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Navigating systemic risks: governance of and for systemic risks

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Abstract

Non-technical summary. Systemic risks such as climate change and pandemics are complex and interconnected. Managing such risks requires effective organisational structures and processes. This publication presents conceptually robust, evidence-based approaches for assessing and managing systemic risks.

Technical summary. Systemic risks originate and evolve in the nexus of tightly coupled dynamic systems, which are a characteristic of modern societies in the Anthropocene. Systemic risk implies the breakdown of a system which provides essential functions to society. Connectivity between systems is a key enabler for systemic risk to manifest through cascading effects. Thus, systemic risks originate and evolve in the nexus of tightly coupled dynamic systems. Cascading effects and the convergence of systemic risks with conventional risks as well as other systemic risks challenge the established modes of risk governance that still rest to a large extent on differentiation and compartmentalisation. Thus, governance of systemic risks requires an integrative approach towards risk governance that combines interdisciplinary risk analysis with iterative, adaptive and inclusive governance procedures. By drawing on the case studies of the COVID-19 pandemic and climate change, this paper proposes an innovative risk governance framework for systemic risks based on the integration of systems analysis and a governance procedure with the salient features of reflection, iteration, inclusion, transparency and accountability.

Social media summary. Systemic risks highlight the interconnected nature of our contemporary societies which calls for tailored responses.

1. Introduction

In many risk domains, such as occupational health and safety, transportation, and food safety, modern risk governance is a success story. Despite these advancements, risk governance still struggles with systemic risks. Systemic risk affects entire systems on which society depends, such as the health care system or the energy system (OECD, 2003). Kaufman and Scott define systemic risk as 'the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components' (Kaufman & Scott, 2003, p. 371). Connectivity between systems is the key enabler for systemic risk to manifest through cascading effects. Thus, systemic risks originate and evolve in the nexus of tightly coupled dynamic systems. Transboundary risks emerge, which play out in an amalgam of economic vulnerabilities, geopolitical tensions, societal and political strains, environmental fragilities and technological instabilities (World Economic Forum, 2023). The convergence of systemic risks – both with conventional risks as well as one systemic risk with another systemic risk, e.g. climate change and biodiversity loss – challenges the established modes of risk analysis and governance that still rest to a large extent on differentiation and compartmentalisation.

Yet the governance of systemic risks requires an encompassing approach towards risk analysis. Assessments of systemic risks need to be based on multiple indicators. The results of these assessments can be aggregated into diverse but coherent scenarios, which are further evaluated in participatory procedures of deliberation. Governance of systemic risks therefore requires interdisciplinary risk analysis, as well as iterative, adaptive and inclusive procedures. At the heart of this matter are questions such as 'What are the goals of governance?', 'Who sets the course and what is their mandate?', 'What are the roles of science, civil society and the economy?' and 'Which course of action is appropriate, effective and efficient?'

In the following, a risk governance framework for systemic risks will be proposed that aims to address these challenges. Section 2 investigates the governance challenges of systemic risks, paying special attention to issues of complexity, uncertainty and ambiguity. Section 3 gives an overview of governance concepts, especially those that relate to the field of risk. This section proposes an innovative approach to risk governance of systemic risks based on the integration of systems analysis and a governance procedure with the salient features of reflection, iteration, inclusion, transparency and accountability. The article concludes with a discussion of the results and identifies research gaps for future research on systemic risk governance. All sections draw on the COVID-19 pandemic and climate change to show how the argument works out in practical context.

2. Governance challenges of systemic risks

Systemic risks originate and evolve in the nexus of tightly coupled dynamic systems, which are a characteristic of modern societies. Systemic risk implies the breakdown of a system which provides essential functions to society. This understanding builds on the one hand on the definition by Kaufman and Scott that states: '[S[ystemic risk refers to the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components, and is evidenced by comovements (correlation) among most or all the parts' (Kaufman & Scott, 2003, p. 371). On the other hand, the definition draws on the OECD 2003 report *Emerging Risks in the 21st Century. An Agenda for Action*, which adds a qualifying element to the definition of systemic risk. Systemic risk is not about breakdown of any kinds of systems, but those on which society depends. The report states: '[A] systemic risk, in the terminology of this report, is one that affects the systems on which society depends – health, transport, environment, telecommunications, etc' (OECD, 2003, p. 30). Systemic risks can occur at different scales – local, regional, national or global – and do not exclusively denote global breakdowns (Aven & Renn, 2020). As a result, connectivity between systems serves as a major risk driver which can cause ripple effects to affect systems beyond the domain in which the risk event originally manifested (Lucas et al., 2018).

Several key features of systemic risk have been identified in the literature that set them apart from conventional risks, e.g. occupational hazards or risks related to road traffic compared to a breakdown of the entire transportation network. Systemic risks are (1) transboundary or cross-sectoral in scope of their consequences leading to multiple ripple effects; (2) highly interconnected and intertwined, leading to complex causal structures, high uncertainty and major interpretative ambiguities; (3) non-linear in their cause–effect relationships that come with tipping points; (4) stochastic in their effect structure, leading to increased uncertainty that is difficult or impossible to characterise by statistical confidence intervals; and (5) there tends to be a lag in policymaking which is at least partially due to social processes of risk perception (Renn et al., 2022; Schweizer, 2021; Schweizer & Renn, 2019; Schweizer et al., 2022).

Systemic risks can be the result of one event that starts a chain of events with devastating effects, e.g. the 2011 Tōhoku earthquake and tsunami that caused the Fukushima Daiichi nuclear disaster. Systemic risks can also be the result of structural conditions that make systems prone to failure. Lawrence et al. (2024) distinguish between fast processes associated with trigger events and slow processes that cause systemic stresses. Slow processes caused by societal dispositions increase complexity perpetually. The outbreak of SARS-CoV-2 (it can be argued that the outbreak of SARS-CoV-2 itself has been the outcome of human intervention as habitat destruction will lead to more zoonotic disease (Gibb et al., 2020)) and the ensuing pandemic demonstrates the susceptibility of various systems (the economy, public health, supply chains, etc.) to widespread, irreversible and cascading failure. The pandemic's manifold severe impacts are the result of systemic properties, which gave rise to emergent processes and phenomena with considerable cascading impacts on health but also for much of the global economy, and concordant high social costs (Hynes et al., 2020, p. 175).

