Lecture 12: Financial Disasters, Power Laws, and Econo-physics

Power laws highlight the importance of the rare hard-to-predict events: the 2008-2009 financial collapse; the surprise Brexit vote in the UK; the Louisiana Flood of 2016 from '1,000-year' rain occurring in 2 days; etc.

1)Nassim Taleb's black swans give message about what can happen if you assume life proceeds in same manner as in the past. The **turkey,** which each day is fed and well taken care of by humans … until Thanksgiving

2)IndyMac, seventh largest mortgage originator in the US until on July 11, 2008, when it collapsed

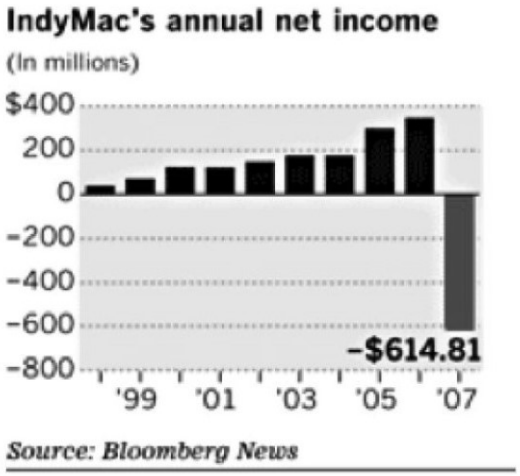


Figure 2 *The graph above shows the fate of close to 1000 financial institutions (includes busts such as FNMA, Bear Stearns, Northern Rock, Lehman Brothers, etc.). The banking system (betting AGAINST rare events) just lost > 1 Trillion dollars (so far*

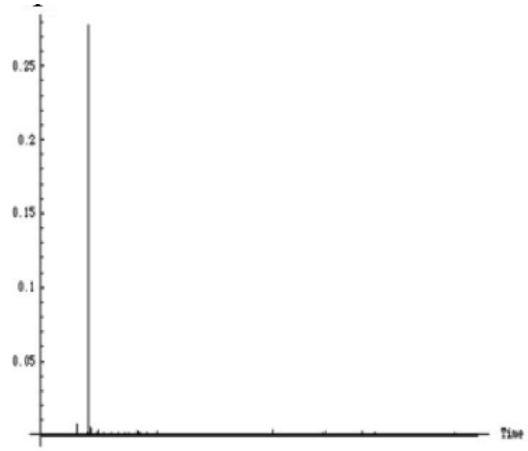


Figure 3 *The graph shows the daily variations a derivatives portfolio exposed to U.K. interest rates between 1988 and 2008. Close to 99% of the variations, over the span of 20 years, will be represented in 1 single day—the day the European Monetary System collapsed. As I show in the appendix, this is typical with*

Financial disasters top the list of discontinuous economic changes that economics should explain.* The "great moderation" in macro-economy post-world war II and belief that financial instruments that spread risk widely created efficient market stability led many specialists to support deregulation of Wall Street that preceded the 2008 financial implosion and ensuing Great Recession. And motivate current efforts to weaken Dodd-Frank restrictions designed to limit bank risk-taking. Whereas it took 70 years after 1929 Wall Street collapse before the Clinton Administration pushed the Financial Services Modernization Act through Congress in 1999, which repealed the 1933 Glass–Steagall legislation that had separated banks, just 10+ years after collapse of Wall Street, pressure is to weaken restrictions.

The Wall Street"quant"models that may have helped the market implode spawned a kick-back in the form of econo-physics work on finance instability. Failure of economists to predict/understand the forces behind the sudden collapse of the financial sector (aka discontinuous change) meant needed rescue team from physics and guess what were the key elements in the physics approach? Power laws and network science!

NATURE PHYSICS March 2013 Volume 9, No 3 pp119-197 : "**The 2008 financial crisis has highlighted major limitations in the modeling of financial and economic systems**. .. an emerging field of research at the frontiers of both physics and economics aims to provide a more fundamental understanding of economic networks, as well as practical insights for policymakers. In this Nature Physics Focus, physicists and economists consider the state-of-the-art in the **application of network science to finance**." The financial crisis has (shown) ...that **financial markets are very complex networks** that, in many cases, we do not really understand and that can easily go out of control. This idea, which would have been shocking only 5 years ago, results from a number of precise reasons.

The European Physical Journal Special Topics · December 2016 Discussion and Debate: Can Economics be a Physical Science? --20 articles with discussion of entropy, statistical mechanics, complexity, time series and extreme value (power law) statistics, search for general laws; network type models – percolation/other models of "phase transition", which directs attention at boundary conditions and changes; *agent-based modeling* with heterogeneous agents (a bit strange since physics draws strength from "electron is electron is electron") statistical mechanics per minority game.

