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POLICY FORUM

Blue uncertainty: Warding off systemic risks in the Anthropocene - Lessons from COVID-19

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Abstract: COVID-19 has made evident that we are ill-prepared to respond to an international health emergency, the complex interdependence of social and ecological systems, and that to reduce the risk of future zoonotic pandemics we must safeguard nature. Approaches based on complexity science taking into account that interdependence and its associated systemic risks must be mainstreamed in current policy making, in general. However, at present, that could result in failure for three main reasons: (1) those approaches might be too sophisticated for current policy making pursuing sustainable development; (2) the reductionist views from conventional economics still deeply influence economic and environmental policy making; (3) it is unlikely that far-reaching policies aimed at stimulating post-pandemic economic development can be steered through radically innovative approaches that remain untested. Here, using COVID-19 as an example, I suggest that the use of innovative complexity-based approaches could be enabled through intermediary approaches equipped to resonate with the mindset pervading current policy making. In particular, I propose to understand the response to unexpected systemic threats as instances of reactive policy making driven by radical

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uncertainty, and advance three notions that could enhance that understanding: modulating contingency, adaptive inference and blue uncertainty.

Keywords: COVID-19; Anthropocene risk; post-normal science; wicked problems; radical uncertainty; adaptive inference; modulating contingency; blue uncertainty; Earth

1. Introduction

Coronavirus Disease 2019 (COVID-19) pandemic, caused by SARS-CoV-2, has exposed our ill-preparedness to respond to an international health emergency of catastrophic magnitude[2]. COVID-19 has also made more evident than ever the complex interdependence and mutual vulnerability of social and ecological systems, and that to reduce the risk of future zoonotic pandemics we must safeguard nature (Gordon 2020, Settele et al. 2020). Its acute impact must not blind us to the fact that this crisis is symptomatic of higher threats and systemic risks due to climate and global environmental change, which are just round the corner (Keys et al. 2019, Andersen and Rockström 2020, UNEP 2020). Our response to confront the present pandemic could be a portent of our readiness to tackle those threats in the near future[3]. Approaches like Anthropocene risk (Keys et al. 2019) and One Health (see e.g., Waltner-Toews 2017, Scagliarini and Alberti 2020), were designed to address global systemic risks and the complex, adaptive and uncertain dynamics of connected systems of people and nature[4].

[2] Thankfully, warnings from international and local authorities and experts, progressively influenced the implementation of strong containment policies across the world as the pandemic hit locally during late February and March 2020 – although with notable differences in their timing (early vs delayed), approach (herd immunity vs suppressed equilibrium) and depth (mitigation vs suppression) (Huang et al. 2020, ILO 2020, Ritchie et al. 2020). As I write from Spain, countries around the world are slowly leaving behind the first contagion wave, de-escalating from the pandemic-enforced measures and proceeding as safely as possible to a future so-called “new normal”.

[3] Such a response must thoroughly consider the global governance architecture required (Biermann and Kim 2020), the social inequality and environmental injustice challenges entailed (Österblom et al. 2015, Hamman et al. 2018), and the democratization of science and public policy (Bardosh et al. 2017)

[4] There is, however, evidence from the media (e.g., The New York Times 2020) and supranational policy (e.g., GNDE 2020) narratives suggesting rising awareness about the double role of nature as a protective space for human survival and as critical for socioeconomic recovery (IPBES 2019, World Economic Forum 2020).

However, at present, the mainstreaming of those approaches in current policy making in general, could result in failure for three main reasons. Firstly, those approaches might be too sophisticated for current policy making pursuing sustainable development, which is largely siloed (OECD 2019), and based on the prescription of blueprint, panacea solutions to highly complex social-ecological problems (Ostrom 2007). Secondly, the reductionist views from conventional economics still deeply influence economic and environmental policy making (Foxon 2013, Thornton 2018), hindering the entry of complexity-based approaches into the mainstream. Thirdly, it is unlikely that far-reaching policies aimed at stimulating post-pandemic economic development can be steered through radically innovative approaches that remain untested.

Here, using COVID-19 as an example, I suggest that the use of innovative complexity-based approaches in policy making aimed at managing systemic risks could be enabled through intermediary approaches equipped to resonate with the mindset pervading current policy making. I first propose to understand the response to unexpected systemic threats as instances of reactive policy making driven by radical uncertainty[5]. Then, I propose three notions that could enhance that understanding, as well as the scientific policy support required in conditions of high systemic risk and uncertainty, namely modulating contingency, adaptive inference and blue uncertainty. My hope is that this approach can contribute to a more robust foundation for policy making in the face of Anthropocene risk.

