Globalization as Adaptive Complexity: Learning from Failure

Miguel Centeno, Peter Callahan, Paul Larcey, and Thayer Patterson

Abstract Our modern global civilization has been facilitated by increasingly technologically-advanced, interconnected, and interdependent systems. These systems have been constructed at an ever-increasing scale and level of complexity without an awareness of the risky mechanisms inherent in their design. At first glance, one may find few similarities between our modern globalized present and ancient civilizations. When we see past civilizations as complex adaptive systems, however, we can begin to recognize patterns, structures, and dynamics that have remained consistent through the centuries. Mechanisms like tipping points, feedback loops, contagions, cascades, synchronous failures, and cycles that can be responsible for systemic collapse are fundamental characteristics of any complex adaptive system, and can therefore serve as an effective common denominator from which to examine collapses through the ages. We argue for an analytical framework that incorporates these systemic characteristics for the study of historical collapse with the belief that these common mechanisms will help illuminate and expose relevant vulnerabilities in historical systems. In the end, we hope to learn from past societies and civilizations and allow our modern systems to benefit from lessons of systemic failures that historians may share with us. We believe these insights could inform how we see our systemic vulnerabilities and help to build a more resilient future.

Keywords Systemic risk · Historical collapse · Systems theory · Globalization · Complexity · Fragility

---

M. Centeno
Department of Sociology, School of Public and International Affairs, PIIRS Global Systemic Risk, Princeton University, Princeton, USA
e-mail: cenmiga@princeton.edu

P. Callahan (✉) · P. Larcey · T. Patterson
PIIRS Global Systemic Risk, Princeton University, Princeton, USA
e-mail: pwcallah@princeton.edu

P. Larcey
e-mail: plarcey@princeton.edu

T. Patterson
e-mail: patterson@princeton.edu

A. Izdebski et al. (eds.), *Perspectives on Public Policy in Societal-Environmental Crises*, Risk, Systems and Decisions, https://doi.org/10.1007/978-3-030-94137-6_6

Introduction

There is a specter haunting globalization and modern life: the potential for widespread civilizational collapse. Stories of dystopian fiction and apocalyptic futures have never been more popular, with audiences flocking to big budget disaster movies (Roberts 2020). Our world is existentially anxious because we sense that our trajectory is not sustainable (Ord 2020). Even the most optimistic possibilities of scientific and technological progress cannot guarantee our collective ongoing stability and prosperity. Global systemic shocks like 9/11, the Global Financial Crisis of 2008, and COVID-19 have heightened the awareness of the fragility of our increasingly globalized and interdependent way of living.

With the goal of understanding this precariousness of our modern world, we investigate "failures" in history and examine whether there are insights from systemic risk that can illuminate.

patterns of historical collapse. A certain teleological triumphalism has dominated modern social science where victors wrote their histories and survivorship biases led us to focus on the civilizations that remain standing. We see value in reversing this view by attempting to learn from failed civilization. We may have access to something that past doomed societies lacked—self-awareness of our own trajectory towards destruction, access to historical hindsight, and an understanding of themes and patterns that led to systemic failures in societies. We seek to identify systemic causes and mechanisms for breakdown that can provide historians with a systemic perspective for analyzing the past and can allow these past collapses to serve as cautionary tales for our present.

The paper begins with a discussion of hubris as a theme in social development. We then present a summary of the structure of globalization as a complex adaptive system. We follow by defining collapse, then moving on to its most significant causes. The penultimate section discusses some of the mechanisms through which isolated failures could lead to systemic collapse. We end with consideration of the governance required, if not to avoid the risk, then to mitigate the consequences with the goal of creating a more stable present and future.

The Enemy Is Us.

> "We have met the enemy and he is us"
>
> (Kelly 1971)

Hubris has been a cautionary theme in mythology, literature, and religion throughout history. Humans have a habit of taking a few successes as a sign of continued and future prosperity, often extrapolating it into a perception of infallibility. This has led to building ever taller edifices on fragile foundations. Dubai's Burj Khalifa may serve as a contemporary analog to the Tower of Babel. What would possess us to build something so incongruous with its natural environment, and surrounded by an unsustainable set of city states? Believing that we have it all under control, and that tomorrow will be just like today, humans create systems on which we depend and then neglect the need to build enough robustness and resilience into the system to assure it can survive crises (Pastor-Satorras et al. 2015; Taleb 2007).

We argue that this characteristic overconfidence also characterizes globalization (Brauer 2018). The global system is a set of tightly coupled interactions that together allow for the continued flow of information, money, goods, services, and people. We have clear evidence that—environmental hazards aside for the moment—globalization has actually been a very good thing for humans collectively. Life expectancy has increased globally by more than two decades since 1960 (Roser et al. 2013) and there is continuing evidence that the science of longevity will sharply accelerate (Schwab 2019). We now produce enough food to feed the planet, and enjoy an unprecedented economic and technological standard of living. Like a Roman during the reign of the Antonines, we can look around us and marvel at what we have created (Birley 2000).

