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FINANCIAL NETWORKS AS A SOURCE OF SYSTEMIC INSTABILITY

Tomasz Zieliński[1]

Abstract

Systemic risk is a fundamental constituent of contemporary financial systems. For the past decades a growing number of abrupt upsets in financial systems could be observed. Due to previous experiences, politicians and regulators prefer to identify the offenders outside the system or to blame one of the entities inside the system. However, nowadays many disasters in anthropogenic systems cannot be perceived that way. They are often results of inappropriate interactions rather than external or internal impulses. This requires a paradigm shift in thinking about systemic risk. A component-oriented perspective should be nowadays replaced with a network-oriented view. Closer insight into the concept of systemic risk can refer to the model of the system composed of a huge number of interconnected components. In such a system, systemic risk is usually considered to have a 'cascading', 'domino' or 'contagion' effect, resulting from strong connections. An initial failure could have disastrous effects and cause extreme damage as the number of network nodes goes to infinity. Strongly interconnected, complex dynamic systems cannot be understood by the simple sum of their components' properties, in contrast to loosely coupled systems. What makes the behaviour of complex financial systems particularly unpredictable is that systemic failures may occur even if everybody involved is highly skilled, highly motivated and behaving properly.

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1 University of Economics in Katowice, Department of Banking and Financial Markets, tomasz.zielinski@ue.katowice.pl.

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Introduction

The contemporary financial system can be presented as permanently increasing in its size and complexity of networks. The information revolution provided completely new opportunities for unlimited growth which seems to be out of any control. The enormous profits the contemporary financial systems provide for a relatively few beneficiaries (Bogaci et al., 2011) is strongly accompanied by the growing level of systemic risk. Experiencing the number of systemic instabilities, financial authorities and supervisors discuss their origins and ways of avoiding the next crunches. In the following sections, after discussion of the nature of systemic risk, a profound diagnosis of complex, strongly coupled network systems is provided. After that, some issues about modelling and management of financial networks are to supplement the current state of knowledge. The main purpose of the paper is to discuss the background of systemic instabilities in financial networks (Acemoglu et al., 2015). The key issue is to emphasize that existing methods of systemic risk management could no longer be fully applicable. Nowadays much more attention should be focused on the new risk drivers, not fully recognized, and deeply hidden behind the nodes and links of financial networks. Ignoring the networked nature of financial systems one can be surprised, the whole system can stop behaving correctly even if apparently every single constituent performs its best. The main findings of the paper suggest that strong and still unrecognised financial interconnectedness plays a crucial role not only in transmitting financial shocks (as they were regarded so far) but also, what is more frustrating, in originating them.

The nature of systemic risk

Risk is typically quantified as the probability of occurrence of adverse events, or obtaining results different from planned goals. Following that concept, risk could be thought of either as a threat or as an opportunity. The general definition of risk does not take sufficiently into account the relations between objects being exposed to risk. The independent characteristics of every single object leads to the concept of specific (idiosyncratic) risk. The volatility of a company's profits, caused by changing management structures, technology failures, strikes, limited demand for produced goods or other factors are characteristic for that particular entity and has nothing (or little) to do with other companies, even if they contribute to the same sector. Watching the risk from the perspective of the system (a set of objects, being characterized with common features) requires distinguishing the concepts of systemic and systematic risk (Carr, 1996) from unsystematic risk.

The term 'systemic risk' is generally addressed to an event that can trigger a collapse in a certain industry, economy or other system. Systemic risk does not have an exact definition, but generally can be described as a risk caused by an event at the firm level that is severe enough to cause instability in the whole system. Typically, the interest of systemic risk analysts focuses on the extreme nature of the events starting the systemic instability (referring to not only the unusual scale of the unfavourable phenomena, but also their unpredictability) and the way it spreads all over the system. Systematic risk, on the other hand, does have a more recognized and universal definition. Sometimes denoted as 'market risk', systematic risk derives from general market volatility that cannot be limited by diversification. Some common sources of systematic risk are recessions, wars, interest rate fluctuations and others that cannot be avoided through a portfolio effect. Though systematic risk cannot be limited by diversification, it can be hedged. The concept of systematic risk can be directly opposed to unsystematic or idiosyncratic risk. It refers to the risk that is specific to a firm or industry and can be solved by diversification. The further discussion undertaken in the paper focuses particularly around the concept of systemic (not systematic) risk concerned as the key source of systemic instability.