"Econophysics will displace economics in both the universities and boardrooms." — Joe McCauley

CULTURE CRASH

Some economists had hoped that physicists might shake up the rigid theories typical of mainstream economics. But so far, they're unimpressed by physicists' handling of the markets. **Philip Ball** reports.

Still, econophysics does not impress some economists. "In my opinion, it is without influence and will continue to be without influence," says Ernst Fehr of the University of Zürich in Switzerland. Physicists apply their models to problems without grasping the details, he says. "I employed a physicist once, and I was really disappointed."

AN INTRODUCTION TO ECONOPHYSICS Correlations and Complexity in Finance Mantegna & STANLEY

1) Apply notions that physical systems of a large number of interacting particles obey scaling laws that are **independent of the microscopic details**. "Since economic systems also consist of a large number of interacting units, it is plausible that scaling theory can be applied to economics" (Stanley et al., 1996).

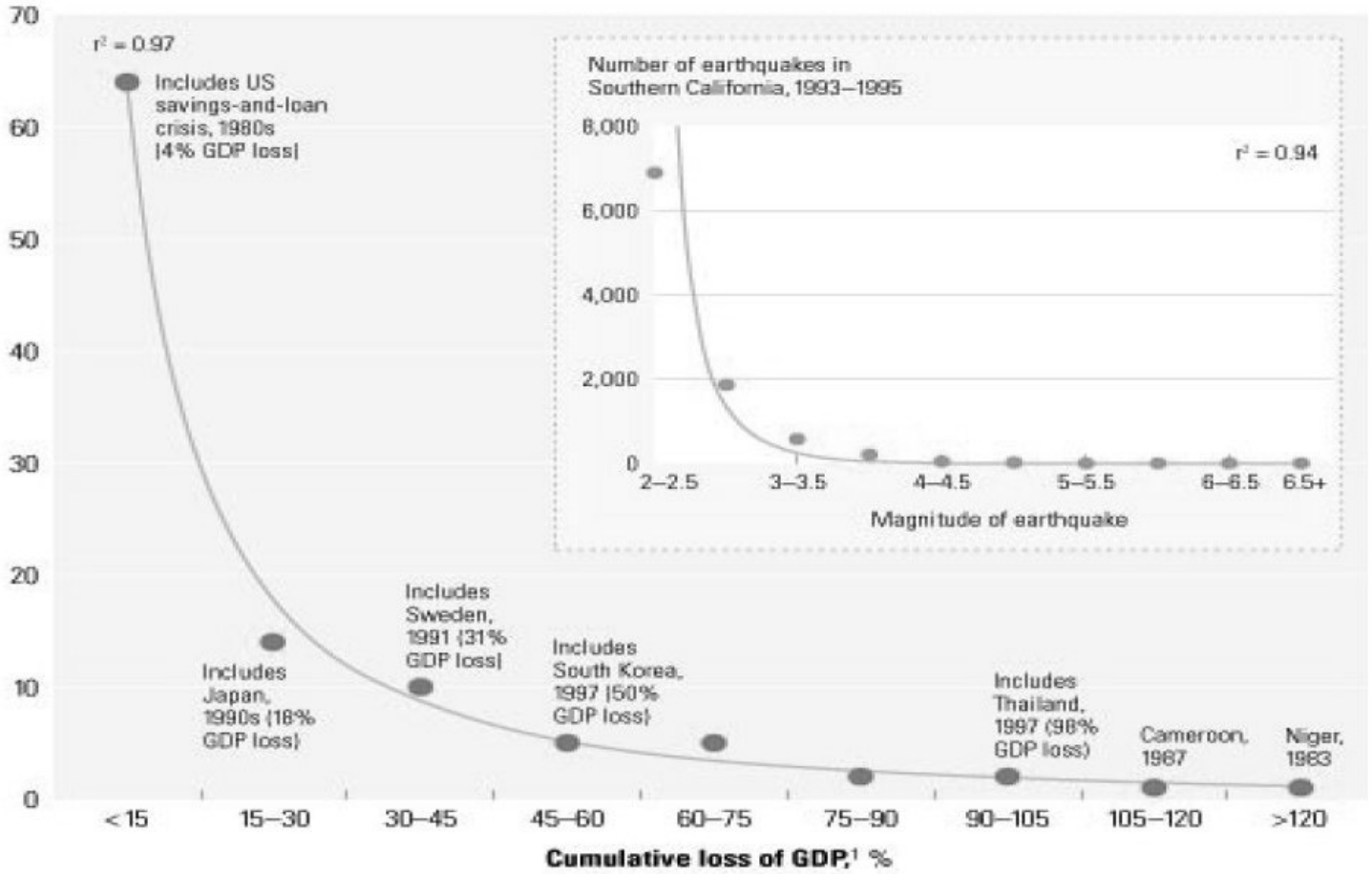
2)Attention to **out-of-equilibrium behavior** of economic system, which show up in bubbles,wide swings, contagion-type behavior, discontinuous change, compared to general equilibrium models subject to modest shocks.