Much of this advance has come through our ability to create systems that are technologically advanced, complex, interdependent, and constructed at massive scale. Expansive networks of telecommunication, transportation, energy, agriculture, trade, among others, have facilitated this progress, but have given rise to new and unprecedented risks (Manheim 2020; Oughton et al. 2018). We see these networks as complex adaptive systems (CAS), where the interactions of components create new dynamics that cannot be explained by the characteristics of the constituent parts. Because of this complexity, the risks associated with maintaining a CAS are non-linear and impossible to predict (Helbing 2009). Emergent risks in such a system are the threats that originate not in any single component, but from the collective structure and dynamics of the system in its entirety. In the case of CAS, risk of systemic failure when looking at the whole may be far greater than when the system is viewed simply as the sum of its parts (Crucitti et al. 2004). This is particularly true of "systems-of-systems" that rely on the coordination of various domains. The agricultural system, for example, relies on networks of finance, trade, water, labor, energy, electricity, transportation, communications and others to efficiently plant, grow, harvest, transport, and sell foodstuffs in a globalized society (Centeno et al. 2015a, b). A miscoordination in any of these underlying and interdependent systems could be catastrophic.

Globalization requires the continued flow of people, money, commodities, goods, services, and the co-operation of vast numbers of individuals (Danku et al. 2019; Foreman-Peck 2007). COVID-19 has shown us that none of us is isolated from the rest of the globe. A novel virus can rapidly emerge to bring down economies, change elections, and humble even the most powerful. Even with warnings, foresight, and suggested mitigation strategies, overconfidence and failure of imagination enabled such a deadly scenario (Cambridge Global Risk Index 2019: Executive Summary 2018; Epstein 2009; Nuzzo et al. 2019).

We now live in a global system-of-systems where a failure in one part could lead to disaster across the whole structure. The sheer quantity and breadth of possible interactions requires a shift in our analysis of interdependence. Moreover, to this complex system we have added a pursuit of optimization and efficiency that leads to short term gains, but lays the foundation for longer term catastrophe (Centeno et al. 2015a, b). Global systems, much like the Burj Khalifa, are wonders to behold, but the increase in complexity and tight coupling make a “normal accident” ever more likely and more dangerous (Perrow 1984; Ledwoch et al. 2018). That is, we have created systems which we can never truly comprehend, whose risk profiles we cannot understand (Wildavsky and Dake 1990), over which no one has responsibility, and on which we have staked our continued survival.

Our hubris lies not only in our overconfidence in our increasingly fragile systems, but more so in our belief that our 21st Century civilization is immune to the tragic fates of fallen societies in history. While our modern societies and the systems upon which they rely are at a scale, scope, and degree of complexity far greater than their historical counterparts, the mechanisms of systemic failure and collapse remain the same. In this way, lessons from the past that relate to the fundamental systemic characteristics still remain relevant today. Because of the unimaginable magnitude of potential contemporary collapse, the study of past systems for insights is more urgent and compelling than ever.

Looking to History

Perhaps the one constant in recorded history is that even the most apparently powerful and successful systems inevitably break down. History demonstrates over and over again that the second law of thermodynamics applies to human created systems: we cannot escape entropy—the inexorable trend toward greater chaos in nature (Meyer and Ponthiere 2020). Consequently, no form of social order is eternal.

Several years ago, we began a scholarly project on Global Systemic Risk (risk.princeton.edu). We sought to bring insights from complexity (Holovatch et al. 2017) and network theory (Barabasi and Frangos 2002) to identify: (1) how the system of globalization works and (2) what are the risks associated with this global complexity. Soon enough, we realized that it was important not just to analyze the system and identify key vectors, but also to imagine how it might all come apart (Vespignani 2010). We began to see that the risks to our increasingly interconnected and globalized systems are substantial and that its widespread failure could be catastrophic. To anticipate the future, we looked to lessons from the past to discover shared characteristics of doomed civilizations, which might offer warning signs for modern collapse.

We held two workshops with scholars whose knowledge and perspective could contribute to a better understanding of what we meant by collapse (risk.princeton.edu/collapse). Participants included biologists, historians, physicists, modelers, mathematicians, and even authors of dystopian essays and fiction. By assembling this group, we sought a more clear image of the modern world and its possible endings.

Analyzing a data set of historical collapses (see Peter Turchin’s work for an excellent example: seshatdatabank.info), we sought to distinguish causality from correlation, and exogenous causes from endogenous ones. What do previous “falls of empire” have to teach us about how we might best prepare for an uncertain and potentially perilous future (Taleb 2012)? We look to our experience from our study of global systemic risk and systemic collapse to provide insights and perspectives that historians may apply to their study of historical collapse. While we do not go in depth into different case studies in this chapter, the systemic mechanisms of collapse we choose to illuminate are heavily influenced by these historical perspectives.

Defining Collapse

We begin with a standard definition of a system: "a regularly interacting or interdependent group of units forming an unified whole" (Merriam-Webster). We are interested in how the structure and dynamics of a system decline over time—how this "unified whole" decreases in scale or scope, and how the central axis of action of the system moves from the system itself to its constituent parts.