Increasing complexity of network systems as the source of systemic risk

Regarding the concept popularized by the famous futurist Alvin Toffler (Tofler, 1997) we are nowadays carried by the third wave of the storm affecting human history. All the waves have been distinguished due to information criteria. Tofler asked the question of what made people rich during the various periods of history and what was the role of information in those days. The history started with the first wave, based on natural resources – particularly on the areas of the land. As

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agriculture was the main source of his well-being in those days, man had to possess or rule over big spaces of land. With the passage of time, more and more people aspired to wealth. Unfortunately, total resources of land were stable. Consequently, the potential for further dynamic growth became limited. People started to look for other drivers of well-being. Their attention was drawn to manufacturing. They started to think about what to do, to make it more effective and profitable. In those days, most of the scientific efforts were focused on inventing new technologies providing more effective production tools. Consequently, the second wave of the storm was carried out by industrial revolution and capitalism, replacing the falling agriculture-based feudalism. The desire to become wealthy could be accomplished with sufficient resources of production capital. A bigger and better equipped factory could give an entrepreneur advantage over his competitor. And again, during the course of the years, that driver of advantage started weaken. Technology and effectiveness of production could still maintain the moderate pace of growth, but couldn't trigger a new "Big Bang". Gradually people started entering the third wave distinguished by a new approach to information (Wojtyna, 2001). Owing to the ongoing information revolution, new extremely effective tools for information processing became accessible. In conditions of diminished effectiveness of land, labour and capital, information started to be informally the most promising and encouraging fourth factor of production. The new economy is promoting the development of those industry sectors which involve information components. Even if the final product requires contribution of land, physical labour and production capital, they are often outsourced (nowadays mainly to China, India and other Asian countries), whilst the local economy is expected to provide most of the information components. A spectacular example of such phenomena is the dominance of services (Tapscott et al., 2011) requiring by default a relatively bigger contribution of knowledge and skills over traditional production, coupled with strong demand for traditional resources.

As aforementioned, the expansion of the post-industrial economy was triggered by the information revolution. Invention of the personal computer was a symbolic beginning for decentralization of data processing. But from the perspective of the present time, the most significant impact on the new economic and social order was made by network technology and in particular by inventing the Internet. For that reason, nowadays the society of global information is characterized by increasing interdependency, interconnectivity and complexity. On one hand, globalization, leveraged by network technology, enables the exchange of people, goods, money, information, and ideas, which has produced many new opportunities, services and benefits for humanity. At the same time, however, the underlying networks have created pathways along which dangerous and damaging events can spread rapidly and globally. This has increased threats of systemic risks.

Closer insight into the concept of systemic risk can refer to the model of the system composed of a huge number of interconnected components. In such a system, systemic risk is usually considered to have a 'cascading', 'domino' or 'contagion' effect derived from strong connections between network nodes. In such a case an initial failure could have disastrous effects and cause, in principle, unbounded damage as the number of network nodes goes to infinity (May, 2006). Strongly interconnected, complex dynamic systems cannot be understood by the simple sum of their components' properties, in contrast to loosely coupled systems. Complex dynamic systems may seem uncontrollable even if every single constituent seems to operate properly. Understanding systemic risk in networks is critical in establishing rules that will effectively manage it.

