical supplies’ stockpiling capacities and locations be optimized, based on an a priori
risk assessment, and the logistics operations during emergency for their management transportation and distribution be carried out in conjunc-
tion with the available information on the evolution of the disaster, in
order to contain its spread and hopefully keep it below critical proportions.

Governmental agencies and health institutions must be prepared in advance for the control and containment of disasters of epidemic out-
breaks. To prepare, they must take risk-informed decisions on contin-
gency plans to be set up so as to ensure the availability of emergency
medical stocks and well-trained personnel, their appropriate deploy-
ment, and the availability of different types of vehicles for the transpor-
tation of essential medical supplies and commodities, etc.

An evident common ground and connection exists between the technical risk assessment & management and the disaster management, stemming from the four stages that meet their purpose: prevention/
mitigation, protection/preparation, response, and recovery. Prevention/
mitigation comprises all activities for avoiding the occurrence of the accident/disaster and reducing its probability. Protection/preparation
relates to all safety measures and activities that are designed and planned
to be put into action when the accident/disaster occurs, in order to
reduce its impact and minimize losses. Response is obtained through the
activities of emergency and crisis management implemented during the
aftermath of the accident/disaster, to prevent additional damage and
loss. Finally, recovery is the phase of restoring the back-to-normal sit-
uation after the accident/disaster. The four stages of disaster manage-
ment, thus, match those of resilience management [57] or business
continuity [54,56], typical of engineered systems and industrial com-
panies, respectively.

In spite of the importance of taking a risk-informed approach to disaster preparedness, and all the associated logistics operations for disaster control and containment, the scientific community has not yet produced well-established approaches that explicitly incorporate risk assessment as a systemic framework for holistically dealing with the problem of disaster preparedness.

3. The coronavirus case and the challenges posed to the assessment and management of risk

This paper is motivated by the pandemic outbreak that the whole world is experiencing because of the Coronavirus, COVID-19. As of April 2, 2020, 9.04 GMT, there are 938,373 confirmed cases of Coronavirus globally. Sadly, there have been 47,273 deaths.

The current Coronavirus pandemic has raised the importance of preparing for disasters, but, unfortunately, once again, only after the fact – once the COVID-19 epidemic outbreak in China had escalated to a global pandemic. And although some claim this event to be a black swan (a surprising, unforeseen extreme event), there are aspects that lead to a different perspective on the matter, which make it not surprising at all, in our globalized world, but actually very likely to occur in, say, a ten-year horizon, having in mind the rather high number of similar events in recent years.

A set of characteristics defines the risk of global crises that we are exposed to, such as that due to the Coronavirus outbreak, and these shape the way we address it. In the specific case of the current pandemic, the probability of and the risk related to the occurrence of the outbreak of such a crisis and of its severity have been judged too low in spite of clear evidence. Large uncertainties and weak knowledge have partially caused this, leading to an insufficient level of preparedness in all countries and from all points of view: material, organizational, financial, political and cultural. What has not helped the preparedness is the in-
dividual and regionally collective “optimistic bias”, which often de-
termines the attitude to risk and the policy measures that follow. From the point of view of individual attitude, the optimistic bias leads people to ignore the risks: it is the superwoman/superman attitude of “it won’t happen to me”, in most cases supported by the illusion of having control over things. It has led some people to feel that they will avoid the

COVID-19 disease and, therefore, they can even ignore protective
measures, including confinement [41]. This is somewhat fed by certain erroneous, or incomplete at best, communication, e.g. that which fosters the belief that the virus is really only dangerous for old and sick people. Communication should, instead, be clear on the fact that nobody can escape infection by the new coronavirus and that the physical reaction to the disease differs from individual to individual, as it is conditioned by a number of factors, mostly unknown. From the point of view of collective communities, it has again to a large extent been an “it won’t happen to me” attitude, until it is suddenly revealed that the pandemic is real and there will be a high number of cases and also deaths in this region/country/area.

