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Inevitable Inequality

Prof. Anirban Chakraborti

Talk title inspiration

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RESEARCH PUBLICATION

Vulnerability and Inevitable Inequality

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ABSTRACT
The abstract legal subject of liberal Western democracies fails to reflect the fundamental reality of the human condition, which is vulnerability. While it is universal and constant, vulnerability is manifested differently in individuals, often resulting in significant differences in position and circumstance. In spite of such differences, political theory positions equality as the foundation for law and policy, and privileges autonomy, independence and self-sufficiency. This article traces the origins and development of a critical legal theory that brings human vulnerability to the fore in assessing individual and state responsibility and redefining the parameters of social justice. The theory arose in the context of struggling with the limitations of equality in situations I will refer to as examples of 'inescapable' inequality. Some paired social relationships, such as parent/child or employer/employee are inherently, even desirably, unequal relationships. In recognition of that fact, the law creates different levels of responsibility, accepting disparate levels of authority, privilege and power. Those laws, and the norms and rules they reflect, must carefully define the limits of those relationships, while also being attentive to how the social institutions in which they exist and operate (i.e. the family and the marketplace) are structured and functioning.

Credit: Hanna Barczyk

Is Inequality Inevitable?

Wealth naturally trickles up in free-market economies, model suggests

By Bruce M. Boghosian

AUTHOR

Bruce M. Boghosian is a professor of mathematics at Tufts University, with research interests in applied dynamical systems and applied probability theory. *Credit: Nick Higgins*

IN BRIEF

- **Wealth inequality is escalating in many countries** at an alarming rate, with the U.S. arguably having the highest inequality in the developed world.
- **A remarkably simple model of wealth distribution** developed by physicists and mathematicians can reproduce inequality in a range of countries with unprecedented accuracy.
- **Surprisingly, several mathematical models of free-market** economies display features of complex macroscopic physical systems such as ferromagnets, including phase transitions, symmetry breaking and duality.

Acknowledgements

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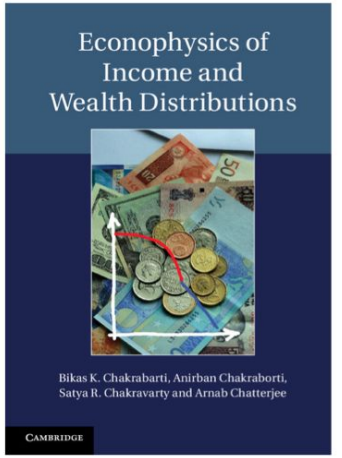
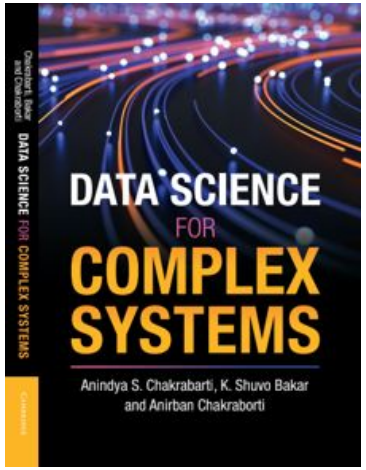
Hrishidev, JNU

My background

- Saha Institute of Nuclear Physics (Jadavpur University), India (1998-2002)
- Aalto University (erstwhile Helsinki University of Technology), Finland (2002-2003)
- Brookhaven National Laboratory, USA (2003-2005)
- Banaras Hindu University, India (2005-2008)
- CentraleSupélec, Université Paris-Saclay, France (2009-2014)
- Jawaharlal Nehru University, India (2014-)
- BML Munjal University, India (2021-)





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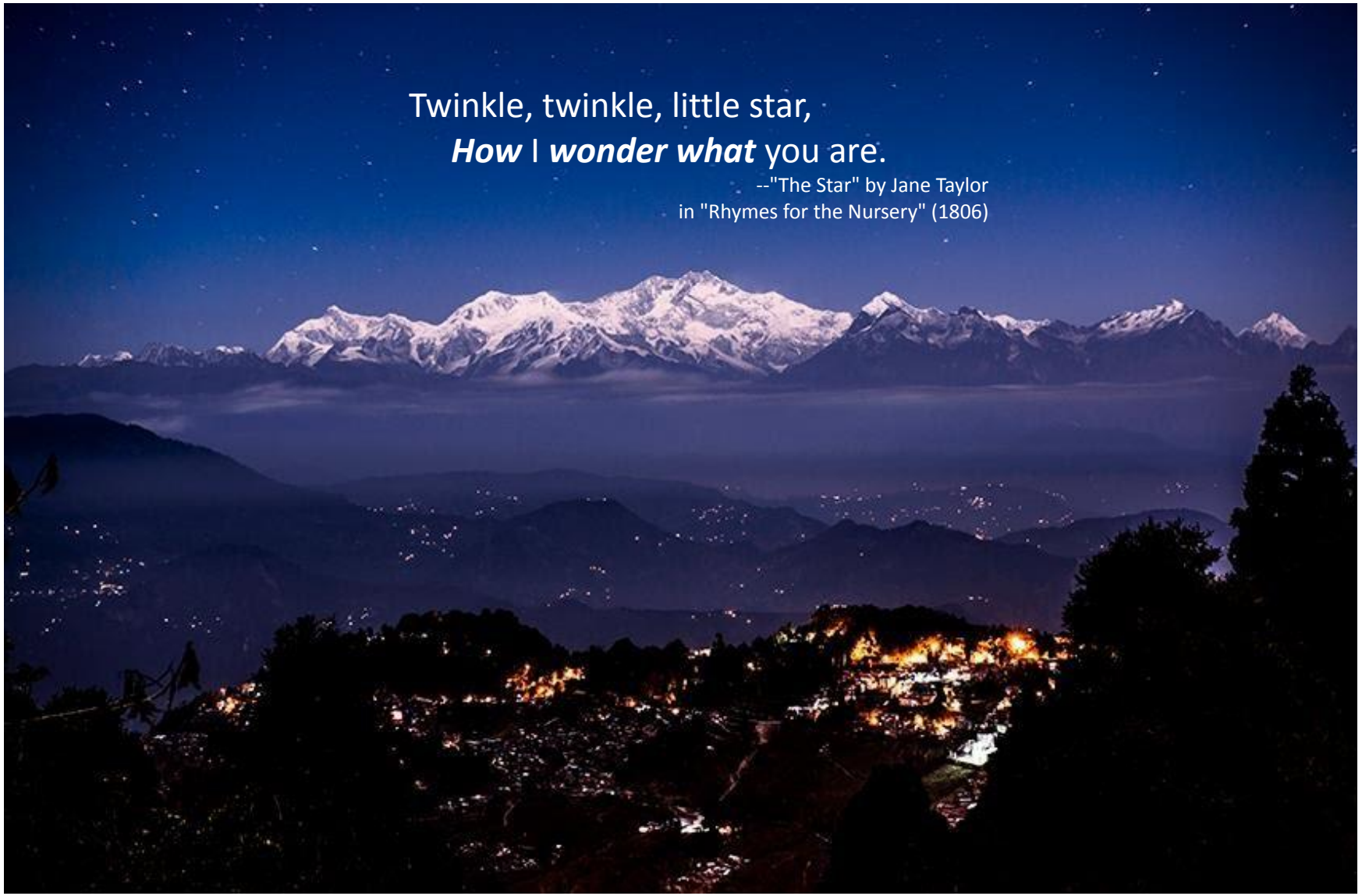
Anirban Chakraborti is a Professor at the School of Computational and Integrative Sciences, Jawaharlal Nehru University, New Delhi. Earlier, he had worked as an Associate Professor at the Chair of Quantitative Finance, École Centrale Paris, France, and as a Lecturer in Theoretical Physics, Banaras Hindu University, Varanasi. He obtained a Ph.D. in Physics from Saha Institute of Nuclear Physics, India and later completed the Habilitation (HDR) in Physics from Université Pierre et Marie Curie (Paris VI), France. He has more than two decades of experience as a scientist, working in many reputed universities and research institutions in India, Europe, Japan, and USA. He was awarded the prestigious Young Scientist Medal of the Indian National Science Academy in 2009. His scholarly works include several books, edited volumes, book chapters and research articles, which have received international acclaim. His main research interests lie in the areas of Econophysics, Sociophysics, Data Science, Complex Systems, Statistical Physics, Quantum Physics and Nanomaterial Science.

https://jgu.edu.in/jsgp/ceasp

Complexity Economics & Applied Spirituality

"I used to think that top environmental problems were biodiversity loss, ecosystem collapse and climate change. I thought that thirty years of good science could address these problems. I was wrong. The top environmental problems are selfishness, greed and apathy, and to deal with these we need a cultural and spiritual transformation. And we scientists don't know how to do that."

James Gustave Speth, a US advisor on climate change


Twinkle, twinkle, little star,
How I wonder what you are.
--"The Star" by Jane Taylor
in "Rhymes for the Nursery" (1806)

Complexity Science & Data Science

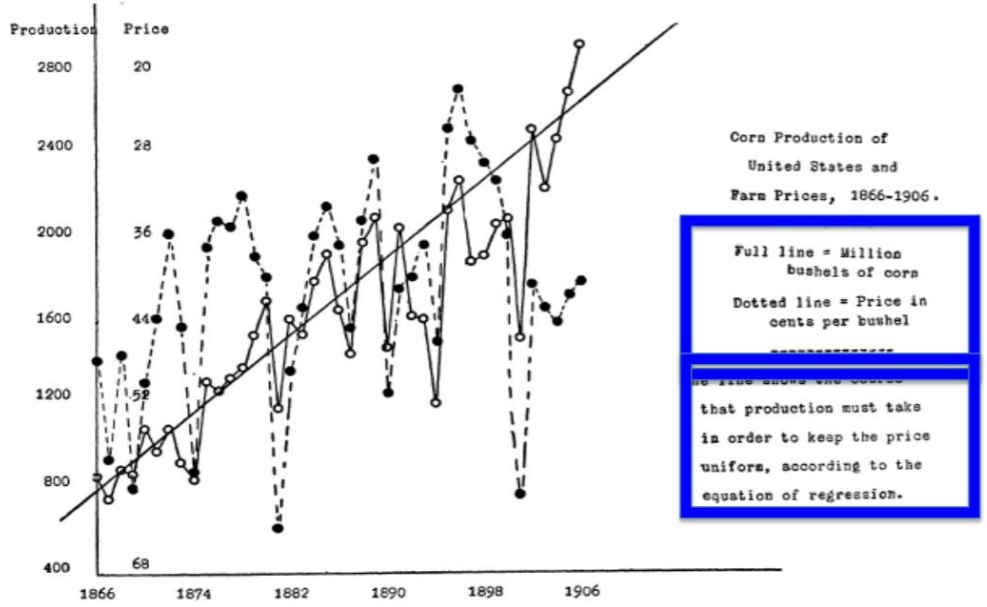
Forecasting based on Data

AMERICAN
STATISTICAL ASSOCIATION.

NEW SERIES, No. 92. DECEMBER, 1910.

THE CORRELATION OF ECONOMIC STATISTICS.

By Warren M. Persons, *Assistant Professor of Economics, Dartmouth College.*



Corn Production of United States and Farm Prices, 1866-1906.

Full line = Million bushels of corn

Dotted line = Price in cents per bushel

[redacted] that production must take in order to keep the price uniform, according to the equation of regression.

The importance of business forecasting

Methods of Business Forecasting based on Fundamental Statistics

James H. Brookmire

The American Economic Review, Vol. 3, No. 1 (Mar., **1913**), pp. 43-58

Stable URL:
http://www.jstor.org/stable/1828258

METHODS OF BUSINESS FORECASTING BASED ON FUNDAMENTAL STATISTICS

A business man succeeds or fails in proportion to his ability to forecast the future trend of the influences determining the relation of supply and demand in his business. Some of these influences are technical and concern his particular business without affecting other lines; others are of a general nature and affect all lines of business definitely and vitally.

1913 composite chart of fundamentals

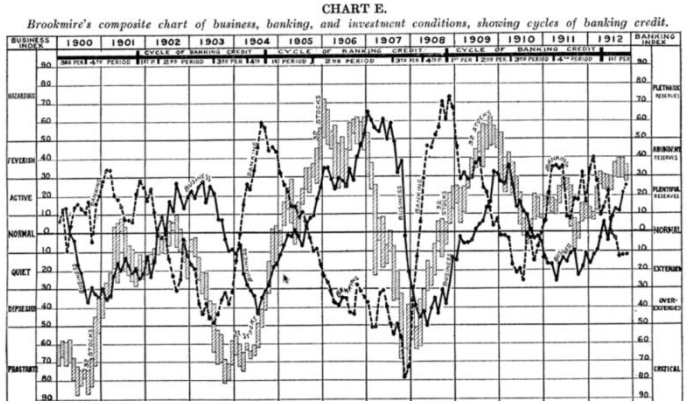
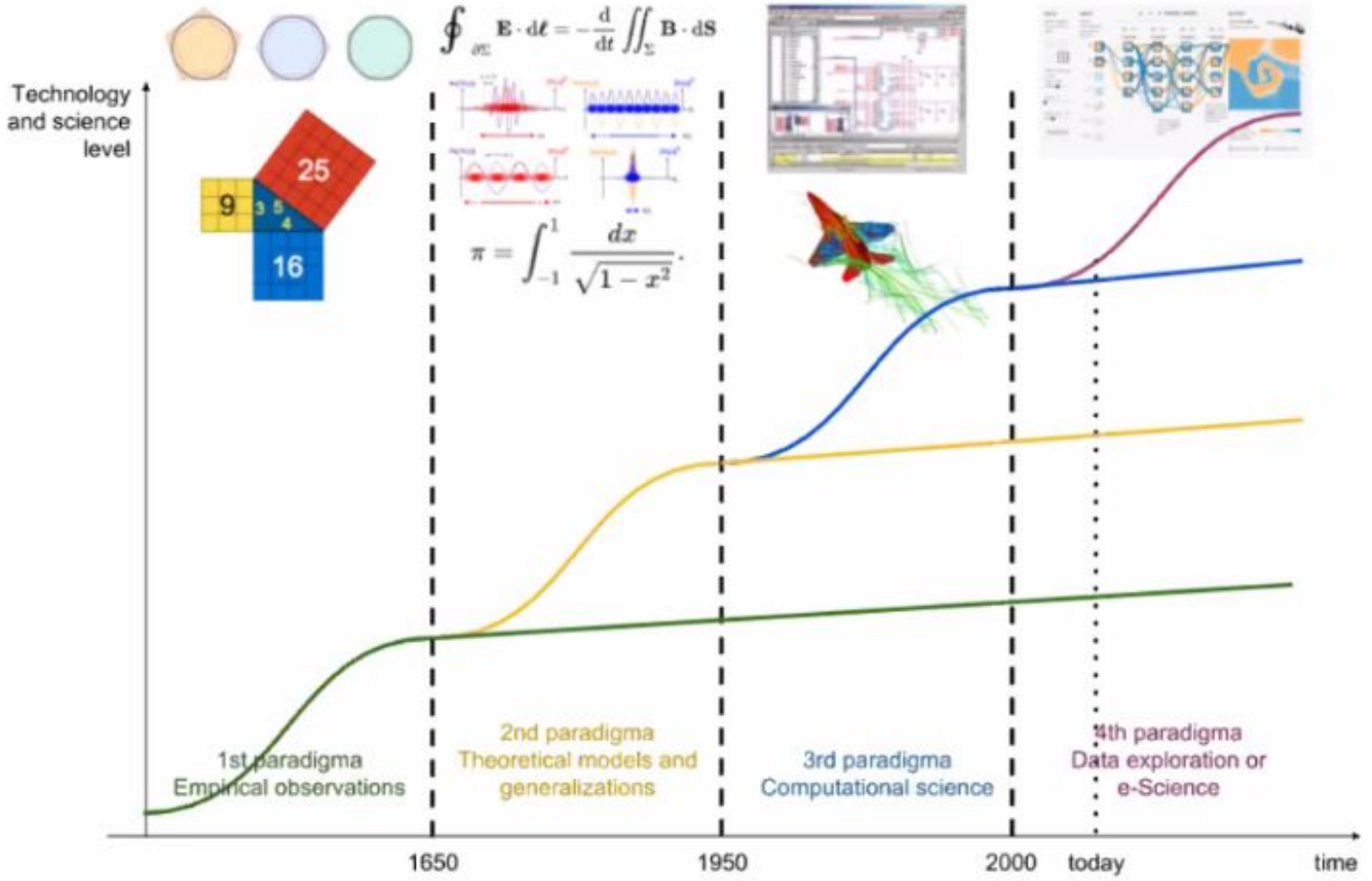


CHART E.

Brookmire's composite chart of business, banking, and investment conditions, showing cycles of banking credit.

Courtesy: Katherine Ensor, Rice University

The four paradigms of science: empirical, theoretical, computational, and data-driven



"Perhaps the right way to move is to understand before one predicts"

-- Herbert A. Simon, Nobel Laureate in Economics

(https://www.ubs.com/microsites/nobel-perspectives/en/laureates/herbert-simon.html)

Caveat

"Remember, the other team is counting on Big Data insights based on previous games. So, kick the ball with your other foot."

New or *alternate* approaches are required for **complex *adaptive* systems**!