[5] For the sake of the argument, I focus on two key policy moments, containment and prevention (past and future; see Fig. 1), making several assumptions: (1) throughout containment and the current de-escalation process, all countries are adding and removing similar policy measures (e.g., social distancing, test and trace, confinement, self-care and personal hygiene) as they learn by doing, with the aim to protect the vulnerable population and not overwhelming public healthcare systems, and thus save as many lives as possible; (2) whether or not we are heading to a second or a succession of infection peaks or waves, policy makers, experts, organizations and the civil society around the world are now thinking about the best courses action for socioeconomic recovery in the post-pandemic future; and (3) all these individual and collective decisions and policies will be based on the best evidence and knowledge, and on sound risk assessments.

2. Radical uncertainty and lessons from the containment of COVID-19

With COVID-19 experts and decision makers were facing, as it unfolded in real time, an extremely "wicked" problem (Rittel and Webber 1973) that falls within the realms of "post-normal science" (Funtowicz and Ravetz 1993) – see Table 1 for a description of criteria. The question that will hold relevance for some significant time is whether the pandemic was entirely unpredictable. The discussion has already started (see e.g., Frankel 2020, Frutos et al. 2020, IIF 2020, McGillivray 2020) and it is subjected to ambiguity, both epistemic – uncertainty about the facts and nature of the phenomenon – and strategic – low consensus about the facts and nature of the phenomenon due to political differences (Hall 2017). The epistemic dimension, moreover, has two sides of the argument that, in principle, do not seem incompatible: (a) the conjunction of events leading to the pandemic as rare enough to be characterized as an unpredictable accident[6] for which we could not have been prepared (see e.g., Frutos et al. 2020); (b) that we already had certain capacity to forecast the occurrence of the pandemic based on rough extrapolations from past outbreaks or, more importantly, on existing knowledge about risk factors for human disease emergence (Morse 1996, Taylor et al. 2001, Cheng et al. 2007, Ge et al. 2013, Menachery et al. 2016)[7].

[6] Frutos et al. (2020) define unpredictable accident as "the occurrence of a very low probability event resulting from the stochastic conjunction of independent low probability events", referring to the conjunction of events that they describe in their article in more detail.

[7] These two sides pertain to the issue of prediction and forecasting in science. A prediction is understood here as an expectation (e.g., value of a random variable) in relation of an information set (e.g., combination of values of predictor variables), calculated through a model obtained, for example, by a fit to some available data (e.g., predictive curve). Prediction turns forecasting when the predictor is time (a continuous variable), and expected values can be derived outside of the range of observed time points through extrapolation.

Table 1. COVID-19, a post-normal wicked swan.

Criterion	Description
Wickedness (Rittel and Weber 1973)	- Real-time solutions couldn't be judged right or wrong, but just better or worse, since they could only be tested trial-and-error; otherwise it would have involved deciding on who lived and who died. - Responsibility for those decisions was anyway passively transferred from the political level to healthcare workers. - The pandemic is a symptom of more profound global problems, but they cannot be tackled now, since resources are scarce and directed towards the resolution of the symptom, as are political action, and media and public attention.
Post-normalness (Funtowicz and Ravetz 1993)	- Decisions were made about a highly complex challenge. - Where the facts were highly uncertain. - Many values were in dispute. - the stakes were high and the decisions urgent.
Black-swanness (Taleb 2007)	- Being an outlier, because nothing in the past can convincingly point to its possibility, hence it lies outside the realm of regular expectations: history shows that infectious diseases, epidemics and pandemics occur regularly and, despite, as shown above, COVID-19 was difficult to predict, it can take decades until we know whether it will be an outlier on the plot. - Carry an extreme impact: the pandemic is carrying an extreme impact, psychological, socioeconomic, on our health systems and, in the near future, chances are that there is a rebound effect on the environment. - In spite of its outlier status, an explanation is sought after the fact, hence making it predictable in hindsight: while this criterion can be understood as normalizing an event by rendering it predictable in hindsight (McGillivray 2020), I conceive it here as the possibility for abductive reasoning, i.e. producing inferences to the best explanation as the pandemic unfolds, based on past knowledge.