However, this phenomenological versatility of systemic risks poses challenges for governance research which has hitherto focused on a relatively limited and heterogeneous set of systemic risks. The financial crisis 2007–2010 and climate change feature as the usual suspects but recent events, such as the COVID-19 pandemic and the war between Russia and Ukraine, have pushed other systemic risks more into the centre of attention. Empirical studies that measure the success of governance approaches in general are still rare (Weyer et al., 2015) and they are even rarer for governance that focuses on systemic risks. Empirical studies that put different modes of governance to a test are necessarily contained to experimental settings, e.g. in agent-based models (e.g. Adelt et al., 2018; Mielke & Geiges, 2018). Models such as these need to consider multiple interrelated factors with unpredictable outcomes due to non-linear dynamics (Helbing, 2013). Furthermore, human beliefs and value orientations shape the behaviour of complex systems in ways that are difficult to be explicitly incorporated in modelling approaches (Hochrainer-Stigler et al., 2019).

Thus, governance of systemic risks faces several epistemological challenges related to the properties of systemic risks sketched out above but also to the unpredictable outcomes of governance interventions. Also, more conceptual and experimental research is needed that investigates integrated assessments of governance interventions for systemic risks, especially in transdisciplinary settings that include stakeholders (Poledna et al., 2020a, 2020b).

This publication aims to prepare the ground for the latter kind of research. We start with an account of the governance challenges posed by systemic risks, with examples drawn from the COVID-19 pandemic and climate change. The following section on the governance challenges of systemic risks will be guided by the categories of complexity, uncertainty and ambiguity as they provide analytical entry points for governance research on systemic risks (Klinke & Renn, 2012; Renn et al., 2022). The categories also inform the subsequent sections in which proposals for governance of systemic risks will be made.

2.1 Complexity

Systemic risks originate in complex adaptive systems, such as ecosystems, markets, the energy grid or the internet. Broadly defined, a system is an entity of interacting elements, and it is defined by boundaries, which set it apart from other systems. As systems become more differentiated, they also become more complex. Increasing complexity is a major trend of the evolution of all systems, be they biological, social, cultural, technological or economic (Laubichler & Renn, 2015). These complex systems are composed of many interconnected parts. Complexity can be defined as a 'causal chain with many intervening variables and feed-back loops that do not allow the understanding or prediction of the system's behaviour on the basis of each component's behaviour' (Aven et al., 2018, p. 5). Increasing interconnectivity therefore results in increasing complexity.

Complex systems can be characterised by the diversity of their parts, density of their interconnections and their size, i.e. their number of parts and connections (Ladyman & Wiesner, 2020). Increasing any of these three dimensions makes the system more complex. Complex systems become dynamic when feedback between interrelated parts and/or the system's environment

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generates the emergence of unexpected system behaviour (Taleb, 2020; Zio, 2016). Especially complex adaptive systems, i.e. systems that involve many components that adapt and change their properties and behaviour as they interact – are at the heart of important contemporary problems (Holland, 2006). Complex adaptive systems depart from linear trajectories of development due to feedback mechanisms. Therefore, interconnectivity increases adaptation but also vulnerability to external stressors, leaving the system prone to cascading effects and regime shifts (Helbing, 2013). Ripple effects may even spread beyond the originating systems, leading to transboundary effects of contagion. The COVID-19 pandemic not only illustrates how pathogens rapidly spread thanks to the global networks of international passenger transport but also the cascading effects of the pandemic. The pandemic affected all our society's vital systems: from the food supply to our economic and financial systems, and from education to culture and social life. Similarly, climate change is caused by emissions in energy and other predominantly human dominated systems. The resulting changes in the climate change system then can have cascading negative effects on biodiversity (Habibullah et al., 2022), food security (Wheeler & von Braun, 2013), human migration and armed conflict (Scheffran et al., 2012). As energy systems are beginning to decarbonise, the effects of warming may impact the ability to produce green energy (Groundstroem & Juhola, 2021), further exemplifying the feedback mechanisms in the complex systems.

2.2 Uncertainty

The category of uncertainty comprises several aspects, such as statistical variation, measurement errors and ignorance (van Asselt, 2000) which challenge the strength of confidence put in cause-and-effect relations. Systemic risks originate in highly complex systems which entail various interdependencies and feedback mechanisms. This makes it difficult to establish the relation between cause and effect, i.e. which events or hazards cause systemic risks and how these risks propagate in society. Furthermore, it is difficult to forecast the effects of manipulating these systems by governance interventions due to stochastic effects (Tannert et al., 2007). In addition, systemic risks originate in dynamic systems that are sensitive to initial conditions. Small differences in initial conditions result in large differences at a later stage. Consequently, each systemic risk develops due to its own set of conditions. This means that 'for predicting any event at any level of precision, all sufficiently past events are approximately probabilistically irrelevant' (Werndl, 2009, p. 197). Thus, generalisations rather pertain to the underlying mechanisms that cause systemic risks than specific events. Evolutionary approaches towards analysing the complex dynamics in social-ecological systems highlight processes of emergence, self-organisation, adaptation and niche construction as key for understanding system change (Currie et al., 2023; Renn et al., 2022).

Additionally, systemic risks develop over long periods of time and come with sudden regime shifts marked by tipping periods or points. The temporal component of regime shifts is nearly impossible to determine, although some indicators signalling transitions have been identified (Kopp et al., 2016; Scheffer, 2010; Scheffer et al., 2009). Extrapolations of future developments from past actuarial data are inhibited by tipping points. The emerging question of how can we 'logically go from specific instances to reach general conclusions' (Taleb, 2010, p. 40) fundamentally challenges inductive approaches to science.