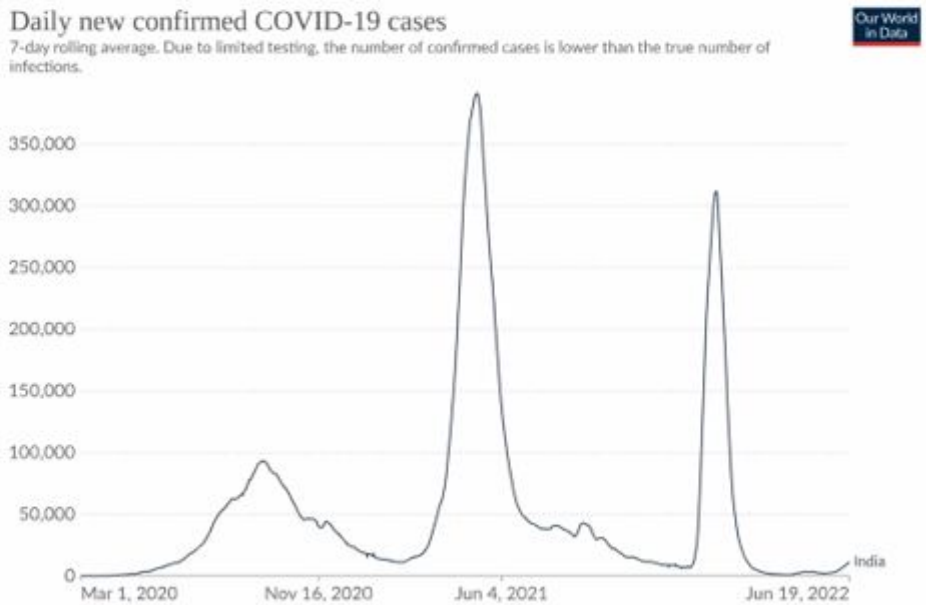
Bridge DATA and SCIENCE!

Complex “wicked” problem: Covid-19 pandemic

First case reported in December 2019 from Wuhan, China.
In India, first few cases started in February, 2020.

Total number cases : 4.33 crores (worldwide : 53.8 crores)

Deaths : 5.24 lakhs (worldwide : 63.2 lakhs)



Courtesy: MS Santhanam, IISER Pune

Pandemic during 2020-2021

bbc.com/news/business-52236936

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Coronavirus: Worst ecor
1930s depression, IMF s

9 April 2020

Coronavirus pandemic

Three-quarters of the world's workers have seen their place of
pandemic, the UN says

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The Damage We're Not Attending To

Scientists who study complex systems offer solutions to the pandemic.

BY DAVID KRAKAUER & GEOFFREY WEST
JULY 8, 2020

ADD A COMMENT FACEBOOK TWITTER EMAIL SHARING

World War II bomber planes returned from their missions riddled with bullet holes. The first response was, not surprisingly, to add armor to those areas most heavily damaged. However, the statistician Abraham Wald made what seemed like the counterintuitive recommendation to add armor to those parts with *no* damage. Wald had uniquely understood that the planes that had been shot where no bullet holes were seen were the planes that never made it back. That's, of course, where the real problem was. Armor was added to the seemingly undamaged places, and losses decreased dramatically.

ISSUE 087
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EXPLORE THIS ISSUE

CHAPTER ONE
UNCERTAINTY

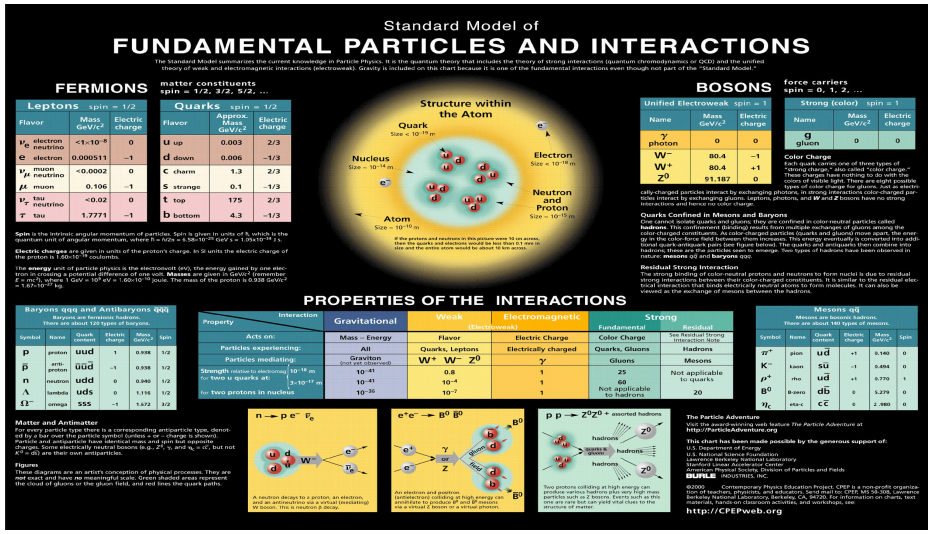
Reductionism in Science

- Reductionism can either mean
  - (a) an approach to understand the nature of complex things by reducing them to the interactions of their parts, or to simpler or more fundamental things or
  - (b) a philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts of individual constituents.

- Reductionist thinking and methods are the basis for many of the well-developed areas of modern science, including much of physics, chemistry and cell biology.

- Q: What is matter made up of?
- A: Elementary particles

- How do they interact with each other? Or what are the Forces between these elementary particles?



Limitations of Reductionism in Science

- Nobel laureate P.W. Anderson in his famous paper in Science in 1972, "*More is different*" exposed some of the limitations of reductionism:
  - The sciences can be arranged roughly linearly in a hierarchy as particle physics, many body physics, chemistry, molecular biology, cellular biology, ..., physiology, psychology and social sciences.
  - The elementary entities of one science obeys the laws of the science that precedes it in the above hierarchy. But, this does not imply that one science is just an applied version of the science that precedes it.
  - "At each stage, entirely new laws, concepts and generalizations are necessary, requiring inspiration and creativity to just as great a degree as in the previous one. Psychology is not applied biology nor is biology applied chemistry."

4 August 1972, Volume 177, Number 4047 SCIENCE

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted without question. The workings of our minds and bodies, and of all the animate or inanimate matter of which we have any detailed knowledge, are assumed to be controlled by the same set of fundamental laws, which except under certain extreme conditions we feel we know pretty well.

It seems inevitable to go on uncritically to what appears at first sight to be an obvious corollary of reductionism: that if everything obeys the same fundamental laws, then the only scientists who are studying anything really fundamental are those who are working on those laws. In practice, that amounts to some astrophysicists, some elementary particle physicists, some logicians and other mathematicians, and few others. This point of view, which it is the main purpose of this article to oppose, is expressed in a rather well-known passage by Weisskopf (*1*):

Looking at the development of science in the Twentieth Century one can distinguish two trends, which I will call "intensive" and "extensive" research, lacking a better terminology. In short: intensive research goes for the fundamental laws, extensive research goes for the explanation of phenomena in terms of known fundamental laws. As always, distinctions of this kind are not unambiguous, but they are clear in most cases. Solid state physics, plasma physics, and perhaps also biology are extensive. High energy physics and a good part of nuclear physics are intensive. There is always much less intensive research going on than extensive. Once new fundamental laws are discovered, a large and ever increasing activity begins in order to apply the discoveries to hitherto unexplained phenomena. Thus, there are two dimensions to basic research. The frontier of science extends all along a long line from the newest and most modern intensive research, over the extensive research recently spawned by the intensive research of yesterday, to the broad and well developed web of extensive research activities based on intensive research of past decades.

The effectiveness of this message may be indicated by the fact that I heard it quoted recently by a leader in the field of materials science, who urged the participants at a meeting dedicated to "fundamental problems in condensed matter physics" to accept that there were few or no such problems and that nothing was left but extensive science, which he seemed to equate with device engineering.

The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe. In fact, the more the elementary particle physicists tell us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science, much less to those of society.

The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other. That is, it seems to me that one may array the sciences roughly linearly in a hierarchy, according to the idea: The elementary entities of science X obey the laws of science Y.

X	Y
solid state or many-body physics	elementary particle physics
chemistry	many-body physics
molecular biology	chemistry
cell biology	molecular biology
.	.
.	.
.	.
psychology	physiology
social sciences	psychology

But this hierarchy does not imply that science X is "just applied Y." At each stage entirely new laws, concepts, and generalizations are necessary, requiring inspiration and creativity to just as great a degree as in the previous one. Psychology is not applied biology, nor is biology applied chemistry.

In my own field of many-body physics, we are, perhaps, closer to our fundamental, intensive underpinnings than in any other science in which nontrivial complexities occur, and as a result we have begun to formulate a general theory of just how this shift from quantitative to qualitative differentiation takes place. This formulation, called the theory of "broken symmetry," may be of help in making more generally clear the breakdown of the constructionist converse of reductionism. I will give an elementary and incomplete explanation of these ideas, and then go on to some more general speculative comments about analogies at

The author is a member of the technical staff of the Bell Telephone Laboratories, Murray Hill, New Jersey 07974, and visiting professor of theoretical physics at Cavendish Laboratory, Cambridge, England. This article is an expanded version of a Regents' Lecture given in 1967 at the University of California, La Jolla.

4 AUGUST 1972

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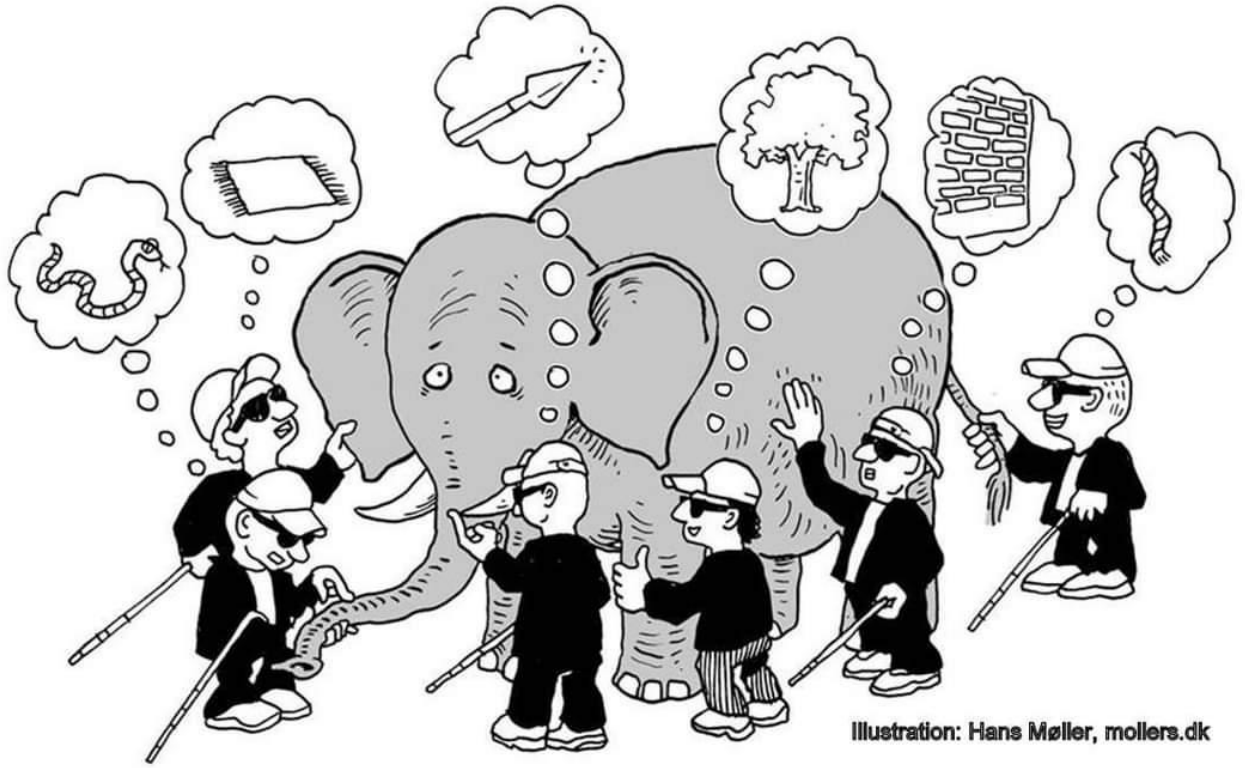
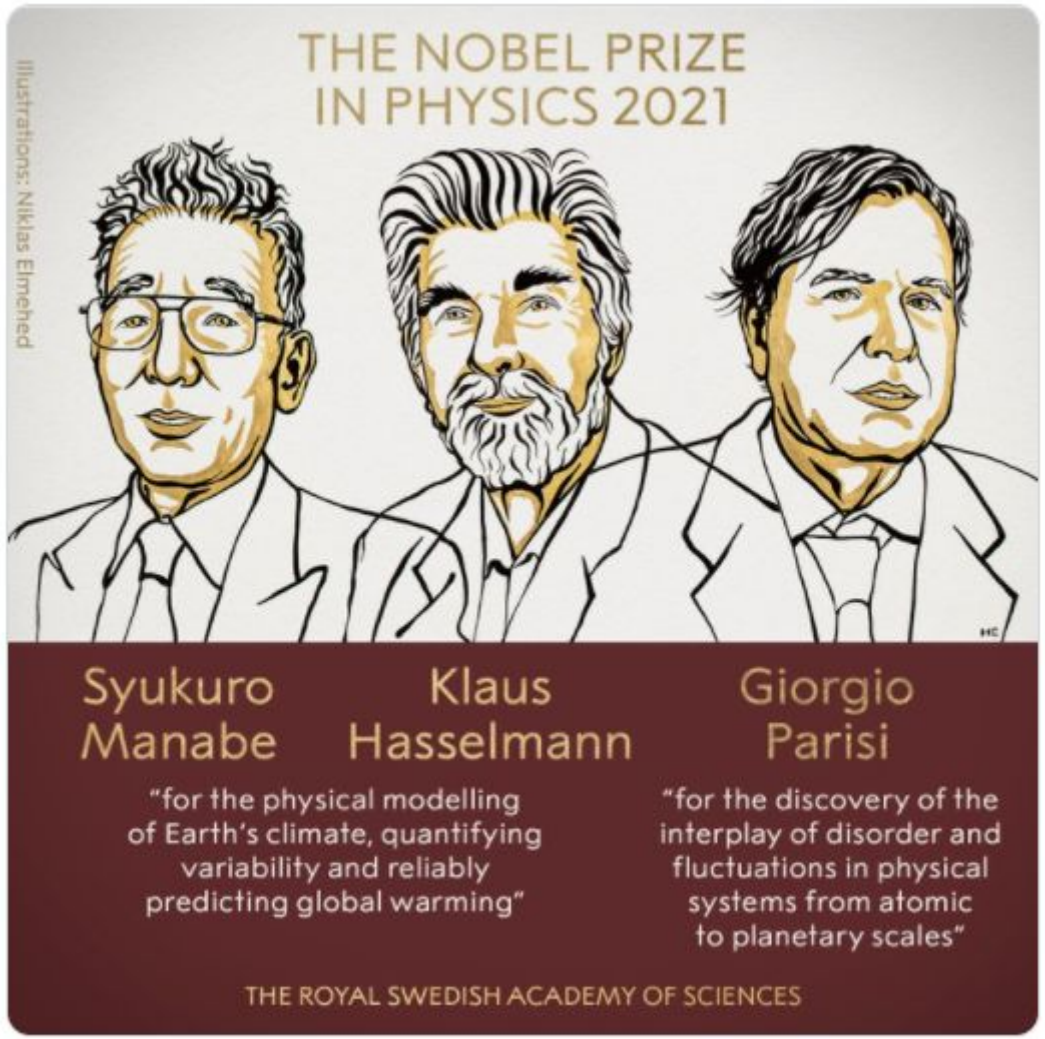
→ "INTEGRATIVE" APROACH, "COMPLEXITY"

Holistic Approach of Complexity Science



Holistic approach!

