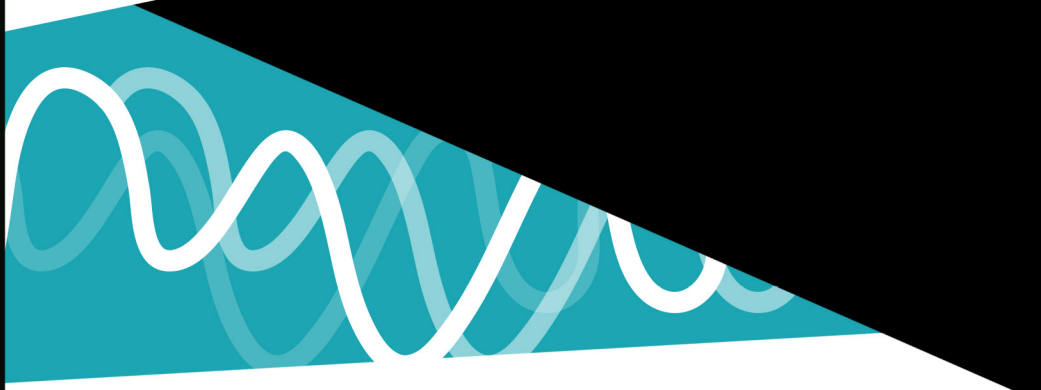
THE STORY OF
ECONOPHYSICS

KISHORE CHANDRA DASH



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By

Kishore Chandra Dash

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PREFACE

I was unaware of the term "Econophysics" before November 2006 when I attended a lecture by Bikas Chakrabarti, a senior Professor at Saha Institute of Nuclear Physics (SINP, Kolkata) at Calcutta University. In fact, the word "Econophysics" was coined in 1995 at Calcutta University by Prof. H. E. Stanley of Boston University, USA, during an international conference. It had taken 11 years for me to realise the existence of such a field. Even 24 years after the birth of Econophysics, I still think many people are unaware of the subject. That is the reason why I was interested in writing this book, "The Story of Econophysics", which is non-technical in nature so that it can reach many people who have a background in neither Economics nor Physics.

As a first step to achieving this goal, I published my article entitled "Evolution of Econophysics" as a conference proceeding in Chapter 14 of the book, "Econophysics of Agent-Based Models" (pp. 235-285), edited by Frederic Abergel et al., published by Springer International Publishing, Switzerland, in 2014. Similarly, I authored another article published in Part IV, the Discussions and Commentary section of the book, "Econophysics and Data driven Modelling of Market Dynamics" (pp. 327-348), edited by Frederic Abergel et al., published by Springer International Publishing, Switzerland, in 2015. The present book, "The Story of Econophysics" is an extension of the above chapters. I also mentioned in the acknowledgement on page 284 of "Econophysics of Agent-Based Models" that this chapter forms a small part of a proposed book.

Chapter One of this present book deals with the background of the development relating to Economics and Physics, leading to Econophysics. For the interest of the readers, bio-boxes of the scientists are included. In Chapter Two, there are contributions from institutes, conferences and workshops, books and journal articles related to Econophysics, courses offered by some Universities, and awards given in Econophysics research etc. Chapter Three emphasises major research work relating to Econophysics. Furthermore, I have added the opinion of different people, views of newspapers etc. on this new subject in Chapter Four of this book. In Chapter Five, I present the results of a questionnaire I conducted with

leading Econophysicists regarding the impact of Econophysics. Chapter Six deals with the remarks of Prof. Bikas Chakrabarti in the concluding session of the Joint International Conference entitled "Econophys-2017 & Asia-Pacific Econophysics Conference (APEC)-2017", held in JNU and DU, New Delhi from 15 to 18 November 2017.

I am grateful to Prof. Bikas Chakrabarti, Ex-Director, Saha Institute of Nuclear Physics for his continued support and encouragement as I have been writing this book. I am thankful to all the scientists who sent their responses to my questionnaire. I extend my thanks to Springer Nature for allowing me to reuse my published work in this book. I am very grateful to my British editor, Eleanor Moore for proofreading and to Cambridge Scholars Publishing, UK for publishing this book.

Kishore C Dash
03.07.2019

CHAPTER ONE

ECONOPHYSICS NOW AND THEN

1.1 Introduction

Education systems originated in ancient times. However, people started learning to write around 3500 BCE. Basic communication skills, trading customs, language and religious practices were taught in Egypt between 3000 and 500 BCE. Vedic education consisted of proper pronunciation and recitation of the Veda, grammar and derivation, understanding of the secrets of nature, composition, versification of the rules of sacrifice, reasoning, including logic, the sciences, and the skills necessary for an occupation. There were five national schools in the capital city, Pi Yong, and four other schools for aristocrats and the nobility, including Shang Xiang in China during the Zhou Dynasty (1045-256 BC). Rites, music, archery, charioteering, calligraphy, and mathematics were taught in those schools. According to modern educational theorist Howard Gardner:

"Greek philosophers may have been the first to raise questions about the nature of matter, living entities, knowledge, will, truth, beauty, and goodness. In recent centuries, however, philosophy has steadily been yielding ground, enthusiastically or reluctantly, to empirical science" (Gardner, 2000, p. 1).

In India, formal education started before it did so in any other country. Sanskrit is the first language and the mother of many languages.

According to American historian, Will Durant (1885-1981):

> "India was the motherland of our race and Sanskrit the mother of Europe's languages. India was the mother of our philosophy, of much of our mathematics, of ideals embodied in Christianity.... of self-government and democracy. In many ways, Mother India is the mother of us all."

According to the magazine, *Forbes* (July 1987), the most suitable language for speech recognition by a computer was considered to be

Sanskrit. It is interesting to note that the principle of writing code was already there in the Sanskrit language in the work of Panini some 2500 years ago, as observed by western scientists.

1.2 Ancient Universities

The first university in the world was established in Takshasila (1000 BC to 500 AD) in present-day Pakistan. It became famous in 700 BC. There was no coordination of the teachers' work nor was there any external authority, such as that of a king who would govern his people. Every teacher had complete freedom and there was no obstruction to his work. Takshasila became the centre of higher education because several teachers who were recognised as authorities in their subjects resided there. One of the greatest achievements in the field of education was brought about by Nalanda University which was established in Bihar, India (425 AD-1205 AD) which was known as the Harvard of its times. Over 60 subjects were taught to more than 10,500 students in this university. Many foreign students were attracted to read in Nalanda.

1.3. Science

Another quotation follows from Grant Duff, British Historian of India:

> "Many of the advances in sciences that we consider today to have been made in Europe were in fact made in India centuries ago."

Some 1200 years before Sir Isaac Newton rediscovered the laws of gravity, Bhaskaracharya spoke about it in his Surya Siddhanta:

> "Objects fall on Earth due to the force of attraction of Earth. Therefore, the Earth, Planets, Constellations, Moon and the Sun are held in orbit by attraction."

Aryabhatta published his theory of the revolution of the Earth, a thousand years before Copernicus, which stated that the Earth revolves around the Sun:

> "Just as a person travelling in a boat feels that the trees on the bank are moving, people on the Earth feel that the Sun is moving."

Indians have even estimated the size of atoms in terms of units familiar to them as follows:

> "A tip of the human hair is divided into 100 parts and each part is in turn divided into 100 parts."

Seven colours of sunlight are mentioned in Rigveda; one quotation from Vedas supports these statements:

> "The Seven rays of the Sun are falling; there I live with my family."

These statements provide evidence of the assumption that the seven colours of sunrays were very well known, even during the Vedic period.

1.4. Economics (Arthashastra)

Chanakya, who is considered as the "Pioneer Economist of India" had written Arthashastra (*Science of Economics*), which is an extraordinary manual on statecraft and is read in Europe even today. Chanakya (350-283 BC) was the adviser and Prime Minister of Emperor Chandragupta and also an expert in economics, warfare, and commerce, and had served as a professor at the University of Takshasila (located in present-day Pakistan). In his work, Artha (wealth) is used in the sense of:

a. Material well-being
b. Livelihood
c. Wealth of Nations

Thus, Arthashastra is "the science of economics". It contains 15 books, which cover numerous topics on economics, government, administration, etc. It contains 380 shlokas. A shloka is a couplet of Sanskrit verse, especially one in which each line contains 16 syllables. The first five books deal with internal administration and the last eight with a state's relations with its neighbours.

"Arthashastra" had existed even before Chanakya, but all the works were lost.

1.5. Econophysics

Econophysics is a transdisciplinary research field, in which applying theories and methods originally developed by *physicists* are applied to the solving of problems in *economics*. *H. Eugene Stanley* coined the term "econophysics" in 1995 during a conference on statistical physics in Calcutta, which addressed the large number of papers written by physicists

on the problems of (stock and other) markets. *János Kertész* and *Imre Kondor* organised the first workshop on econophysics in Budapest in 1998. Some of the pioneer econophysicists are *H. Eugene Stanley*, Victor Yakovenko, Yi-Cheng Zhang, *McCauley*, Enrico Scalas, *Didier Sornette*, *Jean-Philippe Bouchaud*, *Bikas K Chakrabarti*, *Dirk Helbing*, *János Kertész* and Matteo Marsili.

