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Security in the age of Systemic Risk: Strategies, Tactics and Options for Dealing with Femtorisks and Beyond

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Contents

Abstract

The world today is increasingly confronted with systemic threats and challenges, in which femtorisks—small-scale dangers that are inherent to system structures and function and which pose asymmetrically catastrophic risks—can build in consequence, spreading uncontrollably like epidemics in both natural and social systems in such diverse areas as ecology, epidemiology, finance, the Internet, terrorism, and international relations. They have been successfully modeled in ecology in the context of complex adaptive systems: systems made up of individual agents, whose interactions have macroscopic consequences that feed back to influence individual behavior. While acknowledging challenges, this paper argues for the value of applying to societal systems the approaches that natural scientists have developed in quantifying and modeling biological interactions and ecosystems.

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The paper's authors attended a workshop in June 2011 at the International Institute for Applied Systems Analysis (IIASA) entitled *Security in the Age of Systemic Risk.* This paper resulted from the presentations and discussions there.

Workshop principal organizer Simon A. Levin is the Moffett Professor of Biology at Princeton University and the Director of the Center for BioComplexity in the Princeton Environmental Institute. His principal research interests are in understanding how macroscopic patterns and processes are maintained at the level of ecosystems and the biosphere, and he has pioneered the application of those approaches to complexity to other disciplines.

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The world today is increasingly confronted with systemic threats and challenges, in which femtorisks—small-scale dangers that are inherent to system structures and function and which pose asymmetrically catastrophic risks—can build in consequence, spreading uncontrollably like epidemics through global networks that permeate the international system. Such femtorisks are well known in a variety of contexts, and have been recognized in both natural and social systems in such diverse areas as ecology, epidemiology, finance, the Internet, terrorism, and international relations. Many of these risks can be characterized in the context of complex adaptive systems: systems made up of individual agents, whose interactions have macroscopic consequences that feed back to influence individual behavior (Axelrod 1997, Holland 1996, Levin 1999, Miller and Page 2007). In particular, small changes can produce and amplify systemic risks that, because of nonlinear effects and associated path dependencies, cause changes that can be totally or practically irreversible and carry consequences for decades or even centuries. Such risks can never be completely ironed out of systems and cannot be managed using simplistic approaches. These systems may contain multiple stable equilibria, or even no equilibria whatsoever, being subject to perpetual dynamic change (Epstein, 2007; Laver and Sergenti, 2011). Moreover, these risks themselves emerge as inevitable products of advances in areas that are generally socially and economically beneficial. Bioengineering, nanotechnologies, faster and more tightly coupled financial networks, better integrated and efficient infrastructure and a more interconnected network of international regulation and development projects—these are the simultaneous products of, and drivers towards, an increasingly globalized world. They bring new opportunities to develop, manage and sustain open and prosperous societies, but their complexity also provides the seeds of catastrophe and collapse.

Risk Analysis in an Increasingly Complex World

Recent global events such as the financial crash of 2008 and the wave of upheavals in the Middle East that started in the spring of 2011 demonstrated the limitations of classical approaches and tools for measuring and managing risk and for recognizing and responding to systemic instability in international relations. A variety of reasons have been advanced to explain why financial and international relations professionals were taken by surprise by these events, despite the resources and modeling that have gone into tracking and understanding financial and international political systems. Rapid changes in recent decades, including the introduction of new players and tools, have created increasingly complex and tightly interconnected systems, as networks of actors interact in new, sometimes unprecedented, ways. Numerous analysts suggest that approaches which provide greater attention to networks and micro-level actions and interactions will be more likely to offer warnings of instability and can help guide the development of policies and regulatory strategies to prevent collapses and minimize surprises (Urry, 2003; Frank, 2005; Klitgaard and Light, 2005; Harrison, 2006, Ramo, 2009).

Evolutionary and ecological theories offer useful metaphors to improve understanding and structure strategies for mitigating risk in financial and international relations systems, as well as other areas such as international development assistance and counterterrorism. The challenge remains, however, to translate conceptual insights that incorporate cultural and social features as elements of system complexity into models that can provide new insights and guidance on risk assessments and policy analysis.

Traditional risk assessment tools and techniques depend on several structural assumptions about the composition of systems and the knowledge of the people acting within them. They presume a thorough knowledge of the events in the system by the actors, and the independence, or predictable dependence, of events. These assumptions require a knowable and decomposable structure to the system. The techniques often employ a 'divide and conquer' analytic strategy that assesses the system's components and risks independently, with the expectation that they can be understood in isolation and aggregated into a coherent whole successfully. Recent events—such as increasing terrorism, the financial crisis of 2008, and the coupled earthquake-tsunami-Fukushima nuclear power plant failure– have challenged this conventional wisdom of risk analysis.

