

Annex I: List of current definitions, use of terminology

Economics			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
Organization for Economic Co-operation and Development [OECD] (2003)	Emerging Systemic Risks in the 21st Century	Report	"A systemic risk, in the terminology of this report, is one that affects the systems on which society depends – health, transport, environment, telecommunications, etc." (p. 30) "Many conventional risks look set to take on new forms, and new major hazards are emerging – some characterised by both extreme uncertainty and a potential for extensive and perhaps irreversible harm. These trends point to a marked future increase in the probability of major vital systems (technological, infrastructural, ecological, etc.) being severely damaged by a single catastrophic event (natural or man-made), or a complex chain of events" (p.32)
Financial Stability Board [FSB], International Monetary Fund [IMF] & Bank for International Settlements [BIS] (2009)	Guidance to Assess the Systemic Importance of Financial Institutions, Markets and Instruments: Initial Considerations	Report	"The paper defines systemic risk as a risk of disruption to financial services that is (i) caused by an impairment of all or parts of the financial system and (ii) has the potential to have serious negative consequences for the real economy. Fundamental to the definition is the notion of negative externalities from a disruption or failure in a financial institution, market or instrument. All types of financial intermediaries, markets and infrastructure can potentially be systemically important to some degree." (p. 2)
International Association of Insurance Supervisors [IAIS] (2018)	Holistic Framework for Systemic Risk in the Insurance Sector	Public Consultation Document	"Systemic risk, as defined by the IMF, BIS and FSB in 2009 , refers to a risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and has the potential to have serious negative consequences for the real economy. Fundamental to the definition is the notion of negative externalities from a disruption or failure in a financial institution, market or instrument." (p. 12)
The Geneva Association Systemic Risk Working Group (2010)	Systemic Risk in Insurance An analysis of insurance and financial stability	Report	"The risk of disruption to the flow of financial services that is (i) caused by an impairment of all or parts of the financial system; and (ii) has the potential to have serious negative consequences for the real economy" (p. 23) "Fundamental to this definition is the notion that systemic risk is associated with negative externalities and/or market failure and that a financial institution's failure or malfunction may impair the operation of the financial system and/or the real economy" (p. 23)
de Bandt, O. & Hartmann, P./ European Central Bank (2000)	Systemic risk: A survey	Working paper	Systemic risk (in the narrow and broad sense) can then be defined as the risk of experiencing systemic events in the strong sense. In principle, the spectrum of systemic risk ranges from the second-round effect on a single institution or market to the risk of having a systemic crisis affecting most of the (or even the whole) financial system at the upper extreme. The geographical reach of systemic risk can be regional, national or international. (p. 11)
Kaufman, G. G. & Scott, K. E. (2003)	What Is Systemic Risk, and Do Bank Regulators Retard or Contribute to It?	Article	" <i>Systemic risk</i> 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." (p. 371)
Schwarcz, S. L. (2008)	Systemic risk	Article	"A common factor in the various definitions of systemic risk is that a trigger event, such as an economic shock or institutional failure, causes a chain of bad economic consequences - sometimes referred to as a domino effect. These consequences could include (a chain of) financial institution and/or market failures. Less dramatically, these consequences might include (a chain of) significant losses to financial institutions or substantial financial-market price volatility. In either case, the consequences impact financial institutions, markets, or both." (p. 198) "...the risk that (i) an economic shock such as market or institutional failure triggers (through a panic or otherwise) either (X) the failure of a chain of markets or institutions or (Y) a chain of significant losses to financial institutions, (ii) resulting in increases in the cost of capital or decreases in its availability, often evidenced by substantial financial-market price volatility" (p. 204).