3)Statistical tools that use random matrix theory, etc with data driven often descriptive analysis.

Econophysics focuses largely on financial markets which show lots of volatility and data on price variation over short periods of time and little on labor/product markets, which show greater stability and dependence on "fundamentals". Quants of Wall Street fame seek temporary statistical regularities in financial data to make money: "a highly advanced stock market mathematical work that … predicts the stock market in both price and time with incredible accuracy... Not only from a vantage point of maximizing investment returns, but also from a point of diminishing risk associated with not knowing what the stock market will do next … my forecasts resolve both of these issues.... the precision of the analysis in both price and time will truly astonish you." Hmm. BUT JUST NEED TO WORK FOR A WEEK/DAY

Power curves: banking crises compared with earthquakes

Number of worldwide banking crises, 1970–2007



r^2 is the proportion of variance explained by a regression.

[1]IMF economists computed GDP loss by extrapolating real GDP from pre-crisis trend and adding the yearly percentage difference between actual GDP and extrapolated GDP for first 4 years of crisis (for more details, see Luc Laeven and Fabian Valencia, *Systemic Banking Crises: A New Database*, IMF working paper, November 2008).

Source: International Monetary Fund (IMF); US Geological Survey; McKinsey analysis

Facts that resonate between standard economics and econophysics

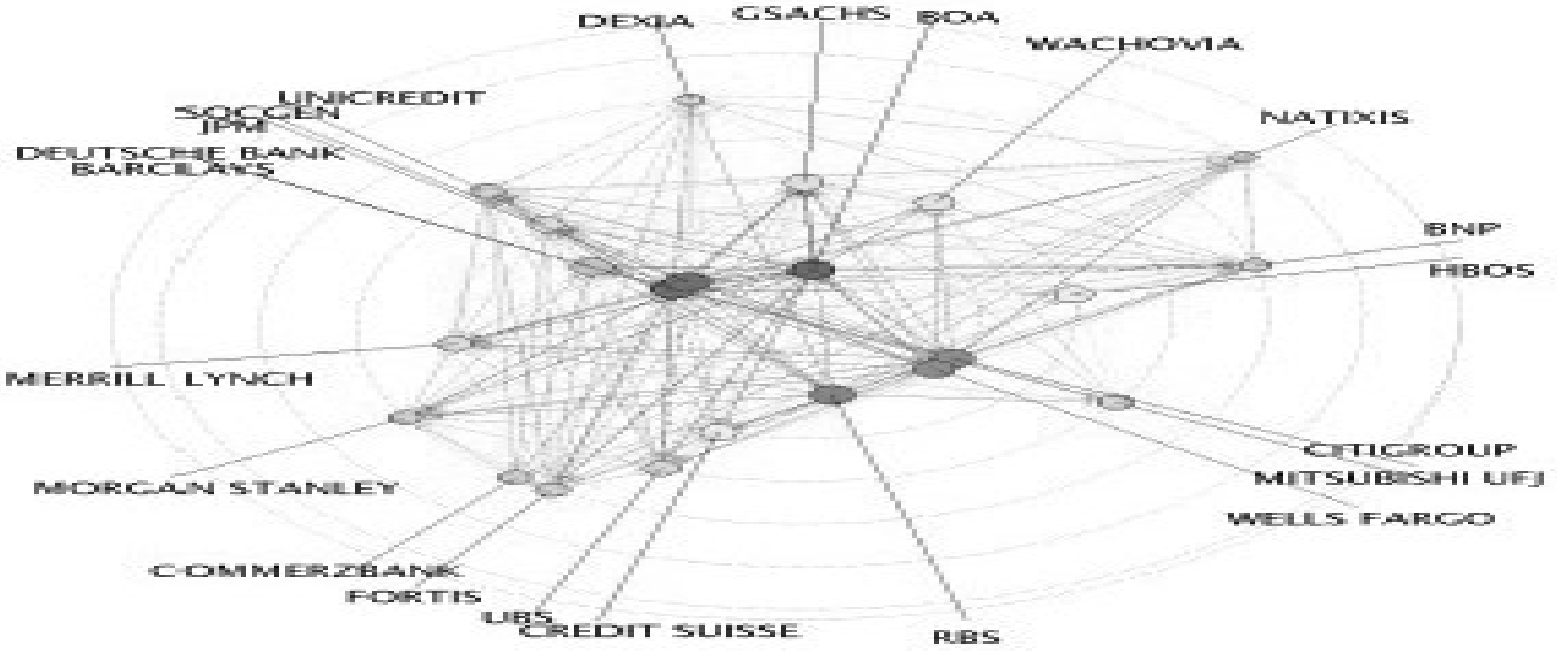
Power laws in economy and finance: (http://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/power-curves-what-natural-and-economic-disasters-have-in-common) T. Lux (2006):

1) Statistical analysis of daily returns offers overwhelming evidence for hyperbolic behavior of the tails: Pr(j rt j> x) »= x_i^{-a} .