These structural assumptions are further weakened by viewing agents as perfectly rational: a common assumption in the social science and risk management disciplines. These agent-level assumptions simultaneously shape expectations about the behavior of actors in complex systems and affect the ability of decision-makers to understand and regulate these systems. When these assumptions are relaxed, the representation of agents must transition from perfectly rational actors capable of making optimal decisions under the most challenging of circumstances to boundedly rational actors who seek just adequate solutions to problems through learning, adapting, and experimenting (Simon, 2000). The situation becomes even more difficult when interactions between actors are strategic, and each actor seeks to anticipate the choices of others—resulting in numerous contingencies based on their ability to coordinate, cooperate, compete, and communicate (Schelling, 1981). Thus, in the cases of terrorism, cybersecurity, and financial markets, the best options available to any actor are contingent on the perceptions and decisions of the others, suggesting a shift from decision theory to game theory (Tsebelis, 1989; Bezell et al., 2010; National Academy of Science, 2010). Moreover, actors often respond to psychological and emotional cues that are impossible to model and difficult to understand, but which lead them to make choices that can be seen as "irrational" from a classical perspective (Stavrakakis and Chrysoloras, 2006).

Robustness and Systemic Risk in Complex Adaptive Systems

In order to cope with the challenges of complexity, it is useful to draw analogies from biology, and in particular from the ways organisms have evolved in response to the challenge of uncertainty. In any complex system, robustness or resilience depends upon the balance among three interrelated aspects (Levin, 1999):

The diversity of the units within the system, which encodes its adaptive capacity;

The extent to which the system contains functional redundancies, providing insurance against the loss of key elements;

The degree of modularity with respect to the coupling between components. Modularity or compartmentalization sets bounds on the contagious spread of destructive events, from epidemic outbreaks to bank crashes, and provides building blocks for recovery or novel advances.

When taken as a whole, the trade-offs among these three features enable a system to keep functioning in the face of changes in its environment, and provide opportunities for experimentation to produce innovations without placing the entire system at risk (Simon, 1996). Indeed diversity and modularity have been key building blocks in the evolution of the biosphere, enabling the major transitions to multicellularity and beyond. Evolution depends on chance and choice, but choice by an unseeing filter rather than an active manager. The contrast has been made clearest, perhaps, by Francois Jacob, who likened the evolutionary process to the work of a tinkerer (Jacob, 1977). In contrast, the rational actor model emphasizes planning and analysis at the expense of engagement, exposure, and learning opportunities, and thereby erodes a system's adaptive capacity: less time engaging and exploring leads to fewer opportunities for learning.

One of the most remarkable triumphs of evolution, the vertebrate immune system, provides an extremely suggestive model for how we might engineer systems to have the requisite robustness to withstand the shocks produced by femtorisks and to generally mitigate systemic risks. The key features of this model include:

The maintenance of a set of generic defenses that can rapidly identify and respond to threats, (as the body does when it recognizes a pathogen and rushes generalized antibodies to the site of the threat);

Persistent engagements that enable rapid learning through interaction with threatening actors or processes (as the body produces specialized antibodies in response to the invader);

Translating lessons from prior experiences into customized, localized defenses against previously encountered threats (the body produces permanent defenses against the infection);

The maintenance of an archive of previously experienced threats and the addition of successful countermeasures to the set of generic responses in order to mitigate future encounters rapidly (the body's antibody repertoire).

Many of the aspects of the immune system model have comparable features in international systems. For example, studies of military innovation often emphasize the complexity of peacetime developments, when uncertainties proliferate due to a lack of engagement and the resulting need to maximize flexibility through the creation of generic capabilities that can be modified as new information about rivals' goals, strategies, tactics, and technologies become available (Rosen, 1994; Murray and Millett, 1998; Murray and Knox, 2001). Likewise, foreign policy professionals often express concerns about nations cutting off ties with rogue states, arguing that severing diplomatic relations hinders experts' perspective, insights, and strategic context, and reduced interaction lessens influence and opportunities for change (Brzezinski, Gates, et al., 2004) – essentially freezing the evolution of specialized defenses, and destroying any opportunity for co-evolution of symbiotic systems.