Before the term was created in 1995, people from other fields had worked and applied their knowledge in the field of economics. The evolution of econophysics can be considered to have taken place in three different stages:

1. Pre-Classical era
2. Classical era
3. Modern era

1. Pre-Classical era – This can be considered as the period when there was no boundary between the study of different subjects. A philosopher was free to think and work in any field. There were no boundaries and no specialisations as there are today. There were no sharply defined fields. It was the pre-Newtonian era; there was no systematic physics and it was long before the development of social science (which started towards the third quarter of the eighteenth century).

2. Classical era – This can be considered as the era after Newton during which many branches of science evolved. Later on, social sciences came into existence in different fields like economics, political science, sociology, etc. In this period, people were jumping from their mainstream subject to other branches, for example physical scientists were moving from their field to social sciences and vice versa. Natural sciences and social sciences are just like two sides of a river, which has no bridge. In this section, we shall deal with the jump and bridging the gap between natural sciences and social sciences.

3. Modern era – Finally, we describe the modern era of econophysics i.e., "institutionalised econophysics" after the word **"econophysics"** was coined by Professor H. Eugene Stanley, in Kolkata, India, in 1995. During this period, people worked in interdisciplinary fields, such as natural scientists who published papers, wrote books and convened workshops in the field of social sciences, thus bridging the gap between the two fields. We can say that bridges have been built over the river, so it is possible to cross the river and reach the other bank without the need to jump over.

1.5.1 Pre-Classical Era

1.5.1.1 Concept of just price

Bio Box 1.1

Thomas Aquinas (1225-1274)
Alma Mater - Cologne and Paris
Known For - Concept of just Price

Thomas Aquinas (1215-1274) According to Thomas Aquinas, an Italian theologist and writer on economic problems, "just price", a concept enunciated by him, means there is just sufficient to cover the *costs of production*, which includes the maintenance of a worker and his family. According to him, it is a kind of theft if one raises the price at a time of high demand.

1.5.1.2 Criticism of Just Price

***Duns Scotus* (1265-1308)** – Scotus, who was a philosopher from Scotland and a professor in Paris, Oxford and Cologne, is critical of the "just price" concept. He defended merchants. He argued, why one would trade if one did not make a profit? He said merchants were doing a social service by making goods available to the public and transporting them from one place to another.

1.5.1.3 The Medieval Concept of Money

Nicole Oresme (1320-1382). Nicole Oresme was a great philosopher before Copernicus, who did a lot of work in almost all fields during the fourteenth century. It is very interesting to note that he had an interest in science, social science, theology, cosmology and the like. Let us now go into his work in more detail:

Bio Box 1.2
Oresme's life

Born c. 1320-1325 in the village of Allemagne (today's Fleury-sur-Orne)

Alma Mater, College of Navarre, University of Paris

Subjects of Study – Arts, Theology

PhD – 1356

1369 – Started translation of the works of Aristotle at the request of Charles

Appointed Bishop of Lisieux – 1377

Nicole Oresme was a great philosopher of the later Middle Ages. He has worked and written on astronomy, philosophy, economics, mathematics, theology and physics.

Oresme's scientific work

Cosmology

According to Oresme, the heavens are in motion but not the Earth.

Mathematics

Tractatus de configurationibus qualitatum et motuum contains his important contributions to mathematics. He conceived the idea of rectangular coordinates and even the three dimensions. He applied his concept to local motion considering speed as length (latitude) and time as longitude, which gives distance travelled represented by area. The movement of a point in space can be figured out from his idea.

Fig 1.1 Portrait of Nicole Oresme

Economics

Oresme's manuscript *Treatise on the origin, nature, law, and alterations of money* delivers an insight into the medieval conception of money.

1.5.1.4 The Value of Money

Nicolaus Copernicus (1473-1543)

Copernicus was an adviser to King Sigismund of Prussia on monetary reforms and had participated in a discussion in East Prussia regarding coinage reform. His recommendations on monetary reform were being followed by the leaders of both Prussia and Poland. His article *Monetae cudendae ratio* in 1526 presented a version of Gresham's law 70 years earlier.

Bio Box 1.3
Nicolaus Copernicus
Portrait, 1580, Toruń Old Town City Hall
Born 19 February 1473 Toruń (Thorn), Royal Prussia, Kingdom of Poland
Died 24 May 1543 (aged 70) Frombork (Frauenburg), Prince-Bishopric of Warmia, Royal Prussia, Kingdom of Poland

Fields – Mathematics, astronomy, canon law, medicine, economics
Alma mater Kraków University, Bologna University, University of Padua, University of Ferrara

Known for Heliocentrism, Copernicus' Law
Signature

1.5.2 Classical Era

Mathematics is the oldest of all sciences and existed before Galileo Galilei (1564-1642). However, it is an analytical science. Physics, a science based on observations and experiments, would develop later on. The development of mathematics was probably due to the demands of astronomical studies. Astronomical studies had a deep impact on the development of physics, giving rise to the birth of classical physics which was achieved almost single-handedly by Sir Isaac Newton (1643-1727). However, people with a science background made a jump to social science during this era and we shall discuss their contribution to the field of economics, while remaining in their core field.

1.5.2.1 The Origin of the Gold Standard

Sir Isaac Newton (1642-1727)

Newton was a mathematician and physicist who was born in 1642 in Woolsthorpe in Lincolnshire. Systematic physics is considered to have originated from Newton. His apple story gives a good explanation of gravity. The entire field of classical mechanics is named after him as Newtonian physics. He is honoured as the greatest physicist of all times and generations. However, Newton was quite humble and had written in his own words:

"I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea-shore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Fig 1.2 Descendants of Newton's *apple tree*.

The Gold Standard

Newton's works were not just confined to physics or mathematics; rather he spent a precious 30 years of his life contributing to economics, by reforming the coinage of England. He was also the master of the mint, who valued gold over silver so that it became the standard in Great Britain. In 1696, he took charge as the warden, and in 1699, he became the Master of the Royal Mint until his death in 1727. During his 30 years at the Royal Mint, Newton brought a lot of reforms to the nation's coinage.

He is indeed a celebrated part of a distinguished history. Queen Anne knighted him in Cambridge in 1705 and he was buried in Westminster Abbey.

Bio Box 1.4
Sir Isaac Newton
Born 25 December 1642, *Lincolnshire*, England
Died 20 March 1727 (aged 84)
Kensington, Middlesex, England
Residence – England Nationality – English
Fields – Physics, mathematics, astronomy, natural philosophy, alchemy, Christian theology
Institutions – University of Cambridge, Royal Society , Royal Mint
Alma mater – Trinity College, Cambridge. Known for Newtonian mechanics, Universal gravitation, Infinitesimal calculus Optics, Binomial series, Newton's method, Philosophiæ Naturalis Principia Mathematica
Signature

Newton not only standardised Britain's coinage, but he also profited from it nicely as his remuneration was six hundred pounds a year. However, this was a time of expansion for England's economy, as merchants began trading all over the world. More coins were needed to keep up with the demand for trade. This could fetch him up to 1000 pounds a year as his salary. He was also able to prosecute 28 people engaged in counterfeiting coins.

Fig 1.3

1.5.2.2 The actuarial foundations of life assurance

Edmond Halley (1656-1742) He was the sponsor of Sir Isaac Newton's Principia, and the Editor of Philosophical Transactions. He was an Oceanographer, Meteorologist, Geophysicist, Inventor and Navigator and was quite famous for his research in determining longitude. Halley had predicted that a transit of Venus would occur in 1761 and it would be an ideal situation to make measurements from all locations of the Earth.

Bio Box 1.5
Edmond Halley – born in 1656 at Haggerston, London
Alma mater – St Paul's School and Queen's College, Oxford which he left in 1676 without a degree

Most influential work – to calculate the orbits of over twenty comets
1721– appointed Astronomer Royal and was the first to predict the return in 1758 of the periodic comet which now bears his name

Died in Greenwich on 14 January 1742

Besides astronomical inventions, he laid **the actuarial foundations of life assurance**.

Underwriters calculate risk and decide premiums based on statistics. In 1693, the astronomer Halley was the first to develop the mortality table. The problem was that the table had the same rate for all ages, which was corrected by Dodson in 1756.

Fig 1.4

Memorial of Halley

> "This memorial marks the comet's return in 1986, intercepted by the European spacecraft Giotto and built by British Aerospace."

1.5.2.3 Actuarial legacy

James Dodson (1705-1757) Besides being a mathematician, Dodson was an actuary and innovator in the insurance industry.

Bio Box 1.6
James Dodson

Born – 1705
Died – 23rd Nov, 1757
Work – Accountant and Teacher
Major contribution -The anti-logarithm canon (1742), The Calculator-1747
Field – Mathematics
Fellow of Royal Society – 1755
Elected Master of Royal Society - 1755

Actuarial legacy

Actuarial science is the study of assessing risk in the finance and insurance industries. Mathematics, statistics, economics, programming, etc. are different components of actuarial science. Premiums are calculated for long-term life insurance policies using mathematics, statistics, and deterministic models as a tool. Actuarial principles developed by Dodson

were used by The Equitable Life Assurance Society (1762). As Dodson was aged over 45, he was not considered for membership of the Amicable Life Assurance Society, so he formed a new society and built on the mortality tables developed by Edmond Halley in 1693.

His mathematical marvels are contained in *The Anti-Logarithmic Canon* published in 1742 consisting of all logarithms under 100,000 and *The Mathematical Miscellany* published in 1747, which contains analytical and algebraic solutions to a large number of problems in various branches of mathematics, as well as problems relating to insurances, annuities, etc.