Another characteristic refers to the perception that people have of different risks. Irrespective of whether there is more or less risk, tangible hazards like those arising from activities like car driving are perceived to be less severe than intangible hazards, like those related to epidemics or nuclear accidents. In the specific case of the Coronavirus, the high speed at which it spreads makes it legitimate to feel worried and, so, legitimate questions arise: How does this novel pandemic compare to the “normal” or accepted risk of infectious death? What is the “worst case” scenario? Should we panic and shun other people who may be carrying what might kill us? And, although it is rational to advocate that there is no need to become paranoid and fearful, but, on the contrary, there is a need to evaluate the risk and manage it scientifically, this is difficult to do in practice because:

- The risk level depends on the characteristics of the virus, including how it spreads to people
- A number of factors affect the behavior of the virus and of people, and all are highly uncertain because of lack of knowledge on the
physics of the virus and uncertainty in the actions and reactions of
people, at all levels
- Uncertainty affects the effectiveness of measures put in place to control the pandemic.

So, the rational and logical approach to dealing with the risk of the occurring pandemic (as with any other risk, for that matter) is not to panic but to limit one’s own personal and potential exposure and to minimize both the size and scale of the potentially exposed population. But the risk values produced to guide the decisions on how to do that cannot be exact, as they are based on weak and even potentially erro-
neous knowledge related to, for example, the spread of the virus and the
actuation and respect of the measures implemented. And if risk were judged based on how it is perceived (also biased by “street” news and politics), then intangible hazards would receive the highest attention, as is the case for operating nuclear power plants and today’s pandemic.

So, professional risk numbers are not enough to deal with situations like the Coronavirus crisis. Policies crave to be science-based, but science does not have clear answers in cases like this, characterized by large uncertainties due to a weak knowledge base on the phenomenon and the factors involved. And the communication of the risk becomes difficult itself: how to explain what risk is in situations of large un-
certainties and little knowledge? How can one say that it is small or large, relating it to uncertainties and knowledge? A risk professional may say that the risk is low (e.g. in the early phases of the outbreak), but the uncertainties are large: how can this be communicated, so that it is properly understood and used for decision making?

In a case like this, when the stakes involved and uncertainties are so large, there are no alternatives but to give weight to the precautionary principle. The health experts have been crystal clear about the need for some type of societal lockdown, and politicians, faced with a potential for catastrophic events with thousands and even millions of deaths, have had no other choice than to follow the recommendations of the experts and even to take the precautionary measures some steps further. While trying to limit the spread and control of the pandemic, the healthcare systems have been pushed to the edge of their capacity. The expected
economic and social costs are, however, enormous, and this brings strong pressure to lift the measures and reopen everything as soon as possible. In support to this, real-time tests are performed, and extensive research is conducted, to find ways of treating the patients and developing efficient vaccines against the virus, while some form of adaptive, learning-based risk management policy is applied in basically all countries [15,14].

4. Current perspectives and approaches for assessing and handling these types of risks

We imagine that we are confronted with the Coronavirus pandemic, in its early stages of development. Authorities must make decisions and take countermeasures to control the pandemic. These decisions and countermeasures imply public investments and can be restrictive for people’s activities. The potential impacts of the pandemic are huge and the uncertainties are large concerning the actual evolution of the outbreak and its consequences, as well as the effects of the possible interventions. Predictions on the scenarios of the evolution of the spread of the virus are highly desirable, but the influencing factors are many and the models of the phenomena involved need to be based on many assumptions, for most of which there is no absolute justification. This is because the physical, medical, social and economic phenomena involved are not really understood, in spite of the fact that there is field experience and considerable knowledge on such types of viruses, in general, and also on how to best handle their spread and the risks they carry. For situations like this, characterized by large uncertainties, the traditional textbook approaches to risk assessment and management cannot be used. Formal risk assessments cannot be applied as is, to accurately predict scenarios of evolution and estimate their consequences, accounting for the effects of alternative countermeasures. Thus, the decision-making remains intrinsically dynamic and adaptation to the evolution of the situation is inevitable, as shown by the different decision strategies taken back and forth by the authorities of the countries affected by the COVID-19 pandemic.