Weaknesses of Traditional Risk Management Analysis for Policy

The adaptive model described above can offer an important alternative to more traditional risk management approaches. The limitations of the traditional approach are displayed in the context of decision-making under uncertainty and intelligence failure. Because decision-making within the international system is often decentralized and negotiated, policymakers make significant investments of their time, energy, and resources in efforts to forge a shared vision with others and agree on a course of action. The costs of reaching a consensus can be high, and are not easily undone. Those who support decision makers, such as intelligence professionals, policy analysts, and risk managers, face significant incentives to inform these negotiations with predictions about the future and the behavior of complex systems in order to convert uncertainty into risk. As a result, intelligence failures may occur for three reasons:

Limits of prediction: The complexity of the system being examined may be sufficiently intricate that prediction is not analytically viable. In these cases, classical risk analysis tools may break down in their ability to assist analysts and decision makers understand the likelihood of specific events or their consequences (Betts, 2007). For example, the long-term consequences of alternative industrial policies on the global economy and climate system may be epistemologically unknowable.

Inappropriate indicators: Analysts and decision makers may be improperly oriented, focusing their attention on the collection and analysis of information that does not capture the character of system risk or impending phase transitions or regime changes in complex systems. The surprises of the Iranian Revolution in 1979 or the recent Arab Spring uprisings provide examples where the mindsets of analysts and decision makers oriented them toward sets of indicators that pointed toward the long-term stability of fragile governing regimes, while a different orientation might have identified alternative revolutionary trends (MacEachin, 2005; Davis, 2008).

Policy and decision makers’ inertia: Analysts may correctly predict serious risks within the international system, but policymakers may be vested in preserving their hard-won political agreements and therefore ignore or reject information that doesn’t conform to their world views, resulting in peculiar producer-consumer dynamics (Hilsman, 1956; Kent, 1968; Betts, 2007; 2008; Treverton, 2008, Rovner, 2011). For example, senior decision makers within the US Department of Defense ignored numerous warnings from other departments, professional military officers, the intelligence community, and allies regarding the likely post-Saddam conditions in Iraq and brushed off concerns that the available US military forces were unprepared to secure the Iraqi population and borders after the fall of the regime.

Traditional risk assessment models encourage failures of these types by assuming that all possible outcomes can be identified and assigned probabilities of occurrence and estimates of their associated costs, and that such parameters are stable through time and across different economic and political conditions. This analytic process can strip systems of their complexity and deny the consideration of outcomes that may result from strategic interaction or novel innovations. Traditional risk analysis is highly exploitative of known information, but limits the exploration for alternative views of the system.

Limits of Prediction

The first type of failure is grounded in conventional risk management and policy making paradigms that assume the behavior of systems are predictable, either with certainty or probabilistically. This approach emphasizes the design of rational, utility maximizing policies and seeks improvements through the refinement of predictive models. An implicit assumption in such predictive efforts is that the world is a stable system and historical data can be used to infer the probabilistic structure of the future.

By comparison, evolved systems cope with uncertainty by emphasizing engagement and increasing their rate of learning and feedback. Because evolutionary systems learn through exposure and interaction, the survival of their units is based on their capacity to respond to new discoveries, rather than their ability to predict the future. From the policy-making perspective, an over-commitment to planning places unrealistic burdens on analysts and decision makers to correctly predict the outcomes of alternative policy options, many of which are contingent on the choices of others, while denying opportunities for learning through engagement (Danzig, 2011). Failures to engage not only deprive analysts and decision makers of valuable experiences, but enable their mindsets to go unchallenged, exacerbating the second source of failure while limiting the options of policy makers. At the same time systems have to retain the ability to ignore past experience when it is no longer applicable, and this presents an unusual challenge: the ability to rapidly shift modes to understand that a situation has not been seen before, and thus demands a different reaction. Thus, for instance, responses to terrorist problems or structural international relations problems like the rise of a new nation in a globalized world cannot be confronted with Cold War approaches that might, for instance, frame terrorism as “islamofascism” or treat China as a new USSR.

A complex adaptive systems approach to international systems changes the emphasis of policy making for governance regimes. It also suggests the importance of new structural arrangements. Rather than base international development or security policies primarily or exclusively on analytic predictions, this alternative seeks to increase rates of interaction and learning through constant engagement and experimentation. The result is a policymaking framework that is increasingly robust, adaptive, and less vulnerable to surprise.