Nobel Prize on Complex Systems



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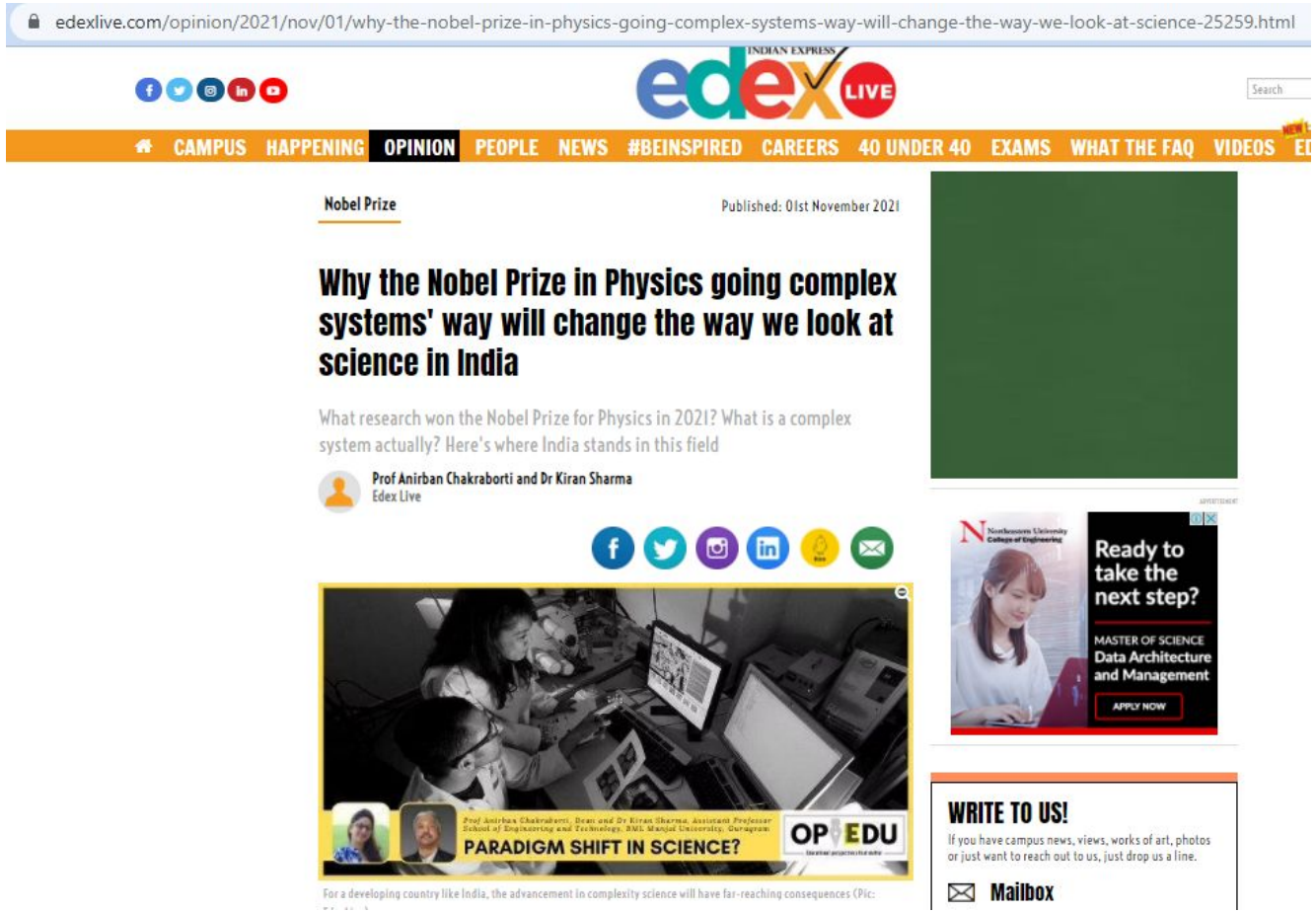
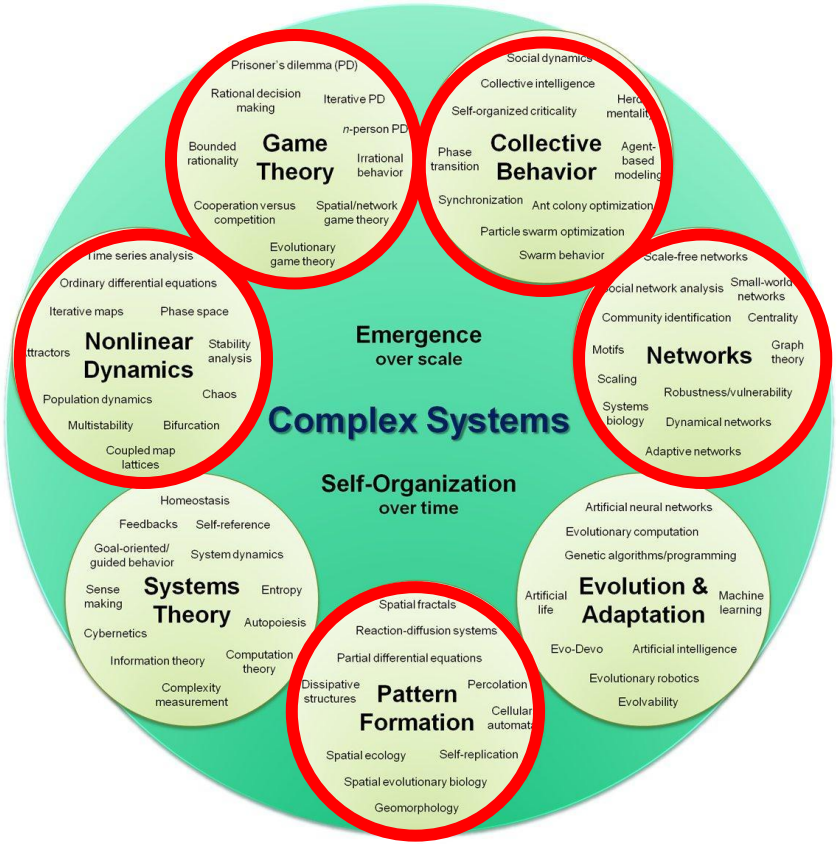


Complex Systems Studies

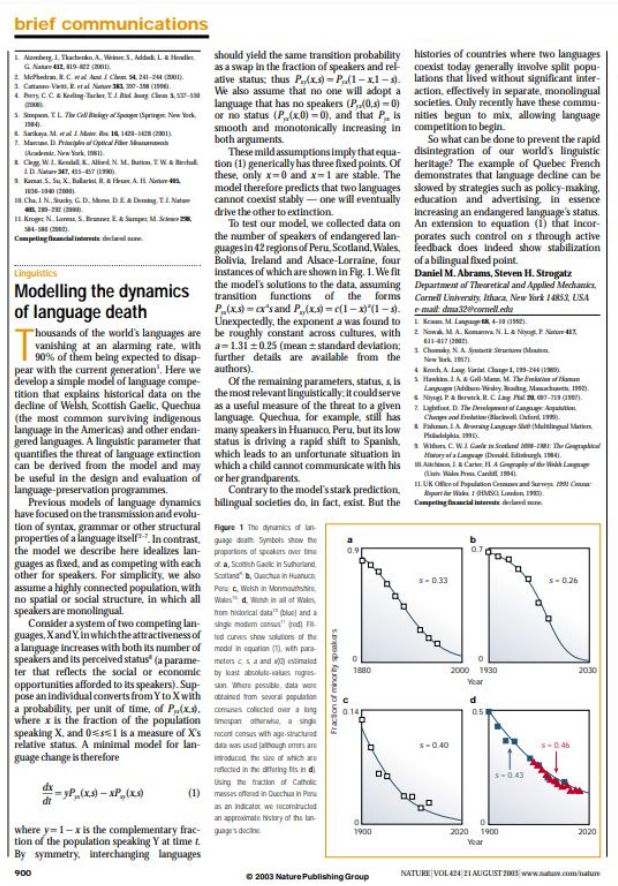
COMPLEX SYSTEMS

Complex Systems is a new field of science studying how parts of a system give rise to the collective behaviors of the system, and how the system interacts with its environment. Systems that are "complex" have distinct properties that arise from these relationships, such as *nonlinearity, emergence, spontaneous order, adaptation, and feedback loops*, among others.

Special edition, Science, April 1999



Complex network analysis of languages



brief communications

Linguistics

Modelling the dynamics of language death

Thousands of the world's languages are vanishing at an alarming rate, with 90% of them being expected to disappear with the current generation[1]. Here we develop a simple model of language competition that explains historical data on the decline of Welsh, Scottish Gaelic, Quechua (the most common surviving indigenous language in the Americas) and other endangered languages. A linguistic parameter that quantifies the threat of language extinction can be derived from the model and may be useful in the design and evaluation of language-preservation programmes.

Previous models of language dynamics have focused on the transmission and evolution of syntax, grammar or other structural properties of a language itself[2,3]. In contrast, the model we describe here idealizes languages as fixed, and as competing with each other for speakers. For simplicity, we also assume a highly connected population, with no spatial or social structure, in which all speakers are monolingual.

Consider a system of two competing languages, X and Y, in which the attractiveness of a language increases with both its number of speakers and its perceived status[4] (a parameter that reflects the social or economic opportunities afforded to its speakers). Suppose an individual converts from Y to X with a probability, per unit of time, of $P_{yx}(x,s)$, where x is the fraction of the population speaking X, and $0 \le s \le 1$ is a measure of X's relative status. A minimal model for language change is therefore

$$\frac{dx}{dt} = yP_{yx}(x,s) - xP_{xy}(x,s) \qquad (1)$$

where $y = 1 - x$ is the complementary fraction of the population speaking Y at time t. By symmetry, interchanging languages should yield the same transition probability as a swap in the fraction of speakers and relative status; thus $P_{yx}(x,s) = P_{xy}(1-x,1-s)$. We also assume that no one will adopt a language that has no speakers ($P_{xy}(0,s) = 0$) or no status ($P_{yx}(x,0) = 0$), and that P_{yx} is smooth and monotonically increasing in both arguments.

These mild assumptions imply that equation (1) generically has three fixed points. Of these, only $x = 0$ and $x = 1$ are stable. The model therefore predicts that two languages cannot coexist stably — one will eventually drive the other to extinction.

To test our model, we collected data on the number of speakers of endangered languages in 42 regions of Peru, Scotland, Wales, Bolivia, Ireland and Alsace-Lorraine, four instances of which are shown in Fig. 1. We fit the model's solutions to the data, assuming transition functions of the forms $P_{yx}(x,s) = cx^a s$ and $P_{xy}(x,s) = c(1-x)^a(1-s)$. Unexpectedly, the exponent a was found to be roughly constant across cultures, with $a = 1.31 \pm 0.25$ (mean ± standard deviation; further details are available from the authors).

Of the remaining parameters, status, s, is the most relevant linguistically; it could serve as a useful measure of the threat to a given language. Quechua, for example, still has many speakers in Huanuco, Peru, but its low status is driving a rapid shift to Spanish, which leads to an unfortunate situation in which a child cannot communicate with his or her grandparents.

Contrary to the model's stark prediction, bilingual societies do, in fact, exist. But the histories of countries where two languages coexist today generally involve split populations that lived without significant interaction, effectively in separate, monolingual societies. Only recently have these communities begun to mix, allowing language competition to begin.

So what can be done to prevent the rapid disintegration of our world's linguistic heritage? The example of Quebec French demonstrates that language decline can be slowed by strategies such as policy-making, education and advertising. In essence increasing an endangered language's status. An extension to equation (1) that incorporates such control on s through active feedback does indeed show stabilization of a bilingual fixed point.

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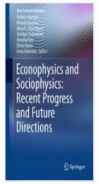
Figure 1 The dynamics of language death. Symbols show the proportions of speakers over time of: **a**, Scottish Gaelic in Sutherland, Scotland[5]; **b**, Quechua in Huanuco, Peru; **c**, Welsh in Monmouthshire, Wales[10]; **d**, Welsh in all of Wales, from historical data[10] (blue) and a single modern census[11] (red). Fitted curves show solutions of the model in equation (1), with parameters c, s, a and $x(0)$ estimated by least absolute-values regression. Where possible, data were obtained from several population censuses collected over a long timespan; otherwise, a single recent census with age-structured data was used (although errors are introduced, the size of which are reflected in the differing fits in **d**). Using the fraction of Catholic masses offered in Quechua in Peru as an indicator, we reconstructed an approximate history of the language's decline.



Econophysics and Sociophysics: Recent Progress and Future Directions pp 227-251

Patterns of Linguistic Diffusion in Space and Time: The Case of Mazatec

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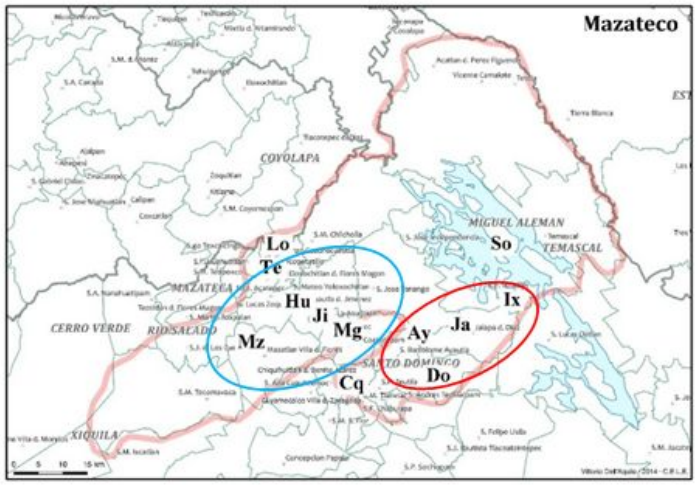

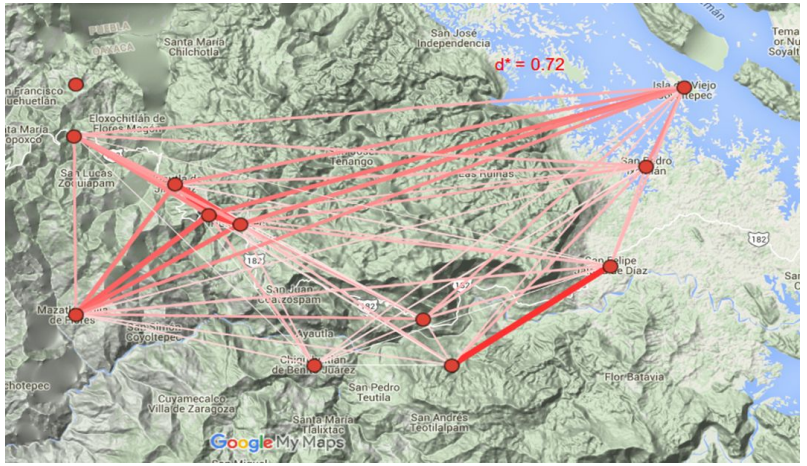

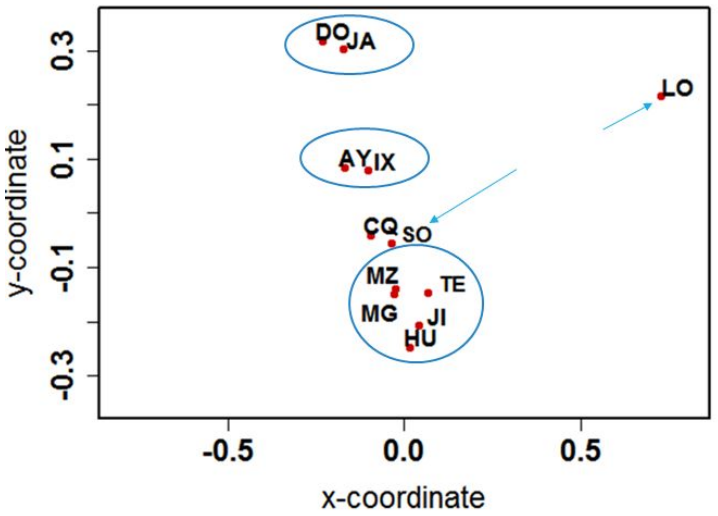

Complex network analyses of conflicts & more

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SCIENTIFIC REPORTS

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A complex network analysis of ethnic conflicts and human rights violations

Received: 12 May 2017
Accepted: 21 July 2017
Published online: 15 August 2017

Kiran Sharma[1], Gunjan Sehgal[2], Bindu Gupta[2], Geetika Sharma[2], Arnab Chatterjee[2], Anirban Chakraborti[1] & Gautam Shroff[2]

News reports in media contain records of a wide range of socio-economic and political events in time. Using a publicly available, large digital database of news records, and aggregating them over time, we study the network of ethnic conflicts and human rights violations. Complex network analyses of the events and the involved actors provide important insights on the engaging actors, groups, establishments and sometimes nations, pointing at their long range effect over space and time. We find power law decays in distributions of actor mentions, co-actor mentions and degrees and dominance of influential actors and groups. Most influential actors or groups form a giant connected component which grows in time, and is expected to encompass all actors globally in the long run. We demonstrate how targeted removal of actors may help stop spreading unruly events. We study the cause-effect relation between types of events, and our quantitative analysis confirm that ethnic conflicts lead to human rights violations, while it does not support the converse.

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Identifying the global terror hubs and vulnerable motifs using complex network dynamics

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ABSTRACT

Terrorism instills fear in the minds of people and takes away the freedom of individuals to act as they will. Terrorism has turned out to be an international menace today. Here, we study the terrorist attack incidents which occurred in the last half-century across the globe from the open source, Global Terrorism Database, and develop a view on their spatio-temporal dynamics. We construct a complex network of global terrorism and study its growth dynamics, along with the statistical properties of the anti-social network, which are quite intriguing. Normally, each nation pursues its own vision of international security based upon its mandate and particular notions of politics and its policies to counter the threat of terrorism that could naturally include the use of tactical measures and strategic negotiations, or even physical power. We study the network resilience against targeted attacks and random failures, which could guide the counter-terrorist outfits in designing strategies to fight terrorism. We then use a disparity filter

Spatio-temporal networks of social conflicts: analysis and modeling

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***Abstract*—Social interactions can be both positive and negative, and at various spatial and temporal scales. Negative interactions such as conflicts are often influenced by political, economic and social pre-conditions. The signatures of conflicts can be mapped and studied in the form of complex social networks. Using publicly available large digital databases of media records, we construct networks of actors involved in conflicts by aggregating the events over time. We then study the spatio-temporal dynamics and network topology of conflicts, which can provide important insights on the engaging individuals, groups, establishments and sometimes nations, pointing at their long range effect over space and time. Network analyses of the empirical data reveal certain statistical regularities, which can be reproduced using agent based models. The fat tails of actor mentions and network degree distributions indicate dominant roles of the influential actors and groups, which over time, form a part of a giant connected component. Targeted removal of actors may help preventing unruly events of conflicts. Inspired by the empirical findings, we also propose a model for interacting actors that can reproduce the most important features of our datasets.**

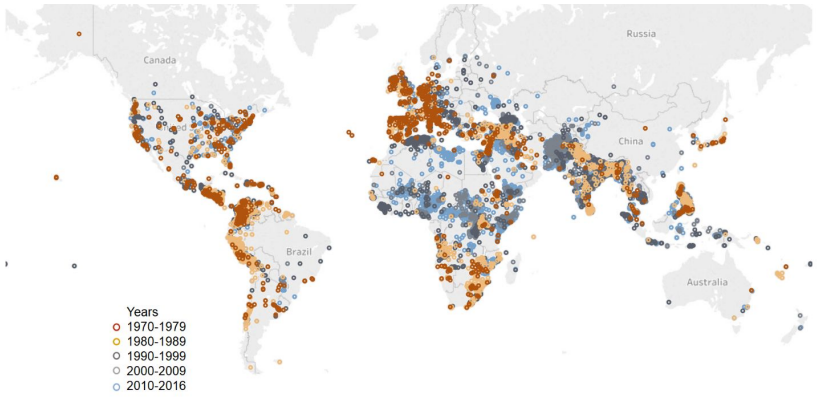
stable democracies rarely go to war with other democracies, countries that are socio-politically unstable report frequent conflicts between groups with opposing interests [7]. Ethnic conflicts can escalate to human rights violations [8]. Hence, the spatio-temporal studies of conflict formations and the statistical studies of the associated variables are important.