If there is one central theme in the collapse literature it is that there is notable disagreement about the meaning of the term "collapse" (Middleton 2013; Yoffee 2005; Yoffee and Cowgill 1988). One area of debate is what exactly constitutes a collapse. Another criticism is that our historical view of collapse tends to have multiple cognitive biases—cultural bias, availability bias, confirmation bias, etc. Another critique is that speaking only of collapse ignores comparable scenarios where civilizations survived hardships and shocks, and thereby conceals or ignores significant elements of robustness and resilience that are important to identify (Nicoll and Zerboni 2019). We have to also address *what* exactly collapses. One standard measure is the level of social complexity of a society (e.g., level of interdependence, control, coordination Renfrew 1973; Tainter 1988)). Another is the level of political control or simple performance measures, such as nutrition or life expectancy (van Zanden et al. 2014).

We recognize that the term "collapse" is somewhat ambiguous with different definitions across academic disciplines. In this analysis we propose borrowing the usage of the term "collapse" from the literature on networks, systems, and complexity. In these fields, collapse refers to the disaggregation and breaking apart of a connected network. Collapsing complex systems break down or fragment into smaller units requiring less order, complexity, coordination, and organization to function. The systemic dynamics are thus reduced on a macro scale. The best question for such network analyses may be: has the system lost a significant part of its aggregate functionality (Hernández-Lemus and Siqueiros-García 2013)?

In this type of analysis, what collapses is not necessarily an entire society or civilization, but instead the larger organizational framework (Yoffee 2005; Kauffman 1993). So, the Maya late-classic city states decentralized and became smaller agglomerations of farmers, but the larger Maya "civilization" remained. Similarly, the radius of collapse may also differ such that the failure of some systemic elements does not imply the collapse of the entire *status quo ante*. The Western Roman Empire became a collection of much smaller political units—with significantly fewer interactions between them—yet the Eastern portion maintained its structure and societal identity in a semblance of its former self for a further thousand years (Mango 2002). We are therefore interested in the dynamics of aggregation and fragmentation over short to long-term periods.

For this fragmentation to be relevant to our discussion of collapse, it must have significant negative long-term consequences or costs associated with it. That is, social collapse must involve the loss of basic structure or function, or at the very least a decline in critical measures such as nutrition, life expectancy, or peace. Ibn Khaldûn's term *asabiyyah*, meaning "group feeling" or "social cohesion," might represent the antithesis of collapse. Interestingly, in 1377, Ibn Khaldûn wrote in his *Muqaddimah* that all social systems have collapse written into their structures and that the cycles of rise and decline may be inevitable (Khaldûn 2015).

We need to differentiate between the gradual cycles of rise and decline and the more rapid collapses. The two may have very different causes. Most discussions of collapse focus on a dramatic event or moment when key indicators begin to mark social breakdown. For our purposes, we identify collapse as a clear inflection point followed by a perceived fall in living conditions for those within the system (see Haldon et al. 2020 pp. 3–7).

We also need to distinguish a simple crisis from a collapse. While the Global Financial Crisis of 2008 was a major systemic shock with significant costs, it did not precipitate a collapse of the entire financial system (Coggan 2020, 338–47). The "Second 30 Years War" (1914–1945), however, did produce a collapse in the global, social, and political order (Ferguson 2006). This last example should also remind us that one person's collapse may be another's opportunity. Similarly, the collapse of 19th Century colonial empires might be lamented in some parts of the world, but celebrated in others. The most dramatic collapse of all, caused by an asteroid 65 million years ago, was certainly a disaster for the dinosaurs, but it provided an ecological opening for mammals.[1]

It is therefore important to remove, in a sense, the normative aspects of collapses and analyze these systemic transformations descriptively as ecological phenomena with niches disappearing and appearing. In ecological systems, for example, "collapse" or "release" is a critical phase of cyclical regeneration, which allows for new reorganization as different feedbacks and competition within the system allow for new systemic characteristics to emerge with regrowth (Gunderson and Holling 2002).

Identifying the Causes of Collapse

Given the intractable complexity in many historical civilizational systems, it is often difficult to reach consensus on the causes of various collapses. Historian Alexander Demandt (1984) famously counted 210 different explanations given for the collapse of the Roman Empire (Demandt 1984). Others argue that the Roman Empire never

[1] Note that there remains some discomfort with the Asteroid theory with others focusing on the volcanic activity in the Deccan Plateau.

truly collapsed but instead fragmented and slowly faded away (Brown 1976).[2] More recently, environmental change or failure has become a frequent explanation for the collapse of certain complex societies (Middleton 2017). As with any tragic denouement, it may be impossible to string together the various episodes, mistakes, and challenges that might have led to the loss of *asabiyyah*. Each observer might choose a different critical moment or decision that precipitated the downfall.[3]

Generally, we can distinguish between two broad categories of explanations for collapse: exogenous, and endogenous. Narratives of exogenous causality—where a shock from outside the system is responsible for its downfall—are the most common. Volcanic eruptions, earthquakes, and sudden climate shifts are common in human history and are often associated with systemic collapse (Bostrom and Cirkovic 2008; Ord 2020). Similarly, much of history is the story of human invasion, conquest, and brutality, viewed as an exogenous cause by all of the civilizations conquered. From the 15th Century onwards, the “rise of the West” (Hoffman 2015) meant catastrophe for almost all of the world outside Europe, which led Stephen Hawking to his famous caution against searching for life in the universe whence “such advanced aliens would perhaps become nomads, looking to conquer and colonize whatever planets they can reach” (Stephen Hawking’s Universe 2010).