Slow Variables as Indicators in Complex Systems

The second type of failure results when systems are poorly understood, so that analysts and policy makers focus their attention on variables that neither accurately reflect the state of the system nor provide meaningful insights into its operations. Improper orientation enables small systemic risks, which may be easy to mitigate early on, to grow into major problems and crises by the time they are identified. Alternatively, continuous attention and resources may be devoted to monitoring and attempting to alter variables that possess little dynamism, while neglecting other variables that are considerably more dynamic, further increasing the opportunity costs of failed interventions and missed opportunities by expending resources on what cannot be changed while ignoring what can. This is particularly true for strategies that must interact with and shape global systems, and cannot rely on discrete “on/off” interactions and or employ “exit strategies” whenever contact between actors is persistent.

An example of the need for persistent engagement, even in cases where systems appear stable and relatively unimportant, can be seen in the roots of ongoing financial crisis. In 1998, Commodities and Futures Trading Commission Chairman Brooksley Born warned of systemic risks resulting from Credit Default Swaps (CDS) and other derivatives securities. However, at the time these markets were relatively small, stable, and liquid. Thus, her warning was overruled by Fed Chairman Alan Greenspan, Treasury Secretary Robert Rubin, and Treasury Undersecretary Lawrence Summers. At that time, the aggregate notional exposure of the CDS market in 1998 was $180 billion, a small fraction of the financial industry’s total assets. Thus, regulators believed that intervention into the market was unnecessary. However, the growth of the CDS market went unacknowledged, and it totaled $6 trillion in 2004, and $58 trillion in 2007. As a result, market volatility that was regarded as unimportant a decade earlier brought down AIG, one of the largest and most respected insurance companies in the world. The nature of the regulatory mechanisms as either “on” or “off” meant that regulators and traders failed to notice or adapt to the changing circumstances of the market, the capital devoted to it, and the characteristics of its dynamics and volatility. Thus systemic risks proliferated and ultimately crashed the industry.

Complex adaptive systems contain evolving networks, the properties of which fluctuate on varying temporal and spatial scales. Fast-changing variables, generally easy to identify, pose one set of challenges to policymakers, but a different set of issues arises from the characteristics that change in slower and less obvious ways. These changes may be difficult to perceive, but subtle changes in some ‘slow variables’ can portend major transitions, and may provide policymakers with means to identify and engage systemic risks before crises ensue. Determining and measuring these 'slow variables', which develop and change as a result of the self-organization of the system rather than an outcome of foresight and planning, may define the epistemological limitations of what can be forecast about an international system.

If slow variables can be identified and trends reliably observed, these new indicators may be adapted to conventional risk and planning approaches. They may enable new conceptual frameworks that orient analysts and decision makers in ways better suited towards managing and mitigating the complexity of contemporary and emerging threats. Without some 'slow variables' to capture these trends, policymakers and analysts operating in a complex system must emphasize an adaptive decision making model that regularly checks outcomes and revises policies in order to adapt to unforeseen consequences of more familiar planning paradigms.

Slow variables may also be useful in the design of feedback mechanisms for providing actors with situational awareness. This challenge is evident with regard to financial markets, where those engaged in the riskiest behaviors are able to offload the negative consequences of their decisions onto others. In doing so, normal feedback channels that warn actors when they are engaging in dangerous behaviors may break down, decreasing the awareness of agents whose choices are the largest sources of systemic risk. For example, the collapse of the real-estate market in the US resulted from the combination of rising home prices, low interest rates, and access to large amounts of credit. Under normal conditions, analysts would regard each of these factors as contributing to financial stability. However, no systemic feedback mechanism existed to let lenders, borrowers, and regulators know that these three drivers had combined to create an increasingly unstable and unsustainable state (Khandani, Lo, and Merton, 2009). The lack of feedback in the system, e.g. a 'slow variable' constructed to indicate the extent that investors were leveraging their resources, meant that regulators and traders had significantly underestimated the potential risk and magnitude of losses in the system. When prices fell, the result was a global crash.

Complex Adaptive Systems Analysis to Overcome Policy and Decision Makers' Inertia

The third source of failure in traditional risk analysis provides a window into the relationship between producers and consumers of analysis. This relationship has repeatedly undermined the assumptions of rational action inherent in traditional risk assessments or the belief that states are unified actors that rationally pursue their national interests. In their producer-consumer relationship, policymakers and the analysts who support them confront problems differently, based on their distinct responsibilities and roles in decision making processes. Analysts focus on the substantive aspects of a system, whether financial markets, protecting critical infrastructure, or sponsoring and executing international development projects. By contrast, decision makers must consider a wider range of concerns, but possess a narrower organizational or even personal set of interests, compelling them to focus on the types of actions that they and other stakeholders can agree upon, or that can be imposed given their relative power. Because decision makers are involved in a political process, as opposed to a technical engineering or design process, they are often reluctant to change policies, particularly if the costs of doing so would open hard fought decisions to renegotiation. As a result, decision makers can become vested in particular solutions, and resource commitments can get locked in, diminishing the adaptive capacity of the actors in the system. Once committed, decision makers often neglect new information that might indicate that their policies were failing, or ignore the analysis of specialists that contradicts their expectations. This willful blindness can allow the harmful effects of small risks to proliferate, diffuse, and amplify.