Welburn, J. W., Strong, A., Nekoul, F. E., Grana, J., Marcinek, K., Osoba, O. A., Koirala, N. & Setodji, C. M./ RAND (2020)	Systemic Risk in the Broad Economy. Interfirm Networks and Shocks in the U.S. Economy	Research report	"The ability of small, seemingly isolated risks to grow and spread across heavily interconnected systems—a problem summarized by the term <i>systemic risk</i> —has emerged as a central focus for research and policy change." (p. ix)

Annex I: List of current definitions, use of terminology

Eling, M. & Pankoke, D. A. (2016)	Systemic Risk in the Insurance Sector: A Review and Directions for Future Research	Article	<p>We reviewed 26 definitions of systemic risk and identified three important elements:</p> <ol style="list-style-type: none"> Risk of an event: For each risk, there must be an associated event that can occur. The associated event is the dysfunction of financial services, default of financial institutions, or a shock to the economy. Impact of the event: Most definitions specify the consequences if the event occurs, which are typically that the real economy is negatively affected. Causation of the event: Some definitions require the risk to have a certain causation before it is labeled systemic. These causations can be general in nature and/or specific and are mostly related to the financial services sector. (p. 250-251). <p>“In this article, as a working definition of systemic risk, we use that established by the FSB (2009) and the International Association of Insurance Supervisors (IAIS, 2009). Systemic risk is defined as “a risk of disruption to financial services that is (1) caused by an impairment of all or parts of the financial system and (2) has the potential to have serious negative consequences for the real economy.” This definition’s occurring event meets our requirements. Additionally, the definition covers spillover effects to the real economy and causational relationships. Moreover, only risks that emerge due to issues within the financial system are included. » (p.253)</p>
Social sciences			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
Centeno, M. A., Nag, M., Patterson, T. S., Shaver, A. & Windawi, A. J. (2015)	The Emergence of Global Systemic Risk	Article	“We define systemic risk as the threat that individual failures, accidents, or disruptions present to a system through the process of contagion. This is the risk that unexpected and unlikely interactions may lead to unpredicted threats to system survival.” (p. 68)
Risk			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
Renn, O., Laubichler, M., Lucas, K., Kröger, W., Schanze, J., Scholz, R. W. & Schweizer, P.-J. (2020)	Systemic Risks from Different Perspectives	Article	<p>"In our understanding, systemic risks refer to potential threats that endanger the functionality of systems of critical importance for society and their scope in time and space. The impacts may extend beyond the system of origin to affect other systems and functions (Renn, 2016)." (p. 2)</p> <p>"Four major characteristics should be considered to identify appropriate analytic entry points for developing a comprehensive understanding of a complex phenomenon such as systemic risks (Aven & Renn, 2019; Klinke & Renn, 2002).</p> <ul style="list-style-type: none"> • Complexity: Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential elements and specific adverse effects. The nature of this difficulty may be traced back to interactive effects among these elements (synergisms and antagonisms), positive and negative feedback loops, short or long delay periods between cause and effect, interindividual variation, intervening variables, and others. It is precisely this complexity that makes sophisticated scientific investigations necessary since the cause–effect relationship is neither obvious nor directly observable. Nonlinear response functions may also result from feedback loops that constitute a complex web of intervening variables. • Uncertainty: Uncertainty comprises different and distinct components, such as statistical variation, measurement errors, ignorance, and in-determinacy (van Asselt, 2000). They all have one feature in common: uncertainty reduces the strength of confidence in the estimated cause and effect chain(s). If complexity cannot be resolved by scientific methods and available data, uncertainty increases. But even simple relationships may be associated with high uncertainty if either the knowledge base is missing or the effects are indeterminate due to the stochastic (randomly structured) nature of the functional relationships. • Ambiguity: Ambiguity denotes the variability of (legitimate) interpretations based on identical observations or data assessments. Most of the scientific disputes in risk analysis do not refer to differences in methodology, data sets, algorithms, models, or statistical procedures but to the question of what all this means for human health and environmental protection (Renn & Klinke, 2012). Emission data are hardly disputed. Most experts debate, however, whether an emission of x constitutes a serious threat to the environment or to human health. Ambiguity may come from differences in interpreting