This motivates a reflection on the approaches to risk assessment and management for different types of risk problems. There are, indeed, many ways of categorizing risk problems. Many relate to the severity of the consequences (the stakes involved) and their degrees of uncertainty (e.g. [6,16,43]). From the perspective of these two dimensions, the pandemic situation that we are addressing corresponds to a high risk problem (large consequences with high uncertainty), and the traditional approach to risk assessment and management just does not work. As mentioned in Section 1, different ‘schools’ exist, to meet this type of situation. In the following, we briefly recall some of these, the main aim being to show that, in fact, they all provide useful perspectives for and approaches to how to meet the challenges of assessing and managing risk in relation to critical situations of the kind that we are experiencing due to the Coronavirus pandemic.

Post-normal science [16,42] acknowledges the need for an alternative and supplementary approach to science and policy making, when the stakes involved and the related uncertainties are large – and, typically, with different values in dispute and decisions urgently needed on which actions to take. This requires extending beyond the traditional perspective that science is not only certain but also value-free, calling for the need of new methods capable of going beyond numbers through different aspects of knowledge and information, dialogue and participation. The post-normal science emphasizes uncertainty and qualitative analysis, and a scheme for how to perform such analysis has been proposed – the NUSAP system [15,16,51]. NUSAP uses five categories for the management and communication of uncertainty in science for policy: Numeral, Unit, Spread, Assessment and Pedigree. Through NUSAP, a qualitative study of the quality and strength of the knowledge base behind the relevant scientific information and risk findings can be made, to inform policy making.

The risk governance and systemic risk frameworks [8,9,23,43,45] build on similar ideas. The frameworks were developed to meet a need for proper risk handling, where the situations considered are characterized by complex systems, large uncertainties and/or different views about the values involved. The frameworks build on governance principles and adopt a ‘broad’ understanding of risk, which acknowledges uncertainty as a main component of risk and the need to see beyond probability when assessing, communicating and handling risk. The concept of systemic risk is highlighted. This concept was introduced by the Organisation for Economic Co-operation and Development ([39], p. 9) to address risks that affect the systems on which society depends, like health, transport, environment, energy, telecommunication systems, etc. Since then, considerable research and development has been conducted to further enhance the concept (e.g. [9,35,45,50]). It is undoubtedly that pandemics, like the one we are experiencing, do pose systemic risk and, from this perspective, must be assessed and managed. System thinking, based on seeing wholes and interconnections, is, then, needed if we are to identify potential surprises and the unforeseen – as stressed by many scholars of organizational theory, accident analysis, and the quality discourse [12,21,31,49] – and effectively deal with their consequences.

Risk governance and systemic risk frameworks rely on three main categories of strategies for handling risk: risk-informed (based on risk assessments), robustness/resilience (based on the precautionary and cautionary principles) and discursive strategies [44]. The strategy to apply in practice, to confront a systemic risk such as that brought by a pandemic, is normally a combination of these three types of strategies, with robustness/resilience as a main instrument for dealing with uncertainties (including potential surprises and the unforeseen), and dialogue for addressing differences in values.

Acknowledging complexity and dealing with uncertainties and the potential for surprises, through robustness and resilience-based approaches are key features of the risk governance school. This leads to safety science, and its roots in the ‘sociotechnical perspectives on safety’, which builds on three pillars [10]: i) a holistic view is needed to manage safety, using knowledge and experiential insights from different fields and disciplines (including technology and social sciences); ii) it is not possible to predict with sufficient accuracy and manage with sufficient control the behaviour of complex systems, their vulnerabilities and their response to accidents and disasters; and iii) robustness and resilience, thus, need to be accommodated, in addition to risk analysis.