Moreover, conflicts of interest can compromise the effectiveness of regulatory oversight. For example, the U.S. Federal Reserve was designed to be the lender of last resort in the face of systemic liquidity shocks. However, the Fed also sets interest rates so as to encourage lending and economic growth, which can enhance the likelihood of asset bubbles and systemic risk. Balancing these conflicting roles would be challenging even under a best-case scenario, and becomes virtually impossible to do properly during periods of financial distress and market instability. This conflict would be tantamount to mandating the Food and Drug Administration to sell diet pills, or licensing the Environmental Protection Agency to run helicopter tours through the Grand Canyon.

As the challenges facing policy makers have become increasingly more complex, the traditional risk assessment paradigm is breaking down, exposing how assumptions of rationality and predictability are limiting the ability of policy makers to cope with the most difficult and pressing of problems in the international system. Given these deficiencies, the biologically based conceptual framework of complex adaptive systems seems even more attractive, emphasizing engagement, learning, and adaptation over the more traditional approach that overemphasized prediction and planning.

Complexity to Enrich the Policy Framework

Emphasizing robustness and adaptiveness can reveal weaknesses in the conceptualizations of the actors in international systems. For example, despite the global diversity of systems of governance and types of regimes, the institutions that manage risk in the international systems have largely divided the world's governments into two categories: democratic or authoritarian. This labeling scheme, however, obscures more than it reveals, limiting the ability of decision makers to measure the similarities and differences between actors. Developing a new set of concepts for identifying and measuring similarity and difference among governments would assist in characterizing the diversity, and therefore the robustness, of the international system.

The dynamics of complex systems are particularly important for providing a new set of concepts for thinking about international affairs. Whereas traditional theories of international relations emphasized the balance of power between the system's most powerful states, new concepts place a greater emphasis on dynamics rather than equilibrium. For example, analyses of international relations privilege relations between elites and official state institutions, yet non-state actors—whether international corporations that manage global capital flows, nongovernmental organizations promoting environmental and social responsibility, or terrorist groups committing acts of violence—play an increasingly prominent and dynamic role in creating and mitigating systemic risks. The complexity of the networks engenders complexity of interactions, and these interactions can include elements of contagion and diffusion processes, synchrony, hysteresis, and phase transitions between multiple equilibria, or even the possibility of non-equilibrium systems.

The relationship between the dynamics of international systems and the decision making capabilities of the actors within them provides contrast between two competing perspectives of systemic risk. International relations theorists and practitioners have often worried about contagions that may diffuse throughout the system, e.g. the 'domino theory' that postulated the spread of communism, or regional arms races that might result from the development of weapons of mass destruction. Alternatively, there are also 'trap doors' in which several risks self-organize and occur simultaneously. These trap door dynamics may occur in financial crises, where once the norm and stigma of defaulting is removed by the first actor to default, others may rush to be the 'second,' resulting in a correlated, simultaneous action.

The difference between falling dominoes and trap doors, however, is a matter of scale and the adaptive capacity of risk managers to intervene. As long as decision making cycles are slow, predicated on the classical predictive model, then policymakers will possess limited means for identifying risks, altering their behavior, and developing countermeasures quickly. As a result, more and more threats may be experienced as synchronized trap doors. By comparison, when policymakers who are engaged in a problem can detect changes in the system's dynamics, and possess the ability to act quickly, even if imperfectly, their opportunities for action will expand, and risks to the system's stability will be seen more as a contagion. Such a situation, while difficult to contain, may nevertheless be mitigated by a series of quick, adaptive interventions.

Another topic of importance is the way relationships between actors transition from mutualism to parasitism or predation. Trends in the international system indicate that previously held balances between actors of different types change over time, and as a result, the costs and benefits of particular relationships have shifted. In the case of national and global economics, the percentage of national wealth devoted to financial services has steadily grown, exceeding the resources devoted to other sectors. Likewise, an important trend in the area of economic development has been the proliferation of donor organizations, each with its own agenda and processes that overwhelm the managerial capacity of recipients. In each case, relationships designed to add liquidity, transparency, or accountability to an international system evolve in a way that reduces, not increases, the effectiveness of the markets and development projects in which they invest. What began as positive developments ceases to be mutually beneficial for the parties involved.