Considerations of knowledge strength are therefore important in this context. Subjective probability is 'an exercise of judgement, especially under conditions where actuarial data is unavailable or meagre' (Rosa, 2008, p. 111). It expresses degrees of beliefs about events or unknown quantities based on some knowledge. First, the analysis of systemic risks is framed at the outset by the demarcation of a system's boundaries (Juhola et al., 2022a). Bearing in mind that boundaries are analytical (not empirical) constructs, the answers to the questions of what counts as the 'inside' of the systems and what as its 'outside' is based on suppositions that could hide 'critical assumptions and therefore provide a misleading description of the possible occurrence of future events' (Aven, 2013, p. 46). Thus, the definition of system boundaries *a priori* entails an exercise of judgement. Second, judgements about the state of knowledge are made regarding model deployment. Models are inevitably entrenched in disciplinary thinking. Furthermore, epistemic uncertainty comes from taking estimates from well-controlled experiments or from modelling and applying them to specific contexts that may differ from the context where knowledge was developed in ways that inhibit transferability (Dietz, 2023; Rosa, 1998).

Decisions about which models are appropriate for the analysis of systemic risks already determine the frame of analysis and limit the spectrum of potential results. Although quantitative methods which deal with uncertainty exist, e.g. Monte Carlo simulation or Bayesian updating, these methods alone are insufficient for an analysis of systemic risks because quantifiable uncertainties are interspersed with unquantifiable uncertainties. For instance, unquantifiable uncertainties are associated with problem framings, model structures, system boundaries and value-ladenness (van der Sluijs et al., 2005, p. 482).

This situation has been termed deep uncertainty. Cox (2012) describes deep uncertainty as a situation in which 'trustworthy risk models giving the probabilities of future consequences for alternative present decisions are not available; the relevance of past data for predicting future outcomes is in doubt; experts disagree about the probable consequences of alternative policies – or, worse, reach an unwarranted consensus that replaces acknowledgement of uncertainties and information gaps with groupthink – and policymakers (and probably various political constituencies) are divided about what actions to take to reduce risks and increase benefits. For such risks, there is little or no agreement even about what decision models to use' (Cox, 2012, p. 1607). Therefore, modelling systemic risks requires not only multi-method model architectures but also a genuine effort at prudent judgement and interdisciplinary integration.

The COVID-19 pandemic's diverse impacts gave rise to emergent processes and phenomena. Agent-based models aim to demonstrate emergent effects due to system dynamics as they simulate the behaviour of individual or collective agents (e.g. Billari et al., 2006; Bonabeau, 2002). Agent-based models thus allow assessing the impact of economic shocks by considering adaptive human behaviour and disaggregated information for targeted policy interventions (Poledna et al., 2020a, 2020b). For instance, the agent-based model developed by Poledna et al. (2020a) has been used to forecast the macroeconomic effects of the COVID-19 pandemic at the sectoral level in Austria (Poledna et al., 2020a). These promising developments hopefully spark further research on interdisciplinary coupled models. With regards to climate change, uncertainty related to modelling efforts has been recognised for a long time now (Reilly et al., 2001), but consideration and search of consensus on uncertainty in climate

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change (Adler & Hirsch Hadorn, 2014) or energy systems modelling continues to be a challenge (Plaga & Bertsch, 2023). Further, a recent review of uncertainties related to adaptation to climate impacts, reveals that multiple sources of uncertainty affect adaptation decisions (Moure et al., 2023). While previously scientific uncertainties have been at the centre of study, increasingly attention is paid to uncertainties in terms of the role and function of the decision maker and timeframes associated with the decisions (Moure et al., 2023). A review of US local level adaptation plans shows that while the presence of uncertainty is acknowledged at the local planning level, no specific measures are taken to address it (Woodruff, 2016).

2.3 Ambiguity

Ambiguity stems from unresolved issues of complexity and uncertainty. Uncertainty and complexity give rise to controversies about knowledge base, differences in framing of the problem, and inadequacies of the institutional arrangement at the science–-policy interface (van der Sluijs et al., 2005), all of which result in ambiguity. Ambiguity denotes the variability of interpretations based on identical observations or data assessments (Renn et al., 2022). A plurality of viewpoints for evaluating data exists under conditions of ambiguity. More precisely, two kinds of ambiguity can be identified. Interpretative ambiguity refers to a legitimate range of interpretations of data and research results. Several interpretations of the results are possible with stochastic statements, all of which are based on the same evidence even though they suggest different governance measures. For instance, given the logistical constraints on the rollout of the COVID-19 vaccine, decisions had to be made which susceptible groups of the population to vaccinate first. Most countries decided to start with the most elderly. Another route would have been to start the rollout with persons who have weak immune systems irrespective of their age, e.g. persons who are receiving cancer treatment. Decisions such as these must be made based on incomplete knowledge and often under time pressure. Similar observations have been noted in relation to climate policy (Millner et al., 2013). Decision-making in such situations is aided by heuristics. Heuristics are mental strategies for situations in which individuals act under conditions of limited information (Simon, 1991). Heuristics therefore play an important role in decision- and policy making by allowing people to focus on specific aspects (and ignoring others) of a task or problem thereby reducing the complexity of decision-making (Gilovich & Griffin, 2002; Kahneman, 2011). Heuristics for climate change adaptation have emphasised an incremental approach for governing, including no-regret options in order to retain flexibility (Nalau et al., 2021).

