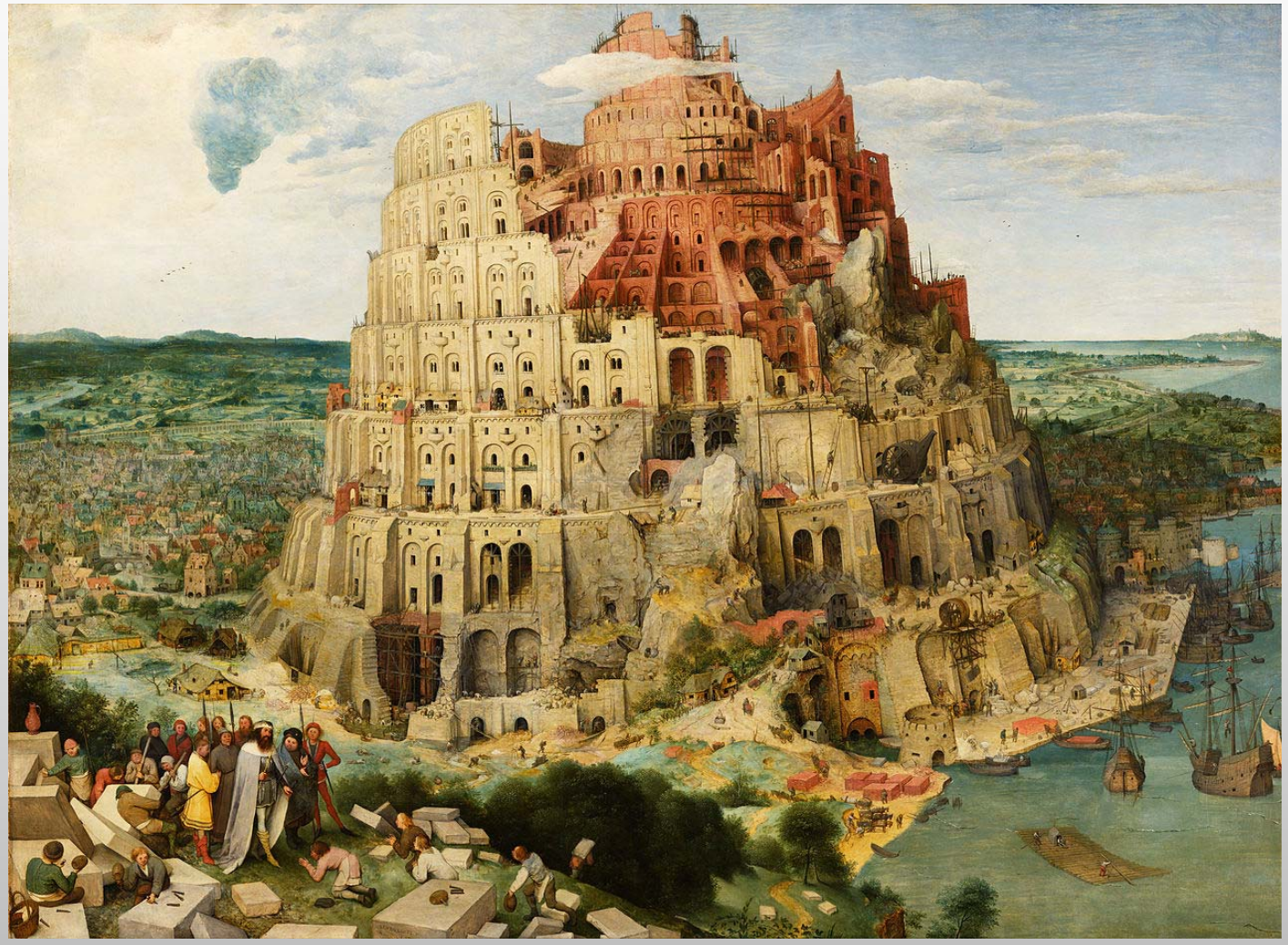
Global Systemic Risk:
A research agenda

Royal Society

January 16, 2017

Miguel Angel Centeno

Princeton University



Global Systemic Risk

- In our fourth year, this research community investigates the causes and consequences of global systemic risk (GSR) through the analysis of human-made networks and the robustness or fragility of these structures to endogenous forces and exogenous shocks.
- Investigate the theoretical and methodological approaches to analyzing the construction and dynamics of complex systems and the inherent robustness and fragility.
- We have sought to define a series of questions and a framework of discovering patterns, meta-themes, and commonalities among the disparate domains that could motivate generalizable models of emergent risk.