Along these lines of thought, a rich body of literature on resilience has arisen in recent years, as a supplement to the traditional quantitative risk assessment approach, which has shown strong limitations when confronted with the analysis of complex systems and interconnected activities subject to large uncertainties regarding events’ occurrences and consequences’ evolution. The underlying idea is that, by strengthening the resilience of the system, the safety is improved without the need to calculate all probabilities and risks. We do not need to identify all events – hazards and threats – that can occur as we have to do in traditional, quantitative risk assessments based on probabilistic methods. Theories are developed providing a rationale for moving from ‘Safety-I’, where the focus is on ensuring that ‘as few things as possible go wrong’, to ‘Safety-II’, where the aim is to ensure that ‘as many things as possible go right’ [20]. In contrast somewhat to this perspective, the High Reliability Organizations (HROs) tradition emphasizes the importance of failures, and that high performance and reliability can be achieved even in complex organizations if properly managed; five principles are highlighted therein: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience and deference to expertise [52].

Potential surprises are also a key focus of the quality discourse ([12], Bergman [11]), with its distinction between ‘common-cause variation’ and ‘special-cause variation’. The former variation relates to ‘normal’ system variation, whereas the latter is associated with the unusual variation, the surprises (the black swans). Understanding the system causes is seen as the key to improving the system.
Risk science is the final school to be mentioned in this brief overview. It is based on the idea that the concepts, principles, approaches, methods and models for assessing, communicating, managing and governing risk form a distinct science [5,6,46–48]. This science provides guidance for all types of situations, including those characterized by the potential for severe consequences and large (deep) uncertainties, like the one we are facing in the COVID-19 pandemic. It provides knowledge about risk fundamentals, for example related to what risk is, how to characterize risk, what methods are suitable for analyzing risk, how to treat uncertainties in risk assessment, how to understand and use the precautionary principle, the difference between professional risk judgments and risk perception, how to best deal with risk related to potential surprises and the unforeseen (black swans), and how to understand the link between risk and resilience. All the other schools can be viewed as providing knowledge to this science. A broad perspective on risk is adopted [6,46], which sees uncertainty as a main component of risk and stresses the importance of knowledge and its strength when assessing and describing risk. The perspective allows for the inclusion of many safety, security, resilience and quality issues and is applicable to all domains (engineering, health, business, etc.).

In addition, many different risk management frameworks have been developed to deal with specific issues and domains, for example enterprise risk management (ERM) and business continuity management (BCM), in the case of commercial activities. BCM is of special relevance in this context, as it highlights disaster and crisis management, resilience and recovery planning [56].

As a final note on the perspectives taken above on risk, resilience, robustness, safety and security, these follow fundamental work by the Society for Risk Analysis (SRA), see SRA [46,47]. There are other perspectives than these, as for example that by the US National Academy of Sciences which defines risk as part of resilience (see e.g. [34], Linkov et al. [33][17]). We also refer to Ale et al [2,3], Jongejan [24] and Aven [6] for discussions related to the nexus between risk and resilience. It is beyond the scope of the present paper to discuss the justification and rationale of the different perspectives, but one key point should be made clear: the difference is to large extent rooted in different conceptual understandings and terminology. There is a broad recognition of the importance of resilience to meet uncertain and unknown types of threats and disturbances. Recent works on resilience and risk analysis and management in relation to COVID-19 (e.g. [7,18,22]) demonstrate this by their focus on system response measures and policies to prepare, absorb, recover and adapt. However, the resources are limited and what measures and policies to implement is challenging – considerations of what will or can happen are needed, as well as overall judgments of what is acceptable levels of risk and vulnerabilities. Risk science as referred to above provides one framework for conceptualising and understanding these phenomena; resilience analysis and management others, see the above references.

For the purposes of the present paper, such differences in perspectives just underscore the point being made in the coming section: there are many ‘schools’ providing knowledge on how to handle risk when the uncertainties are large, which to varying degree work together.