Normative ambiguity refers to heterogeneous normative assumptions that lead to divergent opinions on policies and management options (Renn et al., 2011). Systemic risks often touch upon common pool problems for which normative ambiguity plays a role (Renn et al., 2022). Common pool problems are the result of overconsumption and depletion of common resources due to the selfish individual behaviour of a few (McCay, 2002; Ostrom, 1990, 2010b, 2010a). If all users were to restrain themselves, the resources could be sustained. A dilemma arises, however. If some people limit their use of resources and others do not, then the resource still collapses, leaving the first set of people without the short-term benefits of taking their share (Dietz et al., 2002). (In fact, their restraint results in a bigger slice of the cake for the free-riders who use up their share in addition to their own.) These problems are therefore closely related to the ‘free rider problem’ which occurs when those benefiting from public goods or common resources do not pay for them. Systemic risks often play out as a tragedy of the commons, a prominent example being greenhouse gas emissions resulting from carbon-intensive industries and lifestyles.

Normative ambiguity also surrounds the COVID-19 pandemic. For instance, governance measures implemented in many countries around the world put severe restrictions on people’s lives. Basic human rights such as freedom of movement have been curtailed for the greater good. People whose occupation allows a smooth transition to home office work can continue with their jobs whereas others face short-time work or unemployment. Issues of normative ambiguity and equity ensue. To overcome normative ambiguity in relation to climate change, there have been calls for ensuring accountability of actions remains, as well as ensuring ethical interactions among knowledge exchange processes (Fleming & Howden, 2016) and recognising different forms of knowledge (Latulippe & Klenk, 2020).

3. Inclusive governance of systemic risks – combining factual and ethical considerations

Governance of systemic risks needs to meet the challenges posed by the complexities, uncertainties and ambiguities of these risks. Governance is at the same time tasked with risk reduction, e.g. reducing the risk of people becoming infected with SARS-CoV-2 in public spaces or of climate change impacts, while allowing for trade-offs and conflicting values. Governance of systemic risks must therefore guarantee procedural considerations of inclusion and deliberation as well as feedback loops in the system. The following sections propose a governance framework that constitutes an adaptive, coping and participatory response to systemic risks.

Governance departs from assumptions of formal regulation, goal attainment and control signified by the government. The term governance implies a paradigm shift in authority, influence and coordination away from the state to other actors in society. These shifts are ‘conceptualised in three different directions: upward (to the regional, transnational, intergovernmental and global), downward (to the local, regional and the metropolitan) and horizontally (to private and civil spheres of authority)’ (Levi-Faur, 2012, p. 7). Governance, therefore, signifies a change in the meaning of government, referring to new processes of governing, changed conditions of ordered rule, and new methods by which society is governed (Rhodes, 2012, p. 33). Governance has also been associated with an ideological and cultural shift towards individualism and the market as the superior resource allocation mechanism (Pierre, 2000). As Levi-Faur points out, governance is neither a homogeneous field of study nor does it provide a unified theory of causal relations concerning politics, economics and society (Levi-Faur, 2012, p. 9). However, according to Levi-Faur (2012), governance refers to a structure, a process, a mechanism or a strategy. As a structure, governance

> signifies the architecture of formal and informal institutions; as the process it signifies the dynamics and steering functions involved in lengthy never ending processes of policy-making; as a mechanism it signifies institutional procedures of decision-making, of compliance and of control (or instruments); finally, as a strategy it signifies the actors’ efforts to govern and manipulate the design of institutions and mechanisms in order to shape choice and preferences (Levi-Faur, 2012, p. 8).

This conceptual versatility offers possibilities for a wide range of applications. Favourable links emerge for the convergence of governance and risk. For instance, the debate about risk discourses implies the involvement of a greater range of societal actors in processes of governance (Fisher, 2012, p. 418). Risk governance therefore refers to deliberative processes of stakeholder engagement and public participation, which become a democratic source of legitimacy in governing risk and incorporates extended peer, stakeholder and public communities (Klinke & Renn, 2021).

Three general arguments for participation (substantive, instrumental and normative) can be identified regarding the engagement of the affected public and their representatives (i.e. stakeholders) in risk decision-making processes (Fiorino, 1990; Stirling, 2006; Stirling et al., 2008).

1. The substantive argument claims that the substantive quality of information in a process will be improved by including a variety of perspectives in decision-making. Therefore, stakeholder and public engagement in risk governance are motivated by the realisation that these groups provide crucial information for assessment from diverse standpoints, including scientific knowledge and other knowledge systems (Fischhoff, 1995).
2. The instrumental argument suggests that including the public in decision-making can lead to decisions that are more likely to be supported or implemented successfully (Beierle, 1999; Slovic, 1993). Participation therefore leads to improved overall effectiveness of risk governance.
3. The normative argument for participation claims that participation may address highly contested issues and initiate a dialogue even in social contexts afflicted by strife and distrust resulting in improved social cohesion (National Research Council, 2008), fairness and justice by giving voice to those who have been excluded from traditional decision-making (Innes & Booher, 2004), and empowerment of citizens (Arnstein, 1969).

Thus, public participation and stakeholder engagement has become a standard feature of many risk governance efforts (Webler & Tuler, 2006). 'Inclusive risk governance' (Klinke & Renn, 2012), therefore, has become an 'inclusive and participatory activity that integrates various stakeholder perspectives, engages in the co-generation of practical knowledge, and resolves contingencies by developing discrete scenarios that translate different concerns and positions in negotiable and communicable narratives' (Klinke & Renn, 2021, p. 546).

3.1 Analysis of systemic risk

Governance of systemic risks is concerned with the analysis of tightly coupled systems, their various interdependencies and the resulting dynamics. Risk analysis here investigates feedback mechanisms between components of a system at the intra-system level and at the interaction with other systems at the inter-system level which result in transboundary cascading effects. Three levels of abstraction can be differentiated to map out the complex embeddedness of nested systems.

First, at the level of system I, analysis is concerned with the intricacies of the risk-emitting system, such as a financial or technological system. In many cases, the systemic risk is being emitted from a convergence of systems. For instance, the convergence of the biohazard SARS-CoV-2 with the societal dispositions of complexity and functional differentiation, e.g. in the form of global supply chains, gave rise to the systemic properties of the COVID-19 pandemic, which make this pandemic stand out compared to previous pandemics, such as the Spanish flu and the plague. Thus, risk analysis needs to capture the dynamics of feedback mechanisms and the stochasticity of non-linear systems at both the intra- as well as the inter-system level. Modelling these complex interrelations is (even at this level) a challenging enterprise which calls for interdisciplinary cooperation and a modular approach towards model frameworks, with a focus on systemic thinking (Groundstroem & Juhola, 2021).