2)Power law for large returns has a similar feature which also seems to characterize all data sets: hyperbolic decay of the auto-covariance of any measure of volatility of returns, such as absolute or squared returns . Taking absolute returns ... the second pervasive power law can be characterized *Cov*(Rt, Rt*jr*ı*r*$_{t_i}$¢*j*) » ¢t_i

3)literature has also pointed out additional power-law features of financial data. From the wealth of statistical analyses it seems that long-range dependence of trading volume is as universal as long-term dependency in volatility

Analysis of Networks: Economic/financial markets are interactions among economic agents in a dynamic system subject to outside shocks. A starting point are empirical studies to help uncover the anatomy and regularities or "empirical laws" that may govern markets. Influence of decision-makers on what others are doing, using mean-field approach in which an agent's opinion was influenced by the average opinion of all other traders



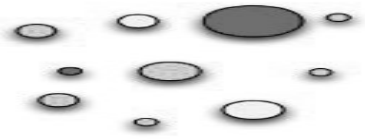
Power law distribution of # of links; Measures of centrality of nodes:

The algorithm DebtRank finds ties connecting financial institutions; projecting/ estimating global effect of bankruptcy; using network theory to help control and recover. If XX fails what is likely total $ loss to the system.

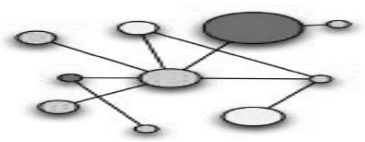
- A node is more important if it impacts on many valuable and important nodes

$$c_i = \sum_j W_{ij} v_j + \sum_j W_{ij} c_j \rightarrow c = (I - W)^{-1} Wv$$

W is impact of i on j depending on % of capital that j has invested in i.-- if i goes bad how much does j lose
v is relative economic value of j in finance – share of finance assets owned by j. This analysis measures centrality in terms of out-going flows. Equation resembles classical INPUT-OUTPUT ANALYSIS in which matrix Wij would measure fixed coefficient matrix showing how production of industry i "requires" purchases from industry j and X= $(I-W)^{-1}$ f where X is total output of sector i and f is final demand.



- Vertex Status (*too big to fail*)



- Degree (*too connected to fail*)

Model needs huge data base on transactions of banks. Analysts use "web scraping techniques and tools to estimate the macroscopic characteristics of a network as well as its resilience starting from limited information on the existing links: "based on time series of certain market indices such as the spread of credit default swaps associated to a given institution. BUT **incentives for market players to engage in an intricate web of complex derivative contracts that amplify gain and losses** and make it hard to track. So financial health of Bank A depends on the financial health of other agents in the network, which depends on … producting **highly non-linear and intrinsically unstable system with POSITIVE feedback loops**. **"**We are not yet able to model the dynamics of its components and far from being able to predict its global dynamics. One view is that derivatives, although they can be used to hedge risks, are used to take excessive risk at the expenses of society at large, raising huge moral hazard issue."

One set of analysts would like to do out of equilibrium modeling to see how the composition of the population determines stability or instability of the steady state. Quite plausible (and in line with a large body of literature in behavioral finance), a dominance of chartists with their reinforcement of price changes will be destabilizing. Bifurcation analysis could identify a threshold for the number of chartists at which the system becomes unstable.

Problems with Data To overcome confidentiality that monopoly type business seeks to protect so that can act as discriminating monopolist with derivatives/swaps etc with different players, financial entities need asymmetric information and thus wants to keep their financial contracts undisclosed. This prevents the regulator from assessing precisely the systemic risk, which depends critically on the overall structure of the network.

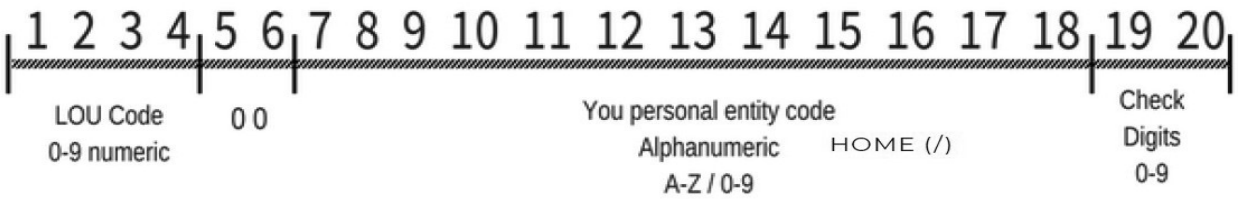
The original FED dataset consists of 30 thousands pdf pages. Each entry reports the name of the borrowing institution, the credit channel used for financing, the origination date and the maturity date of each loan.