Globalization as a Complex System

- The global system is the set of tightly coupled interactions that together allow for the continued flow of information, money, goods, services, and people.
- Though these connections are not in themselves new, the level of interdependence, the tight couplings between many of these domains, and the speed and scale of interactions have created new configurations of opportunity and risk.
- Modern systems are built to exploit the benefits and efficiencies resulting from specialization of labor, economies of scale, collective knowledge, and information sharing.
- These same systems that underwrite our way of life also create and expose us to catastrophic outcomes that may derive from the characteristics of the relationships themselves.

Complex Adaptive Systems

- Complex adaptive systems (CAS) arise endogenously out of the interactions of components, and have collective behaviors that cannot be reduced to those of their components
- The complex interactions of components create new dynamics that cannot be explained solely by the behavior of constituents, whether intended or not.
- Such systems can often give the appearance of stability even as their fragility increases.
- This fragility is due to the fact that complex systems may gradually become susceptible to small perturbations that have catastrophic results.

Edge of Chaos

- Systems that reach this threshold at the "edge of chaos" are particularly prone to sudden, nonlinear transitions from one state to another.
- Such critical transitions can be the result of either external perturbations or the endogenous functioning of the system itself, and are both difficult to forecast and potentially irreversible.
- Systems that are both complex and densely interconnected are especially prone to "complexity catastrophe."

No Exit

- CAS may also provide a heuristic for the new level analysis required by a globalized world.
- We are living with a new and unprecedented level of aggregation of social space.
- The sheer quantity and breadth of interactions may require a shift in our analysis of interdependence.
- Such interdependence has produce a myriad of benefits, but potential instability may be an endogenous characteristic of a system as complex as what we have created.

Paradox of Modernity

- Growing connectedness of the world is the most important social fact of our times.
- Increased mobility and increasing complexity
- Greater integration
- Increased capacity for aggregation and control

- **But....**
  - Growing dependence
    - On effective functioning of multiple networks
  - Increased social vulnerability in the face of accidental and intentional disruption

Risk and Uncertainty

- Not referring to the pure Knightian definition of risk as a calculable "measurable uncertainty."
- Uncertainty is a ubiquitous concept in the physical world, in human behavior, and in social, economic, and financial outcomes, yet these uncertainties will always continue to be commonly referred to as "risk."
  - A possible source of systemic fragility is confusing the two.
- Proceed under the assumption that systemic risks we discuss are necessarily unquantifiable uncertainties, in the sense of Knightian uncertainty.

Systemic and Emergent Risk

- Systemic risk is risk to the "system" that is posed by the interconnections or network of its constituent parts.
  - About connections, cascades, and thresholds; it is about how local risk scales up to and develops as global risk.
- Emergent risk arises from how individual parts are connected to form the whole, but – and this is the distinguishing point from systemic risk – *it is not reducible to the individual components.*

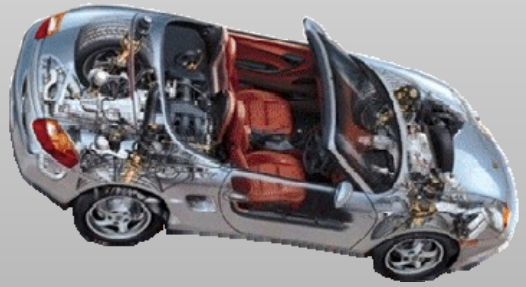
Robustness vs. Fragility

Robustness

- Ability of a system to absorb large shocks
  - Complex systems display surprising degree of tolerance against errors.
  - Display surprising degree of robustness.
  - Local failures rarely lead to systemic failure.

