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Perception and risk of Covid-19 and climate change: investigating analogies in a common framework

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This paper investigates analogies in the dynamics of Covid-19 pandemic and climate change. A comparison of their common features (such as nonlinearity and inertia) and differences helps us to achieve a correct scientific perception of both situations, increasing the chances of actions for their solutions. Besides, applying to both the risk equation provides different angles to analyse them, something that may result useful especially at the policy level. It shows that not only short-term interventions are needed, but also long-term strategies involving some structural changes. More specifically, it also shows that, even if climate change is probably more critical and long-lasting than the Covid-19 crisis, we still have, at least currently, more options for reducing its related risk.

Social media summary

A risk equation shows that now we have more options for fighting climate change than reducing the risks from Covid-19.

1. The context

Science is one of the 'high level' activities of our brain and a refined expression of human creativity and abstraction ability. Besides, it allows us to reach a 'correct' perception of the concrete issues we have to face, forming the basis to distinguish between *doxa* (i.e. unreflected opinions) and *episteme* (i.e. reliable knowledge). Nowadays, at the time of the complex worldwide crises we are living, that is, the coronavirus pandemic and climate change, this is particularly important: the shape of our future critically depends on the types of responses we will enact right now.

2. Perception

The example of the Covid-19 pandemic is paradigmatic. During its first phase, when the numbers of infected people and deaths were low, the common perception was that of a normally manageable infection. But scientists (epidemiologists in this case) warned policy makers and common people that this perception was wrong and the natural mathematical law for the expansion of an epidemic is nonlinear, in this case even exponential (Lammers et al., 2020). Thus, in the absence of prompt actions to avoid contacts and infections, the situation would have become rapidly unmanageable by healthcare systems (Nature Editorial, 2020).

We may understand even better the need for a rapid response if we consider that an epidemic is endowed with 'inertia' in its exponential behaviour. This inertia is due to a delay between actions aiming at containing epidemic and their results. In the case of Covid-19 this delay is about a few days, that is, the incubation period of this disease is currently expected to range between 2 and 14 days, although in most cases Covid-19 symptoms begin 4 to 6 days after exposure (Lauer et al., 2020).

If today we act with people separation measures, we can see the first results of these provisions after about 15 days: in the meantime, the epidemic evolves exponentially. This short delay and suitable measures adopted by governments allowed many countries, during the first wave of the outbreak, to contain infections in a reasonable number of months (WHO, 2020), and in one case even to nearly eradicate Covid-19 (Cousins, 2020). Yet, this happened only because concrete actions have been driven by a proper understanding of the problem, borrowed by scientific knowledge. As a further consequence, at present also common people have become aware of the immediacy of the threat and the importance of timely measures.

At any rate, the coronavirus dynamics has now become self-evident. Although people still may not be able to understand it scientifically, consequences of the disease (e.g. people getting sick or dying) are both specific and indisputable: we should not struggle to perceive them. It is true that there are some people who deny the existence or severity of the coronavirus crisis,