Second, at the system II level, institutional and organisational structures, as well as the regulatory arrangements that engulf risk-emitting systems come into focus. Modern organisations are susceptible to 'normal accidents', which start out small before cascading through tightly coupled systems (Perrow, 1984). Risk analysis is therefore concerned with organisational structures as well as organisational risk management protocols and practice. Furthermore, risk-emitting systems are surrounded by a vast number of institutions at various levels of scale and responsibility. Institutional fragmentation leads to a spread of authority across multiple state and non-state institutions with various political and functional overlaps. As a result, responsibilities and legitimacy become clouded (Widerberg, 2016). System II analysis therefore must focus on mapping out institutions and networks concerned by the risk-emitting systems on the system I level. Institutional mapping will lead to a clearer picture of responsibilities, legitimacy and accountability, thereby fostering effectiveness of governance.

Third, system III analysis is concerned with societal risk controversies that engulf risk-emitting systems and their institutional apparatus. Risk controversies speak of epistemic controversies, stakeholder and public interests, diverging beliefs and values, as well as manifestations of power. These controversies need to be mapped out to analyse the complex workings between public risk debates, more covert channels of risk proliferation (Beck & Kropp, 2011), mechanisms of risk perception and modes of risk amplification and attenuation. Furthermore, maps of risk controversies support argument-based tools for conflict resolution, which can serve as guidance for decision-making (Beck, 2016). Mapping risk controversies will neither reconcile power plays nor competing epistemic claims. Yet, it may improve understanding among parties and therefore can fundamentally enhance transparency of risk governance (National Research Council, 2008).

In sum, analysis of systems I, II and III provides the epistemic foundation for risk governance of systemic risks. Demarcation of system boundaries is an issue that needs to be settled for each systemic risk individually. Nevertheless, some universal features stand out. Risk analysis of systemic risks needs to be concerned with interdependencies within and between systems as these cause cascading effects that surpass system boundaries. System modelling is therefore tasked with replicating system complexity (insofar as it is necessary), associated interdependencies and dynamics as well as potential cascading effects. Modelling systemic risks is also concerned with the task of demonstrating tipping points and early warning signals that herald transition periods (Lucas, 2022; Lucas et al., 2018). Research on network analysis approaches system dynamics from a perspective of evolving network dynamics. This framing focuses on connections among agents as a dynamic and evolving system. From a governance perspective, this approach seems promising as network scholars analyse the pathologies and potentials of network dynamics for reflection, innovation and social learning (Henry, 2020, 2023; Masuda et al., 2018).

Modelling system I, II, III complexities and interrelations requires interdisciplinary collaboration and a modular model framework. This also calls for a transdisciplinary approach towards modelling and scenario building including experiential and tacit knowledge. However, model-based risk assessment and foresight are accompanied by uncertainties, only some of which are quantifiable (Funtowicz & Ravetz, 1990). Systemic risk modelling therefore needs to consider empirical and subjective uncertainties which are associated with 'problem framings, model structures, assumptions, system boundaries, indeterminacies, and value ladenness' (van der Sluijs et al., 2005, p. 482). Van der Sluijs et al. propose the NUSAP (Numeral Unit Spread Assessment Pedigree) method to complement state-of-the-art quantitative uncertainty methods with systematic qualitative assessments that address the methodological, epistemological and societal dimensions of uncertainty (van der Sluijs et al., 2005, p. 482). NUSAP is a notational system originally proposed by Funtowicz and Ravetz (1990) which provides an analysis and diagnosis of uncertainty in the knowledge base of complex policy problems. This approach aims to capture both quantitative and qualitative dimensions of uncertainty by means of the five qualifiers of the NUSAP acronym, i.e. numeral, unit, spread, assessment and pedigree (van der Sluijs et al., 2005, p. 482). Assessment and pedigree constitute the more qualitative side of the NUSAP expression. Assessment expresses qualitative judgements about the information. Pedigree conveys an evaluative account of the process of information and knowledge production (van der Sluijs et al., 2005).

3.2 Governance principles for systemic risk: reflection, iteration, inclusion, transparency and accountability

Governance of systemic risks is also concerned with procedural considerations of governance. Concepts such as participatory governance (Fischer, 2006; Fung & Wright, 2001, 2011) and governance through networks (Torfing, 2012) focus on which kind of (institutional) actors will engage with each other in which ways. At a meta-level, governance research focuses on modes of governance and their self-reflexive and provisional nature. For instance, Kuhlmann et al. (2019), based on a review of the scholars in the field, propose tentative governance, which aims to create spaces for probing and learning instead of stipulating definitive targets, as a meta-criterion that permeates other forms of governance (Kuhlmann et al., 2019, p. 1091). In a similar vein, experimentalist governance continuously reflects on its assumptions, treats all solutions as provisional and corrigible, as well as considers and compares alternative approaches to advancing general aims (Sabel, 2006). Experimentalist governance focuses on multi-level concertation that relies on networking various types of decision-makers at several levels (Sabel & Zeitlin, 2008). Consequently, 'experimentalist governance structures have emerged as a widespread response to turbulent, polyarchic environments, where strategic uncertainty means that effective solutions to problems can only be defined in the course of pursuing them, while a multipolar distribution of power means that no single actor can impose her own preferred solution without taking into account the views of others' (Zeitlin, 2015, p. 11). By the same token, adaptive governance starts with the premise of multilevel governance of nested, coupled systems. Adaptive governance implies power sharing that promotes participation by means of self-organised social networks that draw on various knowledge systems and experiences (Folke et al., 2005; Juhola, 2023).