5. Discussion

The overview in the previous section has shown that there are many perspectives and schools providing knowledge on how to understand, assess, communicate and handle risk, in relation to hazards and threats with the potential for extreme consequences, where the uncertainties are large. These perspectives and schools are founded on different scientific fields, developing in, to a large extent, separate activities, such as conferences, research activities, scientific journals and educational programs. Yet, we argue here that the similarities and overlaps in the fundamental ideas are stronger than their differences. Specifically, we highlight the following theses as common to all these perspectives and schools:

a) Uncertainty is a key element of all the relevant frameworks.

b) An important source of uncertainty is potential surprises and the unforeseen.

c) It is essential to distinguish between uncertainty and ways of measuring uncertainty.

d) Risk assessments provide knowledge about what type of events may occur, how often they may occur and what could be the consequences of these events if they were to occur.

e) Risk perception reflects aspects like fear and dread, but could also include conscious judgments of uncertainties.

f) Robustness and resilience are fundamental strategies to deal with the uncertainties.

g) Sciences about activities, events, processes developing in the world (for example, about the global spread of a virus) are supported by all perspectives and schools through their process of generation of knowledge on how to understand, assess, communicate and handle the risk (vulnerabilities, resilience, etc) and the uncertainties associated with these activities, events, processes.

h) Precautionary thinking is necessary in cases when the stakes involved are high and there are large (scientific) uncertainties, but the degree of precaution remains a political issue more than a science issue. As a matter of fact, scientific work can be regarded as a precautionary measure to reduce the uncertainties.

i) Adaptive, learning-based risk handling is suitable and advisable, given the occurrence of the hazard or threat.

j) Prevention of the occurrence of the potential crises-initiating hazards and threats remains a major priority.

k) Science informs decision-makers; it does not prescribe what is the best policy, arrangement or measure.

l) Openness, transparency, dialogue and participation are general features of prudent risk-handling frameworks.

Acknowledging uncertainty as a key component of risk is critical if we are to properly understand, assess and communicate risk. The traditional approaches to risk assessment and management jump more or less directly to the uncertainty measurement tool – probability – the result being that key aspects of uncertainty are not given the attention they require. All the schools discussed in Section 4 see this challenge and provide broader frameworks for allowing the analysts to take some steps back from the operational measurement tool and look more deeply into the knowledge supporting the analyses and the uncertainty measures used. Risk assessments cannot produce accurate predictions of what is coming; rather, they help us to see what we know and what we do not know. They report the knowledge we have and are used as instruments for gaining new knowledge by, for example, studying how assumptions and model parameters influence key risk metrics. In the current Coronavirus case, we have seen a number of models used to estimate the number of deaths, with uncertainty intervals showing the dependencies on key assumptions. However, seldom or never have we seen communicated the actual meaning of these uncertainty intervals and their dependencies on the knowledge basis supporting the evaluation of these intervals.

At an early stage of the development of the Coronavirus epidemic, many people raised their concerns. However, some experts indicated that lay people’s concerns were the result of risk perceptional factors and biases, well-known from the scientific literature on this topic (e.g. [25,26]). The point made was that Coronavirus hits all the ‘hot buttons’; a risk situation which amplifies risk by features like unknown, new and delayed effects, lack of control and catastrophic potential, commonly summarized by the two dimensions: newness and dread. The implication is that the risk is amplified, and there is a potential for overreaction.

But how can we conclude that the response is an overreaction? At the time of concern, we are still faced with considerable uncertainties, and overreaction is a human attitude which reflects that. There is no ground truth to be used as reference for what is or is not an adequate response in

5
such uncertain situations. Lay people’s risk perception can also include conscious judgments of uncertainties, partly ignored by the professional risk judgments. The insights provided by the different schools referred to above acknowledge that the experts’ assessments have limitations and other knowledge sources can also provide valuable input to the overall risk considerations and should be considered.