Exogenous explanations, however, while salient and dramatic, can be misleading as they often neglect the importance of internal systemic characteristics. For example, two distinct systems could experience a comparable exogenous shock, leading one system to succumb while the other survives and prospers. Thus, of greater relevance than the exogenous shock itself are the qualitative differences between the two systems that explain these disparate results. In this way, viewing collapse as simply the consequence of unlucky exogenous shocks makes for an unsatisfying account (Bailey 2011).

By contrast, narratives of endogenous causality—where a system’s internal characteristics are responsible for causing or perpetuating a downfall—perhaps offer greater explanatory power for past societal collapses. The most relevant causes of collapse may not be the specific factors that initiate the process, but the structure that allows perturbation and contagion to amplify through the system as in a chemical reaction. Thus, collapse may not be precipitated by the failure of any single component, but instead by the unexpected dynamic interactions of these nodes in a complex network. Instead of individual causes, we might better focus on the systemic mechanisms that escalate local challenges into existential crises.

Unlike the randomness and *sui generis* qualities of many exogenous shocks, endogenous collapses seem to share a common theme: managerial failure. These failures include loss of legitimacy, unsustainable inequality, hyperbolic discounting, overuse of resources, misplaced faith in the reliability of advanced technologies, and an overemphasis on efficiency. Managerial failures of human agency and fiduciary leadership reduce the system’s internal capacity to withstand shocks (both exogenous

[2] A similar argument has flared concerning the Meghalayan Age beginning around 2200 BC with disputes about the extent of global civilizational collapse.

[3] For an excellent overview of the literature see (Haldon et al. 2020).

and endogenous), making them more vulnerable to the mechanisms of collapse we identify below.

Systemic Mechanisms of Collapse

All ecological and human-made systems share components (Siskin 2016)and behaviors that allow for growth or development (Kauffman 2013). However, like healthy cells that become cancerous, these once beneficial features may evolve into threats that can ultimately destroy the system as a whole. Below, we discuss common mechanisms of collapse.

Tipping Points

Every complex social system contains thresholds beyond which social cohesion falls apart. These tipping points are the levels of tolerance within a system that, when exceeded, mark the rapid transition to a new state or equilibrium. For societies, this could be the moment when a behavior in which the person or society has engaged in for many years suddenly has more drastic consequences than expected. This is a consequence of inertia, force, stress, or momentum building up that leads to a phase change, causing the system to transition into a different equilibrium state of structure or dynamics. Tipping points can serve as gateways of opportunity or pathways to failure (Milkoreit et al. 2018). Examples of tipping points with negative consequences include a final straw breaking a camel's back or a rubber band stretched beyond its breaking point: after a minor additional stress, it loses its functionality. An example of a tipping point that leads to greater systemic resilience is that of herd immunity—after a certain level of inoculation is reached, the population is protected from further infection. The key in all instances is the persistence or irreversibility of the transformation (Dakos et al. 2019; Bentley et al. 2014).

Different individuals or groups will have different attitudes towards such points of inflection (Bossomaier et al. 2013). Some might be totally unaware of the negative consequences—or again, the positive contributions—that could be precipitated by this small additional stress. In these instances, the inflection point comes as a total surprise, which adds to the precariousness of the transition to the new state. Other individuals or societies might be well aware of the potential change and have established a monitoring system, a sort of "Geiger counter" offering reassurance. Yet other societies may actually be aware of the danger, yet appear to do little to avert it—global pandemics and climate change are two such examples.

It may well be impossible to predict the tipping point or even identify it post hoc, because tipping points may be contextual—only becoming critical under certain circumstances. The most frequent examples of tipping points may be found in the start of wars where antagonism, fears, and perceived injustices lead to the creation of a spiral into violence. In Thucydides' account of the negotiations between Sparta and Athens, the debate in Corinth may be seen as the tipping point leading to the resolution of the Thucydides trap (Robinson 2017). Or consider a doomsday weapon a la *Dr. Strangelove*, established precisely as a public "red line," or "line in the sand," the crossing of which begins a chain-reaction that cannot be stopped. Caesar's crossing of the Rubicon can be regarded as one such tipping point. Again, the central lesson from tipping points is that an apparently small perturbation can set off a series of events that leads to irreversible change, or in the worst scenario, collapse.

Feedback Loops

Stable social systems are fundamentally cooperative and reciprocal, with systemic dynamics that reinforce (or undermine) this social cohesion through feedback loops. These are structures that use the measure of output from a process to determine the subsequent input back into the beginning of the cycle (Martin 1997). The critical element is that the start of some action or process is at least partly determined by its previous ending. Perhaps the simplest feedback loop in our everyday lives is a faucet, where the last felt or monitored temperature of the water is used to recalibrate the subsequent flows. Many incentive systems are forms of feedback loops: as a result of a certain level of performance, rewards or punishments are determined for the next round. The human nervous system (Lessard 2009) is an example of a feedback loop where we are encouraged or discouraged from certain forms of behavior by signals of pain or pleasure.

Within social systems, social norms and even institutionalized rules are forms of feedback loops, as they determine responses to individual actions. It is also possible for feedback loops to operate within "black boxes"—hidden from the observer or obscure enough so as to not be part of a conscious strategy, but the result of a pre-programmed set of responses. Feedback loops are critical to establishing equilibria. The relationship between supply, demand, and price may be seen as a constantly iterative loop of inputs and outputs, feeding back on each other.