Tentative, experimentalist and adaptive governance concepts, together with the inclusive risk governance approach mentioned above, provide stepping stones for governance of systemic risks. These include the governance principles of reflection, iteration, inclusion, transparency and accountability. *Reflection* considers the volatile nature of systemic risks. The opacity of systemic risks relates foremost to uncertainties about tipping points and (to a somewhat lesser extent) cascading effects. In this respect, systemic risks resemble black swan events (Taleb, 2010). Black swans are extreme events with regards to their potential impacts that are associated with a low probability of occurrence based on current knowledge and beliefs (Aven, 2013, p. 49). Several types of black swan events are relevant to the discussion on systemic risks. The first type of black swan events denotes risk phenomena totally unknown to science (unknown unknown risks). Risk governance can only offer generic guidance for this type of event, such as constant vigilance, continuous research and the enhancement of the risk-absorbing system's resilience. The second type of black swan event relates to unknown known risks. These events have not been considered by those carrying out risk analysis, yet they are known to other experts or stakeholders (Aven & Krohn, 2014).

Thus, the process of governing systemic risks demands continuous reflection of the underlying premises not only of system I, II and II risk analysis but also of the governance process itself. Continuous reflection requires *iteration*. The third type of black swan event is on the 'list of known events in the risk analysis but judged to have negligible probability of occurrence, and thus [is] not believed to occur' (Aven, 2015, p. 84). The COVID-19 pandemic falls under the latter category with the caveat that there was no error about negligible probability of occurrence on the part of risk science. For instance, the German parliament had received a briefing document in 2013 that sketches out a potential scenario of a SARS virus pandemic for Germany (Deutscher Bundestag, 2013). In this document, the pandemic is expected to occur once every 100–1,000 years and the anticipated adverse effects on human health, the economy and democracy are supposed to be tremendous (Deutscher Bundestag, 2013, p. 56). This risk analysis conducted by the Robert Koch Institute and other German federal agencies has been verified by the outbreak of the COVID-19 pandemic in 2019.

Furthermore, the systemic risks of pandemics have been pointed out by Ian Golding and Mike Mariathasan in their seminal work *The Butterfly Defect*. Goldin and Mariathasan (2015) suggest that globalisation causes societal interdependencies that give rise to systemic risks such as pandemics. Thus, knowledge about probability and adverse effects of pandemics in general, and SARS mutations in particular, had been available prior to the COVID-19 pandemic. Yet the pandemic turned out to be an 'extreme event relative to current knowledge and beliefs' and thus qualifies as a black swan event according to Aven's definition (Aven, 2013, p. 49). For climate change, this means broadening the perspective from single extreme events to considering to what extent climate change poses an existential risk to humanity (Huggel et al., 2022; Magnan et al., 2023). The same dispositions that made contemporary societal systems susceptible to systemic risks also brought about unprecedented levels of human welfare and prosperity to an increasing number of people. Risk governance that aims to ameliorate the effects of this latter type of event must consider beliefs and value orientations for finding trade-offs between risks and benefits in iterative deliberative processes.

Governance of systemic risks therefore requires deliberation and *inclusion*. Governance implies the sharing of power with and amongst stakeholders and affected publics. Hence, participation, which serves to improve governance on substantive, instrumental and normative dimensions, is a core feature of governance for systemic risks. Participation and communication are also means to achieve *transparency*. Potential openings and stumbling blocks for governance are mapped out by an analysis of institutional and regulatory settings (system II) as well as societal debates (system III), which both permeate risk-emitting systems (system I). Trade-offs can be negotiated and management options can be identified through deliberation (Bächtiger & Parkinson, 2019), which clarifies interests of stakeholders and reveals value orientations of the public, and knowledge co-production (Hochrainer-Stigler et al., 2024). Thus, governance of systemic risks aims to establish *accountability* for risk management measures taken to ward off detrimental effects of systemic risks. However, accountability for systemic risks is difficult to establish and even harder to enforce in practice. Systemic risks are transboundary regarding the demarcation of system boundaries as well as cascading effects that spread across systems. Their modes of action also surpass national responsibilities and jurisdiction, thus calling for multi-level governance (Hooghe, 1996) and international cooperation. Furthermore, systemic risks often touch upon common pool problems. For instance, climate change can be phrased (albeit in simplistic terms) as a common pool problem that has been caused by the overuse of fossil fuels by some with repercussions for the wellbeing of (almost) all. Classical suggestions for governing the commons focus on the community level, especially on design principles of rule-making and rule enforcement such as manageable size and well-defined borders of the resource system as well as the community (Agrawal, 2002). Most notably, Elinor Ostrom's findings suggest that governing the commons requires collective-choice arrangements that allow participation by all affected individuals (Ostrom, 1990). These suggestions have proven to be successful, especially at the community level. Governance of systemic risks, however, cannot be downscaled to the community level due to the transboundary nature of systemic risks which negates institutional containment and analytic compartmentalisation. Hence, effective governance on an aggregate level requires dealing with conflicts and factual information about the environment, human actions as well as information about uncertainty and values (Dietz, 2023; Dietz et al., 2003; Ostrom, 1990).

At the same time, supranational institutions have been proposed to facilitate rule enforcement at the international level (Sandholtz & Stone Sweet, 1998). Empirical observations challenge this proposition. The Paris Agreement within the United Nations Framework Convention on Climate Change, for instance, can be interpreted as an attempt to transfer rule enforcement of climate change mitigation, adaptation and finance back to the national level. By the same token, multilateral agreements struggle with a backswing in the current political climate of international relations towards bilateral agreements. Current practice to curb carbon emissions focuses on a threefold strategy consisting of privatisation, e.g. via an emissions trading system, governmental control and voluntary cooperation. Against the backdrop of the challenges of governing common pool problems, governance of systemic risks needs to explore other paths and their intersections. Governance via networks seems a promising road to travel. Governance networks operate at any level in a multi-level governance framework at various degrees of institutionalisation (Torfing, 2012). Governance networks provide a platform for stakeholder engagement, thus facilitating participation (Hirst, 2000). Participatory and deliberative approaches in support of cross-national and global governance can achieve a number of distinct goals, e.g. ethical and epistemic functions in addition to providing legitimacy (Bidwell & Schweizer, 2021). However, those functions can come into conflict with each other which calls for a careful design of deliberative processes that takes into account different deliberative tasks and agents at different moments within a process (Beauvais & Baechtiger, 2016).