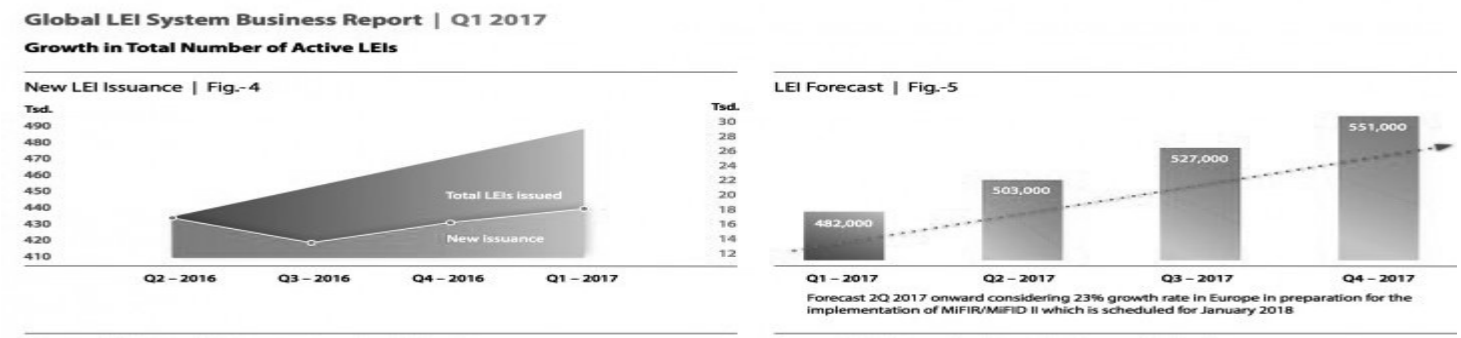
Bloomberg data

Bloomberg analysed the FED dataset releasing a set of excel files on Dec 23, 2011. Data consists of a set of 407 daily timeseries' of outstanding debt and market capitalizations.

To the rescue? **LEGAL ENTITY IDENTIFIERS (LEI) – BAR CODES:** a unique ID associated with a single corporate entity. Lack of a standard id system for financial counter-parties makes it difficult for financial firms to develop an integrated view of their exposures, such as in the case of default of counterparty. This is a challenge for firms and for regulators to aggregate and share information to effectively monitor risks. (SIFMA). US Treasury OFR; Regulatory Oversight Committee of over 70 public authorities from 40+ countries **established in January 2013** to coordinate and oversee a worldwide framework of legal entity identification, the Global LEI System.

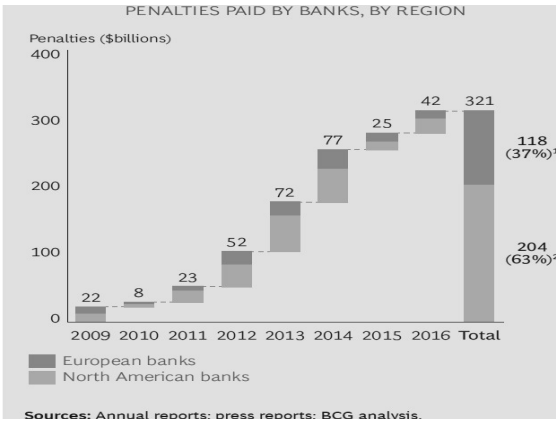
The Global LEI system is based on the ISO 17442 standard, and was created in response to the Global Financial Crisis, whereby the leaders of the World's top 20 largest economies, the G20, endorsed the LEI system. The LEI is a 20 digit numerical code assigned to each Legal Entity in order to bring about some transparency by linking parties to financial transactions and increasing visibility in the global financial data systems.

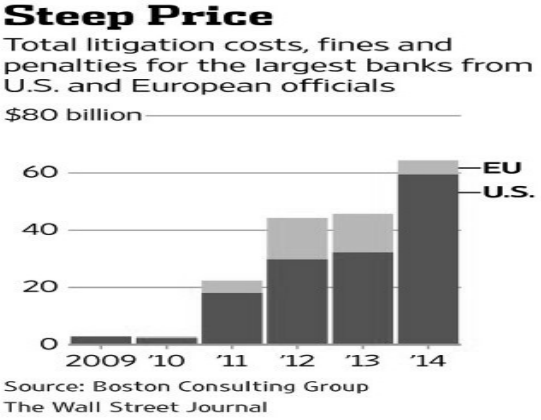




Meanwhile in the back rooms, crime/near crime – Missing in the econophysics networks and financial economists models: bankers as individuals who make decisions and who commit crimes/near crimes for huge sums.