Positive feedback loops can move a system away from its equilibrium, while negative feedback loops can diminish the effects of perturbations, returning the system to its steady state. In this way, negative feedback loops can lead to important improvements in behavior or functionality by reinforcing the current steady state. Unhealthy positive feedback loops exist when a society may reward a kind of behavior until such a point at which that behavior is no longer appropriate (Kolmes 2008). This is often the case when feedback loops for some are misaligned with a collective good. When studying instances of historical collapse it may be important to identify feedback loops, with either positive feedback loops causing a stable society to spiral into disorder, or negative feedback loops enabling a social system to absorb otherwise catastrophic shocks.

Contagions

COVID-19 has made the phenomenon of contagion far too familiar and highlights the inexorable systemic risk inherent in globalization (Smil 2019). From a network science perspective, contagion involves the passing of objects, effects, or characteristics from one node to another transmitted through contact or a systemic connection. A person may infect a group by coughing, someone shouting "Fire!" may lead to the spread of alarm or panic, or the failure of one part of a system may lead to malfunction elsewhere or even of the whole. Similar to tipping points and feedback loops, contagion might be considered beneficial or positive if the resulting behavior is one that is considered valuable. Inventions and their subsequent "viral" diffusion are an example of a beneficial contagion.

Cascades

A cascade—or uncontrollable domino effect—might be best thought of as a combination of contagion and tipping points. A normally regulated flow may transition into a cascade if it results in an increase in output that overwhelms its neighboring nodes that are receiving these flows. When a gradually spreading contagion reaches a tipping point and triggers failure in some components or regions of a system, this can precipitate a cascading sequence of failures—the magnitude of each failure is significant enough to touch off an even greater neighboring failure. In this way, complex systems can contain within them leverage that increases the magnitude of the failure at each step in the cascade.

Perhaps the best known cascading failures in our modern systems are within highly coupled energy infrastructures (Korkali et al. 2017). In political systems, the assassination of Franz Ferdinand in 1914 is perhaps the most infamous instance in modern history of a cascading failure. Interdependent nations tightly coupled through alliances designed to increase geopolitical systemic resilience created pathways and dynamics for a cataclysmic cascading failure. One domino fell and ultimately led to a world-transforming global conflict.

Synchronous Failures

While complex systems may be designed to survive individual localized failures, a certain number of such simultaneous failures will overwhelm any system. Such a "perfect storm" of events is considered a synchronous failure. Probability theory dictates that random events will eventually occur simultaneously, or at least in close proximity of time or location. Such a clustering of these failures, or the simultaneous and synergistic interaction of several failures, may result in a challenge unimagined by designers, and for which the system is not prepared (Homer-Dixon et al. 2015).

Charles Perrow's concept of a "normal accident" illustrates how such an apparently innocuous confluence of events can lead to catastrophe (Perrow 1984). In tightly coupled and complex systems, two apparently unrelated events can lead to a disastrous outcome. Natural disasters are particularly dangerous because they often involve the failure of various social systems simultaneously. The response to the failure of one part of a system might then lead to a strain in another part that leads to systemic breakdown.

Synchronous failures are particularly threatening because no individual or society can prepare for the infinite number of disastrous combinations and consequences (West 2017). We might be able to create mechanisms to deal with individual problems, but in the face of multiple failures, resources may be taxed beyond their limits. In the case of complex systems, the interaction of failures may lead to consequences not expected from the isolated failure of each. Invaded societies weakened by novel pathogens found themselves fighting two battles instead of one. While either invasion or pandemic may have been manageable shocks on their own, the confluence of both served as a coup de grâce.

Cycles

The notion of civilizational or biological cycles is central to natural and behavioral sciences. The organic cycle of death and life is one that dominates our planet (Walker et al. 2017). Without death and decomposition, new biological life may be impossible. For over a half-century, economic policy has been guided by attempts to regulate the cyclical nature of inflation and unemployment, booms and busts. The central notion of Keynesianism is to avoid the deep troughs of the cycle through monetary and fiscal intervention. Ecological systems experience oscillating cycles of population growth and decline based on factors such as predator–prey dynamics. Similarly, climate systems experience natural cycles through the activity of sunspots, and astronomical interactions, resulting in temperature fluctuations and drought. These cycles in the environmental systems can be catastrophic for civilizations that are unexpectedly deprived of food or water (Parker 2013).

Many societies, such as the Mexica, organized their lives in accordance with a calendar of rise and decline. Cultures and religions have embraced the notion of reincarnation reflecting their social faith in the inevitability of the cycle of death and rebirth. Since at least the Enlightenment, or even the Renaissance, European and associated societies have sought to escape the inevitability of cyclicality and have constructed the expectation of linear progress. While this aspirational desire to transcend cyclicality may account for economic and social dynamism (Sweezy 1943), it also makes the cyclical decline a threatening prospect. Much like Shelley's *Ozymandias*, even the mightiest of civilizations that expected to prosper eternally have ultimately declined, transformed, or collapsed (Shelley 1818).