Fragility

- Often comes with high performance
  - Fragility allows small shocks to be magnified exponentially
  - Highly vulnerable to attacks
  - MOREOVER, when networks are coupled together with one another, vulnerability increases



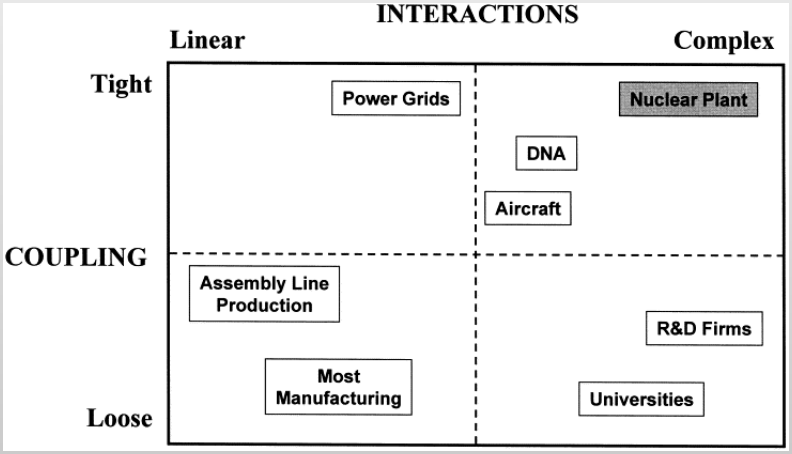
Exogenous Sources of Uncertainty

Endogenous Sources of Uncertainty

- Endogenous threats are very different.
- Do not need malfeasance, disaster, or God.
- They are BUILT IN to the system.

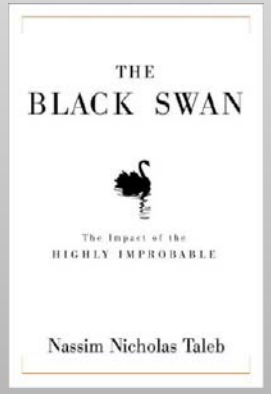
Normal Accidents

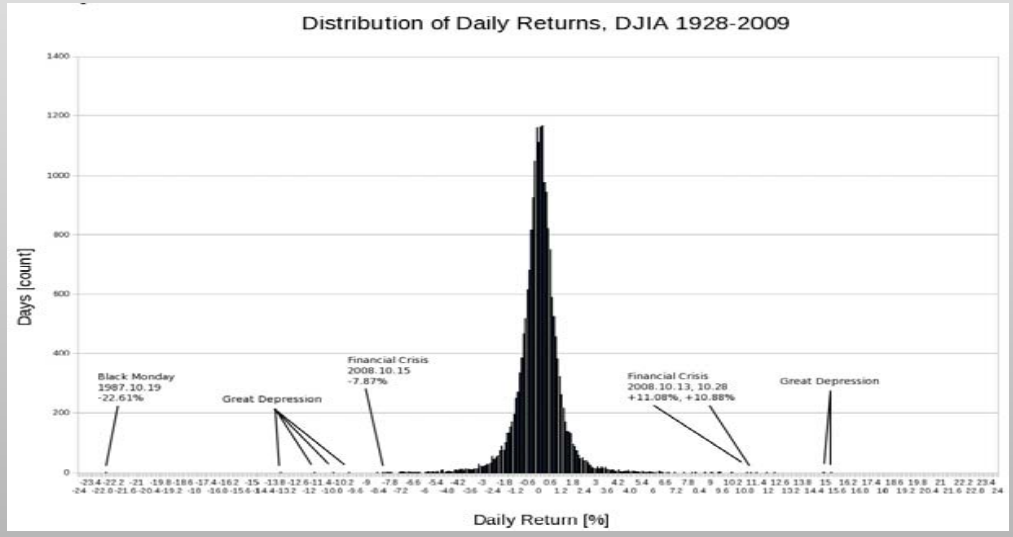
- Inherent unpredictability of complex and tightly coupled interactions



Black Swans

- With any event there are "tails" to the probability distribution that make the non-probable possible.
- The number and complexity of transactions and interactions makes any kind of conventional description or analysis arguably impossible to compute or comprehend. Mathematical combinatorics shows us that with just 100 agents or actors in a system, there are 2^{100} (1.3×10^{30}) possible combinations or groups of these agents, there are 100- factorial (9.3×10^{157}) possible ways for 100 agents to be ranked or ordered, and as you linearly increase a system with *n* agents by adding one more agent, the number of pairwise links in the system increases by *n*. System with n actors has $\approx n^2$ links. The larger the system, the faster its potential complexity grows with each additional element.