1.5.2.4 The expected utility hypothesis and Bernoulli's formulation

Daniel Bernoulli **(1687-1759)**

Daniel Bernoulli initiated his theory in 1738, in which he showed the mathematical relationship between uncertain outcomes like gambles (whether in money or other goods) with the probabilities of occurrence.

Bernoulli's formulation

Nicolas Bernoulli described the St. Petersburg paradox (involving infinite expected values) in 1713, which helped two Swiss mathematicians to develop the expected utility theory as a solution.

Daniel Bernoulli (Cousin of Nicolas Bernoulli), published *a New Theory on the Measurement of Risk* in 1738. Daniel used the probability for risk aversion and proposed a higher risk premium for low probability events.

Bernoulli's concept of marginal utility from many years ago is applied to economics now.

While Bernoulli's paper was concise and brilliant, the theory is seriously flawed. It was not until 2000 that the behavioural economist, Matthew Rabin finally mathematically proved that the utility of wealth cannot explain loss aversion and that attempts to use it in that way will fail. One of the flaws of Bernoulli's theory was that it lacked a reference point but it remained a dominant theory for over 250 years.

Bio Box 1.7
Daniel Bernoulli

Born	8 February 1700 in Groningen, Dutch Republic
Died	17 March 1782, Basel
Nationality	Swiss
Alma mater	Heidelberg University, University of Basel (M.D., 1721), University of Strasbourg
Known for	Bernoulli's principle, Thermodynamics, The early kinetic theory of gases,
Fields	Mathematics, physics, medicine

1.5.2.5 The Physiocrat's Model

Francois Quesnay (1694-1774)

Quesnay was a physician and surgeon who applied his ideas of blood circulation to economic circulation and accordingly his economic model is known as the Physiocrat's model. Quesnay was in his early sixties around 1750, and he became interested in economics. According to his thinking, the economic circle of commodities is similar to the circulation of the blood. According to Quesnay, the heart plays the same role in blood circulation as agriculture does in the social and economic system. Quesnay's argument about "unproductive labour" was one of his central propositions. Smith intended to dedicate *The Wealth of Nations* to Quesnay, had Quesnay not died before its publication. Quesnay said that the future of France depended on agricultural development and not on industry. Quesnay's economic theory is synonymous with the texts of today's mainstream neoclassical theory.

Bio Box 1.8

François Quesnay, after a portrait by Jean-Martial Frédou. Born June 4 1694 at Méré near Versailles
Died December 16, 1774 (aged 80) Versailles
Nationality – French
Field – Political economics

1.5.2.6 The Unpredictable Can Be Predictable

Pierre-Simon Laplace (1749-1827) Laplace, famous for his "Laplace's demon", was a mathematical physicist. In his *Essai Philosophique Sur les Probabilities* in 1812, he said that events that might seem random and unpredictable can be quite predictable and can be shown to obey simple power laws. Adolphe Quetelet studied the ideas of Laplace and went a step further by proving the existence of patterns in datasets ranging from economic to social problems.

Bio Box 1.9
Pierre-Simon, Marquis de Laplace
Pierre-Simon Laplace (1749-1827). Posthumous portrait by Madame Feytaud, 1842. Born 23 March 1749, Beaumont-en-Auge, Normandy, France. Died 5 March 1827 (aged 77), Paris, France
Nationality – French
Fields – Astronomy and Mathematics
Institutions – École Militaire (1769–1776)
Alma mater – University of Caen

1.5.2.7 Social Physics

Lambert Adolphe Jacques Quetelet (1796 – 1874)

Quetelet was a Belgian astronomer, who founded and directed the Brussels Observatory. He was also a mathematician, sociologist and statistician. He introduced statistical methods to the social sciences. He has contributed a lot to mathematics, sociology, criminology, etc.

Social Physics

Quetelet attempted to apply probability and statistics to social science and called it "social physics". He tried to understand the statistical laws involved in such phenomena as crime rates, marriage rates or suicide rates. He published his work in his book *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale* in 1835 and its English version is entitled *Treatise on Man.*

Bio Box 1.10
Adolphe Quetelet
Born – 22 February 1796 Ghent, Belgium
Died – 17 February 1874 (aged 77) Brussels, Belgium
Nationality – Belgian
Fields – astronomer, mathematician statistician, sociologist
Institutions – Brussels Observatory
Alma mater – University of Ghent
Known for sociology

1.5.2.8 Science of Society

Auguste Comte (1798-1857) Comte studied in the École Polytechnique in Paris and then at the Medical School at Montpellier.

Comte published his work *A General View of Positivism* in 1865 in five volumes of which the first three contain the physical sciences, which were

already in existence. The other two volumes deal with social sciences. He is considered as the first philosopher of science. He was the first to distinguish between social science and natural science. Comte's classification of science is inorganic and organic physics. Astronomy, earth science and chemistry belong to inorganic physics, whereas biology and "sociologie" (physique sociologie) belong to organic physics. He neologised the term "Sociologie" in 1938. Comte had used the term "social physics" earlier but discarded it as it was used by others such as Quetelet.

Bio Box 1.11
Comte (1798-1857)
Born – 19 January 1798, Montpellier, France
Died – September 5, 1857 (aged 59) Paris, France
Alma mater – University of Montpellier, École Polytechnique in Paris
Notable ideas – Positivism, Sociology, Law of three stages, Encyclopaedic law

1.5.2.9 Monopolies

Antoine Augustin Cournot (1801-1877) Cournot was mainly a mathematician but also had an influence in economics and his application of mathematics to economic analysis is contained in his book *Researches on the Mathematical Principles of the Theory of Wealth* published in 1838. He was the first to draw supply and demand curves, 30 years before Alfred Marshall. According to his "One monopoly profit" theorem, "a monopolist can extract only one premium for being a monopolist, and getting into complementary markets does not pay". However, it is not applicable when

the monopolist's market is price-regulated (Baxter's Law). Nowadays, Cournot's work is recognised in econometrics. He is also credited as one of the sources of inspiration for Léon Walras and his equilibrium theory. He is well known for oligopoly theory – the Cournot competition in the field of economics.

Bio Box 1.12
Cournot

Born	28 August 1801, Gray, Haute-Saône, France
Died	31 March 1877 (aged 75), Paris, France
Nationality	French
Alma mater	Sorbonne University
Known for	Cournot competition, Oligopoly
Fields	Economics, Mathematics
Institutions	University of Grenoble

1.5.2.10 Marginalism

Léon Walras (1834-1910) Walras was a French mathematical economist. Before studying economics, he had studied mining engineering, and he had been a bank manager, a railway clerk and a novelist. Walras was in favour of the nationalisation of land. Being influenced by Cournot, he used mathematics in economics. Walras' work was too difficult for readers as it was mathematically complex. In the modern era, it is read extensively for its in-depth study of the market. To his credit, he was one independent enunciator of marginality theory. He is also considered as the father of the *general equilibrium theory* because of his work, *Elements of Pure Economics*, published in 1874 and 1877.

Walras' Law states that "considering any particular market, if all other markets in an economy are in equilibrium, then that specific market must also be in equilibrium". According to this law, excess market supply and demand must add up to zero. His thinking about equilibrium was very clear but to demonstrate the existence of equilibrium, his counting of equations and variables was severely flawed. In the 1950s, Kenneth Arrow and Gérard Debreu developed a new version of the argument.

In 1941 *George Stigler* wrote about Walras:

> "There is no general history of economic thought in English which devotes more than a passing reference to his work. … This sort of empty fame in English-speaking countries is of course attributable in large part to Walras' use of his mother tongue, French, and his depressing array of mathematical formulas". Whatever caused the U-turn of Walras' consideration in the US, the influx of German-speaking scientists the German version of the *Elements* is from 1881 after Hitler's rule was the initial start. To Schumpeter: "Walras is the … greatest of all economists. His system of economic equilibrium, uniting, as it does, the quality of 'revolutionary' creativeness with the quality of classic synthesis, is the only work by an economist that will stand comparison with the achievements of theoretical physics".

1.5.2.11 Stock Exchange Science

Jules Regnault (1834-1894)

Regnault was the first to use random walk theory and to suggest a modern theory of stock price changes. Based on statistical and probabilistic analysis, he tried to create a "stock exchange science". Later on, the famous economist *Louis Bachelier* used his hypotheses. He applied his financial theory and thus became rich. He tried to create "stock exchange science" using statistics and probability.

1.5.2.12 Entropy as a measure of volatility

Bio box 1.14
Rudolf Clausius
Born – 1822
Alma Mater – University of Berlin
Field – Physics

Clausius (1822-1888) Rudolf Clausius was born in 1822. He became a professor of physics, first in Zurich and then later in Würzburg and Bonn. According to Clausius, "heat does not pass spontaneously from a colder to a hotter body", which led to the Second Law of Thermodynamics. Another statement of the Second Law is that the entropy of an isolated system can never decrease: it can only either increase or remain constant. This principle was intensely controversial at that time, but Kelvin and Maxwell fought vigorously in its defence, and it was eventually accepted into the canon of Natural Law.