Furthermore, an important question is which meta-objectives inform the quest for management options. Resilience has been proposed as a guiding principle for risk management of systemic risks. The National Research Council (1996) defines resilience as ‘the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events’ (National Research Council, 1996, p. 16). Resilience acknowledges that systemic risks will materialise, and disruptions will happen. The objective of risk management then is to enhance systems' capacity for recovery and adaptation to ensure their survival and potential improvement through broader systemic changes (Hynes et al., 2020, p. 178f). While scholars refer to resilience as a yardstick for managing risks under conditions of uncertainty, the concept does not provide criteria for assessing which systems and functions should be sustained and which changes in the status quo would qualify as improvements. For instance, Trump and Linkov (2020) raise these questions about ‘broader societal resilience to bounce back from the range of outcomes afflicting public health, economics, and general societal harmony and well-being’ (Trump & Linkov, 2020, p. 173) in the context of the COVID-19 pandemic.

Suggestions have been made for rephrasing the resilience concept to accommodate normative meta-objectives such as equity (e.g. Logan & Guikema, 2020) and sustainability (e.g. Berkes & Ross, 2016) (for an in-depth view on the relationship between resilience and sustainability, see e.g. Derissen et al. (2011) and Renn (2020)). However, the relationship between resilience and sustainability when applied to risk management remains a contested issue (Renn, 2020). The Brundlandt report published in 1987 defines sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (United Nations, 1987). Thus, sustainability is about safeguarding the needs of present and future generations all over the world which puts equity and participation front and centre for sustainable development (Grunwald, 2009). Thus, both resilience and sustainability aim to establish humane living conditions for present and future generations. Yet it has been argued that sustainability is the wider-ranging concept as it also strives for intra- and intergenerational justice and calls for due democratic processes of decision-making based on moral principles (Renn, 2020, p. 6466). The latter two issues especially require stakeholder and public engagement for assigning and justifying trade-offs between management options. The COVID-19 pandemic has demonstrated that current societies are prone to systemic risks. Resilience and sustainability should guide recovery from the pandemic and adaptation to systemic risks. Thus, this article aims to contribute to resilient functionalities for sustainable societies by proposing an adaptive and participatory risk governance framework for systemic risks.

3.3 A procedural framework for systemic risk governance

Reflection, iteration, inclusion, transparency and accountability serve as guiding principles for the procedural aspects of governing systemic risks. Procedural and analytical dimensions need to be considered for governance of systemic risks. The risk governance framework by the International Risk Governance Council (2017) serves as a reference point for merging both dimensions together (Figure 1). On the one hand, the risk governance framework combines quantitative risk analysis with qualitative assessments. On the other hand, the risk governance framework includes stakeholder participation and public engagement, thus offering a comprehensive (regarding facts) as well as inclusive (regarding values) risk governance framework. The risk governance framework consists of four consecutive phases, i.e. pre-assessment, appraisal, characterisation and evaluation, and management. All phases can be iterated, if necessary. Furthermore, they are linked by continuous modes of stakeholder engagement and public participation. Thus, the risk governance framework provides a platform for implementing the procedural dimension of governance for systemic risks. A system analysis as sketched out above must be performed in each phase to integrate the analytic dimension into the governance process.

The *pre-assessment phase* aims to provide a comprehensive understanding of the risk problem. In this initial phase, system analysis is crucial. At this stage, the analysis need not yet be overly concerned with the interrelations of systems I, II and III. Yet attention should be paid to the underlying assumptions of demarcating system boundaries because they will carry over to the following phases, thus framing the process and its outcomes. Ideally, transdisciplinary teams, which include an interdisciplinary set of scholars and experts as well as stakeholders, reflect on system boundaries and underlying assumptions. These transdisciplinary teams also select conventions and procedural rules for 'the handling of distributional effects which may cover inter-individual, inter-group, regional, social, time-related and inter-generational aspects' (Renn, 2008, p. 13). The COVID-19 pandemic demonstrated that issues of gender inequality (Czymara et al., 2020) as well as educational inequality (Andrew et al., 2020) are reinforced during lockdown. One of the lessons to be learnt from the pandemic is to pay attention to distributional aspects of governance measures and to decide upon rules for dealing with these issues in the earliest stages of the governance cycle. Scholars also point out distributional issues and injustices with regards to climate change impacts (Pellow, 2018; Whyte, 2020), some of which could be addressed during the planning of adaptation to climate change (Juhola et al., 2022a, 2022b).

Figure 1. Risk Governance Framework, adapted from IRGC (2017).

The *appraisal phase* comprises risk assessment, i.e. hazard identification and estimation, appraisal of exposure and variability, as well as risk estimation, and concern assessment that investigates risk perceptions, societal concerns and socio-political impacts. Risk appraisal includes quantitative, as well as qualitative forms of assessments. Approaches based on multi-model frameworks, such as scenario building, can be deployed to analyse cascading effects and tipping points of systemic risks. Concern assessment calls for participation of stakeholders and the public to investigate perceptions and map out societal concerns. This stage focuses on system analysis at all three levels of system I, II and III; with risk assessment targeting system I and II levels and concern assessment targeting the system III level. The results from both risk assessment, which provides an estimate of the physical harm (this may also include financial losses if the systemic risk originates in the economy), and concern assessment, which investigates the social and (wider) economic implications, need to be integrated for a comprehensive appraisal of a given systemic risk. The COVID-19 pandemic has shown that priority is given to risk assessment while concern assessment takes a backseat. This was understandable in the initial stages of the pandemic when governments needed to act under time constraints and political pressure. However, comprehensive, and systematic concern assessment during the lull between the first and second wave of the pandemic would have unveiled much of the dissatisfactions and concerns that inhibited the success of many governance measures during the second wave. For climate change risks, existing studies stress the need to engage stakeholders in participatory processes to better address and account for the uncertainty of risks in planning and to facilitate social learning (Döll & Romero-Lankao, 2017).