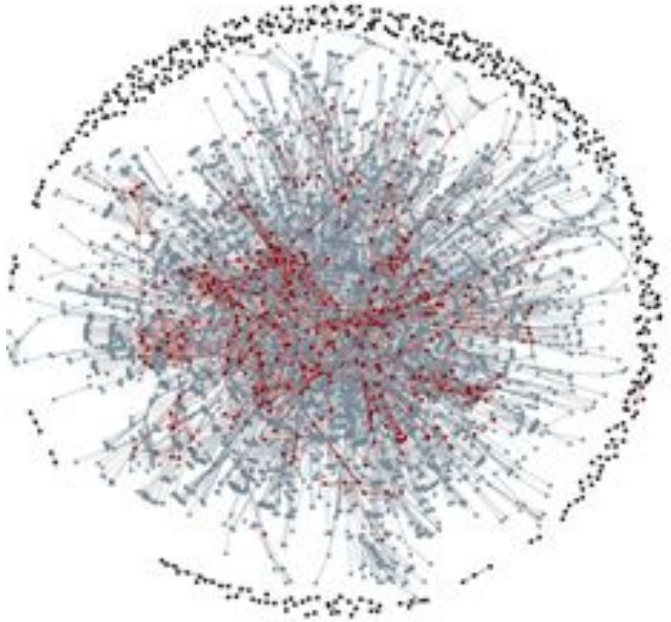
Temporal data for human to human communications and physical contacts/proximity has been studied extensively (see e.g., Holme and Saramäki [9]). We have studied the scale and topology of conflicts, using data from publicly accessible databases, which keep account of events from news available in media. We particularly focus on conflicts in general, as well as *armed conflicts* from two separate databases. The availability of high precision data along with precise spatio-temporal information makes it possible to look for correlations between events, involved actors (individuals, groups, organizations or states) and the geographical pattern of spreading of conflicts,

Dynamical evolution of anti social phenomena: A data science approach

Syed Shariq Husain and Kiran Sharma

Abstract News reports in media contain records of a wide range of socio-economic and political events in time. Using a publicly available, large digital database of news records, and aggregating them over time, we study the temporal evolution of events of ethnic conflicts and human rights violations. We study the cause-effect relation between types of events, and our quantitative analysis confirm that ethnic conflicts lead to human rights violations, while it does not support the converse.In addition to this we study terrorism data from GTD. Terrorism instills fear in the minds of people and takes away the freedom of individuals to act as they will. Terrorism has turned out to be an international menace today. Here, we study the terrorist attack incidents which occurred in the last half-century across the globe from the open source, Global Terrorism Database, and develop a view on their spatio-temporal dynamics. We construct a timeseries and analyzed it for various measure including that of EC,HR and GTD. along with





Access to education: Colleges in India (1850-2017)

nature COMMUNICATIONS

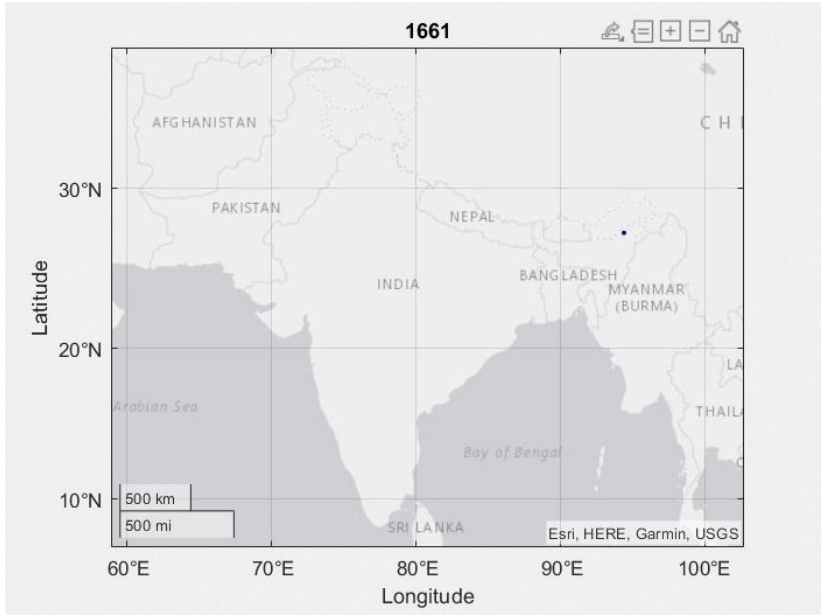
ARTICLE

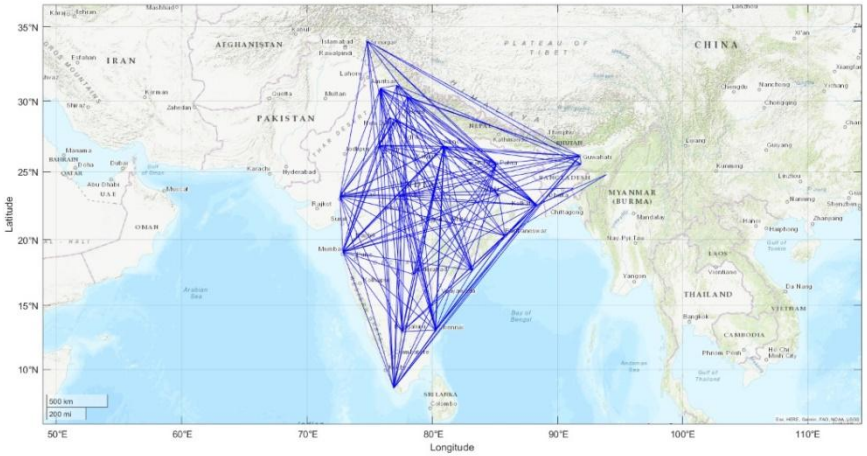
https://doi.org/10.1038/s41467-020-17634-2 OPEN

Spatiotemporal data analysis with chronological networks

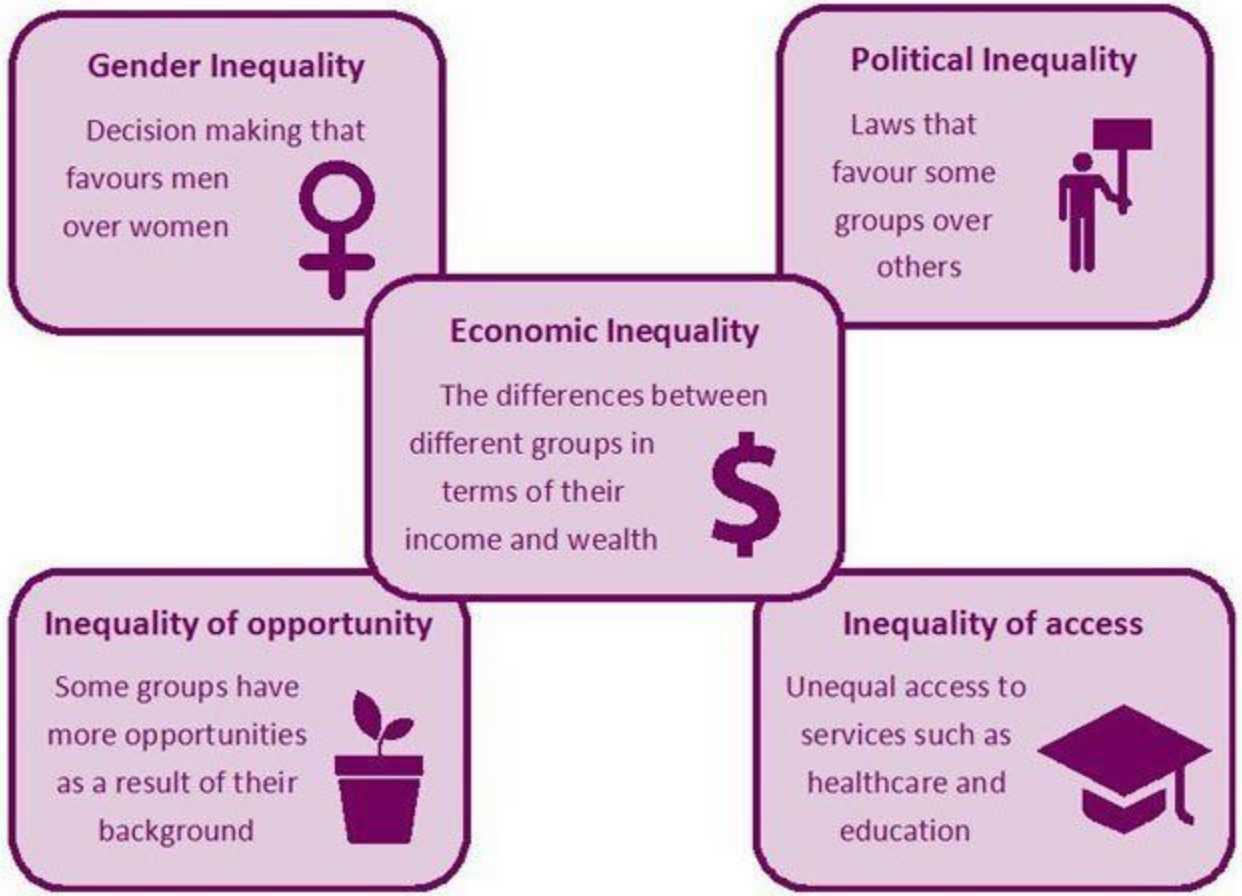
Leonardo N. Ferreira[1,2,3✉], Didier A. Vega-Oliveros[4,5], Moshé Cotacallapa[1], Manoel F. Cardoso[6], Marcos G. Quiles[7], Liang Zhao[8] & Elbert E. N. Macau[1,7]

The number of spatiotemporal data sets has increased rapidly in the last years, which demands robust and fast methods to extract information from this kind of data. Here, we propose a network-based model, called Chronnet, for spatiotemporal data analysis. The network construction process consists of dividing a geometric space into grid cells represented by nodes connected chronologically. Strong links in the network represent consecutive recurrent events between cells. The chronnet construction process is fast, making the model suitable to process large data sets. Using artificial and real data sets, we show how chronnets can capture data properties beyond simple statistics, like frequent patterns, spatial changes, outliers, and spatiotemporal clusters. Therefore, we conclude that chronnets represent a robust tool for the analysis of spatiotemporal data sets.





Socio-economic inequalities: Kinetic exchange models



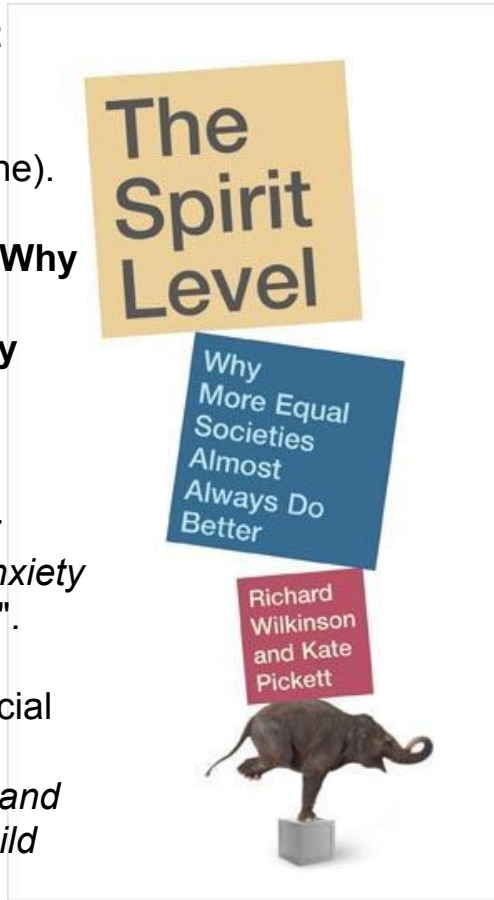
https://www.rgs.org/schools/teaching-resources/inequality-and-its-management/

Social inequality

The Spirit Level: Why More Equal Societies Almost Always Do Better

Richard G. Wilkinson and Kate Pickett (2009, Allen Lane).

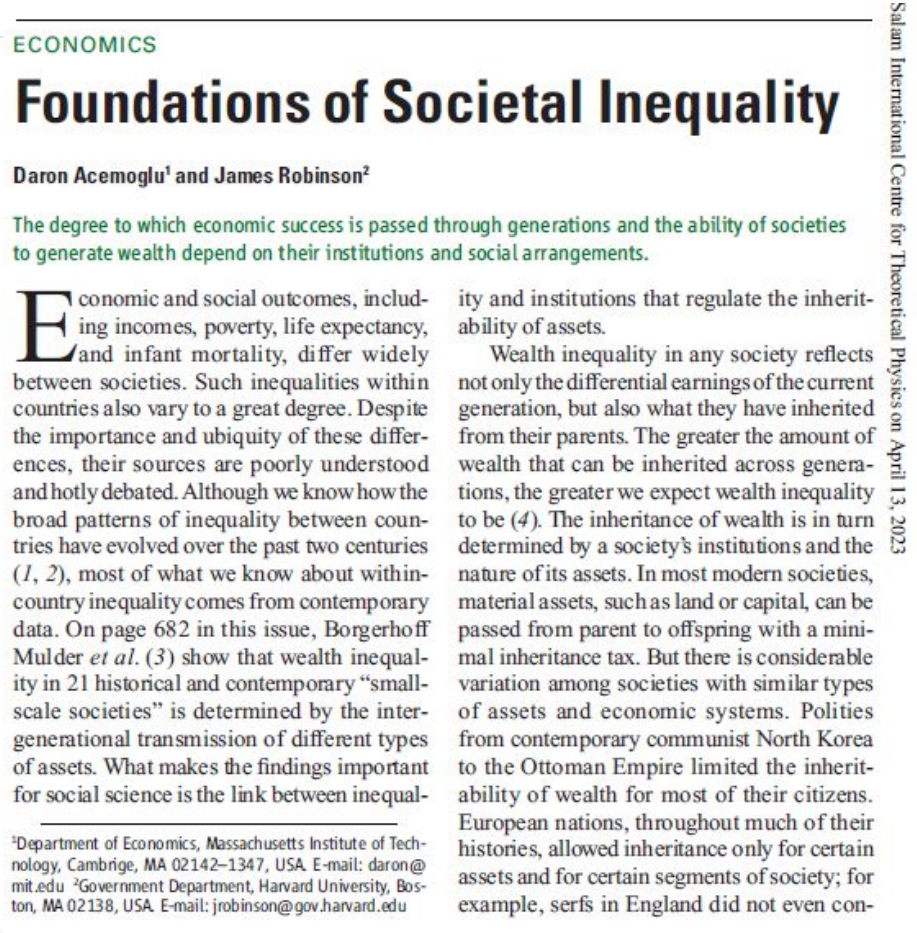
In the US by Bloomsbury Press (December, 2009) as: **Why Greater Equality Makes Societies Stronger**
In the UK by Penguin Books (November 2010) as: **Why Equality is Better for Everyone**



The book argues that there are "*pernicious effects that inequality has on societies: eroding trust, increasing anxiety and illness, (and) encouraging excessive consumption*".

It claims that for each of eleven different health and social problems: *physical health, mental health, drug abuse, education, imprisonment, obesity, social mobility, trust and community life, violence, teenage pregnancies, and child well-being*, outcomes are significantly worse in more unequal rich countries.

The book contains graphs that are available online.



ECONOMICS

Foundations of Societal Inequality

Daron Acemoglu[1] and James Robinson[2]

The degree to which economic success is passed through generations and the ability of societies to generate wealth depend on their institutions and social arrangements.

Economic and social outcomes, including incomes, poverty, life expectancy, and infant mortality, differ widely between societies. Such inequalities within countries also vary to a great degree. Despite the importance and ubiquity of these differences, their sources are poorly understood and hotly debated. Although we know how the broad patterns of inequality between countries have evolved over the past two centuries (*1*, *2*), most of what we know about within-country inequality comes from contemporary data. On page 682 in this issue, Borgerhoff Mulder *et al.* (*3*) show that wealth inequality in 21 historical and contemporary "small-scale societies" is determined by the intergenerational transmission of different types of assets. What makes the findings important for social science is the link between inequality and institutions that regulate the inheritability of assets.