The financial system as an anthropogenic network exposed to systemic risk

At the same beginning of the post-industrial, information dominated age, trends such as globalization, increasing network densities, decentralized (sparse) use of production resources, higher complexity of economic processes, and an acceleration of institutional decision processes have been considered extremely beneficial for the economy and for other aspects of social life. However, with the passage of time, people started to discover that those factors may ultimately push man-made systems towards systemic instability (Haldane, 2009). Particularly financial networks, relatively separated for a long time, now become strongly interdependent (Maier, 2012). This has made them much more vulnerable to abrupt failures. Systemic risk could mean the possible collapse of a financial market or of the whole financial system. "With the financial market around the world so interconnected,

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thy analysis of "networks" in the financial system would help deepen understanding of systemic risk and is key to preventing future financial crisis." (Financial Networks …, 2014) Actually, the financial system should be considered as an even more complex structure than only a network of simple objects. More often it should be modelled as a network of networks which denotes coupling of different kinds of systems. In such systems, extreme vulnerabilities result not only from the increasing interdependencies between individual systems, but also from their internal complexity (Allen, 2008). Strong interdependencies in a 'hyper-connected world'' shifted the level of perceived risk, establishing a new category of 'hyper-risks'. It inevitably leads to a state in which things will get out of control sooner or later.

For the past decades a growing number of abrupt distresses in financial systems could be observed. Due to prior experiences, politicians and regulators want to identify the offenders outside the system or to blame particular objects inside the system. However, nowadays, many disasters in anthropogenic systems cannot be perceived that way. They are often results of inappropriate interactions rather than external or internal impulses. That requires a paradigm shift in thinking about systemic risk in financial systems. Common in former times, the component-oriented perspective should be nowadays replaced with a network-oriented view.

What makes the behaviour of complex financial systems particularly unpredictable is that systemic failures may occur even if everybody involved is highly skilled, highly motivated and behaving properly, even if the financial subsystem is composed of well-behaved components, described with variables normally distributed around their equilibrium state. But connecting them strongly with others may nevertheless cause cascade effects and extreme distortions of outcomes.

A few years before the financial meltdown of 2007 Warren Buffett warned that massive trade in financial derivatives would create mega-catastrophic risks for the economy. In the same context, he spoke of an investment ''time bomb'' and of financial derivatives as ''weapons of mass destruction'' (Buffett warns …, 2003). Five years later, the financial bubble imploded and destroyed trillions of stock value. During this time, the overall volume of credit default swaps and other financial derivatives had grown to several times the world gross domestic product. But what exactly caused the collapse? In response to the question by the Queen of England who asked why nobody had foreseen the financial crisis, the British Academy concluded: ''Everyone seemed to be doing their own job properly on its own merit. And according to standard measures of success, they were often doing it well. The failure was to see how collectively this added up to a series of interconnected imbalances... Individual risks may rightly have been viewed as small, but the risk to the system as a whole was vast.'' (Hennessy, 2009).

The case of financial crisis outbreak could be referred to a category of crowd disasters. In terms of amplifying feedback effects, even if any individual wants to harm anybody else, people may be fatally injured. The interaction strength increases with the crowd density, as people come closer together. When the density becomes too high, inadvertent contact forces are transferred from one person to another and add up. The resulting forces vary significantly in direction and size. Turbulent waves cause people to fall over each other starting a fatal domino effect. Very often the instability is created not by strong individual actions, but by the unavoidable amplification of small fluctuations above a critical density threshold. Consequently, crowd disasters cannot simply be avoided by policy, aimed at imposing 'better behaviour' of individuals.

Drivers of systemic instability in financial networked systems

Contemporary financial systems constitute a particular exemplification of anthropogenic systems, highlighting an increase in structural, dynamic, functional and algorithmic complexity. Considered as a system of systems (Gandi et al., 2015), they transfer the output variables of one system to the inputs of other ones via various types of channels (Zieliński, 2013). This poses many new and big challenges for their operation, durability, reliability and efficiency. They derive particularly from an unusually powerful cascade effect (domino effect, avalanche effect, financial contagion effect) starting most of the studies about systemic instabilities (Zieliński, 2013). Cascade effects are due to local failures of nodes or links between them which may trigger overloads and consequential failures of other nodes or links. What make things worse, as aforementioned, abrupt systemic failures may result from interdependencies between networks or other mechanisms carried by various