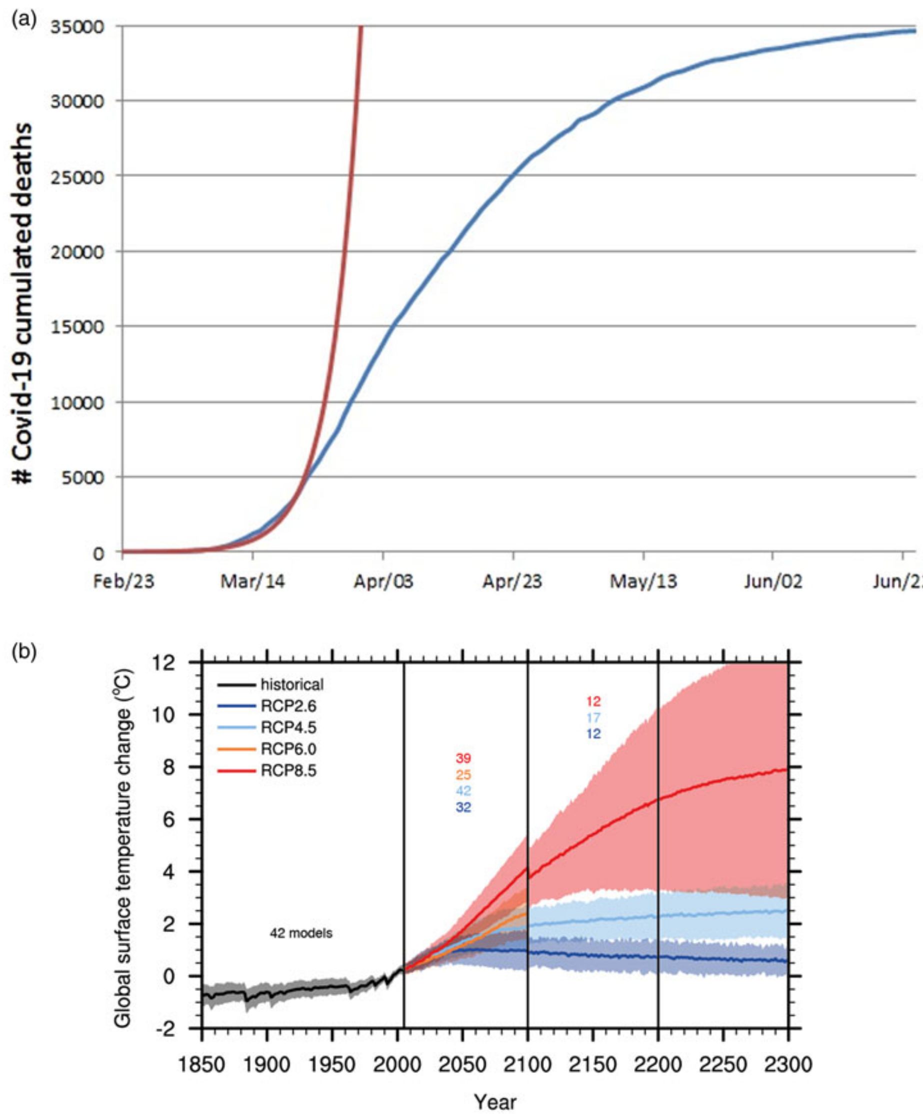

Fig. 1. A comparison of the Covid-19 curve and climate change projections: (a) cumulated deaths in Italy during the first wave of the Covid-19 infection (blue line), compared with the natural exponential behaviour of the first month (red line) (data from https://data.europa.eu/euodp/it/data/dataset/covid-19-coronavirus-data), exponential fitting by authors; and (b) projections of future global temperatures (red line = BAU scenario) (*source*: IPCC, 2013).

and that some national political leaders are among them with serious consequences for their respective countries; however, it is also true that the situation is quite different from climate change denialism, that is, a highly organized phenomenon that sponsors inaction or false data and has been supported by the fossil fuel industry (Oreskes, 2019).

The other big challenge for the future of humanity and the whole planet is precisely climate change. In this case, even if expected to be more devastating and long-lasting, it is still not perceived by many people with the same level of urgency. However, even in this case, scientific knowledge is able to shift our wrong perception to a proper one.

A comparison of the characteristic features of these two phenomena is quite instructive: both of them are nonlinear and endowed with inertia. Setting side by side the graph of cumulated deaths due to Covid-19 in Italy (one of the countries that was first impacted by the coronavirus outbreak) and the curve of future global temperature projected in the so-called business-as-usual (BAU) scenario is somewhat illuminating (see Figure 1). The two curves are quite similar: both of them show a nonlinear increase followed by a 'saturation' period. In particular, the curve of cumulated deaths follows a clear exponential law during the first part of the epidemic and, even if probably the increase of future temperatures in the BAU scenario does not follow exactly an exponential law, it also appears increasing in a clear nonlinear way until 2100. The departure from the exponential law for the epidemic was due to 'lockdown' actions which preserved the healthcare system from collapse, while the saturation of the temperature curve is due to the fact that the RCP8.5 scenario assumes a policy response which limits CO_2 emissions late in the 21st century. In the first case, we were able to limit the damages to our life, in the second case, unfortunately, it would be too late for avoiding the worst climate impacts, just happened until 2100.