Entropy as a Measure of Volatility:

An alternative way to study stock market volatility is by applying concepts of physics. Significant literature has already shown this to be helpful in describing financial and economic phenomena. One measure that can be applied to describe the nonlinear dynamics of volatility is the concept of

entropy. In 1865, Clausius introduced this to explain the tendency of density, temperature, pressure and chemical gradients to flatten out and gradually disappear over time. On this basis, Clausius developed the Second Law of Thermodynamics.

1.5.2.13 Mathematical Method in Economics

William Stanley Jevons: Jevons, a natural scientist, was also a prolific writer on logic and economics. His book, *The Theory of Political Economy* (1871) was the beginning of the mathematical method in economics. He was the first person to enunciate the "final" (marginal) utility theory of value. This marked the opening of a new period in the history of economic thought. His marginal utility theory of value was explained in his book *General Mathematical Theory of Political Economy.* He had also published a book *A Serious Fall in the Value of Gold* in 1863. The theory of utility was practically formulated around 1860 and according to him, "philosophy would be found to consist solely in pointing out the likeness of things". According to him, economics is essentially a mathematical science. This led to the start of the Neoclassical Revolution in economics.

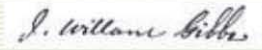
Applied economics: His opinion was that economics is a science. So, he wrote some works on practical economics like *A Serious Fall in the Value of Gold* (1863) and *The Coal Question* (1865), which recognised him as a writer of high rank. He wrote many other works such as *Money and the Mechanism of Exchange* (1875), a *Primer on Political Economy* (1878), *The State in Relation to Labour* (1882), *Methods of Social Reform* and *Investigations in Currency and Finance* (published after his death). In his work *Commercial Crises and Sunspots*, Jevons had studied the statistics relating to business cycles with sunspots. He argued that the weather depends on sunspots and crops depend on the weather, which may be the cause of the crises in the economy. He constructed a logical machine by means of which the conclusion derivable from any given set of premises could be mechanically obtained. He designed the "Logic Piano", a mechanical computer he designed and had built in 1869.

Bio Box 1.15
William Stanley Jevons

Born	1 September 1835, Liverpool, UK
Died	13 August 1882 (aged 46), Bexhill near Hastings, UK
Fields	Economics, Logic
Institutions	University College London 1876–80, Owens College 1863–1875
Alma mater	University College London

Known for Marginal utility theory

Notable awards – Rumford Prize (1880), Copley Medal (1901)



1.5.2.14 Statistical Mechanics

Josiah Willard Gibbs (1839-1903)

Gibbs is a great scientist who made a lot of contributions to the field of physics, chemistry, and mathematics. He invented the modern vector calculus. Gibbs was awarded the first American doctorate in engineering by Yale University.

Along with James Clerk Maxwell and Ludwig Boltzmann, Gibbs is considered to be one of the founders of statistical mechanics. Gibbs coined the phrase "statistical mechanics", and introduced the term "phase space".

He defined the microcanonical, canonical, and grand canonical ensembles. Many scientists, economists and Nobel Prize winners were influenced by Gibbs. Indeed, the 1910 Nobel Prize winner, J. D. van der Waals, acknowledged the great influence Gibbs had on his work.

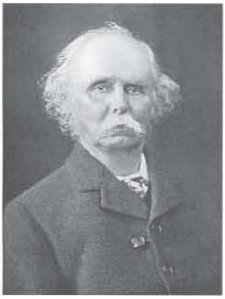
Gibbs' Influence on Economics

Indirectly, Gibbs had an influence both on mathematical economics and on *general equilibrium theory*. Gibbs supervised the thesis of *Irving Fisher,* who received the first PhD in Economics from Yale in 1891.

1.5.2.15 Neo-Classical Economics

Alfred Marshall (1842-1924) Marshall had shown an aptitude for mathematics while studying at St John's College, Cambridge and achieved the rank of Second Wrangler, meaning a student who attained the second-highest score in a mathematics degree at the University of Cambridge. He abandoned physics and switched to mathematics and then philosophy. Again, he studied metaphysics, related to theology. That led him to ethics and finally, to economics. He felt the duty of economics was to improve material conditions. The vision of Marshall was the elimination of poverty and a sharp reduction in inequality. In 1885, Marshall became a professor of political economics at Cambridge. He was one of the most influential economists of his time and regarded as one of the founders of economics. The ideas of supply and demand, marginal utility, and the costs of production were the main new features of his book, *Principles of Economics* (1890), which dominated the study of economics for many years in England. He improved the mathematical rigour of economics and transformed it into a more scientific profession. His other publications include *The Pure Theory of Foreign Trade: The Pure Theory of Domestic Values*, and *The Economics of Industry* (with his wife Mary Paley Marshall) in 1879.

Marshall had proposed that sale price be dependent on different factors and this is considered as his main contribution to economic theory. In a short period, supply does not change, and market value depends mainly on demand. In an intermediate time period, sale price is not influenced as fixed assets like buildings and machinery do not require renewal within this period, without changing production cost. However, in the long run, sale price becomes higher as product price increases due to the replacement of machinery, the cost of repairing buildings and accessories, etc.



Bio Box 1.17

Alfred Marshall (1842-1924)
Nationality – British
Alma Mater – St. John's College, Cambridge
Institution – Cambridge
Contributions – Founder of neoclassical economics
Principles of Economics (1890)

The concept of the demand and supply curve demonstrating supply and demand, market equilibrium, the law of marginal utility, the law of diminishing return, and the relationship between quantity and price was first developed by Marshall. It is used nowadays to demonstrate several other economic principles.

Marshall was one of the founders of the school of *neoclassical economics* and founder of the "*marginalist* revolution". Other important notions of Marshall's are "the *price elasticity of demand*", and "*producer surplus* and *consumer surplus*" which are used to rigorously analyse the effect of taxes and price shifts on market welfare.

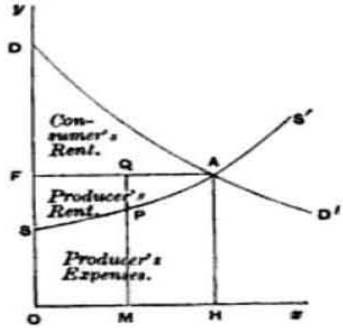


Fig. 1.5 Supply and Demand curve by Marshall.

1.5.2.16 Micro-Economics and Income Distribution

Vilfredo Pareto (1848-1923)

Pareto was a civil engineer until his mid-forties. His interest in economics was developed only after that. In addition, he was a sociologist, political scientist and philosopher. The title of his PhD thesis was *The Fundamental Principles of Equilibrium in Solid Bodies*. This study might have influenced his interest in equilibrium analysis in economics and sociology. He became a lecturer in economics and management at the University of Florence, leaving his engineering job. He was a liberal and attacked any form of government intervention in the free market. His contributions to economics are:

- Income Distribution
- Pareto efficiency
- Pareto Principle.

According to him, income follows a Pareto distribution. Pareto had gathered reams of data on the wealth and income of individuals from different countries through different centuries and found quite interesting results. He plotted the data on graph paper, with income on one axis, and the number of people with that income on the other, and it was striking to note that the picture is nearly the same everywhere in every era. The curve was very broad at the bottom where most men live, and very thin at the top where the wealthy elite are placed. Mandelbrot's summary regarding the curve is:

"At the bottom of the Wealth curve, he wrote, men and women starve and children die young. In the broad middle of the curve, all is turmoil and motion: people rising and falling, climbing by talent or luck and falling by alcoholism, tuberculosis and other kinds of unfitness. The top of the curve belongs to billionaires. The Pareto index is a measure of the inequality of income distribution".

Bio Box 1.18

Vilfredo Pareto (15 July 1848-19 August 1923)

Nationality	Italian
Field	Microeconomics, Socioeconomics
Influenced	Luigi Amoroso
Contributions	Pareto index, Pareto chart, Pareto's law, Pareto efficiency, Pareto distribution, Pareto principle

He observed that the distribution of income in all societies obeys the following regular logarithmic pattern:

$$1. \qquad \log N = \log A + m \log x$$

where N is the number of people with wealth higher than x, and A and m are constants. Over the years, Pareto's Law has proved remarkably close to the observed data.

His concept of Pareto efficiency helped to develop the field of *microeconomics*.

Pareto Principle – It was observed by Pareto in 1906 that 20 per cent of the population owned 80 per cent of the property in Italy. It was later generalised by *Joseph M. Juran*, who showed that the *Pareto distribution*

of wealth is true "through any human society, in any age, or country". It is also known as the 80-20 rule.

His books marked a departure from the textbooks of that period and look more like modern economics, with the use of statistics, calculus, charts and graphs. He also contributed to the fields of *sociology* and *mathematics*.

1.5.2.17 *Financial Mathematics* and Stochastic Processes.

Louis Bachelier (1870-1946)

Bio Box 1.19
Louis Bachelier, aged 15

Nationality France

Fields -Mathematics

Institutions University of Paris, Université de Franche-Comté, Université de Dijon, Université de Rennes

Alma mater University of Paris

Doctoral advisor Henri Poincaré

Known for Contributions to mathematical finance

Bachelier is considered to be a pioneer in the study of financial mathematics and stochastic processes (now called Brownian motion).

Modelling the stochastic process was part of his PhD thesis *The Theory of Speculation* (1900). In his thesis, the evaluation of stock options has been discussed by the use of Brownian motion. It is historically the first paper to use advanced mathematics in the study of finance. He had developed the theory of diffusion processes and was published in prestigious

journals. Bachelier's book *Le Jeu, la Chance, et le Hasard* (Games, Chance, and Randomness), published in 1914 was a best seller. It is to be noted that Bachelier's work on random walks was more mathematical and predates Einstein's celebrated study of Brownian motion by five years.