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channels. Unfortunately, the same channels constitute the ways through which unwanted shocks might also be transmitted starting the process of contagion. Financial contagion occurs when a shock to one or a group of financial markets, countries, or institutions, spreads to other markets, countries, or institutions (Pritsker, 2000). The nature of contagion is not profoundly examined. Neither the nature of contagion channels, nor the key characteristics of particular objects in financial networks are unambiguous enough to diagnose clearly the ways systemic instability emerges and transmits. The only thing taken for granted is the conviction that cascade effects are the rule rather than the exception in today's economy and therefore systemic risk is a key concern for institutions responsible for overall financial stability. Happily, some drivers of systemic instability can be pointed out as worthy of particular attention (Helbing, 2013).

Changes of parameters in financial systems are often fast and potentially outstripping the rate at which one can learn about system behaviour, or at which one can react. It is related to the strong time-varying, not static nature of financial networks. "Static networks are a useful starting point, but future research should allow for time-varying risk in networks, that is, risk that varies over the business cycle." (Financial Networks Key …, 2014)

In sparse and linear systems, small and gradual changes of variables cause usually gradual and also small changes in response. But not the same in complex and dense systems. Due to the strongly coupled and complex structure of financial networks, sudden failures such as rapid deterioration of performance or crisis outbreaks are a very likely response t, apparently not very significant incoming changes. Disasters may result from discontinuous transitions in response to even very small and gradual changes in parameters. That rapid an event can occur at a certain threshold (tipping point, breaking point), the point at which a series of small changes or incidents become significant enough to cause a larger, more important change and set different system properties (Georg & Minoiu , 2014).

The systemic reaction to small changes can be amplified due to highly correlated transitions of many system components or variables from a stable to an unstable state, thereby driving the system out of equilibrium. Additionally, cascade effects are carried through nonlinear channels. Unfortunately, both correlation ratios and nonlinear characteristics of transmission channels in financial systems are extremely dynamic. That makes modelling efforts often totally aimless. "The essential problem is that our models – both risk models and econometric models – as complex as they have become, are still too simple to capture the full array of governing variables that drive global economic reality. A model, of necessity, is an abstraction from the full detail of the real world. In line with the time-honoured observation that diversification lowers risk, computers crunched reams of historical data in quest of negative correlations between prices of tradeable assets; correlations that could help insulate investment portfolios from the broad swings in an economy. When such asset prices, rather than offsetting each other's movements, fell in unison on and following August 9 last year, huge losses across virtually all risk-asset classes ensued." (Greenspan, 2008)

The combination of nonlinear interactions, network effects, delayed response and randomness may not only increase sensitivity of financial systems to small changes, but also lead systems to numerous different behaviours, depending on the respective initial prerequisites. Moreover, the diversity of the goals pursued by the financial system come also from the conflict of interest (a natural factor of competitive relations) occurring between financial institutions, financial markets and other participants in the financial system

The vulnerability of complex financial systems to gradual and small imbalances is often neglected. Apparently, as long as risk factor changes stay within a limited boundary, risk management systems seem to easily cope with it. That wishful approach, due to the above mentioned strong internal couplings, is only partially realistic. To make matters worse, a more intuitive diagnosis, that mostly extreme events are perceived as the main source of instabilities and that they are easy to control, is also misleading. Even if those extreme events are expected to be external (by default more predictable), they are very hard to diagnose and forecast due to limitations of EVT (Extreme Value Theory) (Zieliński, 2014). One of them refers to the 'heavy tails' feature of statistical distributions describing the empirical behaviour of many parameters. To make matters even less unambiguous, extreme events emerge often from inherent system dynamics rather than from unexpected external stresses.

Network systems may be often automatically and inevitably driven towards a critical point. Lasting for a long

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time, an unjustified gradual growth of stock indexes will definitely trigger a rapid breakdown. Gradual, and long-lasting increase in population of poor people, leads for sure to unrest and revolutions. The experience for many emerging economies of gradual growth of prices (inflation) nearly always ends up with collapse of the economy. Gradual growth of indebtedness, after exceeding a certain tipping point, nearly always leads to insolvency. All of these are caused by internal positive feedbacks which are often difficult to diagnose.