When faced with uncertainties, robustness and resilience-based strategies are important, as we do not know what will happen next. We need to be ready to tackle different types of scenarios, also surprising ones. At the same time, we need to build on the available knowledge and strengthen it to better understand what is happening – we adapt and learn. The schools discussed in Section 4 support this approach to tackling risks, based on adaptation and learning, by providing concepts, principles, approaches, methods and models for how to do this. The perspectives differ partly on terminology and tools but remain similar on the fundamental ideas.

Inevitably, there is always a balance to be made between measures to create values, on the one hand, and measures to protect, on the other. Science does not give us the formula for finding the right balance. It provides relevant knowledge and is, thus, informing the decision-maker, but it does not prescribe what should be done. The authorities in different countries have all labelled their policies “science-based”, indicating that their policies are determined by the science findings. This type of notion is misleading, as the policies are at best science-informed. As we know, science produces justified claims about the world, but claims are not facts nor the truth. Policies also reflect values, in particular related to how to give weight to uncertainties. In the case of large uncertainties, there is a considerable leap between insights provided by science and the considerations and policies derived by the political institutions.

When faced with high stakes and large (scientific) uncertainties, precautionary measures will be and should be given weight in informing the decisions, as in the risk handling related to the Coronavirus. The point is simply that we will avoid very high losses, and, given the uncertainties about the virus and the process of its spread, this leads to extraordinarily cautious policies. All governments now seem to have adopted such policies. Some scholars are skeptical about the use of the precautionary principle/approach, indicating that it is not rational and scientific. However, the principle, as interpreted here as a guiding perspective, is in no way non-scientific: because of the uncertainties, there is not sufficient knowledge available to guide us differently on a solid basis. A key precautionary measure becomes, then, research to strengthen the knowledge base.

It is acknowledged that different situations call for different approaches for assessing and handling risk – “simple” problems with no or very limited uncertainties require different strategies than those required by problems with high stakes involved and large uncertainties, as considered in this paper. All schools referred to in Section 4 acknowledge this, although the different ways of classifying the “problems” vary. Uncertainty is, however, a common feature in all classification systems used.

These schools also highlight the importance of openness, transparency, dialogue and participation for dealing with situations of the kind discussed in this paper (high stakes—large uncertainties). There are always some limitations to this in practice, for example on the extent of openness that one can really achieve/obtain, but in many ways these features characterize an ideal in our democratic societies and we should be concerned when they are threatened in any way.

Finally, we conclude this section with some reflections about the actual risk handling in the Coronavirus case.

Today, the world is faced with an extreme crisis as a result of the Coronavirus. Thus, we can conclude that the risk handling has failed. The failure can be traced back to i) the origin of the virus, ii) the lack of early control, and iii) the mitigation measures adopted, given its spread.

The first type of failure is difficult to analyze at this stage, but thorough investigations and efforts are needed to see whether there are some fundamental problems in our societies, creating this type of threat. Openness and international cooperation are required to meet this challenge, but it could be difficult to obtain necessary changes in activities that are grounded in traditional and cultural practices. Nonetheless, this issue is a major concern. Is it possible to avoid such a virus occurring? Nothing would be better than the solution to this question.

Secondly, it was a failure that the signals and warnings were not taken seriously, which led to a delay in actuating measures for the control of the spread. The health organizations have warned governments and politicians for years that a serious pandemic is likely to occur. National and global risk assessments all point to pandemics as a major risk. Yet the signals and warnings were to a large extent ignored. As such, the Coronavirus pandemic is not to be seen as a black swan; its occurrence is not a surprising event relative to our knowledge. Maybe we could classify the event as a known unknown, indicating that there was knowledge that a serious pandemic could occur quite soon, but when it would occur was unknown to us. Surely there is a need to improve the way the world deals with this type of alarms and warnings. International cooperation is needed to develop relevant tools and institutions to look into this.