It is true, however, that there are two significant differences between the situations, which are also reflected in their contrasting perception: first, while deaths by Covid-19 are observed, BAU temperatures are projected by models; second, temporal evolutions of the two phenomena are very different: tens of days for coronavirus epidemic, tens of years (decades) for global warming. Therefore, in order to grasp the real climate situation, we turn once again to the already available scientific evidence:

(1) A nonlinear increase in global temperature is evident if we will do nothing in due time to reduce our greenhouse gas

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emissions (BAU scenario). In this context, it is worthwhile to note that programming unexpected feedback loops in climate models is not really possible and the global climate models (GCMs) used for obtaining these temperature projections have only a limited ability to recognize the achievement of tipping points in the climate system due to the overpassing of certain thresholds, which lead to self-reinforcing feedback loops in the Earth system. The typical example is that of permafrost melting with subsequent release of CH_4 in the atmosphere, but there are other possible feedback loops, even with a cascade of effects (Lenton et al., 2019; Steffen et al., 2018). If these latter phenomena shall happen, temperature should increase dramatically and the new pathway shall not be easily influenced by human interventions.

(2) This nonlinear increase of temperature will be recognized only in the next future decades, following model results. Nevertheless, the GCMs' ability to reconstruct past climate as a result of anthropogenic influences, the robustness of these results (Mazzocchi & Pasini, 2017) and their good performance in past projections (Hausfather et al., 2019) let us be confident about their capability to obtain reliable projections under future behaviour of these human forcings, too.

(3) The quasi-linear temperature evolution observed in the last century should not mislead us and push to delayed actions, exactly as happened with the initial small number of deaths in Covid-19 epidemic. Temperature increase, as Covid-19 epidemic, shows inertia, which in this case is due to the long persistence time of CO_2 in the system (at least several decades) and to the slow response time of the oceans. Thus, if we act now by decisive and prolonged actions on CO_2 emission reductions and absorption increments, we will see their final results on temperature after some decades.

In short, scientific knowledge allows us to reach a correct perception of the coronavirus pandemic and climate change as large and existing threats, whose solution requires immediate actions. On the other hand, the features of these threats could also be figured out in some more specific way, which we will discuss in the following section.

3. Risk

Analysing the risks coming from both Covid-19 and meteo-climatic extreme events could be beneficial for a better understanding of these phenomena, but also for comparing our possibilities of action aimed at minimizing their impacts. This has been recently done by Vinke et al. (2020) through the use of an equation first introduced by Lenton et al. (2019) for assessing the 'emergency status' of the climatic crisis. Here, in a way which is complementary to their treatise, we suggest the adoption of the so called 'risk equation' (well known in any risk assessment of natural hazards on territories and population) as a 'unified framework'. This equation reads as:

$$R = H \times V \times E, \tag{1}$$

where H = hazard, V = vulnerability and E = exposure. Equation (1) 'splits off' the risk in its main factors and, when applied to different fields, obviously the meaning of the single factors is not unique. Here, we refer to its use in applications of civil protection and compare it with an epidemic analogue, as in Pasini (2020). Within a civil protection context, risk R is defined as the probability of harmful consequences or expected losses (deaths and injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards H, vulnerable conditions V of territories and exposure E of assets and population (UNISDR, 2009). R is therefore calculated as a product of (independent) probabilities of occurrence for the single factors.