1.5.2.18 The Yule Distribution

Udny Yule (1871-1951)

Bio Box 1.20
George Udny Yule

Born – 18 February 1871 , Morham, Scotland
Died – 26 June 1951 (aged 80), Cambridge, England
Residence – England
Fields – Statistics, Genetics
Institutions – University College London, Cambridge University
Alma mater – University College, London
Known for – Yule distribution

Udny Yule studied engineering at *University College, London*. Then he began a research project in experimental physics under *Heinrich Rudolf Hertz* in Bonn, but left after one year and returned to University College and started to work on statistics. He made a lot of important contributions to the theory and practice of *time series* analysis. His pioneering work is the use of *preferential attachment* stochastic processes to explain the origin of power-law distribution. A power law, *Yule distribution* is named after him.

He has written many influential books such as *Introduction to the Theory of Statistics* and *The Statistical Study of Literary Vocabulary*.

Yule is credited with many important published papers such as *On the Correlation of Total Pauperism with Proportion of Out-relief*, indicating

that Yule was interested in applying statistical techniques to social problems. He has written many important papers on *correlation* and *regression*. *Why Do We Sometimes Get Nonsense Correlations between Time-series?* (1926), *On a Method of Investigating Periodicities in Disturbed Series, with Special Reference to Wolfer's Sunspot Numbers* (1927) and *On the time-correlation problem* (1921) are his three influential papers. *A Mathematical Theory of Evolution*, based on the conclusions of Dr J. C. Willis, is one of his most important papers, where he proposes a stochastic process that leads to a distribution with a power-law tail, which was later called Yule's distribution.

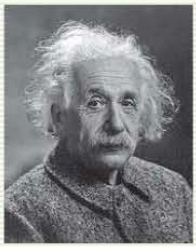
1.5.2.19 The Relevance of Brownian Motion in the Stock Market

Albert Einstein (1879-1955)

"If two factories produce the same sort of goods, other things being equal, that factory will be able to produce them more cheaply which employs fewer workmen i.e., that, with methods of production as they are today, only a portion of the available labour can be used. While unreasonable demands are made on this portion, the remainder is automatically excluded from the process of production. This leads to a fall in sales and profits. Businesses go smash, which further increases unemployment and diminishes confidence in industrial concerns and therewith public participation in the mediating banks; finally, the banks become insolvent through the sudden withdrawal of accounts and the wheels of industry therewith come to a complete standstill." (**Albert Einstein**, 1934).

The four important papers by Albert Einstein published in 1905 were on the *photoelectric effect* (which gave rise to *quantum theory*), *Brownian motion*, mass-energy relation and the *special theory of relativity*. His paper on the Brownian motion was on the motion of small particles suspended in a stationary liquid and was instrumental in the argument for the existence of molecules. Nowadays, Brownian motion is relevant in the analysis of the stock market as it has desirable mathematical characteristics, where statistics can be estimated and probabilities can be calculated. Osborne derived a steady-state distribution function of a particle in Brownian motion using a PDF (Probability Distribution Function) and the prices of the same random stock choices at random times. He has shown in his paper that prices of different stocks do not vary in the same way as molecules in Brownian motion. According to Mantegna, the spectral density of the price index is close to one expected for a Brownian motion.

Einstein's theory was also used by William Smith to analyse the effects of price stabilisation schemes on investment when demand is uncertain.



Bio Box 1.21
Albert Einstein (1879-1955)
Field – Physics
Institutions – University of Zurich, Charles University in Prague, ETH Zurich, Prussian Academy of Sciences, Kaiser Wilhelm Institute, University of Leiden, Institute for Advanced Study
Alma mater – ETH Zurich, University of Zurich
Known for – General relativity and special relativity, Photoelectric effect, Mass-energy equivalence, Theory of Brownian Motion Einstein field equations, Bose-Einstein statistics, Unified Field Theory, EPR paradox

Notable awards
Nobel Prize in Physics (1921), Matteucci Medal (1921), Copley Medal (1925), Max Planck Medal (1929), *Time* Person of the Century (1999)

Albert Einstein as an Investor

Albert Einstein and his scientific achievements are world-renowned but, at the same time, he was also a successful investor in the stock market. He made $250,000 investing a few thousand dollars.

1.5.2.20 Income Distribution in Societies: The Indian Origin of Econophysics

Meghnad Saha (1893-1956) Saha is an Indian astrophysicist noted for his thermal ionisation equation in 1920.

Bio Box 1.22
Meghnad Saha

মেঘনাদ সাহা

Meghnad Saha in Berlin
Born 6 October 1893
Shaoratoli, Dhaka, Bengal, British India Died 16 February 1956
(aged 62)
Residence – India
Nationality – Indian
Fields – Physics
Institutions – Allahabad University, University of Calcutta
Imperial College London
Alma mater – Dhaka College
Presidency College of the University of Calcutta
Known for Thermal ionisation

Saha was the founder of the journal *Science and Culture* in the year 1935. *A Treatise on Heat* (1931) and *A Treatise on Modern Physics* (1934) were the books he had co-authored.

Saha was unfortunate not to get a Nobel Prize although he was nominated four times.

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.

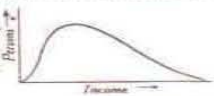


Fig. 6.—Distribution of income among persons.

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.

Tributes to Saha

"Meghnad Saha's ionisation equation (c. 1920), which opened the door to stellar astrophysics was one of the top ten achievements of 20th century Indian science [and] could be considered in the Nobel Prize class." – *Jayant Vishnu Narlikar.*

"It is a pleasure to have the opportunity of congratulating you on the occasion of your sixtieth birthday for your outstanding achievements, especially in the field of thermodynamics. As you know, I at one time had the honour of nominating you for the Nobel Prize for your work in the area..." – *Arthur Compton*

"I still remember with great pleasure the inspiration that I received from reading Professor Meghnad Saha's fundamental contributions to the theory of gas ionisation..." - *Enrico Fermi.*

Income Distribution in Societies

M. Saha is the founder of the Saha Institute of Nuclear Physics (SINP), in Kolkata. In his textbook, *A treatise on heat* in the 1950s, he and his collaborators expressed the possibility of using a Maxwell-Boltzmann velocity distribution (a gamma distribution) in an ideal gas to represent the income distribution in societies:

> "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 a similar way . . . (the income distribution) 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 the population has an average income." ("Distribution of velocities" in *A Treatise on Heat*, M.N. Saha and B.N. Srivastava, Indian Press, Allahabad, 1950; pp. 132–134).

Thus, the origin of econophysics in India can be considered as starting in 1931 with Meghnad Saha. Saha's interest in social science is extensively mentioned in arXiv:1808.09279v1 [q-fin.GN] 28 Aug 2018 by Bikas K Chakrabarti, which will soon be published in the journal *Science and Culture*.

1.5.2.21 Mahalanobis Distance

Prasanta Chandra Mahalanobis FRS (Bengali: প্রশান্ত চন্দ্র মহলানবিস) (1893-1972) Mahalanobis received a B.Sc. degree with honours in physics in 1912 from Presidency College, Calcutta and then joined Cambridge University. His important discoveries are the utility of statistics to solving problems in meteorology and anthropology, the **Mahalanobis distance**, pioneering studies in anthropometry, contribution to the design of large-scale sample surveys. Through his efforts, along with the Professors of Applied Mathematics and Economics at Presidency College, the Indian Statistical Institute (ISI) was established and formally registered on 28 April 1932.

It was truly a remarkable experiment with resounding success! In those days, both degrees awarded and subjects taught in the social sciences used to be offered by the Arts faculty, in most universities (both Indian and foreign). Social sciences, including economics, was mainly considered, until recently, to be part of Fine Arts, and not Science (as mathematics, statistics or computer science). As such, the ISI had been truly original, not a copy of any European or American model institution (contrary to many other institutions in India, established just before and after

independence). [Ref – *Science & Culture* Vol. 76 no 9 and 10, editorial, B.K. Chakrabarti & A. Chakraborti]

Bio Box 1.23
P.C. Mahalanobis
Born 29 June 1893, Calcutta, Bengal, British India
Died 28 June 1972 (aged 78), Calcutta, West Bengal, India
Residence India, United Kingdom, United States
Nationality Indian, **Fields** Mathematics, Statistics
Institutions University of Cambridge, Indian Statistical Institute
Alma mater University of Calcutta, University of Cambridge
Doctoral advisor Ronald Fisher
Known for Mahalanobis distance
Notable awards Weldon Memorial Prize (1944), Padma Vibhushan 1968

Mahalanobis completed many sample surveys like crop acreage, plant disease, tea-drinking habits, etc. and analysed university exam results and anthropometric measurements of Anglo-Indians of Calcutta, which led to Mahalanobis distance, D^2 and to resolving some meteorological problems.

Harold Hotelling wrote: "No technique of random sample has, so far as I can find, been developed in the United States or elsewhere, which can be compared accurately with that described by Professor Mahalanobis" and Sir *R. A. Fisher* commented that "The ISI has taken the lead in the original

development of the technique of sample surveys, the most potent fact finding process available to the administration".