Thirdly, governments struggle to justify investments in preparedness measures. There are many threats that we must be protected from and using a lot of public money for something that might happen requires a strong economy and strict prioritizations. However, for pandemic risks, the evidence has been strong and clear, but still the Coronavirus spread has been enormous, whereas its mitigation has been weak in many respects. The problems that we are facing have demonstrated the extreme degree of vulnerability that our societies face today because of globalization. Necessary equipment is not available locally. All countries now depend on deliveries from specific producers often far away. Following the Coronavirus case, fundamental pillars for how we have organized the world will be questioned. More decentralized systems will challenge the globalist perspective.

One of the reviewers of the original version of this paper questioned the above conclusion that the risk handling in this case has failed. The point made was that some risks were taken and accepted, and the potential consequences were known, see also discussions in Ale et al [2,3]. Yes, decision-making about risk acceptance is an important task of risk management and governance, but it also makes sense to challenge this decision-making process and its rationale. We should question why many risk aspects were accepted and why vulnerabilities were not reduced or eliminated. That is exactly what this paper and many others are doing. It is about scrutinizing the current risk handling in order to identify weaknesses and look for ways that it can be improved. The risk management and governance is not based on a destiny perspective, expressing that serious events will occur if we have calculated a probability for these events to occur. An ultimate goal of risk management and governance is to avoid disasters. Above, we have pointed to some issues that we consider critical for being able to do this. It is about improving current approaches for risk handling. We also point to the need for the sciences and schools dealing with these challenges to do their job together, supporting the actual risk handling in the world.

This is about risk analysts and scientists to make constructive reflections on systems and processes of the world, and on how to improve the handling of these and of their risks, in line with the ideas of science and quality management.

6. Conclusions

In this paper, we have taken the dramatic world crisis of the Coronavirus pandemic to reflect on the current frameworks for risk assessment and management and what they can offer in these situations of high stakes and large uncertainties. We have recognized that the contemporary frameworks struggle to provide authoritative unified societal guidance to adequately handle these types of risks. This is clearly shown by the Coronavirus case, in which the risk handling has failed in
the identification and prevention of the origin of the virus, in the lack of early control and in the efficacy of the decision-making about the mitigation measures to be adopted once the spread had started.

We have highlighted that the existing scientific perspectives and schools related to risk share a number of fundamental principles and theses. They all consider uncertainty as a key element and view risk assessment as providing knowledge on what is known and what is not known about the occurrence and consequences of dangerous events, in the different risk situations. Recognition is given to the fact that risk perception reflects human feelings, like fear and dread, but could also include conscious judgments of uncertainties different from those of the risk professionals. Precautionary thinking, robustness and resilience are necessary approaches to develop adequate policies to address situations of high stakes and large uncertainties. The level of precaution, the decisions on how robust and resilient to be, remain political decisions, which can be informed by science and scientific knowledge: science does not prescribe the best policy of risk handling, but it can provide information for its definition by the decision-makers.

It is time to initiate processes to obtain stronger integration of these perspectives and schools. Only then, it is likely that we will be able to provide guidance for risk handling that really can have an impact. How to proceed is, however, difficult, given the way academic fields and societies work. The current crisis has been an eye-opener for many of us in different ways; perhaps it can also be that in relation to this challenge. We do hope so. Certainly, prevention remains a main priority (“If you think that safety is expensive, try an accident”, [271]), and the capabilities for adaptive, learning-based risk handling are required in the event of an occurrence of the hazard or threat. These aspects need to be dealt with in the current setting of our highly vulnerable world, where factors like population density, urbanization, globalization and climate change influence the uncertain occurrence of disasters and their uncertain consequences. For this, more openness, transparency, dialogue and participation at all levels are needed for prudent risk-handling, to be better able to confront global threats like the Coronavirus in the future.

**Authors statement**

The work has been carried out by Terje Aven and Enrico Zio, based on close collaboration on all aspects of the paper.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the uncertain occurrence of disasters and their uncertain consequences. For this, more openness, transparency, dialogue and participation at all levels are needed for prudent risk-handling, to be better able to confront global threats like the Coronavirus in the future.

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