factual statements about the world or from differences in applying normative rules to evaluate a state of the world. In both cases, ambiguity exists on the ground of differences in criteria or norms to interpret or judge a given situation. Ambiguity arises under conditions of high complexity and uncertainty, but there are also established and well-researched risks that can cause controversy and thus ambiguity. • Ripple-effects beyond the source of risk: Another key characteristic that sets systemic risks apart from conventional risks is the fact that their negative physical impacts (sometimes immediate and manifest, but often subtle and latent) have the potential to trigger severe ripple effects outside the domain where the risk is located. When systemic risks unfold, the resulting ripple effects can cause sequences of secondary and tertiary effects (Kasperson, Kasperson, Pidgeon, & Slovic, 2003). These effects can become tangible in a wide range of seemingly divergent social systems, from the economy to the health system, inflicting harm and damage in domains far beyond their own (De-Witte, Kurth, Allen, & Linkov, 2016). A commercial sector, for example, the food industry, may suffer from the impacts of a systemic risk as has been the case with the financial crisis in 2009 in the form of an increase in food prices or in the case of the COVID-19 crisis in 2020 where labor restrictions in agricultural businesses have resulted in shortages of specific foodstuffs. Another example for a major ripple effect is the BSE (Bovine Spongiform Encephalopathy) debacle in the United Kingdom, which not only effected the farming industry but also the animal feed industry, the national economy, public health procedures, and politics (Wynne & Dressel, 2010). People refused to eat British beef, regardless of tangible evidence showing little threat to their health or safety." (p. 3-4) <p>"Beyond the four general properties of systemic risks, there are more specific attributes that describe the causal structure of systemic risks. They are directly related to the four properties either as an input or as a consequence (Renn, Lucas, Haas,& Jaeger, 2017; Schweizer, 2019). Systemic risks are</p> <ul style="list-style-type: none"> • transboundary or cross-sectoral in scope of their consequences leading to multiple ripple effects; • highly interconnected and intertwined leading to complex causal structures, high uncertainty, and major interpretative ambiguities;

Annex I: List of current definitions, use of terminology

Schweizer, P.-J. & Renn, O. (2019)	Governance of Systemic Risks for Disaster Prevention and Mitigation	Article	<p>"Systemic risks can be characterised by five major properties" (p. 3)</p> <p>"First, systemic risks are characterized by high complexity. On the one hand, complexity stems from influencing factors that determine the emergence of systemic risks and their trajectories of development. On the other hand, systemic risks are tightly coupled with each other and traditional risks. These interdependencies influence all aspects of human life." (p. 4)</p> <p>"Second, systemic risks are transboundary and global in nature. Although systemic risks originate in one subsystem of society or the environment, the ripple effects of these risks affect all social subsystems, such as the economy, politics, and civil society." (p. 4)</p> <p>"Third, systemic risks are characterised by stochastic relationships between trigger and effects. Systemic risks are highly interconnected and complex, stochastic and non-linear in their cause-effect relationships." (p. 4)</p> <p>"Fourth, systemic developments are non-linear and include tipping points. Science struggles to identify these tipping points in advance." (p. 4)</p> <p>"Fifth, systemic risks are often underestimated in public policy arenas and public perception due to uncertainties of point of occurrence and extent of damage." (p. 4)</p>
International Risk Governance Center [IRGC] (2018)	Guidelines for the Governance of Systemic Risks	Report	<p>Systemic risks: "Threats that individual failures, accidents or disruptions present to a system through the process of contagion." (p. 12)</p> <p>Main Features:</p> <ul style="list-style-type: none"> • Highly interconnected risks with complex causal structures, non-linear cause-effect relationships • Lack of knowledge about interconnections in an interdependent and complex environment, prevention"(p.12)
Florini, M.-V. & Trump, B. D. (2018)	Resilience in the Context of Systemic Risks: Perspectives from IRGC's Guidelines for the Governance of Systemic Risks	Resource Guide	<p>"Major shocks and disruptions materialise as the result of systemic risks cascading within and between complex adaptive systems and are often unexpected prior to their arrival. This cascading effect is perhaps one of the more complex and unpredictable components of systemic risk and is particularly dangerous in an environment of increasing system interdependency and connectivity (e.g., the global financial system, industrial agriculture and fishing, digital information systems, etc.)." (p. 1)</p>