The Indian Statistical Institute, Calcutta

The Government of India decided from 2006 to recognise and celebrate Mahalanobis' birthday as National Statistical Day.

1.5.2.22 The First Nobel Prize in Economics

Jan Tinbergen (1903-1994). It is interesting to note that the first Nobel Prize in Economics went to a person whose basic training was in physics. Tinbergen was a student of *mathematics* and *physics* at the *University of Leiden*, the Netherlands. His PhD thesis was also a marriage of natural science and social science entitled *Minimum problemen in de natuurkunde en de economie* (Minimisation problems in Physics and Economics). He worked as a professor at *Erasmus University Rotterdam*. He was the founder of the *Erasmus Universiteit Rotterdam* together with *Henri Theil*. *Ragnar Frisch* and Tinbergen were awarded the first Nobel Prize in 1969, for the development and application of dynamic models to analyse *economic processes*.

Among the notable works of Tinbergen, is the "*Tinbergen Norm*", which is the principle that it will be counterproductive for a company if the difference between the least and greatest income in a company exceeds a rate of 1:5. In this work, Tinbergen classified some economic quantities as targets and others as *instruments*. According to Tinbergen, to achieve the desired values of a certain number of targets, the policymaker has to control an equal number of instruments. This classification remains influential today, underlying the theory of monetary policy used by *central banks*. For example, the control of inflation rates by changing interest rates. Here inflation is the target and the interest rate is the instrument.

Bio Box 1.24
Jan Tinbergen (1903 –1994)

Nationality Dutch
Fields Economics
Alma mater Leiden University
Known for First national macroeconomic model
Notable awards Nobel Prize in Economics (1969)

1.5.2.23 An Analogy Between Physics and Social Science

Ettore Majorana (1906-1938)

Majorana was a gifted physicist, who did a lot of pioneering work during a short period of his lifetime. He earned his engineering degree from the University of Rome La Sapienza, but then switched to physics and obtained a PhD. At a very young age, he joined Enrico Fermi's team in Rome. He was the first to propose the neutral particle (neutron) having a nearly equal mass to that of a proton based on studies of an unknown particle in the experiments of Irene Curie and Frédéric Joliot. This particle is the neutron. Fermi told him to write an article, but Majorana did not bother to write an article about it even on the suggestion of Fermi. Later on, James Chadwick was awarded the Nobel Prize for this discovery. Those particles which are interpreted from the solution of Majorana's equation that are their own anti-particles are now referred to as *Majorana Fermions*. According to BBC News, Science and Environment on 12 April 2012, Jonathan Amos reported on a *Majorana particle glimpsed in the lab*, in experiments on hybrid semiconductor-superconductor wire devices.

Bio Box 1.25
A medal with a portrait of **Ettore Majorana**
Born – August 1906; missing, presumed dead on 27 March 1938
Nationality – Sicilian
Education – Engineering, Physics
Alma mater – University of Rome La Sapienza
Institution – University of Naples
Known for – Majorana equation and Majorana fermions

These findings may be useful for a better understanding of quantum mechanics and may help build a Quantum Computer. Majorana was never interested in taking the credit for his discoveries.

During his first disappearance in 1933, he was more interested in "political economy" than in physics. It was probably at this time that he wrote the paper on *The value of statistical laws in Physics and the Social Sciences* which was found among his papers by his brother Luciano and was published after his disappearance by Giovanni Gentile junior.

It is essentially a paper showing the analogy between physics and social science. According to him,

> "The deterministic conception of nature holds in its very being a real motive of weakness because it irremediably contradicts the most evident data of our conscience. G. Sorel tried to compose this dysfunction by distinguishing between 'artificial nature and natural nature' (this later being a-causal), although in this way he denied the unity of Science."

On the other hand, the formal analogy between the statistical laws of physics and those of social sciences supports the opinion that also human actions were submitted to a rigid determinism. It is important that the principles of quantum mechanics have led to a recognition (as well as a certain absence of objectivity in the description of phenomena) of the statistical character of the ultimate laws of elemental processes. This conclusion has made a substantial analogy between physics and social sciences and has produced between them an identity of value and method.

[Ref. MAJORANA: MATERIALS FOR A BIOGRAPHY (By Carlos Allones Pérez)]

1.5.2.24 Resource Allocation

Bio Box 1.26
Tjalling C. Koopmans

Nationality	Dutch
Fields	Mathematics, Physics, Economics
Alma mater	University of Leiden, Utrecht University
Known for	Exogenous growth model, Econometrics Economics of transportation, Koopmans' Theorem
Notable awards	Nobel Memorial Prize in Economic Sciences (1975)

Tjalling Charles Koopmans (1910-1985) is the winner of the 1975 Nobel Memorial Prize in Economic Sciences for his contributions to the field of resource allocation and the theory of the optimal use of resources. He began his studies with a specialisation in mathematics at Utrecht University in 1927. Then, in 1930, he studied theoretical physics. In 1933 he moved to Amsterdam and studied mathematical economics under Jan Tinbergen, the first Nobel Prize winner in Economics. In addition, he studied econometrics and mathematics.

1.5.2.25 Thermodynamics and Economics

Paul Samuelson (1915-2009)

Samuelson was an American economist noted for his use of analogy concepts, Le Chatelier's principle, equilibrium (physics) and entropy in various economic theories. He was a second generation student of Willard Gibbs, and he used thermodynamics, particularly entropy, in economic models. He was the second Nobel Laureate in Economics (1970) for his theories. Samuelson completed his bachelor's degree at the University of Chicago and his MS (1936) and PhD (1941) at Harvard University. Samuelson studied under the American mathematician, Edwin Wilson (a student of Gibbs'). He had taught Samuelson Le Chatelier's principle, which explained to Samuelson that in a system (chemical or economic) the changes in equilibrium constitute a constrained maximisation problem when one of the constraints is marginally tightened or relaxed and thus solved by the "variation principle". Andrew W. Lo stated that Samuelson modelled each person as an economic agent and assumed that each individual acted so as to maximise a quantity called "expected utility", a model with which he assumed he should be able to predict their behaviour in much the same way that physicists predict the behaviour of physical objects. He generalised and applied mathematical methods developed for the study of thermodynamics to economics. Samuelson's 1947 magnum opus, *Foundations of Economic Analysis*, is based on the classical thermodynamic methods of the American thermodynamicist Willard Gibbs. *Foundations of Economic Analysis* became one of the highest selling college textbooks of all time.

The Swedish Royal Academies stated, when awarding the Nobel Prize, that he "has done more than any other contemporary economist to raise the level of scientific analysis in economic theory". Economic historian, Randall E. Parker called him the "Father of Modern Economics", and The New York Times considered him to be the "foremost academic economist of the 20th century". *James Poterba*, former head of *MIT*'s Department of Economics, noted that through his book, Samuelson "leaves an immense legacy, as a researcher and a teacher, as one of the giants on whose shoulders every contemporary economist stands". In 1996, when he was awarded the National Medal of Science, considered America's top science honour, President Bill Clinton commended Samuelson for his "fundamental contributions to economic science" for over 60 years. Samuelson was instrumental in the initial development of the Indian Institute of Management Calcutta, the first Indian Institute of Management. Stanley

Fischer wrote that, taken together, his 388 published papers to date, were unique in their verve, breadth of economic and general knowledge, mastery of setting, and generosity of allusions to predecessors.

Samuelson used the variational logic of differential equations employed in thermodynamics, where variation goes by the mathematical name of "derivative" and applied it to economics.

Bio Box 1.27
Paul Samuelson (1915-2009)

Nationality	United States
Institution	MIT
Field	Macroeconomics
Alma mater	Harvard University (PhD), University of Chicago (BA)
Contributions	Neoclassical synthesis. Mathematical economics Economic methodology
Awards	John Bates Clark Medal (1947) Nobel Memorial Prize in Economic Sciences (1970)

1.5.2.26 The Bridge between Natural Sciences and Social Sciences

Ilya Prigogine (1917-2003) Prigogine was born in Moscow a few months before the Russian Revolution and later moved to Belgium where he received Belgian citizenship in 1949. Prigogine was a student of chemistry at the Free University of Brussels and he became a professor in the same University. Later he became Professor of Physics and Chemical Engineering at the University of Texas in Austin, USA. Prigogine was considered for the Nobel Prize in Chemistry in 1977 for his definition of dissipative structures and their role in thermodynamic systems far from equilibrium. This discovery became instrumental for pioneering research

in self-organising systems, the irreversible role of time in the natural sciences and the formation of complexity in biological entities.

Ilya Prigogine (1917-2003)
Bio Box 1.28
Nationality Belgian
Fields Chemistry, Physics
Institutions Université Libre de Bruxelles. International Solvay Institute University of Texas, Austin, Université Libre de Bruxelles
Known for Dissipative structures
Notable awards Nobel Prize for Chemistry (1977)

The "self-organisation" mechanism in physics or chemistry of many body systems, where each constituent cell follows very local (space and time) dynamic rules yet the collective system evolves towards a globally organised pattern, is used as a synonym for the "invisible hand" mechanism of the market to evolve towards the "most efficient" and predates the demonstration of the "self-organisation" mechanism in the physics of many systems.

His work bridged the gap between natural sciences and *social sciences.*

Ilya Prigogine received numerous awards, prizes and 53 honorary degrees. He was awarded the *Francqui Prize* for Exact Sciences, the *Rumford Medal*, and the *Nobel Prize* for Chemistry.