The next phase consists of *risk characterisation and risk evaluation*. The available knowledge regarding systems I, II and III (or lack thereof) is sorted in categories of complexity, uncertainty and ambiguity. Risk evaluation is concerned with judgements on the tolerability, acceptability and the need for risk reduction measures based on the results garnered from knowledge characterisation. The inherent normative dimension of these judgements requires an inclusive approach which reveals and considers the plurality of societal values. Thus, risk characterisation determines the evidence-based component and risk evaluation determines the value-based component for making judgements on the tolerability and acceptability of risks (Renn, 2008, p. 31). Both components are necessary for making this judgement. Evidence from the handling of the COVID-19 pandemic in Germany seems to suggest that the government tends to rely operationally on the evidence-based component in its decision-making whereas the value-based component is left to the (more time consuming) parliamentary debate. Although this approach adheres to the separation of power between the legislative, executive and judicial branches, the result leads to an asynchronous handling of risk characterisation and risk evaluation in this case. One potential way out of this structural conundrum would have been to conduct citizen assemblies or similar deliberative formats during the lull between the first and second waves of the pandemic to investigate the value-based component.

The results of knowledge characterisation and risk evaluation are channelled into the final phase of *risk management*. Risk management aims at the design and implementation of actions required to avoid, retain, reduce or transfer risks. This phase consists of decision-making and implementation. The results of risk characterisation and risk evaluation as well as risk assessment and concern assessment form the input material for the selection of risk management options (Renn, 2008, p. 32). As the SARS-CoV-2 virus cannot be eliminated, people's exposure to the virus needs to be restricted, e.g. by wearing masks and social distancing, and vulnerabilities need to be reduced, e.g. by vaccination and increased capacities for intensive care. Resilience-focused strategies seem to be the method of choice for dealing with the pandemic and other systemic risks. They attempt to enhance the risk-absorbing system to better cope with potential risks (Linkov et al., 2014; Renn, 2008). These strategies aim to establish best practices and analytical support to prevent unmitigated disasters although it is impossible to predict where, when or even whether such a compounding crisis may occur (Trump & Linkov, 2020). However, the emergence of polarisation and differences in normative beliefs and values in society cannot be reconciled by scientific risk assessments (see Hamilton, 2024). As personal norms are key to action (Bouman et al., 2021), risk management therefore also requires a broader societal discourse that is aimed at making ambiguities explicit and finding acceptable risk–risk trade-offs, which have also been recognised in relation to climate change (Sharifi, 2020). For COVID-19, this societal discourse could have taken place in the lull between the first and second wave of the pandemic as scientific risk assessments had been available by then and the societal impacts emerged to be tremendous. The response to the pandemic ideally would comprise a combination of epistemic discourses with experts and agency staff to settle cognitive conflicts and advance risk science, reflective discourses with agency staff, experts as well as stakeholders which will settle evaluative conflicts and develop resilience-focused strategies, and participatory discourses including civil society to reconcile normative conflicts in deliberative formats. Similar calls have also been made for climate change with an emphasis on integration of policies from different sectors and action (Li et al., 2021).

4. Conclusions

Several distinctive features of contemporary societies, such as functional differentiation, tightly coupled systems and interconnectivity, have contributed to an unprecedented level of human wellbeing and prosperity. Yet these features have made societies more susceptible to systemic risks – an inherent feature of contemporary societies. Systemic risks cannot be prevented but they might be better managed and governed. This article aims to put forth a coherent framework for the inclusive governance of systemic risks which combines system analysis with procedural aspects. Issues of complexity, uncertainty and ambiguity are associated with systemic risks which challenge decision-making and governance at a fundamental level. Human sense-making activities rely on the recognition and simplification of recurring patterns in a slowly evolving world, even when dealing with risk events of low probabilities of occurrence but potentially devastating effects (Taleb, 2010, p. 69). Governance of systemic risks needs to decide on where to place system boundaries and the focus of analysis. This decision and many others, such as concern assessment and risk evaluation, cannot be left to science and politics alone but public participation and stakeholder engagement are the procedural nuts and bolts of governance for systemic risks. The process of governing should include features of reflection, iteration, inclusion, transparency and accountability as guiding principles.

Both dimensions of governance, analysis and appropriate procedures are even more challenging for systemic risks than for conventional risks, and here emerge further research questions for this field.

First, from the perspective of conceptual development, the existing theories of governance account for aspects of systemic risk but they inadequately capture the role that governance may have in driving systemic risk, as well as identifying the ways in which different modes or policy instruments may reduce that risk or even make it dissipate altogether.

Second, and more pressingly, the proposed risk governance framework here is generic and flexible enough to allow applicability to a variety of known and emerging systemic risks. However, there is a persistent lack of empirical cases and this framework, as well as others similar, needs to be tested empirically to examine its full analytical potential beyond its value as a heuristic tool.

Third, there is a need for further methodological development in terms of governance of systemic risk. For example, agent-based models are a promising approach for testing the impact of governance interventions aimed at containing, reducing and managing systemic risks on system dynamics. While agent-based models offer a way of testing assumptions of agency, e.g. theories of action, and structural features, e.g. institutional settings and risk regimes, in combined simulations, more needs to be known about the ways in which they may illustrate the emergent effects of different governance measures and their combinations. There is also a need to develop participatory methods to capture stakeholder input not only to the modelling but also in terms of the usability of the models in real life simulations or decision-making activities. All three further research areas strongly point towards a need to engage the research community widely in these efforts as multiple disciplines are required, as well the engagement of various actors outside of academia.

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