One of the most significant factor increasing the systemic complexity of financial systems is a high pace of innovations. For instance, the spread of financial derivatives (i.e. credit default swaps) transferring risks from the individuals or institutions to others (Tapscott et al., 2009), thereby encouraging excessive risk taking, drove the whole world into financial instability. "In recent years, the pace of change and innovation in financial markets and institutions here and around the world has increased enormously as have the speed, volume and value of financial transactions. The period has also seen a greatly heightened degree of aggressive competition in the financial sector. All of this is taking place in the context of a legal and a regulatory framework which is increasingly outdated and ill-equipped to meet the challenges of the day. This has led to…concern that the fragility of the system has increased, in part because the degree of operational, liquidity and credit interdependency has risen sharply." (Corrigan, 1987)

Each of the aforementioned factors poses threats to the systemic stability of financial systems, but exceptionally dangerous could be the reaction to their combination. Probabilistic cascade effects in real-life systems are harder to identify and understand than deterministic relationships between 'causes' and 'effects' observable in sparse and small networks. The real - life properties of complex dynamical systems are often surprising and counter-intuitive.

The collapse of the representative agent and equilibrium approach

For the purpose of description and assessment of financial systems, analysts often refer to modelling techniques providing a stylised reflection of the real world. Facing the problem of complex, network structures, they typically use some simplifications. One of the most common is the representative agent and equilibrium approach.

An economic model is said to have a representative agent if all agents of the same type are identical. Testing that strong limitation economists sometimes say a model has a representative agent when agents differ from each other, but act in such a way that the sum of their choices is mathematically equivalent to the decision of one individual or many identical individuals. A representative agent approach enables considering one 'typical' decision maker instead of simultaneously analysing many different decisions.

The representative agent approach is often coupled with the equilibrium paradigm According to the equilibrium paradigm, economic systems tend to evolve towards an unambiguously determined equilibrium state. In such conditions, bubbles and crashes should not happen. Any instabilities could be caused exclusively by external shocks.

Representative agent and equilibrium models, assuming that companies act in the way a representative (average) individual would optimally decide, are more general and allow one to describe dynamic processes. However, such models cannot capture processes well if random events, diversity of system components or correlations between variables matter a lot. What is more, it does not take into account that interactions between system elements can cause amplifying cascade effects even if all components pursue their individual equilibrium state. They ignore the domino effect. Forcing a system to leave its previous (equilibrium) state, with absence of representative dynamics, the domino effect creates various and unpredictable paths of future events. Representative agent models can even make predictions opposite to those of agent-based computer simulations assuming the very same interaction rules.

The reasons for the prominence of the representative agent model are exceptionally important due to policy (supervisory) recommendations (Hartley, 1997). Based on observed past macroeconomic relationships, it may neglect subsequent behavioural changes and completely distort the forecast of the systemic relations. This problem could be avoided in models that explicitly describe the decision-making situation of each individual agent. The policy recommendation could be obtained by recalculating the decision problem of each agent under the new policy rules and then aggregated. However, that approach

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is technically extremely difficult to impose. General equilibrium models with many heterogeneous agents are much more complex, and are therefore a still relatively new field of economic research. In these terms, simpler and more convenient alternative to the representative agent approach could be agent-based simulation models which are capable of dealing with many heterogeneous agents.

How to manage systemic complexity of financial systems

As aforementioned, most scientific studies make idealized assumptions such as homogeneous components, linear, weak or deterministic interactions, optimal and independent behaviours, or other favourable features that make systems well-behaved (see the aforementioned representative agent and equilibrium approach). Real-life systems, in contrast, are characterized by heterogeneous components, irregular interaction networks, nonlinear interactions, probabilistic behaviours, interdependent decisions, and networks of networks. These differences can change the ways, one could effectively manage complex, network systems. The combination of complex interactions with strong couplings can lead to surprising, dangerous and unpredictable behaviour. Currently most scientific investigations of large networks, particularly financial ones, are oriented to cases of sparse and relatively static networks. However, dynamically changing, strongly coupled and interconnected systems are fundamentally different. (Tapscott et al., 2009)