What seems clear for now is that the compound effect of several factors made a reactive containment response to the pandemic unavoidable from the outset (Fig. 1). First, there was a logical unawareness of Wuhan's local communities and authorities of SARS-CoV-2 emerging in the wild and being zoonotically transmitted to humans in anthropic environments (Fig. 1). Transmission and infection then remained stealthy during a phase of latency (Fig. 1), which lasted until an outbreak of a "respiratory contagion owing an uncharted etiology" was first reported in Wuhan (China)[8] (Kumar et al. 2020). By way of an amplification phase, the

[8] The contagion agent was termed as "novel corona virus 2019" by the World Health Organization (WHO) on 29th December 2019, and as SARS-CoV-2 on 11th February 2020 (Guo et al. 2020).

epidemic was well underway in December-January 2019, driven by a tight combination of key social and virological/disease factors (Fig. 1) (Frutos et al. 2020, He et al. 2020). For Frutos et al. (2020), these events, in conjunction with globalization factors such as international hyper-connectivity and high-mobility of people (Fig. 1), constituted a rare "planetary alignment" that led to the emergence of the pandemic.

This alignment of events moves in the quicksand of radical uncertainty (Kay and King 2020), which distinguish between *resolvable* and *radical* uncertainty[9]. During the pre-pandemic phase, we might have known that a new outbreak was possible based on rough forecasting. However, despite all the extant knowledge about emerging diseases and globalization, at the outset of the amplification phase of the pandemic (Fig. 1) we lacked the capacity to predict, with high precision and accuracy, the complex sequence of events that led to it – and much less to foretell its evolution and exact casualty numbers. We were confronting radical uncertainty and high systemic risks (Fig. 1) and, to effectively respond to them, hard containment policies had to be designed and implemented, based on the best available evidence and disease models. And the arrow of time cannot be rerun to verify whether historical empirical reality would have reflected the outputs yielded by the imperfect models that informed containment policies (Panovska-Griffiths 2020, Ioannidis et al. 2020)[10]. Nor we will ever know whether current forecasting scenarios would live up to the test of future empirical evidence, because governments will surely adjust their policies, in one or another direction, depending on them. But let us consider the following counterfactual: what if governments had not followed expert

[9] For Kay and King (2020), the former is resolved through known probability distributions of outcomes, whereas radical uncertainty represents something that "we simply do not know" and cannot be described in probabilistic (game-like) terms – due to, for example, obscurity, ignorance, vagueness, ambiguity, ill-defined problems, or a lack of information.

[10] In the most relevant cases (Ferguson et al. 2020) those models were wrong in orders of magnitude and supposedly flawed (Ball 2020).

advice, even when it was based on models readily available, and in spite of their flaws? What if they had postponed critical decisions until more suitable models were ready?