Wealth inequality in any society reflects not only the differential earnings of the current generation, but also what they have inherited from their parents. The greater the amount of wealth that can be inherited across generations, the greater we expect wealth inequality to be (*4*). The inheritance of wealth is in turn determined by a society's institutions and the nature of its assets. In most modern societies, material assets, such as land or capital, can be passed from parent to offspring with a minimal inheritance tax. But there is considerable variation among societies with similar types of assets and economic systems. Polities from contemporary communist North Korea to the Ottoman Empire limited the inheritability of wealth for most of their citizens. European nations, throughout much of their histories, allowed inheritance only for certain assets and for certain segments of society; for example, serfs in England did not even con-

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Foundations of Societal Inequality
Author(s): Daron Acemoglu and James Robinson
Source: *Science*, Oct. 30, 2009, New Series, Vol. 326, No. 5953 (Oct. 30, 2009), pp. 678-680

Books & arts

The COVID-19 pandemic has been hardest for underprivileged people, such as these children studying in an improvised classroom.

Tackling inequality takes social reform

In separate books, leading economists explore the wide-ranging changes needed to produce a more just society. **By Richard Wilkinson and Kate Pickett**

The cold war rivalry between capitalism and communism ended not because the problems of capitalism had been solved, but because communism had failed as a solution. Still, the rivalry was good for capitalism. From the end of the First World War until around 1980, differences in the incomes of people in rich countries shrank. Welfare systems became increasingly generous and capitalism developed a more human face. But when the Soviet Union and Eastern European countries ceased to be an economic threat to Western capitalism, the rival system that had made capitalism more compassionate disappeared, allowing market systems to become harsher. Top tax rates for high earners were reduced, trade unions were weakened and income gaps widened.

A Brief History of Equality
Thomas Piketty
Belknap (2022)

The Origins and Dynamics of Inequality: Sex, Politics, and Ideology
Jon D. Wisman
Oxford Univ. Press (2022)

Income inequality continues to trend upwards. Since 1995, almost 20 times as much of the increase in global wealth has gone to the richest 1% of people as to the poorest 50%. The global charity Oxfam estimates that 8 men now own the same amount of wealth as the world's poorest 3.6 billion people. But do these grotesque levels of inequality really matter? And if they do, who do they harm, and why?

Two books attempt to tackle these questions and lay out plans for far-reaching reform. The first comes from French economist Thomas Piketty, and the second from US economist Jon Wisman. Both argue that making the world a better place requires a reduction in inequality, and that inequality persists because of ideological beliefs, including that social position reflects innate ability, that the highest incomes are a payment for talent and that the economic system is too delicate to be tampered with. But there are important differences in what these authors think drives inequality and on what can be done to reduce it.

In *The Origins and Dynamics of Inequality*, Wisman takes seriously both the Marxist criticism of the market and the failure of communism. But his solutions to inequality are partly shaped by his view that economic inequality is driven by sexual competition and the aphrodisiac properties of status, wealth and power. He quotes Saint Augustine on the sins of lust for money, power and sex, and says it wasn't until Charles Darwin that it became clear that the first two are driven by the third.

This perspective leads Wisman to argue that inequality can be reduced by taming the forces of sexual competition or, at least, by uncoupling them from money and power. In his view, the 'mating game' should instead be about gaining recognition for achievements in fields such as poetry, science, art or sport, or even through generosity or environmental credentials. He quotes US psychologist Geoffrey Miller, who says that finding better ways to manage human sexual competitiveness should be at the explicit core of social policy.

Routes to economic equality

Piketty is also progressive — and has a stature approaching that of a latter-day John Maynard Keynes. His widely acclaimed *Capital in the Twenty-First Century*, published in 2013, demonstrated how economic inequality had historically arisen because the rate of return on capital, from which rich individuals derive their wealth, normally exceeds the economic growth rates on which most people's incomes depend.

In *A Brief History of Equality*, Piketty shows that greater equality is part of the long arc of historical progress. Between 1780 and 2020, he says, most regions and societies shifted towards greater equality, if not of income, then of rights and recognition — expansion of the right to vote, equality before the law, gender and racial equality, women's property rights and more. Research by others has shown how new institutions and social, economic and political norms move together; for example, societies with smaller overall income differences, such as Scandinavian countries, also tend to have smaller gender differences in pay and political representation. This is not enough, however — societies still need to tackle inequities in people's abilities to flourish, for example in education or governance.

At heart, both these authors approach their subject from an emphatically economic perspective. Both accept the market as a necessity but want to remove its most inegalitarian and antisocial results by changing the context in which it operates. Rather than doing away with private ownership of the productive system, both want to democratize it with forms of employee ownership and autonomy. Capitalism, they each argue, can be transformed by much more progressive taxation, more generous welfare and expanding forms of employee ownership of companies. Piketty explains that the twentieth century demonstrated that having "almost confiscatory tax rates" for the highest incomes — at times exceeding 80% in the United Kingdom and the United States — contributed to the long decline in inequality before 1980. Policies such as these could, as Wisman says, "eliminate the core source of exploitation that Marx identified within capitalism".

> **"Inequality is a defining challenge of these times."**

Harms of inequality

Why do both authors see the degree of inequality as the defining issue of history and as the challenge of our times? There is a striking absence of discussion, in both books, of the harm that inequality does. Perhaps this is a reflection of how, as an academic discipline, economics has failed to see the key psychosocial processes through which inequality makes itself felt. By contrast, a large body of research from other disciplines, including our own field of epidemiology, shows that inequality needs to be understood in more than monetary and structural terms.

Inequality needs to be seen as a social relationship. It places us in a hierarchy, ranked one above another, and — crucially — determines the social distance between us. Instead of encouraging the public spiritedness, cohesion and trust that can flourish in a community of near-equals, big material differences make class and status more important, exacerbating feelings of superiority and inferiority. As a result, people become more conscious of their status. The social structure ossifies and social mobility declines. In short, inequality is a social stressor.

That explains why more-unequal societies have worse physical and mental health, more antisocial behaviour — including higher homicide rates and more people in prison — and lower levels of child well-being and development. Inequality is not just an economic condition; it gets under our skin and into our minds, shapes our behaviours and fundamentally undermines our collective well-being and flourishing. It causes chronic stress.

Similarly, primatologists have shown that subordinate status is damaging to the health of monkeys; it would be unethical to reproduce these experiments with human participants, but the findings mirror observations relating to people with a low social status. Piketty and Wisman travel further than most beyond the narrow boundaries of mainstream economic thinking, but the discipline needs to grapple with the psychological and sociological implications of the subject of inequality to truly understand the interplay of social and economic forces.

Although they are missing some of the human costs of inequality, Piketty and Wisman do agree on one wider harm: inequality greatly impairs our ability to minimize climate change and the cascade of problems it entails. Not only does it intensify status-related consumption, it also increases the political power of wealthy individuals, who cause the most environmental pollution while being affected by it the least.

Piketty ends by showing that tackling inequality is crucial to the kinds of power politics that will make or break efforts to tackle the climate emergency and other environmental crises. He foresees that political hostility will increase towards the high-income countries and individuals most responsible for the environmental crisis. In particular, he points to the likely shift of prestige and influence from the United States to China if the former ceases to be the standard bearer for democracy and the latter is able to remind the world that, despite human-rights abuses, it bears little historical responsibility for carbon dioxide emissions, slavery or colonialism. Piketty predicts that to limit the growing influence of China's authoritarian socialism, Western powers must abandon their hypercapitalist ideology and transition to a participative market socialism that is post-colonial, responsive to low- and middle-income countries, and able to respond effectively to the environmental crisis.

So inequality matters. It matters for people, and for the planet. It matters for all of us, and not just those at the sharp end of poverty and deprivation. Inequality is, as world leaders and thinkers such as Piketty and Wisman point out, a defining challenge of these times. If we want more than just a more equitable distribution of resources, if we want sustainable prosperity for the world, we ignore these important and readable books at our peril.

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Vulnerability and Inevitable Inequality

Martha Albertson Fineman

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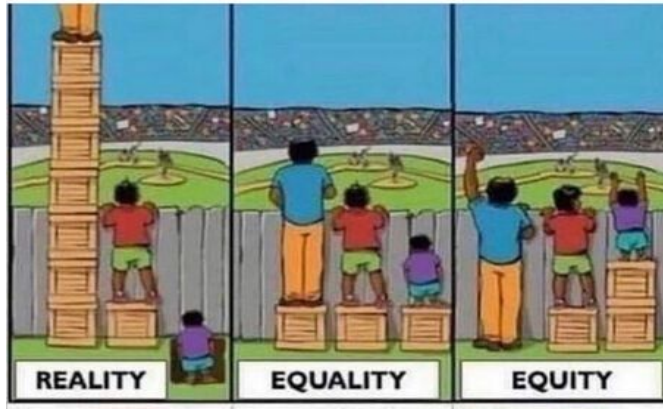
- Recognises the fact that every individual is vulnerable to social, environmental and bodily changes that are not always in their control.
- Claims that societies, states and institutions like families form as a response to human vulnerability.
- The inequalities naturally arise in these social structures, like parent-child, employee-employer, etc.
- Aim is not to demand equality, but to demand equity.



Reference: https://twitter.com/CalcRound/status/1455894963363803141

Gender Equity

- Marital property and joint custody were proposed to establish marriage as an equal partnership, but women faced economic disadvantages and unequal decision-making due to their role as primary caregivers, while workplace culture hostile to caregivers resulted in fewer economic opportunities
- Post-divorce, women usually took primary responsibility for children, leading to reduced income and fewer job opportunities, compounded by workplace culture and loss of the primary wage earner's income.
- The author recommends a case-by-case analysis of family law/divorce cases and decide the reparations according to the social context of the parties involved.

Market and State

- As is well known the market penalises those who take up the role of caregivers in a family and refuses to find value in the work of caregivers that helps in sustaining the society
- The author argues that in such cases the State and social Institutions should step in to “reward” the work of the caregiver and also create facilities that are capable of taking care of the “inevitable” dependents incase they have no other options. (“Inevitable dependents” example: old people and children, sick and infirm, etc.)

University of Chicago

Steven Durlauf - Harris School of Public Policy

Steven Neil Durlauf is the Steans Professor in Educational Policy and the Director of the Stone Center for Research on Wealth...

Featuring this expert

Repairing Children's Mobility

VIDEO *Featuring* Steven Durlauf | MAY 10, 2023

What's really causing inequality in opportunities and outcomes for kids?

Membership Theory of Inequality

VIDEO *Featuring* Steven Durlauf | MAR 15, 2017

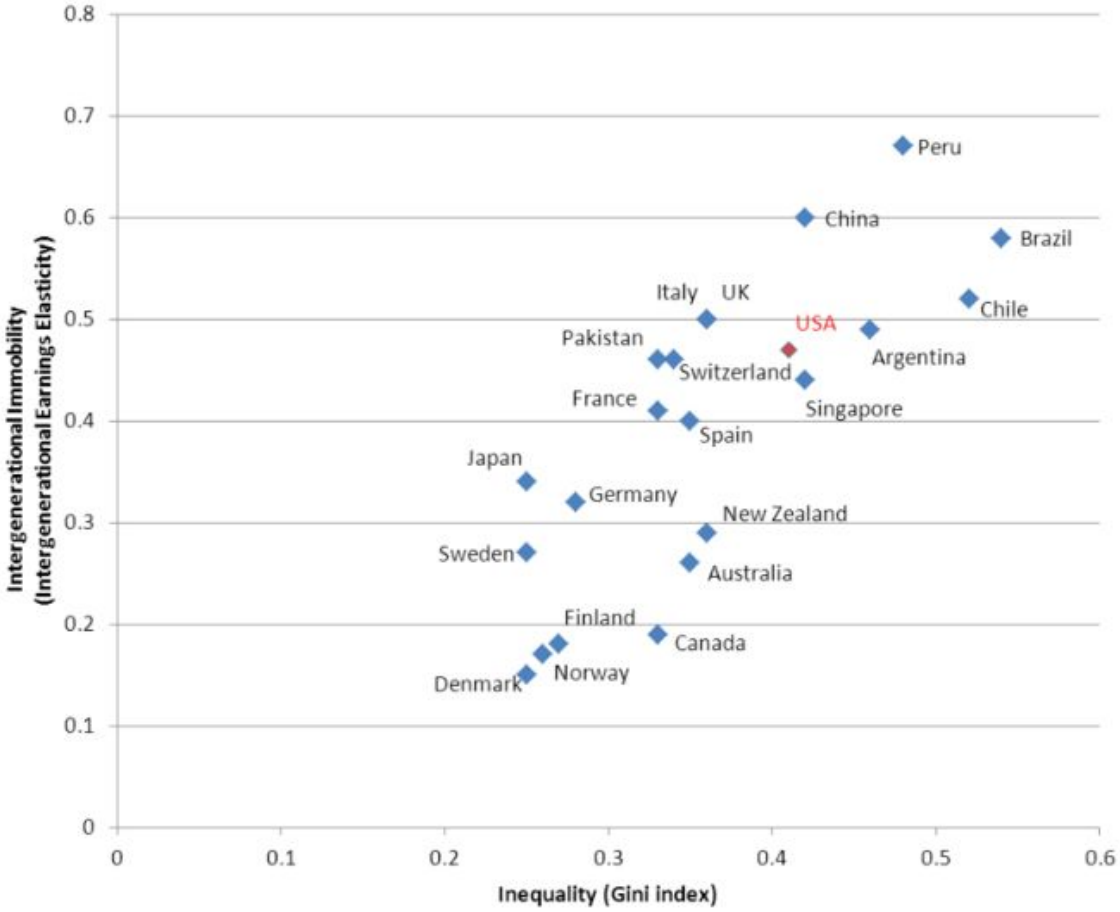
A transition from the conventional policy of "redistributing income" to "redistributing membership", could promote economic integration across communities and intergenerational mobility.

Durlauf, S. N., Kourtellos, A., & Tan, C. M. (2022). The Great Gatsby Curve. https://doi.org/10.1146/annurev-economics-082321-122703

https://www.ineteconomics.org/research/experts/sdurlauf

- An interdisciplinary approach to looking at social problems, in this case of socio-economic inequality and intergenerational social mobility.
- Looking at this problem through a multi-faceted lens combining traditional ideas of economics, with the power of mathematical modelling and including the respective facets of sociology, psychology, politics and law, among others.
- Intergenerational Social Mobility is described as the likelihood that a child earns more than their parents.
- The Great Gatsby Curve is the graph of Economic mobility vs. Gini coefficient. The Economic Mobility metric shows how dependent a child's future income is based on their parent's income

Intergenerational social mobility is measured with the Great Gatsby Curve.



Increasing Social Mobility

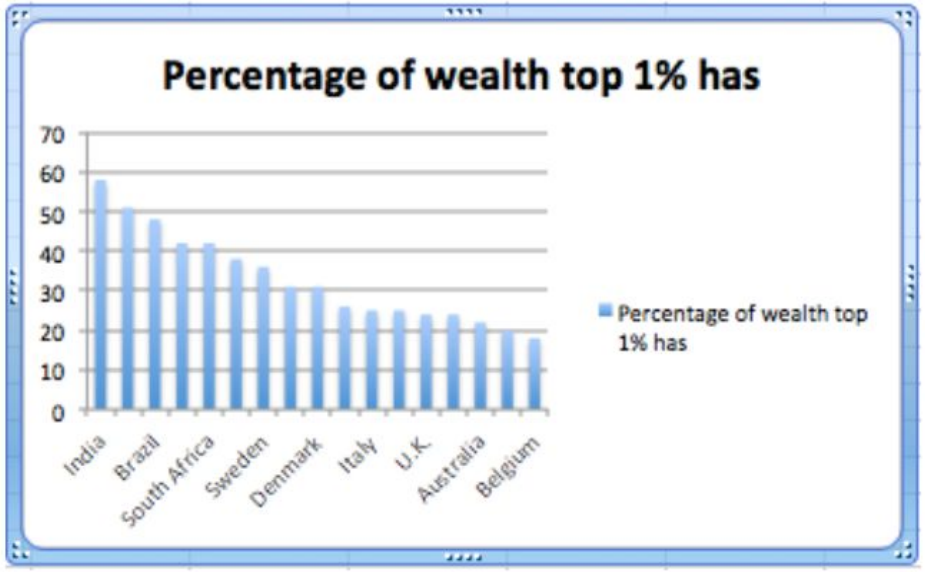
- Inequalities will always be a part of society but a key idea is to reduce the effect of socioeconomic inequalities. This is in the spirit of equity, wherein the more “vulnerable”(“poor”) communities get better access to resources and integration to the rest of the society. (Urban planning, sustainable city design)
- He also talks about the psychological effects of being segregated and then being thrown into a mixed environment like a college. “Poor” students from “bad schools” may not perform well initially, while “Rich” students from “good schools” will perform better. So how does the psychology of these students affect their actions.

Income inequality

Economic Inequality in India and Pakistan

January 18, 2017

Top 1% of Indians own 58% of wealth in India, according to a recent report by Oxfam as published by Wall Street Journal. The report said the global average for wealth ownership of the top 1% is 51%.