Resilience and Mitigation

At its core, resilience refers to the capacity of any system—a human body, a building, a city, a tropical forest—to survive shocks and disruptions (Walker and Cooper 2011). This concept has migrated from engineering and ecology into all disciplines in which systems are studied (Evans and Reid 2013; Levin and Lubchenco 2008). While a distinction is sometimes made between robustness and resilience, for our purposes in this discussion, we use the term resilience to cover attributes of both. In this framing, resilience is a combination of two general qualities: resistance to shocks with the ability to remain unchanged (what is often referred to as robustness); and flexibility, recoverability, or the ability to change enough to survive after a disruption (most commonly referred to as resilience). An example of withstanding shocks would be building a dam to prevent flooding; that of the latter, the provision of boats in case of flooding.

The central difference between these two aspects of resilience might be best understood as a system's ability to prevent a crisis versus its capability to bounce back from one. In regulatory terms, we can either try to prevent failures in our physical, infrastructural, economic, or epidemiological systems, or we can design triage protocols, contingencies, and recovery plans to mitigate the damage.

Why not focus on both prevention and mitigation? The two qualities of resistance and flexibility are complementary, but also represent a series of tradeoffs; it helps to be strong and supple, but building resilience requires resources and you cannot maximize both. The ideal system design or evolution will weigh, balance, and combine these two qualities along some "golden mean" depending on preferences and contexts. It is in these tradeoffs and balances that we find the most challenging policy dilemmas.

Systemic resilience is a "public good" that is eroded by managerial failures that make collapse through endogenous mechanisms more likely. One modern managerial failure that increases systemic fragility is the focus on ever-increasing efficiency, where cost savings and just-in-time management have replaced redundancy, slack, and reserves. This efficiency has created greater systemic interdependence through increased reliance on one's suppliers and neighboring nodes, making modern systems more susceptible to the mechanisms of endogenous collapse.

As another example of managerial failure threatening resilience, decision-makers within systems often focus on their own interests and their relationships with those to whom they are immediately connected, neglecting to consider the inherent endogenous systemic risks beyond the control of any one participant. This creates negative externalities such as the "tragedy of the commons," where short-run self-interest—rather than coordination and cooperation—can lead to collapse (Hardin 1968).

Governance strategies must be devised with an awareness of these mechanisms of collapse, and the managerial failures that can allow these mechanisms to threaten the viability of our modern systems. Resilience can be prioritized through regulations and standards for safeguards, monitoring, and risk management.

Conclusion

Globalization at an ever-increasing scale and level of complexity is a modern tale of hubris. Building increasingly technologically-advanced, interconnected, and interdependent systems without an awareness of the risky mechanisms inherent in their design will inexorably lead to endogenous failures and potential collapse. These risks of globalization have brought us to our study of systemic risk, and to our interest in learning insights about systemic collapse from history.

At first glance, one may find few similarities between ancient civilizations and our modern globalized present. When we see these civilizations as complex adaptive systems, however, we can begin to recognize patterns, structures, and dynamics that have remained consistent through the centuries. Mechanisms like tipping points, feedback loops, contagions, cascades, synchronous failures, and cycles that can be responsible for systemic collapse are fundamental characteristics of any complex adaptive system, and can therefore serve as a useful common denominator from which to examine collapses through the ages. We offer this systemic framework for the study of historical collapse with the belief that these common mechanisms will help illuminate and expose relevant vulnerabilities in historical systems. In the end, our hope is that we may learn from past societies and civilizations and allow our modern systems to benefit from lessons of systemic failure that historians may share with us. We believe these insights could inform the way we see our own systemic vulnerabilities and help to build a more resilient future.

References

Bailey M (2011) Risk and natural catastrophes: the long view. In: Skinns L, Scott M, Cox M (eds) Risk. Cambridge University Press, Cambridge

Barabasi A-L, Frangos J (2002) Linked: the new science of networks science of networks, 1st edn. Perseus Books Group, Cambridge, Mass

Bentley et al., 2014 Bentley RA, Maddison EJ, Ranner PH, Bissell J, Caiado CCS, Bhatanacharoen P, Clark T et al (2014) Social tipping points and earth systems dynamics. Front Environ Sci 2. https://doi.org/10.3389/fenvs.2014.00035

Birley AR (2000) Hadrian to the Antonines. In: Bowman AK, Rathbone D, Garnsey P (eds) The Cambridge Ancient History: Volume 11: The High Empire, AD 70–192, edited by, 2nd ed, 11:132–94. The Cambridge Ancient History. Cambridge University Press, Cambridge. https://doi.org/10.1017/CHOL9780521263351.004

Bossomaier T, Barnett L, Harré M (2013) Information and phase transitions in socio-economic systems. Complex Adapt Syst Model 1. https://doi.org/10.1186/2194-3206-1-9

Bostrom N, Cirkovic MM (2008) Global catastrophic risks, Illustrated. Oxford University Press, Oxford

Brauer D (2018) Theory and practice of historical writing in times of globalization. In: Brauer D, Roldán C, Rohbeck J (eds) Philosophy of globalization, pp 397–408. De Gruyter. https://doi.org/10.1515/9783110492415-029/html

Brown P (1976) The making of late antiquity. 5th Printing edition. Harvard University Press, Cambridge, Mass