United Nations Office for Disaster Risk Reduction [UNDRR] (2019)	Global Assessment Report on Disaster Risk Reduction	Report	<p>"Systemic risk - Risk that is endogenous to, or embedded in, a system that is not itself considered to be a risk and is therefore not generally tracked or managed, but which is understood through systems analysis to have a latent or cumulative risk potential to negatively impact overall system performance when some characteristics of the system change."(p. 45)</p>
Hochrainer-Stigler, S., Colon, C., Boza, G., Poledna, S., Rovenskaya, E. & Dieckmann, U. (2020)	Enhancing resilience of systems to individual and systemic risk: Steps toward an integrative framework	Article	<p>"...individual failures may trigger systemic risks. Systemic risk is sometimes called network risk to emphasize the importance of inter-linkages. In contrast, individual risks originate from single events that directly affect an agent and unfold in isolation from the rest of the system. While usually treated separately, we suggest that individual risks and systemic risks may be seen, in fact, as representing the two ends of a continuum and therefore should not be analyzed in isolation, but rather in an integrative manner. From such a perspective, individual risks describe how an event perturbs a single component in a system and causes a primary failure, whereas systemic risks capture the propensity for cascades of secondary failures to be triggered by such events. The continuum is spanned by the proportion of all failures that are secondary (i.e., by the expected ratio of the number of system components failing secondarily relative to the number of system components failing primarily or secondarily), with larger proportions characterizing risk settings at the more systemic end of the spectrum" (p. 2)</p>
Maskrey, A., Jain, G. & Lavell, A./ United Nations Development Programme [UNDP] (2021)	The Social Construction of Systemic Risk: Towards an Actionable Framework for Risk Governance	Discussion paper	<p>"Systemic risk: The ripple-effects of direct loss and damage, indirect impacts and wider effects, such as the disruption of infrastructure systems and essential services; failure of economic, financial or social systems; effects on employment and income; national and family debt profiles and ecosystem collapse." (s. 5)</p> <p>"Since the turn of the century in particular, the term has been used to refer to physical, biological, social, environmental or technological hazard events triggering not only direct loss and damage but also spiraling, cascading or ripple effects within one or more interdependent social, economic or environmental systems, often associated with feedback loops and non-linear effects (IRGC, 2018; Renn, 2016; UNDRR, 2019).</p> <p>Systemic risk has always existed. Local and national expressions of systemic risk, common throughout history, are now complemented by increasing manifestations of global systemic risk. Events since the turn of the 21st century would seem to indicate that the compression of time and space as a defining characteristic of economic globalization, is consistent with increasing system interdependency, complexity and uncertainty and hence magnified systemic risk. A recent survey by the OECD highlighted that while many countries had strategies to manage risks in some critical infrastructure sectors, few map interdependencies across sectors and only half have the capacity to identify new, unforeseen and complex crisis (OECD, 2018).</p> <p>The triggers of systemic risk and risk in general can be varied including those with physical, biological, technological, environmental, socio-political, and economic/financial origins. They may occur as single and separate occurrences or in more complex, compound, multiple, concatenated or cascading and sequential ways. Systemic risk, characterized by high levels of interdependency, non-linearity, feed-back loops and uncertainty may be expressed and realized as sequential, synchronous or simultaneous crises and failings." (s. 7)</p>
NATECH			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
Suarez-Paba, M. C., Tzioutzios, D., Cruz, A. M., & Krausmann, E. (2020). In: M. Yokomatsu and S. Hochrainer-Stigler (eds.)	Toward Natech Resilient Industries	Book chapter	<p>"Masys et al. (2014) note that systemic risks, that characterize Natech accidents, develop from unanticipated consequences of interactions within and between different types of systems. Furthermore, the authors explain that according to Johnson and Tivnan (2012: 65), "<i>...understanding, controlling and predicting extreme behavior [of Natech] is an important strategic goal to support resilience planning</i>". Masys et al. (2014) call for a new paradigm for disaster risk reduction (DRR), that not only anticipates measures for risk management, but also prepares for the unpredictable and the "unknown" by building organizational resilience. In order to build Natech resilient societies, comprehensive risk management and risk governance are needed whose scope goes beyond the fence line of industrial installations to consider area-wide, or territory-wide impacts and interactions between the installations, neighboring residential areas, the environment and infrastructure, and their interdependencies." (p. 47)</p>