Source: Oxfam

The income and wealth concentration in the hands of the richest top 1% skews the average per capita incomes and makes the material well-being of average citizen look better than it is. The best way to measure how well or poorly an average citizen is doing is to look at the median income and wealth, not the average or mean. The median

https://www.southasiainvestor.com/2017/01/economic-inequality-in-india-and.html

Income inequality

mint

Markets Elections Premium Money Mutual Fund Industry Companie

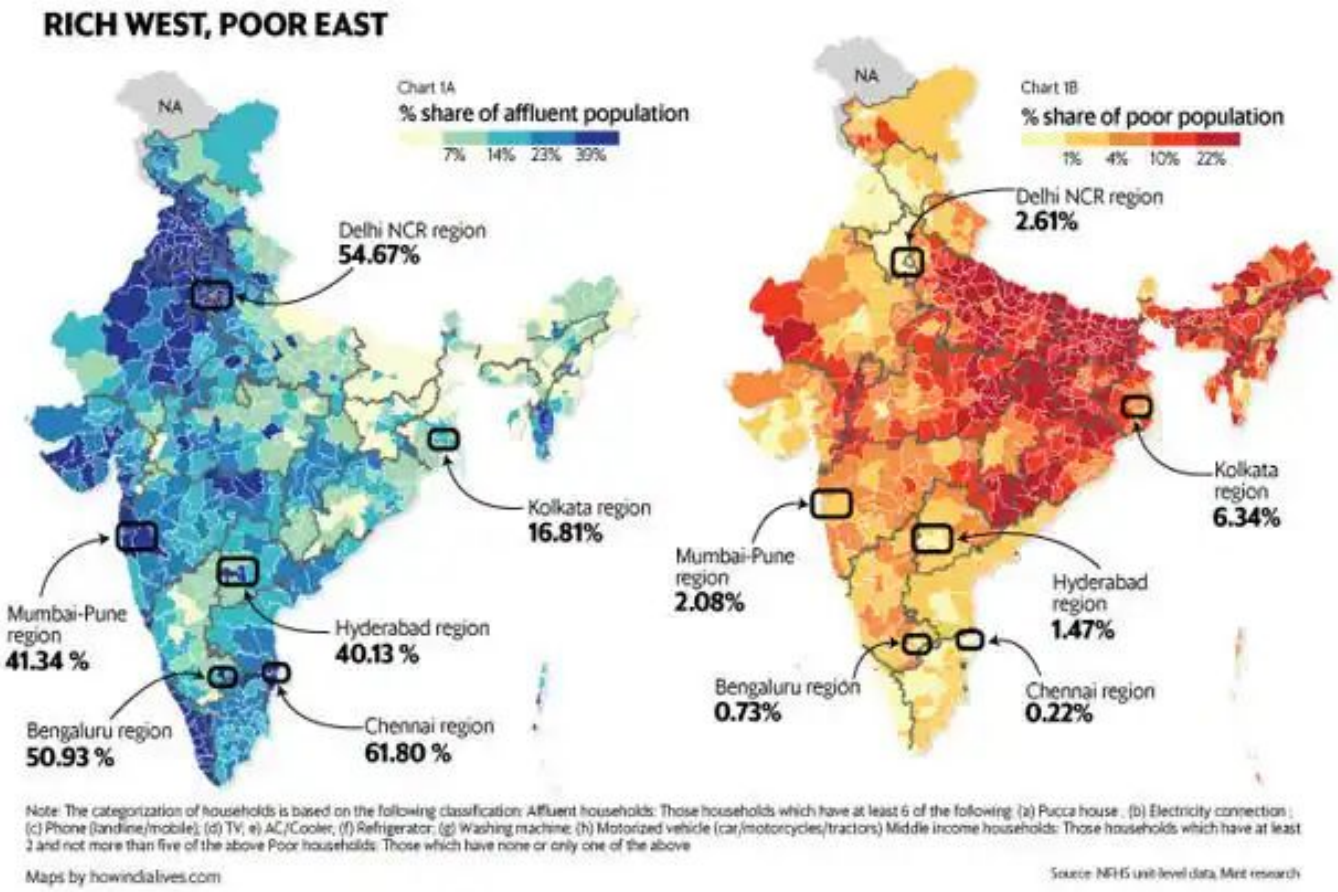
Where India's affluent classes live

3 min read . Updated: 08 Aug 2018, 04:22 PM IST

Tadit Kundu, Pramit Bhattacharya

Among all 640 districts of India, Jalandhar district in Punjab has the highest share (88%) of affluence while Shravasti district in Uttar Pradesh has the highest share (61%) of the poor. Graphic: Mint

India's richest districts are situated along the western coastline while the poorest are clustered in the easternmost parts of the country, shows analysis



https://www.livemint.com/Politics/DymS22taK4EyAbSYRx0rSO/Where-Indias-affluent-classes-live.html

FOREWORDS

Jayati Ghosh taught Economics at Jawaharlal Nehru University, in New Delhi, India, and is now Professor of Economics at the University of Massachusetts at Amherst, USA. She is a member of the World Health Organization's Council on the Economics of Health For All.

Here's a hard truth that the pandemic brought home to us. Unequal access to incomes and opportunities does more than create unjust, unhealthy, and unhappy societies: it actually kills people. Over the past two years, people have died when they contracted an infectious disease because they did not get vaccines in time, even though those vaccines could have been more widely produced and distributed if the technology had been shared. They have died because they did not get essential hospital care or oxygen when they needed it, because of shortages in underfunded public health systems. They have died because other illnesses and diseases could not be treated in time as public health facilities were overburdened and they could not afford private care. They have died because of despair and desperation at the loss of livelihood. They have died of hunger because they could not afford to buy food. They have died because their governments could not or would not provide the social protection essential to survive the crisis. And while they died, the richest people in the world got richer than ever and some of the largest companies made unprecedented profits.

The hundreds of millions of people who have suffered disproportionately during this pandemic were already likely to be more disadvantaged: more likely to live in low- and middle-income countries, to be women or girls, to belong to socially discriminated-against groups, to be informal workers. More likely, therefore, to be unable to influence policy.

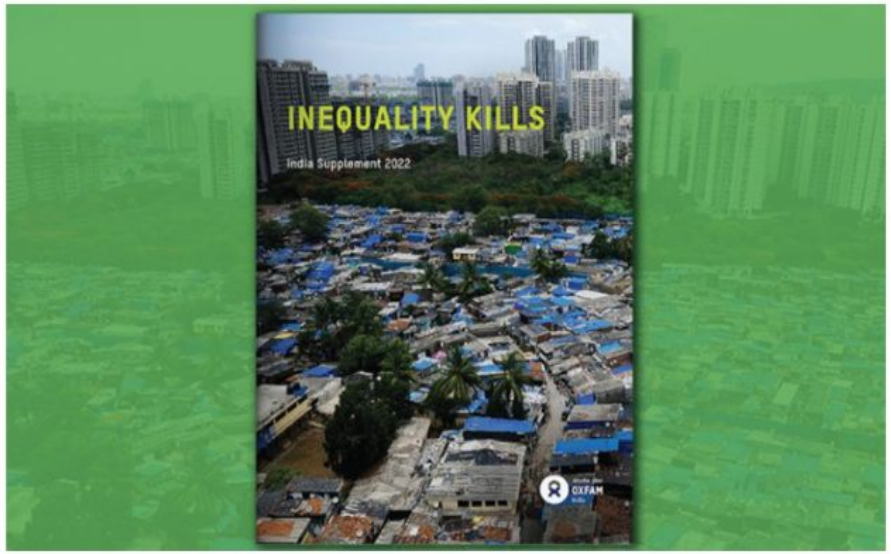
OXFAM India | A movement to end discrimination

WHO WE ARE | WHAT WE DO | HOW

Inequality Kills: India Supplement 2022

By Abhirr VP | 17 Jan, 2022

Share on :



RICHEST 98 INDIANS OWN SAME WEALTH AS THE BOTTOM 55.2 CRORE PEOPLE

Pareto Law

Vilfredo Pareto found that many countries share a power law in the tail of wealth distribution.

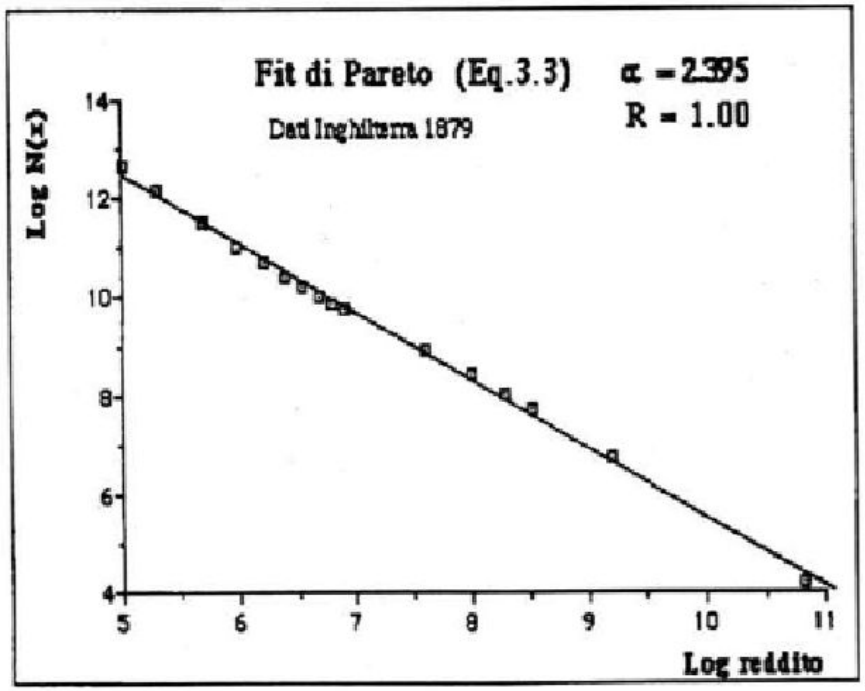
Pareto's law is given in terms of the cumulative distribution function (CDF), i.e. the number of events larger than x is an inverse power of x:

$$P[X > x] \sim x^{-k}.$$

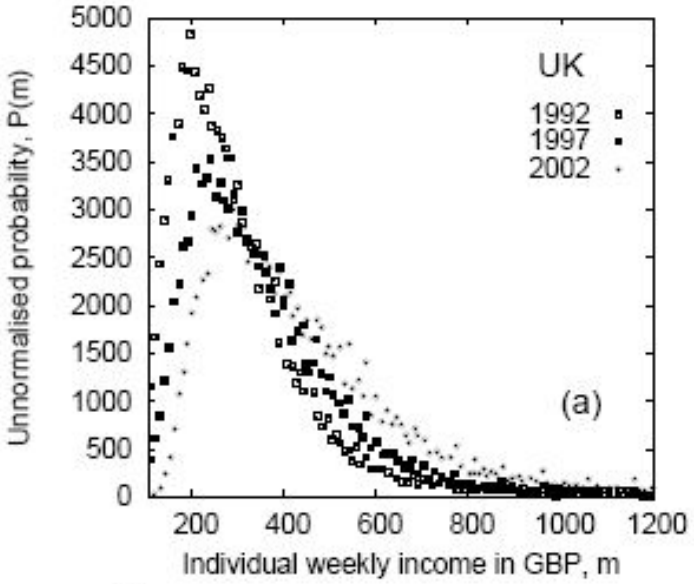
FIGURA 4

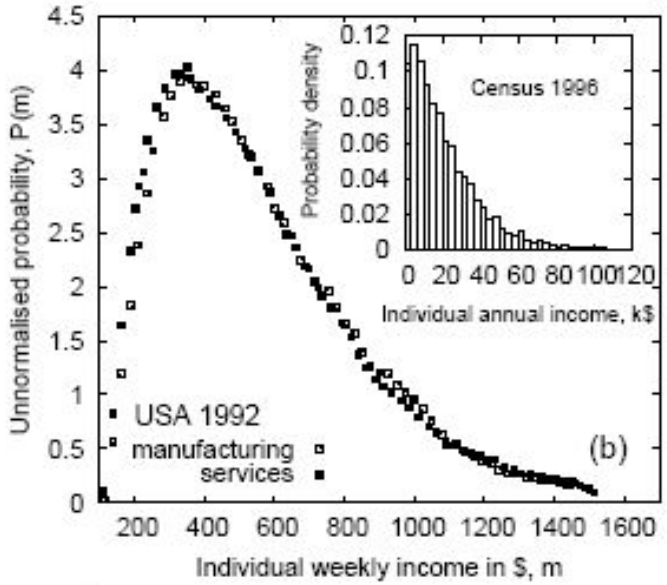
Inghilterra 1879-80. Dati raccolti da Pareto sull'integrale della curva di distribuzione del reddito N(x). In ascissa si ha il logaritmo naturale del reddito espresso in sterline ed in ordinata il logaritmo naturale del numero di individui che eccedono quel determinato reddito. La retta di regressione corrisponde all'esponente α = 2.395. Fonte: V. PARETO (1896).

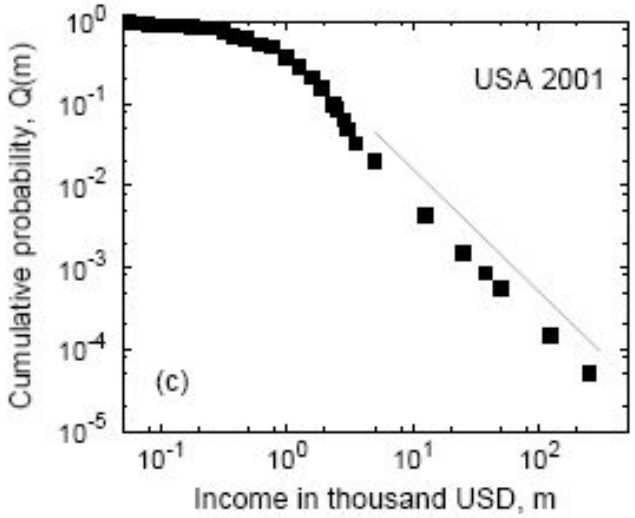
Courtesy: MP

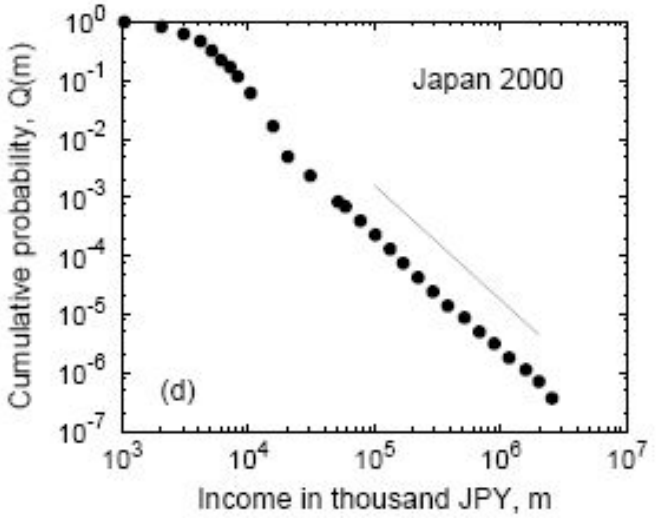


Income distribution









Courtesy: BKC

Wealth distribution

Meghnad Saha

B. N. Srivastava

1931

Courtesy: BKC

Suppose in a country the assessing department is required to find out the average income per head of the population. They will proceed somewhat in the following way. They will find out the number of persons whose income lies within different small ranges. For example, they will find out the number of persons whose income lies between 10s. and 11s., between 11s. and 12s. and so on. Instead of a shilling, they may choose a smaller interval, say 6d. Then it can be easily seen that the number of persons whose income lies between 10s. and 10s.6d. will be approximately half the number found previously for the range 10s. to 11s. We can generalize by saying that the number whose income lies between x and $x+dx$ is $n_x dx$. It should be noted that the number is proportional to the interval chosen (dx). To get the average income they should choose the interval to be as small as possible, say a penny. When this is not possible they will choose a bigger interval but their results will be proportionately inaccurate.

To represent graphically[1] the income of the population they will plot a curve with n_x as ordinate and x as abscissa. The curve will be similar to that given in Fig. 6. This will begin with a minimum at 0, rise to a maximum at some point, and thereafter approach the axis of x, meeting it at a great distance. The curve will have this shape because the number of absolute beggars is very small, and the number of millionaires is also small, while the majority of population have average income.

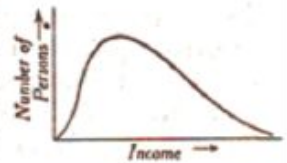


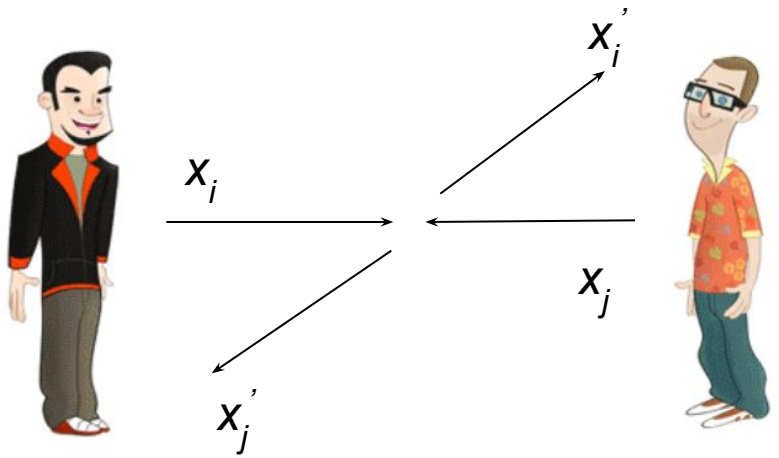
Fig. 6.—Distribution of income among persons.