World's Biggest Banks Fined $321 Billion Since Financial Crisis





A power law in fines, led by BOFA, $77B, JP Morgan Chase, $40B, Citigroup, $18B, ...

And it goes on:

2019's largest regulatory fines

Written by FinTech Futures (https://www.fintechfutures.com/author/bankingtechnology/) 25th December 2019

Regulation and the consequences of non-compliance are ever on the agenda at the world's biggest banks. Unfortunately, that doesn't mean they can't fall foul of them. Here are the biggest fines from 2019:

Standard Chartered fined $1.1bn for AML and sanctions breach (https://www.fintechfutures.com/2019/04/standard-chartered-fined-1-1bn-for-bad-aml-and-sanctions-breach/)

Standard Chartered braced itself in its 2019 projections for a hefty regulatory fine it received in April.

European Commission fines Mastercard €570m for anti-competitive antics (https://www.fintechfutures.com/2019/01/ec-fines-mastercard-e570m-for-anti-competitive-antics/)

MasterCard was charged with limiting the payment options of card users in Europe.


Regulators have been busy in 2019

Five banks fined €1bn for rigging foreign exchange market (https://www.fintechfutures.com/2019/05/five-banks-fined-e1bn-for-rigging-foreign-exchange-market/)

Dodd-Frank Wall Street Reform and Consumer Protection Act established several new whistleblower protections for individuals in the financial services industry. Amendments prohibit employers from discharging or otherwise discriminating against an individual for providing information related to a violation of finance/security laws to the Commodity Futures Trading Commission or Securities and Exchange Commission or initiating, testifying in, or assisting in any investigation or judicial or administrative action of the agencies.

EU set up Forecasting Financial Crisis – set of universities/institutions **http://www.focproject.eu/** published econophysics stuffs 2010-2014 but has since gone quiescent.

Soros money founded **INET** in 2009 to shake up standard economics. Supports mixture of econophysics types, "radical economists" etc. Has it had much effect?

COULD BLOCK CHAIN TECHNOLOGY – DIGITAL LEDGERS – SAVE THE DAY? "Blockchain offers a drastically new way to record, process, and store financial transactions and information, and has the potential to

fundamentally change the landscape of the accounting profession and reshape the business ecosystem." But will the risk-takers or criminals mutate to overcome seemingly safe system?

Two assessments of the Econophysics/Finance Economics "debate"

What has econophysics achieved?

Mark Buchanan (2013):" application of ideas and concepts from physics to finance and economics tends to be quite controversial. Many economists seem to find it annoying. Annoying/useless OR replacement of economics OR Healthy hybrid? Lots of interesting issues linked to economics analysis: Power laws – Pareto income distribution; Arthurs' Sante Fe El Farol Bar//Minority game model; Contagion – Schelling model - cellular automata.

But greater stress on role of leverage beyond a threshold in creating instability. "This boundary of instability is not at all obvious to market participants or made evident by standard economic theories." Developed models in which too much risk sharing in a network of institutions can decrease overall stability. An over connected network makes it too easy for trouble originating in one place to spread elsewhere. Develop Debt-rank to measure this risk.

Ausloos, Jovanovic, Schinckus (2017) On the "usual" misunderstandings between econophysics and finance: Some clarifications on modeling approaches and efficient market hypothesis

But many economists view is annoyance, with some parts of economics oversimplified or misunderstood.

Complaints about econophysics criticisms that non-Gaussian → reject efficient market hypothesis are wrong on grounds that EMH and random character of stock markets are two different elements: the Gaussian dimension of data is neither necessary nor sufficient condition for having EMH. In a market free of arbitrage the stochastic price process for financial assets must have at least one martingale measure.

My view: Helped establish facts about financial markets – such as that probability of large market returns decreases in accordance with an inverse cubic power law in many diverse market. Mandelbrot found evidence for fat tailed distributions in 1960s. But physicists make our knowledge of these regularities more precise. Direct attention at **extreme Tail Events.**

The heavy tail of power distributions shows up in the **moments** of the distribution. Assume Y (frequency) = S^{-a} so ln Y = C -a ln S. **Larger (a)s mean less weight at tail events and more "normal" statistics.**

When a < 3 the 2nd moment does not exist – need a> 3 to get a finite variance as n → infinity because only large drop in frequency can overwhelm the continual addition of squared terms in variance to come to finite value.