1.5.2.27 General Equilibrium Theory

Kenneth J. Arrow (1921-2017) Arrow earned a bachelor's degree from the City College of New York in mathematics and a master's degree and PhD from the University of Columbia. He was also an Assistant Professor in Economics at the University of Chicago.

According to his "Possibility Theorem" he states in his own words, "If we exclude the possibility of interpersonal comparisons of utility, then the only methods of passing from individual tastes to social preferences which will be satisfactory, and which will be defined for a wide range of sets of individual orderings, are either imposed or dictatorial".

Neoclassical economics

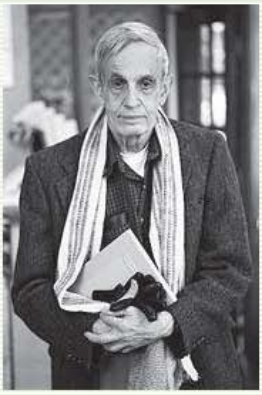
Bio Box 1.29
Kenneth J. Arrow USA
Nationality American
Institution Stanford University
Field Microeconomics, General equilibrium theory, Social choice theory
Alma mater Columbia University, City College of New York
Contributions General equilibrium theory, Fundamental theorems of welfare economics, Arrow's impossibility theorem, Endogenous growth theory
Awards John Bates Clark Medal (1957)
Nobel Prize in Economics (1972)
von Neumann Theory Prize (1986)
National Medal of Science (2004)

Later on, the Arrow-Debreu model of general equilibrium was developed.

His endogenous-growth theory provided standard economic reasons for why firms innovate, leading economists to think of innovation and technical change as determined by economic actors. In Information economics, Arrow investigated the problems caused by asymmetric information in markets. Asymmetric information creates incentives for the party (seller), with more information, to cheat the party with less information (buyer).

1.5.2.28 Game Theory

John Forbes Nash, Jr. (1928- 2015)



Bio Box 1.30
John Forbes Nash Jr. Born June 13, 1928 Bluefield, West Virginia, U.S. Nationality American
Fields Mathematics, Economics
Institutions MIT, Princeton University
Known for Nash equilibrium, Nash embedding theorem
Algebraic geometry, Partial differential equations
Notable awards Nobel Memorial Prize in Economic Sciences (1994)

Nash pursued his studies in advanced mathematics even when he was studying at school. Nash graduated with a master's degree in only three years accepting a scholarship to the Carnegie Institute of Technology. He was offered the John S. Kennedy fellowship by the chairman of the mathematics department of Princeton, Solomon Lefschetz, and he worked on his equilibrium theory. He did his PhD on non-cooperative games in 1950 with a 28-page dissertation, which was known as the "Nash equilibrium".

His works in game theory, differential geometry, and partial differential equations are used to study complex systems in daily life, like market economics, evolutionary biology, accounting, politics and military theory. He received the Nobel Memorial Prize in 1994 in Economics along with two others while he was serving as a Senior Research Mathematician at Princeton University. His other works include the role of money in society. He opined that people can be so controlled and motivated by money that they may not be able to reason rationally about it. He was critical of promoting quasi-doctrines based on Keynesian economics.

1.5.2.29 Price changes in financial markets did not follow a Gaussian distribution

Benoît B. Mandelbrot (1924-2010). Mandelbrot studied in the École Polytechnique and did his master's degree in aeronautics at the California Institute of Technology. In 1952, he obtained his PhD degree from the University of Paris in Mathematical Sciences. A new field called Fractal Geometry was enunciated by Mandelbrot. In addition, he has worked on mathematical physics and quantitative finance.

He was an IBM fellow and later joined Yale University as a Sterling Professor of Mathematical Sciences. In addition to his work in mathematics, he started working on economics, information theory, and fluid dynamics from 1951. He was convinced that two key themes, fat tails and self-similar structure, encountered similar problems in those fields.

He is noted for his contribution that price changes in financial markets did not follow a Gaussian distribution, but rather Lévy stable distributions. He worked on cotton prices and found that they followed a Lévy stable distribution with parameter α equal to 1.7 rather than 2, as in a Gaussian distribution. He has written many books, including *(Mis)Behaviour of Markets*.

Bio Box 1.31
Benoît Mandelbrot
Nationality Polish, French, American
Fields Mathematics, Aerodynamics
Institutions Yale University, International Business Machines(IBM) Pacific Northwest National Laboratory
Alma mater École Polytechnique, California Institute of Technology University of Paris
Known for Mandelbrot set, Fractals, Chaos Theory, Zipf–Mandelbrot law
Notable awards Harvey Prize (1989), Wolf Prize (1993), Japan Prize (2003), Franklin Medal, Légion d'honneur (the Legion of Honour)

Mandelbrot coined the term *"fractal"* to describe the self-similar structures of objects in nature like coastlines, the shape of clouds, mountains, smoke particles, etc., and published his ideas in *Les objets fractals, forme, hasard et dimension* (1975).

1.5.2.30 Sociodynamics

Wolfgang Weidlich (1931-2015) Weidlich, born in 1931 at Dresden, studied physics and mathematics in the Technical University and the Free University of Berlin from 1949-1955. He obtained a Diploma in 1955 and a PhD in 1957 in Physics from the Free University. He had worked as an assistant professor at the Institute of Theoretical physics at FU of Berlin and the University of Erlangen from 1957 to 1963. He became an Associate Professor at the University of Stuttgart and served from 1963 to 1966 and subsequently became a full professor of Theoretical physics from 1966 and served till 1999. In addition to his work in mainstream

physics, he has a number of publications, books and book reviews in interdisciplinary fields, chiefly in sociodynamics. In his book *Sociodynamics- A Systematic Approach to Mathematical Modelling in the Social Sciences*, he has developed a systematic approach to initiating and evaluating mathematical models for a broad class of collective dynamic social processes and events. He has characterised and compared the hierarchies of complex structures in nature and society and their methods of description. He used statistical physics, non-linear dynamics, etc. with concepts of social science to construct sociodynamics.

Bio Box 1.32
Wolfgang Weidlich
Born -1931 in Dresden
Field – Physics and Mathematics
Alma mater – Technical University and Free University, Berlin
Institution – FU, Berlin, University of Erlangen, University of Stuttgart

He has applied sociodynamics to the different sectors of society wherever dynamic phenomena occur like sociology, population dynamics, etc. Using methods of sociodynamics, he has described economic non-equilibrium phenomena. He has derived a master equation for the probability distribution of socio-configurations, called the central equation of sociodynamics.

1.5.2.31 Log-normal Distribution

M.F.M Osborne

According to *Professor Joseph L. McCauley* (University of Houston), Osborne first introduced the log-normal stock pricing model in 1958 and should be honoured as the first econophysicist. According to Steve Hue, Professor of Physics at the University of Oregon, Osborne's book *The Stock Market and Finance from a Physicist's Viewpoint* [Paperback] is quite interesting as he explores market microstructure, market making and supply-demand (bid-ask) in detail, going far beyond the usual idealisations made by economists.

M.F.M Osborne derived a steady-state distribution function, which is precisely the probability distribution for a particle in **Brownian motion**. He found prices in the market did vary in a similar fashion to molecules in Brownian motion. He proposed a geometric Brownian motion, which is an extension of Brownian motion. This is advantageous in financial market modelling since the logarithm can only take positive values—a meaningful assumption for the prices of stocks.

Osborne has remarked that price does not exist as a function of either supply or demand and has shown that one can obtain data on both supply and demand as a function of price.

1.5.3 Modern Era

Econophysics is a transdisciplinary research field, in which theories of physics and statistical mechanics are applied to solve problems in econophysics.

History

Physicists have had an interest and worked in the social sciences for a long time. Daniel Bernoulli was the originator of the Expected Utility hypothesis and published *A New Theory on the Measurement of Risk* in 1738. Irving Fisher, one of the founders of neoclassical economic theory, was a student of the renowned physicist, Gibbs. Similarly, the first Nobel Laureate in Economics, Jan Tinbergen, studied Physics at Leiden University, Netherlands. Many statistical physicists started working in econophysics in the mid-1990s because they were dissatisfied with the traditional explanations and approaches of economists. They tried to apply physics to financial data sets. It all started during this time because an

enormous amount of financial data suddenly became available during the 1980s.

H. Eugene Stanley coined the term "econophysics" in 1995 in Kolkata during a conference on statistical mechanics. He was influenced by a large number of papers on stock and other markets written by physicists. *János Kertész* and *Imre Kondor* were the organisers of the first econophysics conference in Budapest in 1998. Some of the pioneers of econophysics are H. E Stanley, Bikas Chakrabarty, Victor Yakovenko, Yi-Cheng Zhang, Jean-Philippe Bouchaud, Dirk Helbing, János Kertész, Matteo Marsili, Joseph L. McCauley, Enrico Scalla, etc.

Statistical physics is the main tool of econophysics. Percolation models and chaotic models, etc. are the physics models applied to econophysics. Attempts have been made to use the mathematical theory of complexity and information theory also. Random Matrix Theory is used to identify the noise in financial correlation matrices. Other tools like fluid dynamics, classical mechanics and quantum mechanics (including the so-called classical economy, quantum economy and quantum finance), and the path integral formulation of statistical mechanics are also used.