Figure 6: Saha, Srivastava and the income distribution analogy in kinetic theory of gases. In their textbook *A Treatise on Heat* (1931) Meghnad Saha and B. N. Srivastava used the example of reconstructing a distribution curve for incomes to illustrate the problem of determining the distribution of molecular velocities in kinetic theory. The relevant extract from page 105 of their book (given above) prefigures developments in the first decade of this century showing this indeed the bulk of the income distribution follows a Gibbs-like distribution.

KEMs

- **State of the system**. The status of the agents $i=1,2,...N$ at time t is defined by the wealths $\{ x_1(t), x_2(t), ..., x_N(t) \}$
- **Dynamics.** At each time step (1) choose randomly two agents i and j and (2) update the agent wealths according to

$$x_i \rightarrow x_i - \Delta x$$
$$x_j \rightarrow x_j + \Delta x$$



Dragulescu-Yakovenko

Parameters

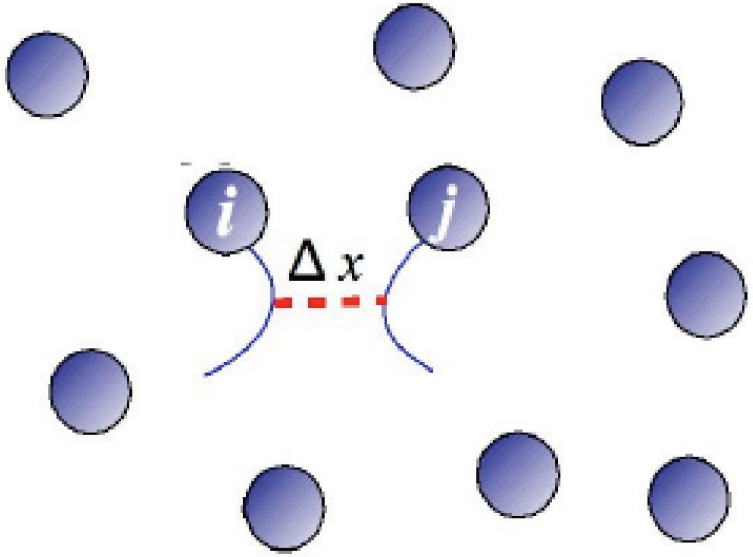
N agents: 1, 2, ..., N
with wealths $x_1, x_2, ..., x_N$

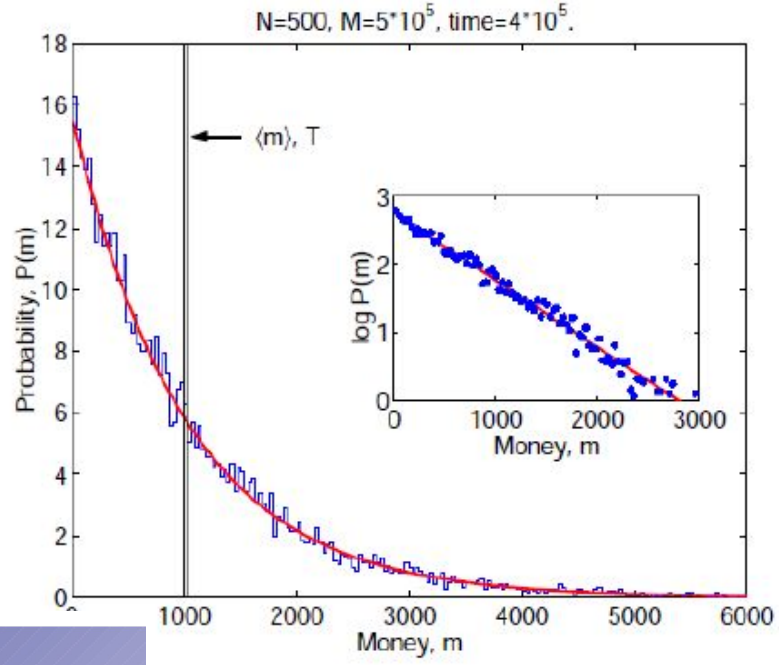
Evolution

at any time step, 1) choose i, j randomly

2)
$$x_i \rightarrow \epsilon(x_j + x_i)$$
$$x_j \rightarrow (1-\epsilon)(x_j + x_i)$$

ϵ = random number in (0,1)





A. Dragulescu, V. M. Yakovenko, Eur. Phys. J. B17(2000)723

Chakraborti-Chakrabarti

Parameters

N agents: 1, 2, ..., N
with wealths $x_1, x_2, ..., x_N$
a single saving propensity λ

Evolution

at any time step, choose i, j randomly

$$x_i \to \lambda x_i + \epsilon(1-\lambda)(x_j + x_i)$$
$$x_j \to \lambda x_j + (1-\epsilon)(1-\lambda)(x_j + x_i)$$

ϵ = random number in (0,1)

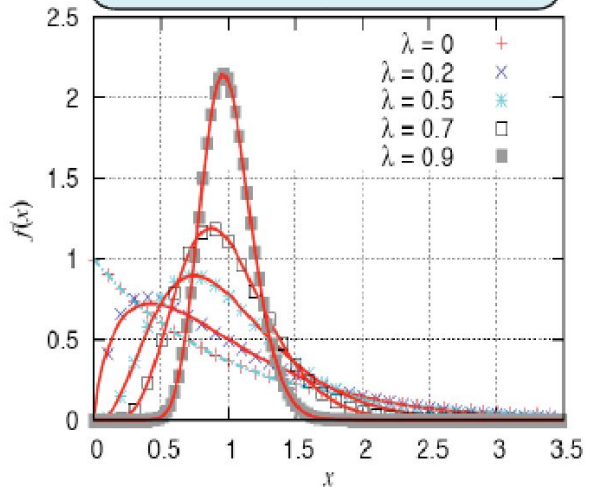
- $D = 2n$ is an effective dimension
- equipartition theorem:

$$\beta^{-1} = \frac{\langle x \rangle}{D/2} \equiv \frac{\langle x \rangle}{n}$$

$$f(x) = \beta \gamma_n(\beta x) = \frac{\beta(\beta x)^{n-1}}{\Gamma(n)} \exp(-\beta x)$$

Model of Chakraborti and Chakrabarti

$$n(\lambda) = 1 + \frac{3\lambda}{1-\lambda} \equiv \frac{N}{2}$$

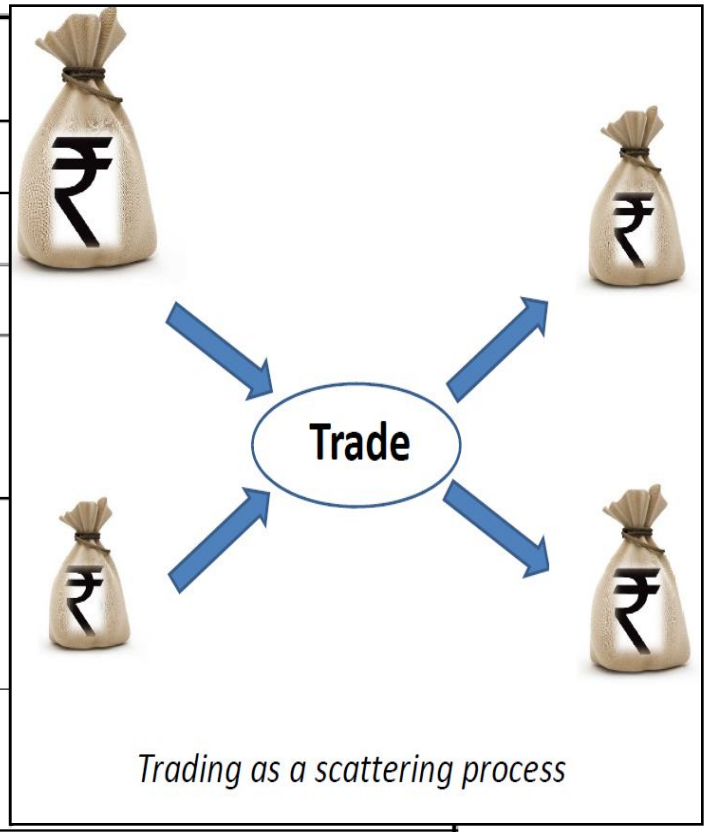


A. Chakraborti and B. K. Chakrabarti, Eur. Phys. J. B 17 (2000) 167.

Marco Patriarca, Anirban Chakraborti, and Kimmo Kaski:
Physica A 340 (2004) 334;
Phys. Rev. E 70 (2004) 016104.

General Mechanism

Economy model	Gas model
x = money	K = kinetic energy
N-agent system	N-particle system
Trades	Collisions
Effective dimension $D = 2(1 + 2\lambda)/(1-\lambda)$	Space dimension D
Effective temperature $T = 2 < x > / D$	Temperature $k_B T = 2 < K > / D$
$\xi = x / T$	$\xi = K / T$



Trading as a scattering process

$$f(\xi) = \gamma_{D/2}(\xi) = \frac{1}{\Gamma(D/2)}\, \xi^{D/2-1} \mathrm{e}^{-\xi}$$

A. Chakraborti and M. Patriarca, Pramana 71, 233 (2008).
M. Patriarca, E. Heinsalu, A. Chakraborti, and G. Germano, Eur. Phys. J. B 57, 219 (2007).

Chatterjee-Chakrabarti-Manna

Model

N agents: 1, 2, ..., N
with wealths $x_1, x_2, ..., x_N$,
saving prop. $\lambda_1, \lambda_2, ..., \lambda_N$

Evolution

choose i and j

$$x_i \to \lambda_i x_i + \epsilon[(1-\lambda_i)x_i + (1-\lambda_j)x_j]$$

$$x_j \to \lambda_j x_j + (1-\epsilon)[(1-\lambda_i)x_i + (1-\lambda_j)x_j]$$

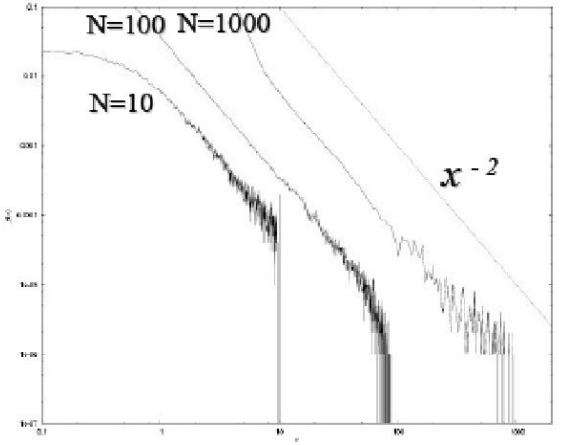
ϵ = uniform random number in (0,1)

Numerical simulations and analytical calculations show that a uniform density

$$\phi(\lambda) = 1 \quad \text{for} \quad 0 < \lambda < 1$$
$$= 0 \quad \text{otherwise}$$

produces a power law tail $f(x) \sim 1/x^2$

Note: choosing $\phi(\lambda) \propto (1-\lambda)^\alpha$
leads to $f(x) \sim 1/x^{2+\alpha}$
(Chatterjee - Chakrabarti - Manna)



A. Chatterjee, B. K. Chakrabarti, S. S. Manna, Physica Scripta T106 (2003) 36.
A. Chatterjee, B. K. Chakrabarti, S. S. Manna, Physica A 335 (2004) 155.
P. Repetowicz, S. Hutzler, P. Richmond, Physica A 356 (2005) 641.
M. Patriarca, A. Chakraborti, K. Kaski, G. Germano in A. Chatterjee, S.Yarlagadda, B. K. Chakrabarti (Eds.), *Econophysics of Wealth Distributions*, Springer, 2005.
P. K. Mohanty, arxiv.org: physics/0603141

Gibbs Law

Variational principle for one degree of freedom

Variational principle approaches based on the variation of an entropy functional find a natural application in the study of social and economic processes.

Entropy	$S[f]=\int dq\, f(q)\ln[f(q)]$
Probability conservation	$I[f]=\int dq\, f(q)$
Wealth conservation	$X_{tot}[f]=\int dq\, f(q)X(q)$

Lagrange method:

$$\delta S_{eff}[f]=\delta\{S[f]+\mu I[f]+\beta X_{tot}[f]\}$$

$$=\delta\int dq\, f(q)\{\ln[f(q)]+\mu+\beta X(q)\}=0 \quad\rightarrow\quad f(x)=\frac{\exp(-\beta x)}{\langle x\rangle}$$

Chakraborti-Patriarca

Variational principle for heterogeneous dimensions

n-density $P(n)$, $1 < n < \infty$

Functional	$S[f] = \int dn P(n) \int dx f_n(x) \left\{ \ln \left[\frac{f_n(x)}{x^{n-1}} \right] + \mu_n + \beta x \right\}$
Constraints on probability conservation	$I[f] = \int dx f_n(x) = 1$
(Single) constraint on energy conservation	$X_{tot}[f] = \int dn P(n) \int dx x f_n(x) = 1$

Aggregate density: $f(x) = \int dn P(n) \beta \gamma_n(\beta x) = \int dn P(n) \frac{\beta^n}{\Gamma(n)} x^n e^{-\beta x}$

Chakraborti-Patriarca

General result for the aggregate distribution

$f(x) = \int_1^\infty dn\, P(n)\, \beta\, \gamma_n(\beta x)$ has a maximum at $\beta x \sim 1$

Rewrite it as $f(x) = \beta \exp(-\beta x) \int dm \exp[-\phi(m)]$,

Use the Stirling approximation, then

$$\phi(m) \approx -\ln[P(m+1)] - m\ln(\beta x) + \ln(\sqrt{2\pi}) + (m+\tfrac{1}{2})\ln(m) - m,$$

Use the saddle-point approximation: $f(x) \approx \beta \exp[-\beta x - \phi(m_0)]$

$$\times \int_{-\infty}^{+\infty} d\epsilon \exp[-\phi''(m_0)\epsilon^2/2]$$

$$= \beta \sqrt{\frac{2\pi}{\phi''(m_0)}} \exp[-\beta x - \phi(m_0)].$$

Result: $f(x \gg \beta^{-1}) \equiv f_2(x) = \beta P(1+\beta x).$

Chakraborti-Patriarca

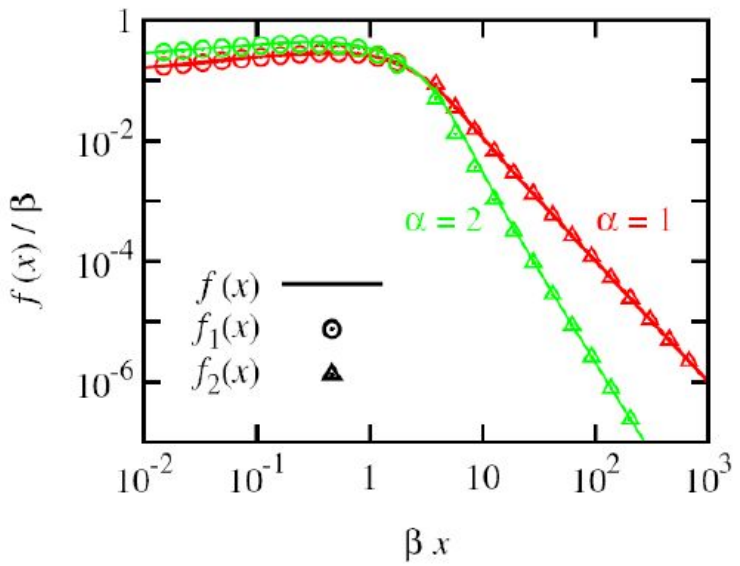
Example: KWEM Aggregate distribution $f(x)$ for distributed λ with density $\Phi(\lambda)$

Simple example: the agents have different saving propensities λ_i with a uniform λ-density $\Phi(\lambda)$.

$$\phi(\lambda)=1 \quad , \quad 0<\lambda<1$$
$$\phi(\lambda)=0 \qquad \text{otherwise}$$

Corresponding form of the n-density

$$P(n) = \frac{d\lambda(n)}{dn}\phi(\lambda(n)) = \frac{3}{(n+2)^2}$$



$$f(x)=\int_1^\infty dn\, P(n)\,\beta\,\gamma_n(\beta x)$$

A. Chakraborti and M. Patriarca, Physical Review Letters 103, 228701 (2009).

Can humans be modelled as atoms?

A single molecule of gas does not have a temperature (T), or a pressure (p). It is simply a point-like particle that moves at a particular speed, depending on how much energy it has, along with many other particles and are altogether governed by the statistical law of Maxwell- Boltzmann distribution of molecular speeds. When there are of the order of 10^{23} or so molecules in an isolated and sealed box of volume V , their collective behavior can be captured by the ideal gas equation of state:

$$pV = RT ,$$

where R is the gas constant; and even though each individual particle of the gas is moving at random, one can predict with extraordinary accuracy, e.g., how many of them will hit the walls of the box at any one time.

Similarly, an individual person is neither an economy, nor has any of the characteristics of the entire economy. However, a million such persons acting individually builds up the economy, and may be described by some rules that perhaps allow an economy to be predicted.

Physicists' approach to studying socio-economic inequalities: Can humans be modelled as atoms?