Complex Systems, Complex Insights

Coping with systemic risks in the international system often involves addressing 'wicked problems' where complex tradeoffs exist and solutions to one source of risk introduce or exacerbate other risks. One example of this tradeoff concerns information and transparency, and how to determine the balance between what information should be public vs. private. The specific details of individual cases dictate different considerations. For example, does an organization such as Wikileaks benefit the public good by exposing government secrets, or does it complicate the ability of diplomats to gather necessary information and speak frankly with their counterparts by subjecting all of their actions to public scrutiny? Does it matter if government secrets reveal that internal communications and private diplomatic efforts are consistent with its public statements and motives? Likewise, if studies of prospective vulnerabilities in critical infrastructure or financial markets identify exploitable weaknesses, should the results be publically disseminated, and if so, when and how?

Ethical issues are also sources of complexity in the international system, constituting one of the slow variables noted earlier. Customs, norms and laws establish what behaviors or decisions are permissible or prohibited; these vary over time and geography, providing sources of non-linear change in the international system. Examinations of financial markets noted that significant social stigmas exist regarding the prospects of defaulting on debts, both for corporations and sovereign states. The prospect for a global financial collapse would be greatly increased if this norm ceased to hold. Likewise, one of the contributing factors to the Arab Spring, particularly in Egypt, was the combination of sustained contacts between the US and Egyptian military officers and the prosecution of war criminals for genocide in the Balkans. The combination of professionalization and concern about precedents criminalizing the use of the military force against civilians served to restrain the use of widespread violence in the service of prolonging the Mubarak regime. Finally, a norm that has significantly affected the structure and dynamics of the international system has been the non-first-use of nuclear weapons—a norm that has survived the challenge of proliferation for almost seven decades, yet is by no means assured to continue.

Conclusion

The outlines of a new approach to assessing systemic risk for complex adaptive systems in international relations, where agents were boundedly rational and engaged in strategic interaction under uncertainty, appears to offer opportunities for new insights and analytic frameworks. This approach shifts the evaluative criteria of policy options away from optimal, often brittle solutions that require accurate predictions, in favor of robust solutions that can adapt in response to new information and experiences, modeled on successful approaches in natural sciences.

In several ways, this biological approach already builds on successful practices in risk assessment that mimic evolutionary processes. Risk analysis rarely can identify optimal policies, but it can eliminate the least appealing options from consideration, helping decision makers understand the features or properties of strategies that are likely to fail. This selection process is similar to natural selection in biology, where those members of a population with the lowest fitness are the most likely to be replaced. A second common feature of successful risk management strategies and biological systems is the importance of building on solutions or capabilities with multiple benefits. For example, improved border security provides benefits to counterterrorism, counternarcotics, and curbing illegal immigration. Just as in biology, successful risk mitigation strategies may be generic, allowing for their reuse in multiple domains or for many purposes.

Evolutionary examples provide promising models for coping with risks, particularly because of their ability to cope with uncertainty and relax the rationality assumptions embedded in more traditional analytic approaches. However, important differences remain between social systems and biological ones. In biological evolution, adaptation occurs as a result of random search, building upon designs that worked in the past. By comparison, adaptation in social systems is not purely the result of random search. Instead, the search for new solutions to challenges is based on the combination of interests, ethical prescriptions, and strategic anticipation. While we advocate the need for an evolutionary model that emphasizes adaptability and robustness as opposed to predictability and optimality, the evolutionary dynamics of the international system may differ from those observed in biological systems due to fundamental differences in their search processes.

The appealing conceptual framework of complex adaptive systems for understanding and containing risks presents a challenge in terms of constructing quantitative and computational models that will offer more detailed insights into the characteristics of a complex international system. A complex adaptive systems approach to international risk management and international relations offers new ways to understand evolving patterns of governance and relationships between regional constituencies, and the interactions between elites and broader, grass-roots actors in the development, maintenance, and transformation of governing regimes. New femtorisks will evolve, as different cultures, economies, and ecological imperatives create new frictions in new configurations. With humility and openness, a new forum to examine these approaches to complex problems might spawn the conversations and community required to gather lessons from the broad experience of this new network, and deploy that experience to help to understand and solve networked problems.

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