Due to the domino effect, which determines contemporary financial systems behaviour, the capacity of a financial system to recover is strongly decreasing. It calls for a strong effort to stop cascades right at the beginning, when the damage is still small and the problem may not even be perceived as threatening. Otherwise, we could face unpredictable uncertainty rather than measurable risk. That approach seems to be prominent in new financial regulatory frameworks (Georg & Minoiu, 2014). Constituting supervisory institutions operating at different levels, such as: Financial Stability Level (worldwide approach), European Systemic Risk Board (the European level) or Financial Stability Committee (Polish safety net) a macro-prudential supervisory and regulatory approach started to be promoted besides the commonly adopted micro-prudential effort (Financial Networks Key …, 2014). Their key focus is early detection of systemic instabilities impulses mostly related to systemically important institutions.

When systems reach a certain size or level of complexity, algorithmic constraints often prohibit efficient top-down management by real-time optimization. However, 'guided self-organization' could be taken into account, as a promising alternative way of managing complex dynamical systems, in a decentralized, bottom-up way. The underlying idea is to use the complex system-immanent tendency to self-organize. That is why it is important to have the right channels of interactions, adaptive feedback mechanisms, institutional settings and tools. By establishing proper rules, within which the system components can self-organize, top-down and bottom-up principles can be combined. To overcome suboptimal solutions and systemic instabilities, the obsolete interaction rules or institutional settings may have to be modified.

To cope with hyper-risks in complex systems, it is necessary to develop risk competence and to prepare and exercise contingency plans for all sorts of possible failure cascades. The perfect solution could be based on providing a backup system. It could be used in case of emergency, ensuring proper (even if not perfect) functionality according to former rules. Unfortunately, that type of protection cannot be explicitly applicable in financial systems. Due to its social nature, it is impossible to preserve the real backup. But it is possible to preserve rules, which could be applied in case of unfavourable events.

One of the most popular ways of managing complex systems, particularly financial ones, is diversity. It may significantly increase systemic resilience (that is, the ability to absorb shocks or recover from them) and systemic adaptability. Furthermore, diversity makes it less likely that all system components fail at the same time. Consequently, early failures of weak system components (critical fluctuations) could provide early warning signals of coming systemic instability. It could allow us to isolate affected parts of the system before others are damaged by cascade effects. Even if a sufficiently rapid, dynamic decoupling cannot be ensured, one can build weak components (breaking points, fuses, crash zones) into the system, preferably in places where damage would be comparatively small. For example, regulations affecting behaviour of financial markets or institutions in case of

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displaying unfavourable events could become that type of 'systemic fuses'.

Important objects of effective management in complex systems refer to the timing issue. If the system dynamics unfold so rapidly that there is a danger of losing control, one could slow it down by introducing frictional effects (such as fees or taxation of financial transactions). In some cases dynamic processes in a system can desynchronize, if the control variables change too quickly compared to the timescale on which the governed components can adjust. For example, stable hierarchical systems typically change slowly on the top and much quicker on the lower levels of the network pyramid. If the influence of the top on the bottom levels becomes too strong and too frequent, this may impair the functionality and self-organization of the hierarchical structure. For instance, frequency of regulatory changes for financial systems shouldn't be forced too quickly. Otherwise the delayed and cumulated impact of regulations could destabilise rather than stabilise a system (Zieliński, 2014).

Significant contribution to effective management of complex systems could be obtained by its size reduction. Contemporary financial systems, with their network based nature, spread all over the word eliminating the linkage with real geography. Discussions of separation of traditional and investment banking (Acharya, 2009; Benson, 2013) or implementation of lean banking strategies (Wancer et al., 2011), respond to the expectations of more effective management. Time required for computational solutions explodes with the system size, resulting in delayed or suboptimal decisions. Smaller companies or markets could be more predictable and eventually have less exposure to systemic instability. Size reduction could be accompanied by limiting the internal connectivity of the system. This implies a change from a dense to a sparser network, which reduces exposure to contagious spreading effects and limits the threats of extreme instabilities.