Kiran Sharma and Anirban Chakraborti

Abstract A brief overview of the models and data analyses of income, wealth, consumption distributions by the physicists, are presented here. It has been found empirically that the distributions of income and wealth possess fairly robust features, like the bulk of both the income and wealth distributions seem to reasonably fit both the log-normal and Gamma distributions, while the tail of the distribution fits well to a power law (as first observed by sociologist Pareto). We also present our recent studies of the unit-level expenditure on consumption across multiple countries and multiple years, where it was found that there exist invariant features of consumption distribution: the bulk is log-normally distributed, followed by a power law tail at the limit. The mechanisms leading to such inequalities and invariant features for the distributions of socio-economic variables are not well-understood. We also present some simple models from physics and demonstrate how they can be used to explain some of these findings and their consequences.

1 Introduction

Physicists have been always keen on exploring domains outside of physics, like biology, geology, astronomy, sociology, economics, etc., often giving birth to very successful interdisciplinary subjects like biophysics, astrophysics, geophysics, sociophysics, econophysics and so on [1]. The last two interdisciplinary fields: Sociophysics [2, 3] and Econophysics [4, 5], have been only recent additions to the long list. However, the physicists interest in the social sciences (Economics and Sociol-

Chakrabarti-Chakrabarti

- N agents; each produces a perishable commodity.
- Bilateral trading process; each agent has a Cobb-Douglas type preference structure:

  $u_1=(x_1)^{\alpha}(x_2)^{\beta}(m_1)^{\lambda}$ and $u_2=(y_1)^{\alpha}(y_2)^{\beta}(m_2)^{\lambda}$.
- Market clears immediately to match supply and demand.

Chakrabarti-Chakrabarti

- Utility maximization:

$$L=(x_1)^{\alpha}(x_2)^{\beta}(m_1)^{\lambda}+\omega(M_1+p_1Q_1-p_1x_1-p_2x_2-m_1)$$

utility function — Lagrange multiplier — budget eqn.

- FOC: $\delta L/\delta x=0$ where $x=x_1,x_2,m_1$ and ω.
- Let us assume that $\alpha+\beta+\lambda=1$.
- Demand functions: $x_1=\alpha(M_1+p_1Q_1)/p_1$,

  $x_2=\beta(M_1+p_1Q_1)/p_2$, $m_1=\lambda(M_1+p_1Q_1)$;

Chakrabarti-Chakrabarti

- Similarly dd. Functions for the 2nd agent:
  $y_1 = \alpha(M_2+p_2Q_2)/p_1$, $y_2 = \beta\,(M_2+p_2Q_2)/p_2$,
  $m_2 = \lambda(M_2+p_2Q_2)$

- Market clearing $\Longrightarrow$ $x_1+y_1=Q_1$ & $x_2+y_2=Q_2$

- Equilibrium prices:
  $p_1=(\alpha/\lambda)(M_1+M_2)/Q_1$ & $p_2=(\beta/\lambda)(M_1+M_2)/Q_2$

Economics
The Open-Access, Open-Assessment E-Journal
Vol. 4, 2010-4 | January 26, 2010 | http://www.economics-ejournal.org/economics/journalarticles/2010-4

Chakrabarti-Chakrabarti

- Money transfer equations (plugging p_1 and p_2 in the money dd. functions) :

$$m_1(t+1)= \lambda m_1(t)+\epsilon(1- \lambda)(m_1(t)+m_2(t))$$

$$m_2(t+1)= \lambda m_2(t)+(1- \epsilon)(1- \lambda)(m_1(t)+m_2(t))$$

where $m_i(t+1)= m_i$ and $m_i(t)=M_i$ for i=1,2

and $\epsilon = \alpha /(\alpha + \beta)$;

- Let λ be fixed and $\alpha \sim$ uni$[0,1- \lambda] \sim \beta$.

Hence, $\epsilon = \alpha /(\alpha + \beta)= \alpha /(1- \lambda) \sim$ uni[0,1].

Entropy maximization (Physics) ⟺ **Utility maximization (Economics)**

A. S. Chakrabarti, B. K. Chakrabarti, Physica A 388 (2009) 4151-4158

Data Science Approach

2018 IEEE 5th International Conference on Data Science and Advanced Analytics

Global Income Inequality and Savings: A Data Science Perspective

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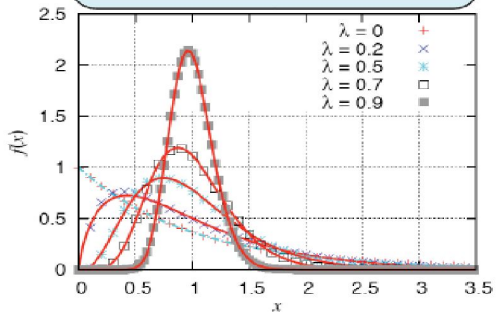
***Abstract*—A society or country with income equally distributed among its people is truly a fiction! The phenomena of socio-economic inequalities have been plaguing mankind from times immemorial. We are interested in gaining an insight about the co-evolution of the countries in the inequality space, from a data science perspective. For this purpose, we use the time series data for Gini indices of different countries, and construct the equal-time cross-correlation matrix. We then use this to construct a similarity matrix and generate a map with the countries as**

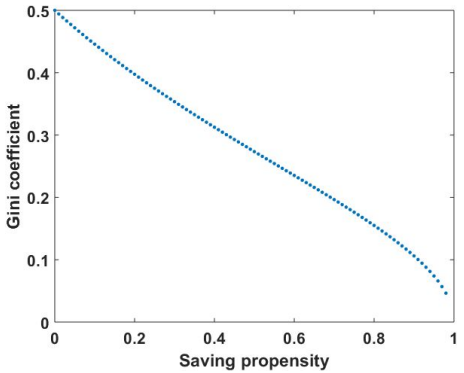
activists, academicians (including sociologists, economists and recently physicists), have passionately put their efforts in understanding the origin/cause and finding remedies to this multifaceted problem [1]–[4]. What has survived the tests of time is that the income inequality is a robust phenomenon, and in fact possesses certain statistical regularities [5]. Many studies have demonstrated that irrespective of the nature and size of the society, irrespective of the status of economy,

$$f(x)=\beta\gamma_n(\beta x)=\frac{\beta(\beta x)^{n-1}}{\Gamma(n)}\exp(-\beta x)$$

Model of Chakraborti and Chakrabarti

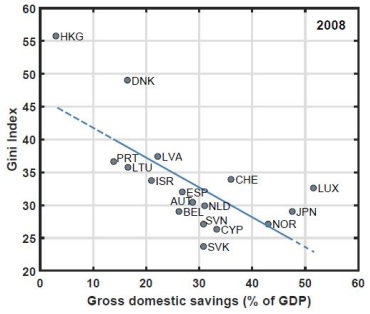
$$n(\lambda)=1+\frac{3\lambda}{1-\lambda}\equiv\frac{N}{2}$$

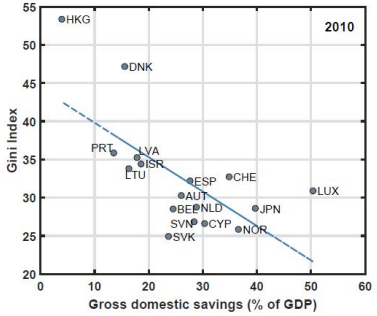


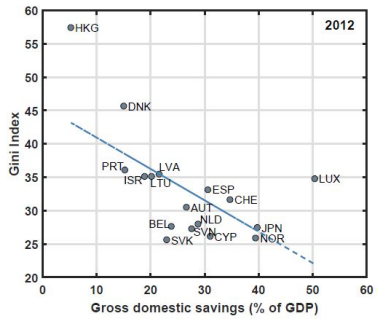


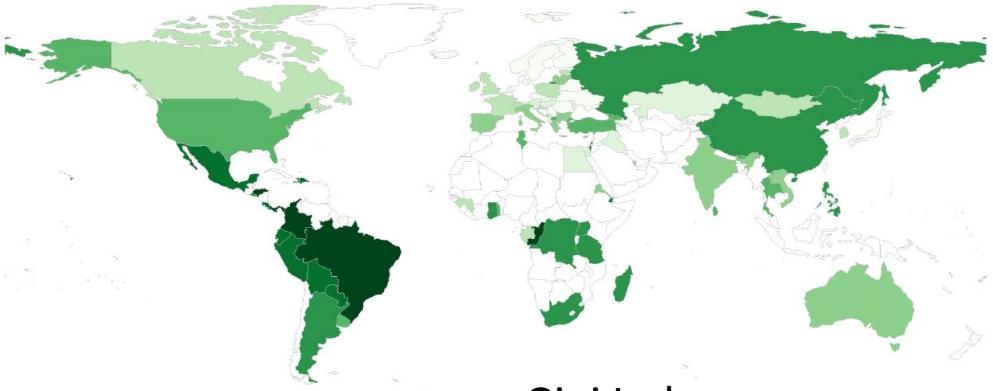
$$G=1-\frac{1}{\mu}\int_0^\infty (1-F(y))^2 dy=\frac{1}{\mu}\int_0^\infty F(y)(1-F(y))dy$$

Kinetic exchange : **Chakraborti-Chakrabarti** model (2000)



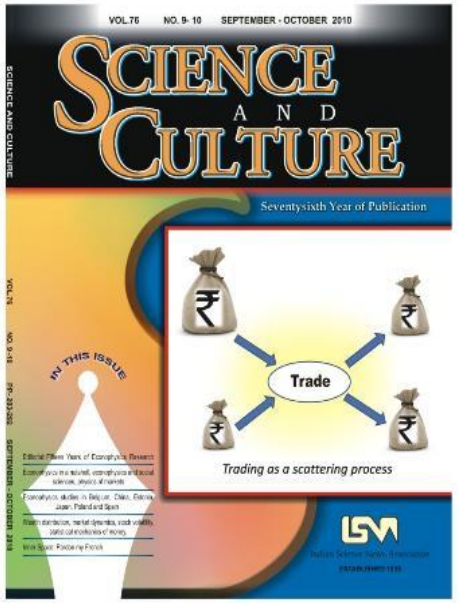






Gini Index

Summary: Kinetic Exchange Models



Economy model	Gas model
x = money	K = kinetic energy
N-agent system	N-particle system
Trades	Collisions
Effective dimension $D = 2(1 + 2\lambda)/(1-\lambda)$	Space dimension D
Effective temperature $T = 2 < x > /D$	Temperature $k_B T = 2 < K > / D$
$\xi = x / T$	$\xi = K / T$

$$f(x) = \beta \gamma_n(\beta x) = \frac{\beta(\beta x)^{n-1}}{\Gamma(n)} \exp(-\beta x)$$

$$f(\xi) = \gamma_{D/2}(\xi) = \frac{1}{\Gamma(D/2)} \xi^{D/2-1} e^{-\xi}$$

Model of Chakraborti and Chakrabarti

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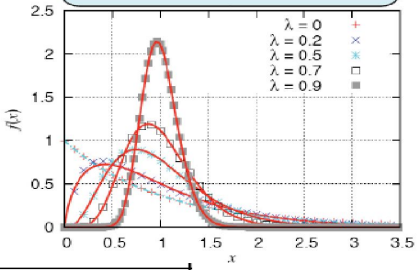
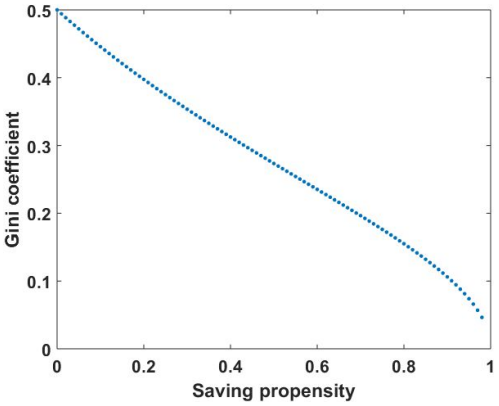
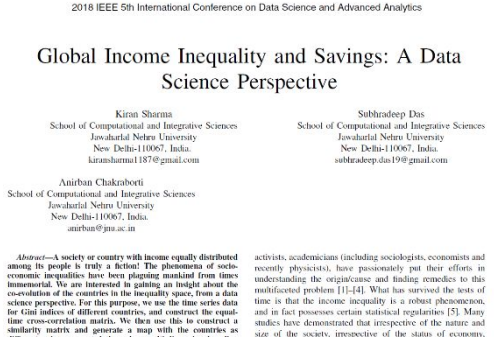




$$G = 1 - \frac{1}{\mu}\int_0^\infty (1 - F(y))^2 dy = \frac{1}{\mu}\int_0^\infty F(y)(1 - F(y)) dy$$

Chakraborti-Chakrabarti Model

EPJB 17, 167-170 (2000)


2018 IEEE 5th International Conference on Data Science and Advanced Analytics

Global Income Inequality and Savings: A Data Science Perspective

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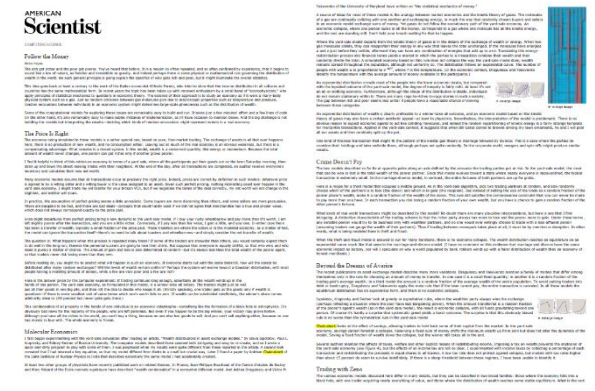


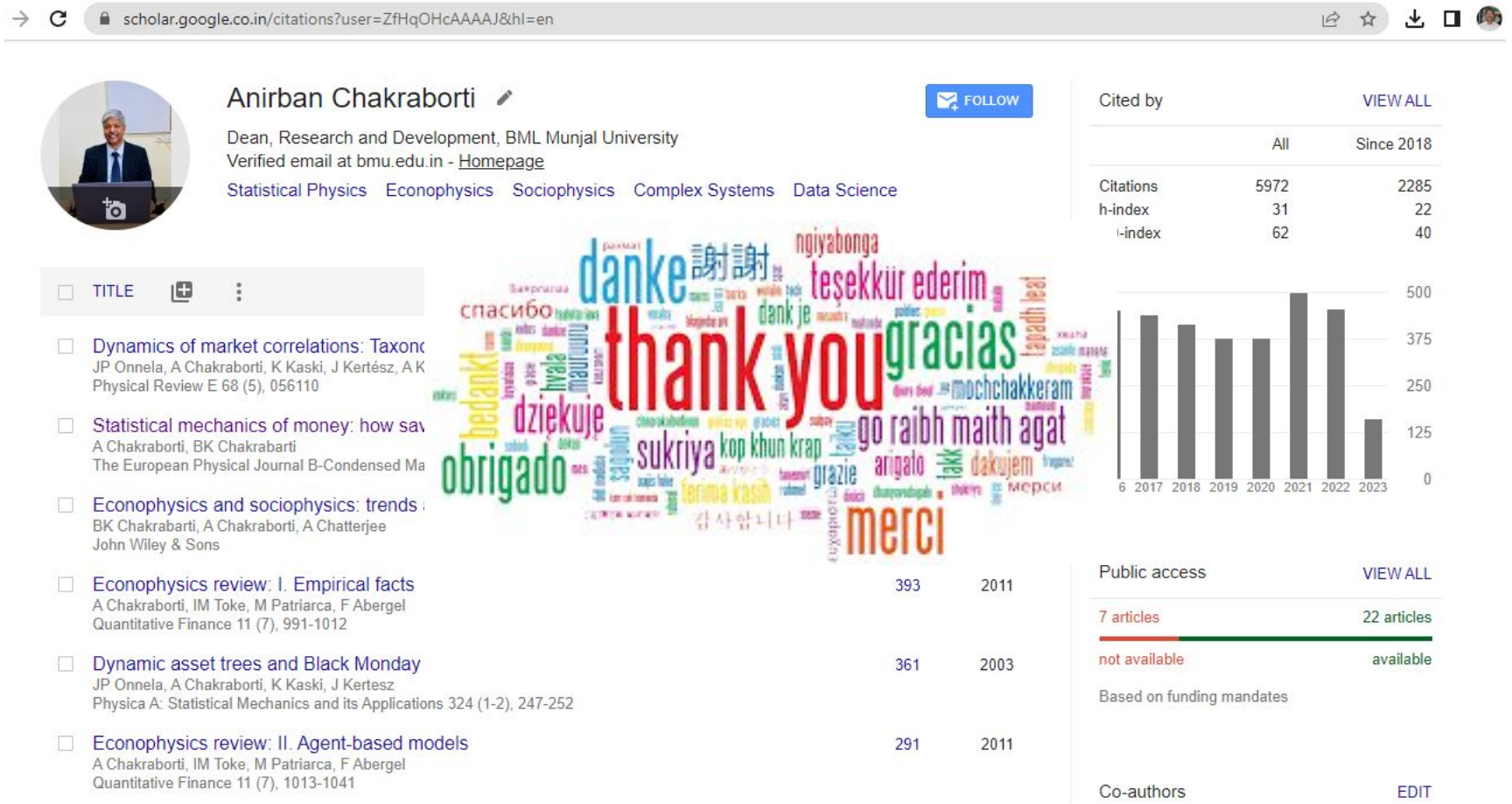
Hayes (2002)

Boghosian (2019)

Yard Sale Model

Chakraborti, IJMPC 13, 1315-1321 (2002)

My research and contact details



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1. Do you think technology advancement and AI exacerbates inequality?

2. How do you think Complexity Science can help in inequality studies?