Annex I: List of current definitions, use of terminology

Masys, A. J., Ray-Bennett, N., Shiroshita, H. & Jackson, P. (2014)	High Impact/Low Frequency Extreme Events: Enabling Reflection and Resilience in a Hyper-connected World	Article	<p>“As argued by Renn, Klinke and van Asselt (2011:234) such risks or hyper-risks are ‘...complex (multi-causal) and surrounded by uncertainty and/or ambiguity’. “ (p. 773)</p> <p>“United Nation’s International Strategy for Disaster Reduction (UNISDR) (2009) defines ‘risk’ as ‘the combination of the probability of an event and its negative consequences’. In the context of this paper this definition is extended to define hyper-risks as not only ‘an event’ but also processes that trigger an event or series of unpredictable events with a likelihood of trans-border cascading effect.” (p. 773)</p>
Systemic cyber risk			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
World Economic Forum (2016)	Understanding Systemic Cyber Risk	White Paper	<p>"Systemic cyber risk is the risk that a cyber event (attack(s) or other adverse event(s)) at an individual component of a critical infrastructure ecosystem will cause significant delay, denial, breakdown, disruption or loss, such that services are impacted not only in the originating component but consequences also cascade into related (logically and/or geographically) ecosystem components, resulting in significant adverse effects to public health or safety, economic security or national security.</p> <p>The adverse real economic, safety and security effects from realized systemic risk are generally seen as arising from significant disruptions to the trust in or certainty about services and/or critical data (i.e. the integrity of data), the disruption of operations and, potentially, the incapacitation or destruction of physical assets." (p. 5)</p>
Welburn, J., W., & Strong, A., M. (2021)	Systemic Cyber Risk and Aggregate Impacts	Article	<p>The interconnections of financial networks that drove the studies of systemic risk following the 2008 financial crisis are highly similar to those of cyberspace. Like financial networks, cyberspace presents a system of heavily interdependent organizations connected through network ties (both in terms of supply chain networks and computer networks in cyberspace). This has given rise to the term, <i>systemic cyber risk</i>, as the deliberate combination of fields—systemic risk and cyber risk. As a result, the study of systemic risks in cyberspace is inherently interdisciplinary; it builds on the fields of cyber security, finance, economics, and risk analysis." (p.2)</p> <p>"Several efforts have been made to reach a common definition of the term systemic cyber risk. The World Economic Forum (2016) defines it as follows: “Systemic cyber risk is the risk that a cyber event (attack(s) or other adverse event(s)) at an individual component of a critical infrastructure ecosystem will cause significant delay, denial, breakdown, disruption or loss, such that services are impacted not only in the originating component but consequences also cascade into related (logically and/or geographically) ecosystem components, resulting in significant adverse effects to public health or safety, economic security or national security. The adverse real economic, safety and security effects from realized systemic risk are generally seen as arising from significant disruptions to the trust in or certainty about services and/or critical data (i.e. the integrity of data), the disruption of operations and, potentially, the incapacitation or destruction of physical assets.” (p.3)</p> <p>"We build on the existing definitions of systemic cyber risk and introduce a framework for understanding and modeling systemic cyber risk, which leverages common concepts from risk analysis and economics" (p. 4)</p> <p>"This article presents a theoretical framework for characterizing systemic cyber risk based in risk analysis and computational economics. In this framework, systemic risk results from cascading and common cause failures in addition to a multitude of independent isolated cyber incidents " (p.14)</p>
Complex climate change risk			
Author(s)	Title	Type of publication	Definition of "Systemic Risk"/ use of terminology
Simpson, N. P., Mach, K. J., Constable, A., Hess, J., Hogarth, R., Howden, M., Lawrence, J., Lempert, R., J., Muccione, V., Mackey, B., New, M., G., O’Neill, B., Otto, F., Pötner, H.-O., Reisinger, A., Roberts, A., Schmidt, D., N., Seneviratne, S., Strongin, S., Aalst, M. v., Totin, E. & Trisos, C. H. (2021)	A framework for complex climate change risk assessment	Article	<p>"...interactions include both those risks caused by climate change and those involving responses to climate change through adaptation and mitigation (hereafter collectively termed climate change risks), where risk is understood to refer to the potential for negative or positive outcomes for human or ecological systems" (p. 490)</p> <p>“systemic risk results from connections between risks (networked risks), where localized initial failure could have disastrous effects and cause, at its most extreme, unbounded damage” (p.491)</p>