So what?

- How resilient is the global system?
  - *"The more human beings proceed by plan, the more effectively they may be hit by accident."* - Friedrich Dürrenmatt
- Near total dependence on global flows
  - Top 20% of countries and top 20% of population in others
- Catastrophic consequences of breakdown of flows

A Wicked Problem

- Capitalism is global, but governance is local
  - WTO et al.
  - UN
  - Treaties
- No central coordinating mechanism except interacting markets
  - *"The sinful heart is ever the same, but sin changes its quality as society develops. Modern sin takes its character from the mutualism of our time. Under our present manner of living, how many of my vital interests I must entrust to others! ...But this spread-out manner of life lays snares for the weak and opens doors to the wicked. Interdependence puts us, as it were, at one another's mercy, and so ushers in a multitude of new forms of wrongdoing. ...Every new fiduciary relation is a fresh opportunity for breach of trust."*

    - E.A. Ross, 1902

Network of Networks

- In many large networks, the connectivity of the various nodes often follows a scale-free or power-law distribution.
- This feature is a consequence of two dynamics: networks tend to expand continuously and links "attach preferentially to sites that are already well connected."
- Scale-free networks are distinguished by their relative stability to random shock, though, they are highly vulnerable to deliberate exogenous attack.
- As various scale-free networks within the global system are connected, the vulnerability of the resulting network is significantly greater than that of either constituent parts observed independently.

We are interested risks resulting from the connections between and among domains

- Energy exploration and production
- Electricity transmission
- Food and water supplies
  - Agriculture (famine & crop diseases)
  - Food production & distribution
- Financial system
- Healthcare & epidemiology
- Infrastructure
- Transportation
  - Human travel
  - Shipping
- Manufacturing & production
  - Energy
  - Commodities & critical inputs

Case Study: Agriculture

- **Motivation:**
  - "We are all only three square meals away from anarchy"
  - The global agricultural system is a critical part of life as we know it.
  - Over the past century, it has become increasingly complex, interconnected, industrialized, and technologically driven.
  - These changes and increased efficiencies come at the cost of greater systemic fragility and risk, with the growing potential for catastrophic consequences.

Case Study: Agriculture

- **Goals:**
  - Use multidisciplinary approach to:
    - Examine the current state of agriculture
    - Start to identify and understand emerging risks
    - Discuss potential solutions
- **Outcome:**
  - Brought together 28 experts from around the world spanning diverse fields of study, including:
    - Economics, Sociology, Psychology
    - Soil Science, Climatology, Ecology
    - Medicine, Law, and Government
  - Hosted six panels over the course of two days with a focus on cross-discipline discussion and collaboration
  - Produced 50-page report outlining the key agricultural risks and potential mitigation strategies described by the participants

Case Study: Agriculture

- **Next Steps for Agriculture:**
  - Publish a short summary of our findings
  - Create an online resource to facilitate network visualization and data analysis
  - Perform a quantitative and visual analysis of the global agricultural system, to further understand vulnerabilities, fragilities, and key threats
  - Develop agricultural systemic risk as a case study, which could provide insight into global systemic risks in other domains:
    - Finance, water, oil and gas, global trade, etc.