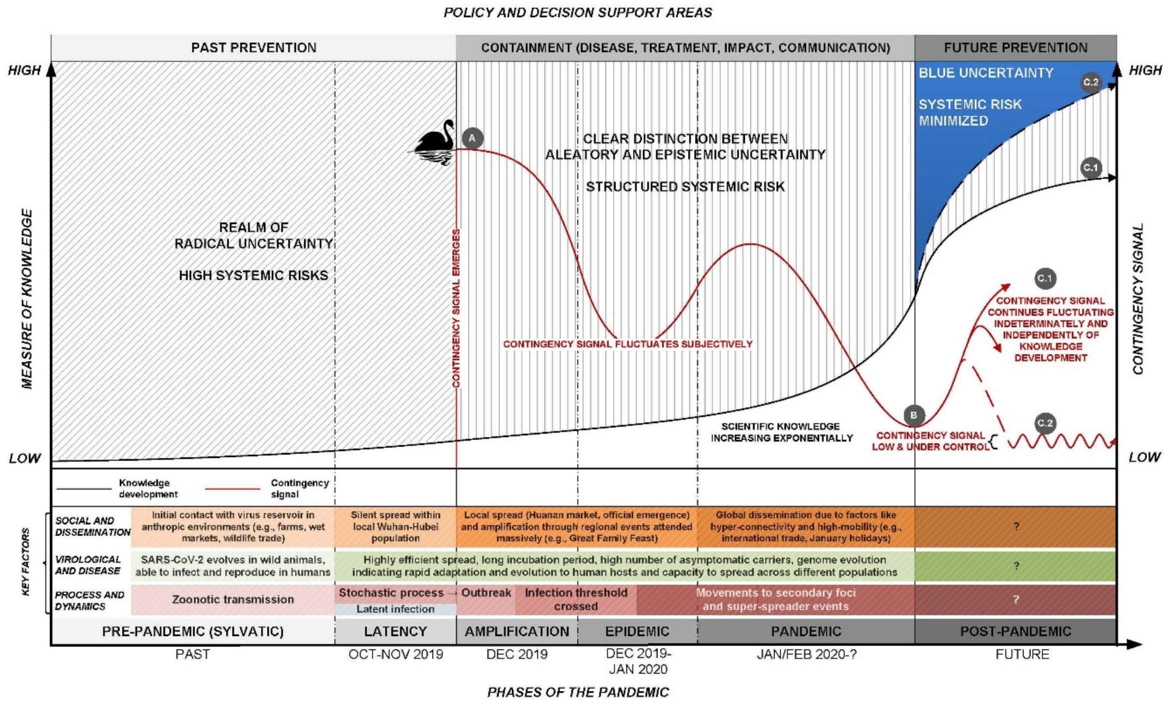

Figure 1. Stylized representation of a measure of our knowledge about pandemics (left y-axis, black arrow) and of the contingency signal (right y-axis, red arrow), against a description of key factors for the emergence of the pandemic through several phases (x axis, based on Frutos et al. 2020, Hen et al. 2020, van Dorp et al. 2020). Policy and decision thematic areas requiring support from science are represented at the top, as corresponding to the phases of the pandemic (thematic areas correspond to those of the Global Health Interdisciplinary Platform of the Spanish National Research Council CSIC, created as a response to the pandemic, https://pti-saludglobal-covid19.corp.csic.es/). Black swan clipart: http://clipart-library.com (Not for commercial use).

The key argument here is that thousands of lives could have been lost, if we have had to rely on more suitable models that still had to be calibrated to a new contagion agent. Some of those models, based on the probabilistic understanding of heavy-tailed phenomena (e.g., Extreme Value Theory), allow for enhanced inferences about the complex, non-linear nature of outbreak-epidemic-pandemic dynamics in a hyper-connected world (see e.g., Bar-Yam 2020, Cirillo and Taleb 2020, Moore 2020, Norman et al. 2020)[11]. However, they still have to show how they incorporate the full complexity of biophysical and socio-technical realities, and of behavioral responses to that reality. There might be failures at technological (e.g., to deliver well-calibrated technology for testing-and-tracing) and medical (e.g., to differentially diagnose a new disease from others that show similar symptoms) levels. Moreover, there is still high uncertainty about how post-recovery immune protection and environmental and seasonal influences affect transmission dynamics (Kissler et al. 2020). And, on top of that, social reality is affected by ideology, politics and power dynamics, which, in turn, are characterized by cultural differences and reflexivity, so the questions arise: how can those models a priori account for strategic ambiguity at political level, for cultural differences in elderly care, for differences in citizens' compliance with public health measures in situations of social unrest, or for the promotion of untested (or even worse, deadly) remedies from authoritative sources? My view is that all these questions and epistemic tensions can turn more productive, informative and realistic if framed within the three epistemological notions that I describe next through an exercise of scientific foresight.

3. Modulating contingency, adaptive inference and blue uncertainty

To frame my argument, I will rely on the criteria that an event or outcome must fulfil to become a "black swan" (Table 1; Taleb 2007)[12]. If we think in those terms, our assessments about the predictability of the pandemic after the fact become, consciously or unconsciously, structured

[11] These models are explicit (and honest) about key philosophical underpinnings (e.g., they address the problem of naïve empiricism, Norman et al. 2020), and factor in measures (e.g., standard contact tracing, door-to-door monitoring of symptomatic carriers) that, despite being culturally contentious in some countries, could have supported less-stringent containment measures (e.g., Shen et al. 2020).