When a < 2 the first moment – the mean – also does not exist – need a>2 to overwhelm the continual addition of terms to the mean. Why does a<2 not have a mean? (S^{-a}) $S = S^{1-a}$ If a = 2 get harmonic series ($\sum 1/S$, which diverges. If a = 1 get $\sum 1$, which is infinite. But infinite variance means high sensitivity of empirical variance to presence/absence of a small number of big events. Most studies find a to be between 2 and 3, but with large SD.

You may calculate those statistics with finite data and will get a finite mean as $\sum X/N$ or finite variance from $\sum(X\text{-Mean } X)^2 /N$ – but true variance is infinite.

Small diff in a has huge impact on the probability of an extreme outcome; variation of estimates in alpha

c	$P(X > c)$		
	Normal	Cauchy	Lévy
0	0.5000	0.5000	1.0000
1	0.1587	0.2500	0.6827
2	0.0228	0.1476	0.5205
3	0.001347	0.1024	0.4363
4	0.00003167	0.0780	0.3829
5	0.0000002866	0.0628	0.3453

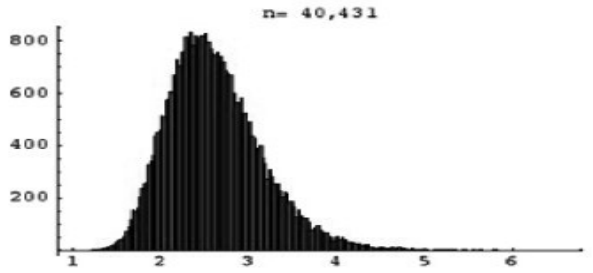


Figure 5—*Estimation error in "alpha" from 40 thousand economic variables. I thank Pallop Angsupun for data.*

Consider the Pareto distribution. If 0< k < 2 –> infinite variance and if 0 < k < 1, get infinite mean (You can do calculus or see http://en.wikipedia.org/wiki/Pareto_distribution.) But in power law form a=k+1, where a is the power law coefficient, translates into if 1 < a < 3, second moment is infinite and if 1 < a < 2, first moment is infinite.

Also identified analogies between markets and natural phenomena – Following large market crash, markets show lingering activity which follows famous Omori law for earthquake aftershocks (events less likely in inverse

proportion to the time after main shock), indicating that market dynamics may well not depend on facts specific to finance and economics but to **more general dynamical principles.**

Helped move analysis (i) representative agent to heterogeneous agent systems; (ii) full rationality to bounded rationality; and (iii) from analytic to more computational approach.

Revealed that Markets work fairly smoothly if participants act using many diverse strategies, but breakdown if many traders chase few opportunities and use similar strategies to do so.

This classical opposition between econophysics and financial economics cannot be reduced to empirical science vs. normative science or micro vs. macro perspectives. "econophysicists and financial economists use a quite similar approach for analysing financial markets"... their approaches appear to be different because these scientists are trained in "different schools" with different aims/vocabularies.:

Suggested papers: How connected are these two schools of thought, as measured by collaborations or citations? Are they separate networks with few links? Who are links?

Why has banking recovered so well despite $321B in fines?

How would central bankers use LEIs?

Analyze papers/citations from FOC or INET supported articles to measure their impact.

POWER LAWS FOR NATURAL DISASTERS

- **Famines and other disasters outside of finance also occur in sudden bursts.**
-
- EM-DAT International Disaster Database by the Center for Research on Epidemiology of Disasters in Belgium contains data on the occurrence and effects of over **22,000 mass disasters** in the world from **1900 to the present day.** The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies. httpw://ww.emdat.be/

The Annals of Applied Statistics
2014, Vol. 8, No. 3, 1612–1639
DOI: 10.1214/14-AOAS743

POWER-LAW MODELS FOR INFECTIOUS DISEASE SPREAD[1]