If we consider the risk coming from meteo-climatic extreme events, hazard H measures the probability of occurrence of phenomena characterized by certain frequency and intensity. Today, owing to climate change, some phenomena, such as heat waves, are changing these characteristic features in many places of the world and their future behaviour is projected to increase in frequency and intensity, with a high level of confidence (IPCC 2012, 2013). As for other phenomena, such as heavy storms, floods, tropical cyclones and even tornadoes, our confidence in a significant change is lower (especially as for their frequency, which critically depends on atmospheric circulation), but thermodynamic fundamental laws and numerical modelling experiments let us think of an increase in their future intensity as anthropogenic forcings will increase: see, for instance, IPCC (2012); Lebeaupin et al. (2006); Miglietta et al. (2017); Trenberth et al. (2015). In some case, we can detect a significant change even in the last few decades (Kossin et al., 2020).

Vulnerability V of territories crucially depends on the use of soils by humans. For instance, waterproofing by asphalt or concrete tremendously modifies rainfall absorption capacity of terrains (Konrad, 2016), so that intense precipitation can cause violent floods and disasters. Of course, it also depends on several additional factors, such as proximity to flood plain, height above sea level for coastal communities, slope of land for mountainous terrains, urban heat island, plus socio-economic matters – that is, capacity for heating/cooling, requirement to work outside, bushfire prone-ness, etc.

Exposure E depends on the presence of buildings, infrastructures and people. Anthropic activities tend to extend the presence of humans and their structures over lands, even vulnerable ones. If we will not follow strict rules and regulations, E will increase its value in the future.

Thus, the application of Eq. (1) to meteo-climatic induced risk is well-posed and largely used. Vice versa, in epidemiological studies more attention is generally devoted to specific risk factors or to equations which describe (and possibly forecast) the evolution of an epidemic. Nevertheless, we propose the use of Eq. (1) in this field also, in order to understand, at least qualitatively, which factors can increase or decrease the risk of suffering from a virus infection and experimenting its worst consequences.

With reference to a virus epidemic, therefore, through hazard H we estimate the 'strength' of the virus itself, which depends on its biological features and spread mode, and the frequency of appearance in our territory. In the case of Covid-19, we are sure that it is more dangerous than a typical winter flu virus and it is also more contagious than Ebola or SARS viruses, even if probably less lethal (Rajgor et al., 2020). Concerning its appearance, this seems quite random. However, some human actions, such as heavy deforestation in tropical countries for setting up monocultures and intensive livestock or expanding towns inside a forest, increase the probability of spillover from wild animals to humans (Afelt et al., 2018; Allen et al., 2017; Rohr et al., 2019). Actually, it is likely that in the future we will more frequently suffer from infectious diseases caused by similar types of viruses (Jones et al., 2008; Morse et al., 2012).

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Vulnerability V estimates the vulnerability of the human body of a person in the presence of Covid-19. One can be young or old, healthy or affected by previous diseases, maybe concerning respiratory system. In these different cases, the consequences of the infections can be more or less serious, also depending on other factors such as the nutritional and hygienic condition of the population involved. Generally, one talks about categories at risk, for example, persons who are asthmatics, affected by cardio-respiratory diseases, etc. In any case, the only direct way to reduce the factor V is to vaccinate population, but at present a specific vaccine (or therapy) for Covid-19 does not exist.

Exposure E estimates the exposure to contacts with infected persons, something that also depends on the population density and travel habits. Obviously, some persons are more exposed than others, for instance physicians or other sanitary personnel, but all of us are at risk when we come into contact with others. Thus, the only way to reduce E is defusing physical connections, through social distancing and isolating infected people (Nature Editorial, 2020). As a matter of fact, this is the principal measure adopted in the fight against Covid-19.