[12] Here I am seizing the descriptive power of the "black swan" concept, not seeking confirmation that COVID-19 constituted a "black swan" event.

within a specific epistemological tension between two extreme senses of contingency (Fig. 2). Between them, a continuum of predictability unfolds, with randomness equating a high level of unpredictability and contingency a property that can be modulated (Méndez et al. 2019). Applying those notions to COVID-19, an initial sense of randomness can be understood as a contingency signal emerging as the fact is known, at some point between November and December 2019, i.e. the situation resonates with the criteria defining a black swan (point A, Fig. 1). Then, the contingency signal fluctuates subjectively, depending on the epistemology at work (e.g., theories and models used by expert advisory groups), but is generally decreasing as new evidences are gathered, knowledge generated, and results and insights shared and discussed across the policy and scientific communities (signal decreasing toward point B, Fig. 1). Making use of abductive reasoning and retrospective methods (e.g., counterfactual experiments, retrospective analysis), a number of competing theories, models and explanations start to emerge about, for example: the evolution of SARS-CoV-2 through its sylvatic phase, its "zoonotic jump" and stochastic latency and amplification phases, the evolution of the epidemic into a pandemic, and the impact and prevention of the latter through the lens of multiple disciplines. We are in a stage during which we start structuring the systemic risks that we were facing, and progress toward a clear distinction between (1) the known unknowns (aleatory uncertainty, e.g., past knowledge describe regular outbreaks and potential predictors, but they are subject to probabilistic variability), and (2) the unknown unknowns (epistemic uncertainty, e.g., every virus evolution and outbreak dynamics are so different that the effect of potential predictors and contextual differences might vary enormously).

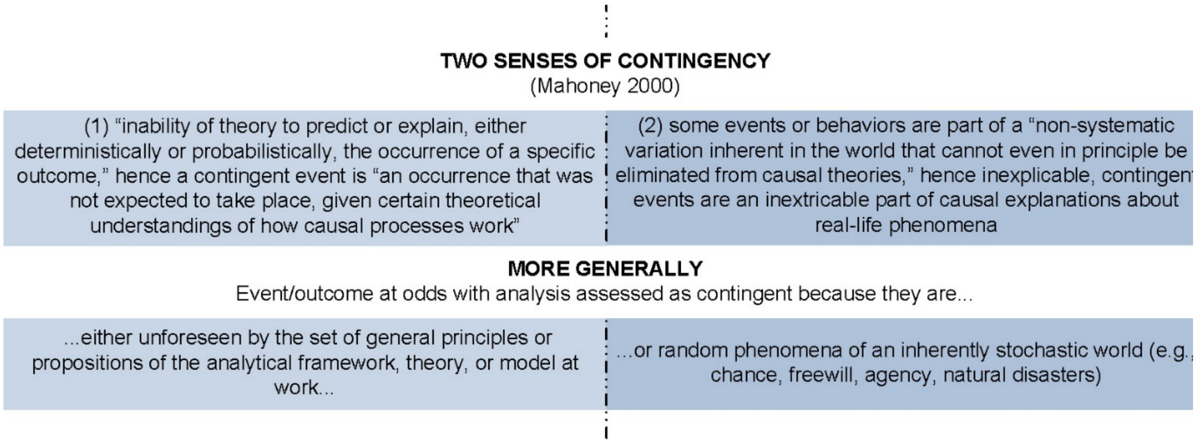

Figure 2. Epistemological tension between two senses of contingency (based on Mahoney 2000, Eagle 2005, Méndez et al. 2019).

At some point, we enter the so-called "new normal" and knowledge development enter a new stage in which it starts to settle. At that stage, though, epistemic uncertainty is still very high, because the unknown unknowns still abound. During the post-pandemic, we will face, at least, two main scenarios regarding contingency and uncertainty. In the first scenario (C.1; Fig. 1), we have failed to assemble whole systems, transdisciplinary teams working to solve Anthropocene risk challenges, so there is still great epistemic uncertainty and the contingency signal remains dependent on subjective judgement. In a second, best case scenario (C.2; Fig. 1), we have successfully assembled whole systems, transdisciplinary teams able to address Anthropocene risk from a holistic perspective, so we progress to minimize uncertainties and systemic risk to the utmost. We have also kept contingency controlled at low levels, due to the collaboration of multiple research teams theorizing and empirically observing the same problem through different epistemological lenses. These teams work and reason through adaptive inference (Holling and Allen 2002), which is used as a long-range protocol to develop competing theories, models and hypotheses that are tested step wise as information is collected through iterative empirical research, until they reach a maturation point (Fig. 3).