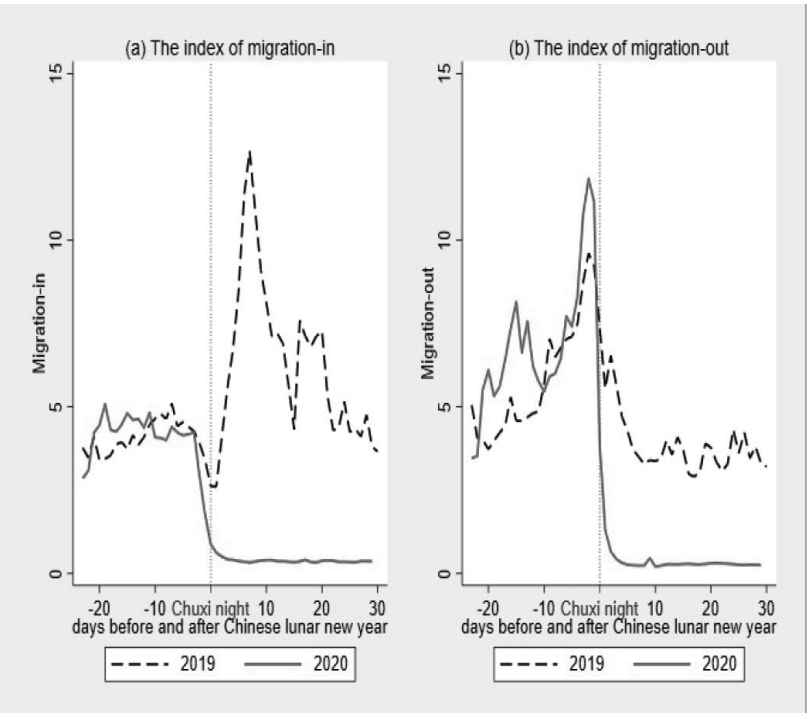
BY SEBASTIAN MEYER AND LEONHARD HELD

TABLE 5

Long-term predictive performance of 5 competing models in the temporal and spatial dimensions measured by mean DSS and RPS for the 2008 wave of influenza

Model	Time		Space		Space–time	
	DSS	RPS	DSS	RPS	DSS	RPS
Endemic only	27.03	149.77	7.85	15.39	2.91	1.31
Endemic + autoregressive	31.36	112.15	7.59	15.04	2.58	1.26
First order	26.46	108.61	7.51	15.63	2.50	1.26
Power law	16.41	110.20	7.36	14.75	2.29	1.25
Power law + population	15.49	111.86	7.24	14.30	2.29	1.24

Current Efforts to Analyze Coronavirus Spread – Some focus on mobility patterns



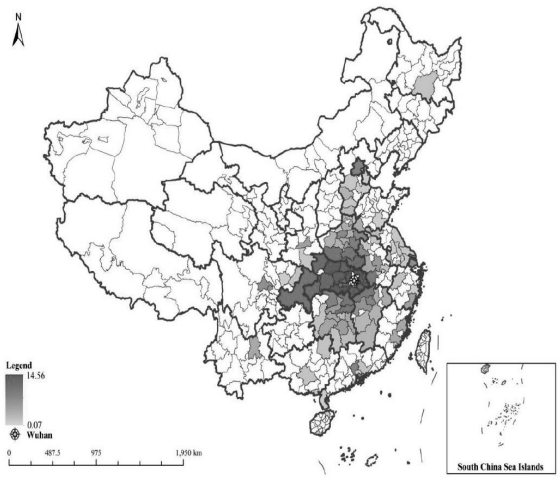


Figure 3. Top 100 destinations for migrants from Wuhan

From Scientific American February 13, 2020

Here's How Computer Models Simulate the Future Spread of New Coronaviru

Using international flight data—without figuring in person-to-person transmission—to predict which airports represent the highest-risk gateways for the coronavirus to spread worldwide. "This risk predicts the expected sequence of countries you would find cases in," Brockmann explains. "The way it unfolded is very much in line with what the mobility model predicted."Flight data can come from official aviation databases, making them fairly reliable, but they do not involve people's movements on the ground.

For that information, rAlessandro Vespignani, a physicist and director of the Laboratory for the Modeling of Biological and Socio-technical Systems at Northeastern University, leads a team that is simulating the novel coronavirus's spread using official air-travel data and predicted commuting patterns among census populations.

Another recent effort to estimate how the coronavirus is spreading—both inside China and internationally—also incorporates individual mobility data from both flights and ground-travel patterns during the period of the Lunar New Year holiday—which fell on January 25 this year—when the outbreak was picking up steam. In a paper published in the Lancet on January 31, Hong Kong–based researchers estimated this year's holiday travel patterns by using information from the 2019 Lunar New Year travels of millions of people who used the WeChat app and other services owned by Chinese tech giant Tencent. Unlike the purely travel-focused models, however, this study also included person-to-person transmission estimates, along with travel patterns based on both official flight data and Tencent's individual mobility data. Its results suggest COVID-19 had already taken root in many major Chinese cities as of January 25 and that those cities' international airports helped spread the virus internationally.

The Hong Kong researchers estimated that China's quarantine of Wuhan, which started on January 23, was limited in the difference it made because the disease had probably already spread to other cities in the nation. Still, the authors did recommend that "draconian measures that limit population mobility should be seriously and immediately considered in affected areas." Public health experts seem uncertain about the effectiveness of such travel restrictions within and between cities. Other studies of past outbreaks suggest that harsh constraints on movement have only limited effects in delaying the international spread of diseases.