4. Action

The risk equation is quite simple and some assumptions, such as the independency of probabilities, are not always satisfied: for instance, in a specific case study anthropization of lands (a change in V) can cause a change in H, specifically in the rainfall intensity by a hurricane (Zhang et al., 2018). In these cases, the estimation of risk by Eq. (1) results in an underestimation of the real risk. As a matter of fact, such an equation represents an oversimplification of the nonlinear and complex interactions between the multiple factors influencing both climate change and the coronavirus pandemic. In any case, here our aim is not to achieve a quantitative specification of R, but to compare two phenomena and investigating analogies in their occurrence. As discussed in the paper, both situations show a similar structural dynamic (involving inertia time and nonlinear mechanisms) and a quite similar public (initially wrong) perception. The risk equation might result to be a useful conceptual heuristic, especially at the policy level, providing distinct yet related angles (for estimating threat) about how to analyse both cases.

Summarizing, this equation shows us that it is of paramount importance to work simultaneously on all the different aspects (and corresponding risk factors) of the situation, something that could require both a multidisciplinary (and even interdisciplinary) engagement (Mazzocchi, 2019) and a continuous calibration of the interplay between scientific knowledge and social institutional action. Though indirectly, it also shows the importance of embracing a systemic approach that does not decompose the many interrelated aspects into separated parts, but integrate them in an overall scheme (Mazzocchi, 2016). Finally, it indicates that not only short term interventions are needed, but also long-term strategies involving some structural changes at many levels.

With regards to the Covid-19 pandemic, it is clear that investigating the virus and its behaviour is prior, also to develop more refined epidemiological models and, of course, to find a vaccine or therapy. Over the long term, it also should be investigated more in-depth the linkages between human, animal and environmental health, which are mutually dependent and should then not be dealt with separately (Bonilla-Aldana et al., 2020). Besides, to act on vulnerability and exposure there is the need for structural changes. With respect to vulnerability, people's health conditions should be improved, enhancing hygiene and nutritional status, reducing poverty and taking into consideration social disparities; furthermore, safer health systems should be created, investing on innovation (e.g. telemedicine) and strengthening territorial medicine. For what concerns exposure, structural transformations become possible especially if emerging pandemic diseases are recognized as expected in the next future; they might include rethinking work organization (reflecting on the possibility of working from home, at least in part, even after the emergency), as well as infrastructures, such as workplaces, recreational and gathering venues (e.g. designing places for social distancing) (Morens & Fauci, 2020). However, it is equally clear that, waiting the outcomes of the aforementioned research and radical changes, our sphere of action is limited. As already said, in order to reduce the risk coming from Covid-19, we have more chances to influence the factor E than the others, by limiting our contacts and social life (something that occurred, at given moments, in a traumatic and emergency way).

What about the risk by climate impacts on territories? In this case, the previous analysis of Eq. (1) shows that now we can act on all factors: each factor's value can be directly influenced by our actions (from measures for reducing greenhouse gas emissions to a more proper use of the land). Furthermore, even if the inertia of the system (some decades) suggests us to act rapidly, we can still plan these actions until we are not in emergency, acting in many synergic ways. On the other hand, as repeatedly pointed out by climate experts, over the long term the issue of climate change cannot be addressed only through some incremental changes. Rather, substantial transformations are required, including decarbonizing the global economy (see, for instance, Rockström et al., 2017) as well as changing the transport and agricultural sectors.

5. Conclusion

This conceptual study focuses on the analogies (e.g. nonlinearity and inertia) in the dynamics of the Covid-19 pandemic and climate change. It highlights how political decisions and social action should be based on a correct perception of these complex phenomena, and how such a perception can in turn only be gained through scientific knowledge. Besides, it suggests to apply to both situations the risk equation, not with the purpose of obtaining a quantitative specification of R, but rather a conceptual heuristic for analysing them according to distinct yet related angles. This approach may result useful especially for guiding action at the policy level, also showing the importance of a systemic and multidisciplinary or interdisciplinary engagement. With regards to the specific situations, it displays that, even if climate change is probably more critical and long-lasting than the contingent Covid-19 crisis, we still have, at least currently, more options for reducing its related risk, although requiring structural changes at many levels.

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