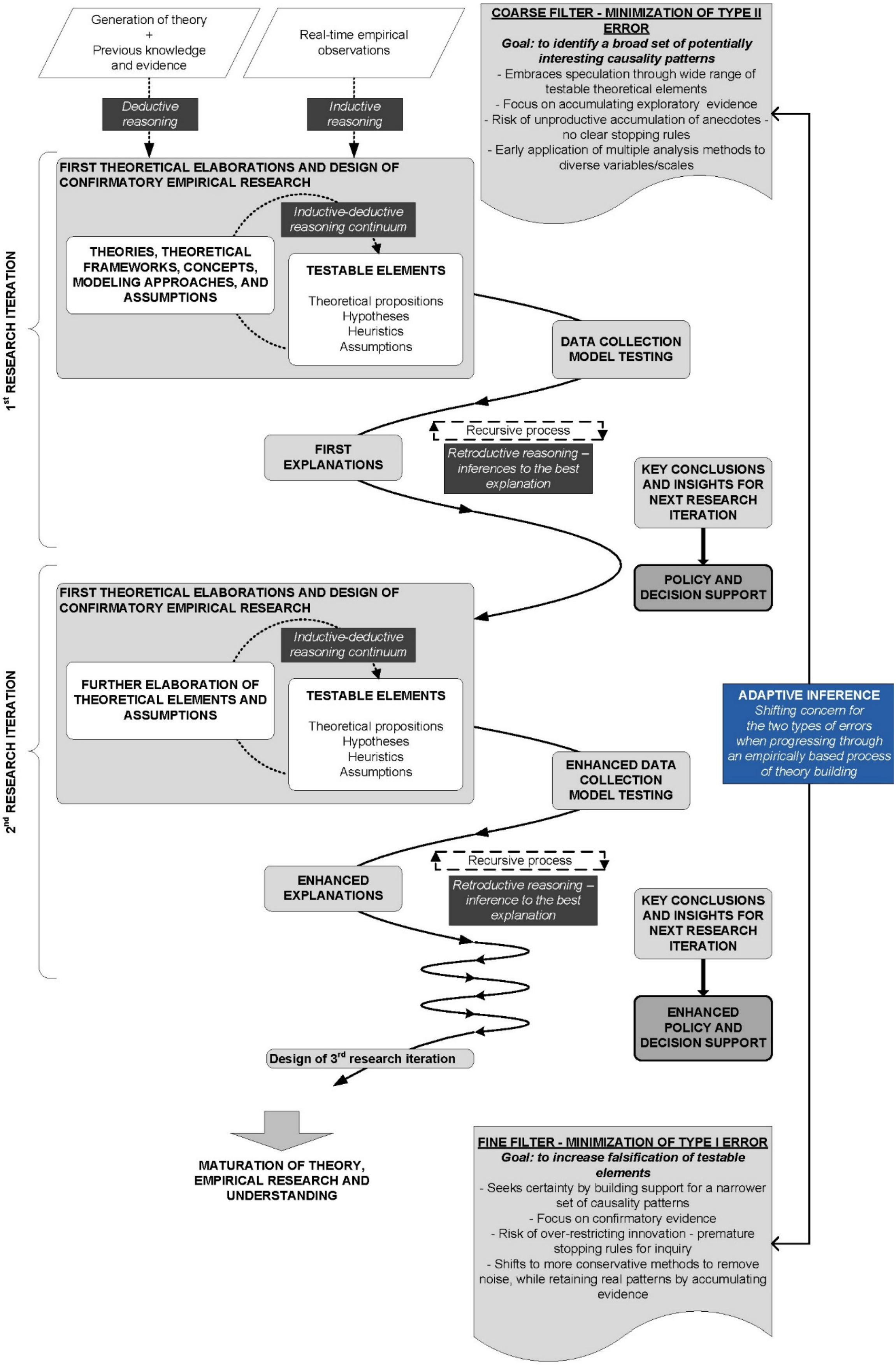

Figure 3. Adaptive inference protocol (based on Holling and Allen 2002, Méndez et al. 2019).

Since this scientific progress would be happening in the realms of basic blue sky research with the main aim of reducing the systemic risks associated to the Anthropocene, I have coined the term “blue uncertainty” (Fig. 1) to refer to a type of randomness inherent in the world that perhaps we will be never able to eliminate from our causal theories, predictions and models. My approach is contingent on a global concerted “mental leap” (Lee 2012) toward a narrative focusing on robustness and resilience in complex systems à la Kay and King (2020) that then morphs into a more sophisticated one fully unpacking the Earth-system aspects of Anthropocene risk à la Keys et al. (2019).

4. Conclusion

Here, I have proposed an approach that can serve as an intermediary enabling the use of innovative complexity-based approaches in policy making aimed at assessing and managing Anthropocene risk. Its power might rely on its resonating properties with the mainstream mindset pervading current policy making in general.

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