To achieve better risk assessment and risk reduction, information transparency, accountability, responsibility and awareness is required (Hull, 2009). The lack of full information obscures the real picture of the system creating a comfortable position for only a few, who are always in power to avoid unfavourable effects. Modern governance sometimes dilutes responsibility so much that nobody can be held responsible anymore. The financial crisis seems to be a good example. It might therefore be necessary to establish a principle of collective responsibility, by which individuals or institutions share responsibility for incurred damage in proportion to their contribution in previous and subsequent gains. It might be also advisable to maintain a higher level of information redundancy (reducing at the same time performance indicators) to improve the system's transparency.

Social aspects of systemic risk in network systems

Many challenges of contemporary financial systems are posed by social components and cannot be solved neither by technology nor by organisational changes alone. Socially interactive systems, be it social or economic systems, artificial societies, or the hybrid system made up of our virtual and real worlds, are characterized by a number of special features, which imply additional risks. The components (for example, individuals) take autonomous decisions based on (uncertain) future expectations. They produce and respond to complex and often ambiguous information. They have cognitive complexity and individual learning histories and therefore different, subjective perception. Individual preferences and intentions are diverse, and may imply conflicts of interest. The behaviour may depend on the context in a sensitive way. For example, the way people behave and interact may change in response to the emergent social dynamics on the macro scale. One of the key factors of that interaction is the ability to be innovative, which may create surprising and unpredictable outcomes.

To assess systemic risks, a better understanding of social capital is also crucial. Social capital is important for economic value generation and wellness, but it may be also easily damaged or exploited. Therefore, humans need to learn how to quantify and protect social capital. Financial losses in the stock markets during the financial crisis were largely caused by a loss of trust. It is important to emphasize that risk insurances today do not take into account damage to social capital. However, it is known that large-scale disasters have a disproportionate public impact, which is related to the fact that they destroy social capital. Neglecting social capital in risk assessment, higher risks are taken would be rational.

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Conclusion

When regular interaction in sparse and small networks are replaced by totally irregular ones, the number of possible system behaviours and proper management strategies becomes overwhelming. There is no one standard solution to that. A new approach to perceiving systemic risk in strongly coupled systems implies a fundamental change in the management frameworks. Unfortunately, due to strong routine, we often try to implement an obsolete set of measures for inadequate purposes. It is often the consequence of a wrong understanding due to the counter-intuitive and misleading nature of the underlying system behaviour. Hence, conventional thinking can cause fateful decisions and the repetition of previous mistakes. Nowadays the state of knowledge in the field of systemic risk, particularly in financial systems, still seems to have a number of shortcomings. They cover in particular:

1) poor estimations of probability distribution and parameters describing rare events,
2) underestimation of the likelihood of coincidences of multiple unfortunate, rare events,
3) insufficiently considered feedback (especially positive),
4) insufficiently covered combination of probabilistic failure analysis with complex dynamics (to understand amplification effects and systemic instabilities),
5) underestimation of the human factor, such as negligence, irresponsible or irrational behaviour, greed, fear, revenge, perception bias, human errors, innovativeness,
6) negligence of social factors such as the value of social capital.

A number of systemic risk limitations are due to common assumptions underlying established ways of thinking. Attempts to identify uncertainties or 'unknown unknowns' are often insufficient. Some crises have happened because of a failure to imagine that they were possible, and they must be guarded against. Also economic, political and personal incentives are not sufficiently analysed as drivers of systemic risks. Many risks can be revealed by looking for stakeholders who could potentially profit from risk-taking, negligence or crises. The key question is: "Cui bono?".

Most of the existing theories do not provide much practical advice on how to respond to global risks, crises and disasters in complex, network systems. Even for financial systems, empirically driven risk-mitigation strategies often remain qualitative and intuitive rather than based on strong quantitative fundaments. The strong conclusion is, despite all our knowledge, much work is still ahead of us.

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