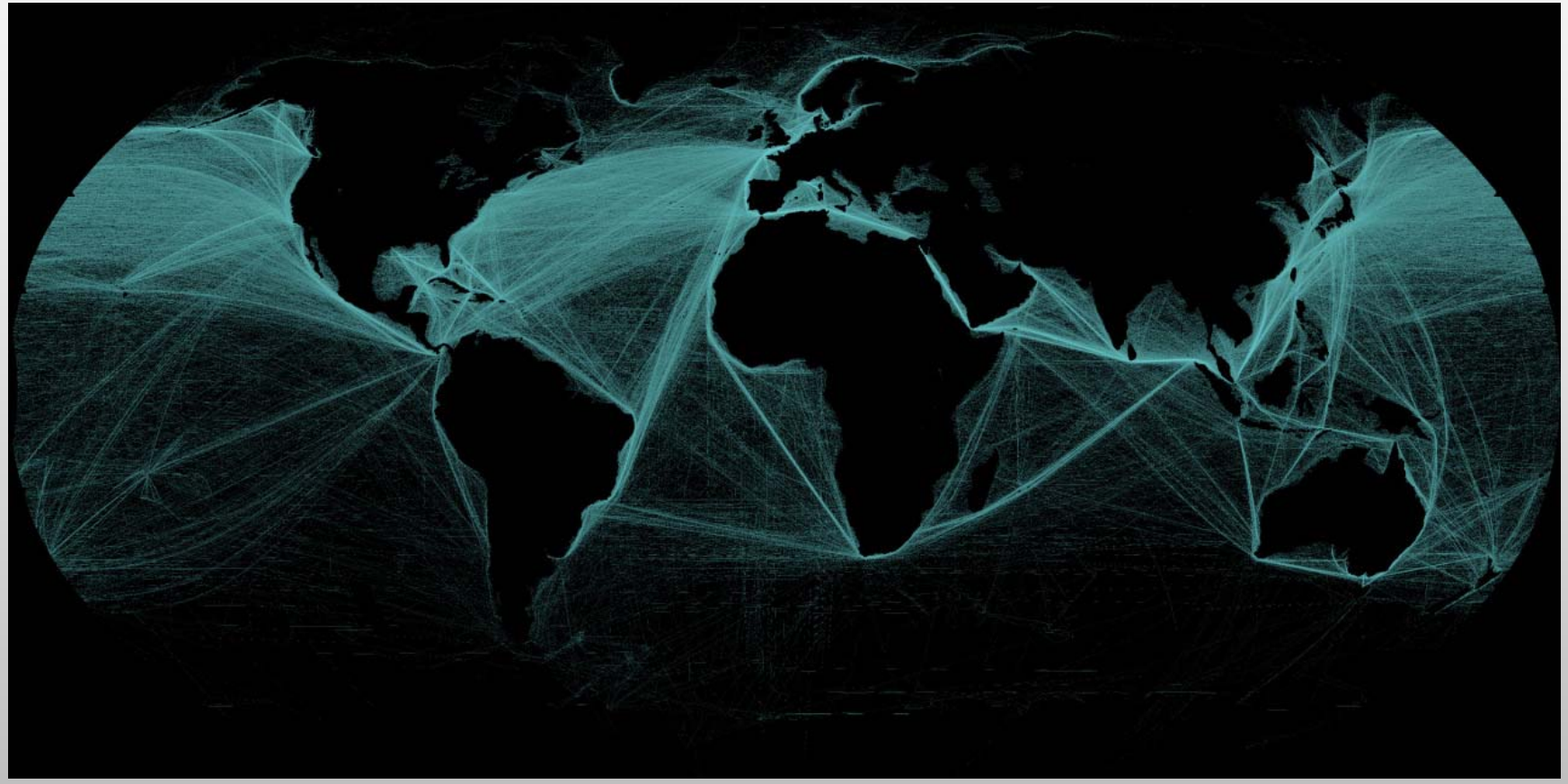
Commonalities for a Generalized Model– Structural

- Specialization of production
  - vs. subsistence & self-sufficiency
  - Comparative advantage
    - Economic history idea that specialization was the one "invention" that led to an explosion of productivity, production, wealth, standard of living, and per capita income
- Diversity of consumption
  - Individuals consume and demand a broader "basket" of goods and services
- Less on reserve, on-hand, low inventory, living at the margin
  - More efficient, tying up less capital in reserves
  - Avoid depreciation, obsolescence, spoilage of inventory
- Reliance on technology
- Interconnectedness
  - Speed of propagation, contagion, dependence
- Greater returns through efficiency, technology, and scale ⇔ Greater risk

Commonalities for a Generalized Model—Human Constraints

- Belief that tomorrow will be just like yesterday
- Hubris/confidence of knowledge and education
- Silos of information
- Selfish behavior to withdraw from network in times of risk
- Statistical benefit of diversification (zero or negative correlation) disappear when herd behavior causes the correlations to go to one
- Difficulty modeling
- Difficulty measuring and agreeing on metrics
- Moral hazard
- Malfeasance

risk.princeton.edu



Thank you