Cambridge Global Risk Index 2019: Executive Summary (2018) University of Cambridge: Cambridge Centre for Risk Studies. https://www.jbs.cam.ac.uk/faculty-research/centres/risk/publications/managing-multi-threat/cambridge-global-risk-index/cambridge-global-risk-index-2019-executive-summary/
Centeno MA, Nag M, Patterson TS, Shaver A, Jason Windawi A (2015a) The emergence of global systemic risk. Ann Rev Sociol 41(1):65–85. https://doi.org/10.1146/annurev-soc-073014-112317
Centeno M, Callahan P, Patterson T (2015b) Systemic risk in global agriculture: conference report. PIIRS Global Systemic Risk & Agriculture and Food Security Center, Princeton, New Jersey. https://risk.princeton.edu/img/Princeton-Columbia_Agriculture_Conf_Report_2014-10-24_(v2016-09-27).pdf
Coggan P (2020) More: the 10,000-year rise of the world economy. Main edition. Economist Books
Crucitti P, Latora V, Marchiori M (2004) Model for cascading failures in complex networks. Phys Rev E Stat Nonlinear Soft Matter Phys 69:045104. https://doi.org/10.1103/PhysRevE.69.045104
Dakos V, Matthews B, Hendry AP, Levine J, Loeuille N, Norberg J, Nosil P, Scheffer M, De Meester L (2019) Ecosystem tipping points in an evolving world. Nat Ecol Evolut 3(3):355–362. https://doi.org/10.1038/s41559-019-0797-2
Danku Z, Perc M, Szolnoki A (2019) Knowing the past improves cooperation in the future. Sci Rep 9(1):262. https://doi.org/10.1038/s41598-018-36486-x
Demandt A (1984) Der Fall Roms: Die Auflösung des römischen Reiches im Urteil der Nachwelt. Beck, München
Epstein JM (2009) Modelling to contain pandemics. Nature 460(7256):687–687. https://doi.org/10.1038/460687a
Evans B, Reid J (2013) Dangerously exposed: the life and death of the resilient subject. Resilience 1(2):83–98. https://doi.org/10.1080/21693293.2013.770703
Ferguson N (2006) The war of the world: history's age of hatred. Allen Lane, London
Foreman-Peck J (2007) European historical economics and globalisation. J Philos Econ 1(1):23–53
Gunderson LH, Holling CS (2002) Panarchy: understanding transformations in human and natural systems. Island Press
Haldon J, Chase A, Eastwood W, Medina-Elizalde M, Izdebski A, Ludlow F, Middleton G, Mordechai L, Nesbitt J, Turner BL (2020) Demystifying collapse: climate, environment, and social agency in pre-modern societies. Millennium 17(November):1–33. https://doi.org/10.1515/mill-2020-0002
Hardin G (1968) The tragedy of the commons. Science 162(3859):1243–1248. https://doi.org/10.1126/science.162.3859.1243
Helbing D (2009) Managing complexity in socio-economic systems*. Europ Rev 17(2):423–438. https://doi.org/10.1017/S1062798709000775
Hernández-Lemus E, Siqueiros-García J (2013) Information theoretical methods for complex network structure reconstruction. Complex Adapt Syst Model 1(April):8. https://doi.org/10.1186/2194-3206-1-8
Hoffman PT (2015) Why did europe conquer the world?, 1st edn. Princeton University Press, Princeton
Holovatch Y, Kenna R, Thurner S (2017) complex systems: physics beyond physics. Eur J Phys 38(2):023002.https://doi.org/10.1088/1361-6404/aa5a87
Homer-Dixon T, Walker B, Biggs R, AS Crépin, Folke C, Lambin E, Peterson G et al (2015) Synchronous failure: the emerging causal architecture of global crisis. Ecol Soc 20(3). https://doi.org/10.5751/ES-07681-200306
Kauffman S (2013) Evolution beyond Newton, Darwin, and Entailing Law: the origin of complexity in the evolving biosphere. In: Lineweaver CH, Davies PCW, Ruse M (eds) Complexity and the arrow of time. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139225700
Kauffman SA (1993) The origins of order: self-organization and selection in evolution. Oxford University Press, New York
Kelly W (1971) Pogo cartoon. Ink and blue pencil on paper

Khaldûn I (2015) The Muqaddimah. Dawood NJ (ed) Translated by Franz Rosenthal. Princeton University Press, Princeton N.J

Kolmes SA (2008) The social feedback loop. Environ Sci Policy Sustain Dev 50(2):57–58. https://doi.org/10.3200/ENVT.50.2.57-58

Korkali M, Veneman JG, Tivnan BF, Bagrow JP, Hines PDH (2017) Reducing cascading failure risk by increasing infrastructure network interdependence. Sci Rep 7(1):44499. https://doi.org/10.1038/srep44499

Ledwoch A, Brintrup A, Mehnen J, Tiwari A (2018) Systemic risk assessment in complex supply networks. IEEE Syst J 12(2):1826–1837. https://doi.org/10.1109/JSYST.2016.2596999

Lessard C (2009) Basic feedback controls in biomedicine: synthesis lectures on biomedical engineering, 1st edn. Morgan and Claypool Publishers, San Rafael, Calif.

Levin SA, Lubchenco J (2008) Resilience, robustness, and marine ecosystem-based management. Bioscience 58(1):27–32. https://doi.org/10.1641/B580107

Mango C (ed) (2002) The oxford history of byzantium. Oxford University Press, Oxford

Manheim D (2020) The fragile world hypothesis: complexity, fragility, and systemic existential risk. Futures 122:102570.https://doi.org/10.1016/j.futures.2020.102570

Martin LA (1997) An introduction to feedback. Massachusetts Institute of Technology

Merriam-Webster. n.d. System. In Mirriam-Webster. https://www.merriam-webster.com/dictionary/system

Meyer P, Ponthiere G (2020) Human lifetime entropy in a historical perspective (1750–2014). Cliometrica J Hist Econ Econ Hist 1:129–167

Middleton G (2013) That old devil called collapse. E-International Relations (blog). https://www.e-ir.info/2013/02/06/that-old-devil-called-collapse/

Middleton GD (2017) Understanding collapse: ancient history and modern myths. Cambridge University Press, New York, NY

Milkoreit M, Hodbod J, Baggio J, Benessaiah K, Calderón-Contreras R, Donges JF, Mathias JD, Rocha JC, Schoon M, Werners SE (2018) Defining tipping points for social-ecological systems scholarship: an interdisciplinary literature review. Environ Res Lett 13(3):033005.https://doi.org/10.1088/1748-9326/aaaa75

Nicoll K, Zerboni A (2019) Is the past key to the present? Observations of cultural continuity and resilience reconstructed from geoarchaeological records. Quaternary International. https://agris.fao.org/agris-search/search.do?recordID=US201900215845

Nuzzo JB, Mullen L, Snyder M, Cicero A, Inglesby TV (2019) Preparedness for a high-impact respiratory pathogen pandemic. The Johns Hopkins Center for Health Security. https://www.centerforhealthsecurity.org/our-work/publications/preparedness-for-a-high-impact-respiratory-pathogen-pandemic

Ord T (2020) The precipice: existential risk and the future of humanity. Hachette Books

Oughton EJ, Usher W, Tyler P, Hall JW (2018) Infrastructure as a complex adaptive system. Research article. Complexity. Hindawi. https://doi.org/10.1155/2018/3427826

Parker G (2013) global crisis: war, climate change and catastrophe in the seventeenth century. Yale University Press, New Haven. http://www.yalebooks.com/book.asp?isbn=9780300153231

Pastor-Satorras R, Castellano C, Van Mieghem P, Vespignani A (2015) Epidemic processes in complex networks. Rev Mod Phys 87(3):925–979. https://doi.org/10.1103/RevModPhys.87.925

Perrow C (1984) Normal accidents: living with high-risk technologies. Basic Books, New York

Renfrew C (1973) Explanation of culture change: models in prehistory. University of Pittsburgh Press, Pittsburgh

Roberts A (2020) It's the end of the world: but what are we really afraid of? Elliott & Thompson

Robinson E (2017) Thucydides on the causes and outbreak of the peloponnesian war. In: Forsdyke S, Foster E, Balot R (eds) The oxford handbook of thucydides. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199340385.001.0001

Roser M, Ortiz-Ospina E, Ritchie H (2013) Life expectancy. Our world in data. https://ourworldindata.org/life-expectancy

Schwab K (2019) Globalization 4.0: a new architecture for the fourth industrial revolution. Foreign Affairs. https://www.foreignaffairs.com/articles/world/2019-01-16/globalization-40
Shelley PB (1818) Ozymandias. Poem
Siskin C (2016) System: the shaping of modern knowledge, 1st edn. The MIT Press, Cambridge, Massachusetts
Smil V (2019) Growth: from microorganisms to megacities, Illustrated. The MIT Press, Cambridge, Massachusetts
Stephen Hawking's Universe (2010)
Sweezy PM (1943) Professor Schumpeter's theory of innovation. Rev Econ Stat 25(1):93–96. https://doi.org/10.2307/1924551
Tainter J (1988) The collapse of complex societies. Cambridge University Press
Taleb N (2007) The black swan: the impact of the highly improbable, 1st edn. Random House, New York
Taleb NN (2012) Antifragile: things that gain from disorder. Random House
Vespignani A (2010) The fragility of interdependency. Nature 464(7291):984–985. https://doi.org/10.1038/464984a
Walker J, Cooper M (2011) Genealogies of resilience: from systems ecology to the political economy of crisis adaptation. Secur Dialogue 42(2):143–160. https://doi.org/10.1177/0967010611399616
Walker SI, Packard N, Cody GD (2017) Re-Conceptualizing the origins of life. Philos Trans Royal Soc Math Phys Eng Sci 375(2109):20160337. https://doi.org/10.1098/rsta.2016.0337
West G (2017) Scale: the universal laws of life, growth, and death in organisms, cities, and companies. Reprint edition. Penguin Books
Wildavsky A, Dake K (1990) Theories of risk perception: who fears what and why? Daedalus 119(4):41–60
Yoffee N (2005) Myths of the archaic state: evolution of the earliest cities, states, and civilizations. Cambridge University Press, New York
Yoffee N, Cowgill GL (1988) The collapse of ancient states and civilizations. University of Arizona Press
Zanden JL, Baten J, Mira d'Ercole M, Rijpma A, Smith C, Timmer M eds (2014) How was life?: Global well-being since 1820. OECD Publishing, Paris. https://www.oecd.org/statistics/how-was-life-9789264214262-en.htm