The Impact on Mainstream Economics and Finance

So far there has not been much impact on mainstream economics and finance. Not many papers have been published in economics journals. Economists are not showing much interest in the new field of econophysics except for a few like Mauro Gallegati, Steve Keen, Paul Ormerod, Thomas Lux, etc. However, econophysics has had some impact on quantitative finance and some models have been introduced for price fluctuation.

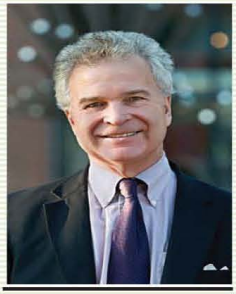
1.5.3.1 The neology of the term "Econophysics"

H. Eugene Stanley (1941-)

Gene Stanley obtained his BA in Physics at Wesleyan University in 1962. He was awarded a PhD in Physics at Harvard in 1967. His monograph *Introduction to Phase Transitions and Critical Phenomena* won the Choice Award for Outstanding Academic Book of 1971. He was Assistant Professor of Physics at MIT in 1969 and Associate Professor in 1971. He became Professor of Physics at Boston in 1976 and Associate Professor of Physiology (in the School of Medicine). He holds concurrent positions of "Honorary Professor" at the East China University of Science and

Technology, Shanghai University, the Institute for Advanced Studies, the University of Pavia, and at Eötvös Loránd University, Budapest.

Stanley, with his students and colleagues, works to understand puzzles of interdisciplinary science, complex systems, etc. The journal, *Physical Review*, reproduced two of his papers in *The Physical Review, The First Hundred Years: A Selection of Seminal Papers and Commentaries.*



Bio Box 1.33 H.
Eugene Stanley
PhD 1967 (Harvard), Asst. Prof. of Physics – 1969 (MIT)
Associate Prof. – 1971 (MIT)
Choice Award for Outstanding Academic Book of 1971

Herman von Helmholtz Associate Professor in 1973
Prof. of Physics and Associate Prof. of Physiology– 1976 Prof. of Physiology – 1978 (Boston)
Boltzmann Medal – 2004, for interdisciplinary contributions
Prof. of Chemistry and Biomedical Eng. – 2007 (Boston)
The Julius Edgar Lilienfeld Prize – 2008

He is the recipient of many awards like the Boltzmann Medal, and the 2008 Julius Edgar Lilienfeld Prize, awarded by the APS. Stanley has served as thesis adviser to more than 100 PhD candidates at MIT and Boston University and has worked with more than 120 research associates.

He published the first book on econophysics co-authored with R.N. Mantegna. He has a large number of publications. In addition, he has

written many books and has published many papers on econophysics and is referred to in physics journals with Mantegna, Gopikrishnan and others.

Stanley's group has attempted to characterise the fluctuations in the (stock) markets by some simple laws. Mantegna and Stanley in 1995 published a probability distribution P(r) decay proportional to exp (const - r), which is also highlighted by Bouchaud and Potters. Gopikrishnan et al. (with Stanley) in 1998 have shown a strong power-law decay roughly as $1/r^4$ for P(r); So, short-time fluctuations are described neither by a Gaussian nor a Lévy distribution and their second moment or standard deviation is finite.

1.5.3.2 The First Econophysics paper in a Physics Journal

Rosario Nunzio Mantegna (1960-)

Mantegna is recognised as one of the leading pioneers in the field of econophysics. His interest in this field started in 1990, before the term econophysics was neologised, when he started working on the analysis and modelling of social and economic systems, using statistical physics. His first paper in this field was published in 1991. In 1995, he co-authored the first econophysics paper in the journal *Nature* and published his first book on econophysics in 1999. He is the founder of the Observatory of Complex Systems, a research group of the Dipartimento di Fisica of Palermo University. He has investigated a wide range of topics in econophysics like (i) the microstructure aspect of price impact and of order book dynamics (ii) the cross-sectional analysis of price returns (iii) the hierarchical structure and correlation-based networks of a portfolio of stocks and (iv) the statistical regularities of univariate time dynamics of high-frequency price returns.

He was the Managing editor of the *International Journal of Theoretical and Applied Finance* (2003-2006) and was on the editorial board of *Quantitative Finance*.

The first book published in econophysics by Rosario N. Mantegna and H. Eugene Stanley is *An Introduction to Econophysics: Correlations and Complexity in Finance,* Cambridge University Press, Cambridge, UK 2000 ISBN 052162008. This book has been translated into Japanese (EconomistSha, Inc.), Polish (Polish Scientific Publishers PWN), Indonesian (Pearson Education Asia), Chinese (Lianjing Publishing House), and Russian (Editorial URSS).

Bio Box 1.34
Rosario Nunzio Mantegna
Field – Applied Physics, Econophysics
Institutions – Università di Palermo, Viale delle Scienze Ed. 18, I-90128, Palermo, Italy
Known for – publishing the first paper in Econophysics in a Physics journal in 1990, co-authored the first econophysics paper in *Nature* in 1995 and published the first book on Econophysics in 1999

In addition, he has many publications on econophysics in different physics journals.

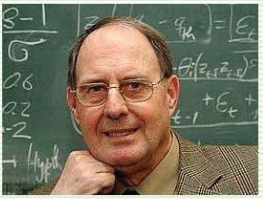
1.5.3.3 The Second Law of Thermodynamics

Reiner Kümmel (1939-)

Kümmel was born in 1939. He studied mathematics and physics at the Technical University of Darmstadt from 1959 to 1964 and received a degree in physics in 1964. Between 1965 and 1967 he was the Research Assistant of John Bardeen (Physics Nobel Prizes in 1956 and 1972) at the University of Illinois at Champaign / Urbana, USA. In 1968 he was awarded a PhD degree at the University of Frankfurt.

In 1985 he was a visiting professor at the University of Utrecht and a guest lecturer at the Universidad del Valle (1976 and 1992). From 1996 to 1998, he was Chairman of the Energy Working Group of the German Physical Society and he was the Co-founder of the "Study Group on development problems of industrial society" (CLIMB eV), associate editor of *Energy–The International Journal* and a member of "Academia Scientiarum et

Artium Europaea". After his retirement in 2004, he has been working as a lecturer in "Thermodynamics and Economics" at the University of Wuerzburg.



Bio Box-1.35
Born – 1939
Fields – Economics and Thermodynamics
Alma mater –Technical University of Darmstadt (Physics and Mathematics), 1959-1964, University of Frankfurt (PhD in 1968)
Institutions – Universidad del Valle in Cali, Colombia. University of Wuerzburg

1.5.3.4 Income distribution revisited; correction of Saha's curve

Bikas K Chakrabarti (1952-)

Chakrabarti received his MSc. in Physics from Calcutta University and a PhD from the Saha Institute of Nuclear Physics, Kolkata. He was a post-doctoral fellow at the Department of Theoretical Physics, University of Oxford and the Institute for Theoretical Physics, the University of Cologne after his PhD. He has been working as a faculty member in the Saha Institute of Nuclear Physics since 1983 and has retired as Director of the Saha Institute of Nuclear Physics (SINP) and Senior Professor. Although he is basically a physicist, he is now interested in economics and is considered as a pioneer in "econophysics". Now he is also a visiting professor of Economics in the Indian Statistical Institute, Kolkata.

He has diversified research interests, ranging from condensed matter physics to complexity in social science. He is working on Fracture, Breakdown and Earthquake, the Statistics of Polymers in Random Media,

Dynamic Hysteresis and Transitions under Periodic and Stochastic Fields, Quantum Phase Transition, Quantum annealing and Computation in Spin Glass Models, Physical and Computational Models of Mind and Brain, Econophysics and Sociophysics. He is credited with three reviews in the esteemed Reviews of Modern Physics. His papers have received more than 2000 citations and his Hirsch index is 25 as reported by Web Science. Formerly he was an editor of *Pramana*. Presently he is on the Editorial Board of *The European Physical Journal B*, *The Indian Journal of Physics*, *The Journal of Economic Interaction & Coordination* and *Natural Science*. In econophysics, he has published the following books:

Bio Box 1.36
Bikas K Chakrabarti

Born	14 December 1952, *Calcutta*, India
Nationality	Indian
Fields	*Physics, Economics*
Institutions	*Saha Institute of Nuclear Physics*, Kolkata *Indian Statistical Institute*, Kolkata
Alma mater	University of Calcutta

Awards – Shanti Swaroop Bhatnagar award

- *Econophysics: An Introduction*, S. Sinha, A. Chatterjee, A. Chakraborti and B. K. Chakrabarti, Wiley-VCH, Berlin (2010) ["Verplicht" (Dutch; "Required/Mandatory" English) in Econophysics 3rd year Graduate Course in Leiden University (2011)]

- *Econophysics of Income & Wealth Distributions*, B. K. Chakrabarti, A. Chakraborti, S. R. Chakravarty and A. Chatterjee Cambridge University Press, Cambridge.

In addition, he is credited with more than 15 edited books and reports.

It may be mentioned here that the **Saha Institute of Nuclear Physics, Kolkata,** was established by the noted physicist, Meghnad Saha (1893–1956). Meghnad Saha and collaborators had already discussed at length the possibility of using Maxwell-Boltzmann velocity distribution (a gamma distribution) in an ideal gas to represent the income distribution in societies in their textbook *A treatise on heat* in the 1950s. Chakrabarti along with his collaborators could capture both the initial gamma/log-normal distribution for the income distribution of poor and middle-income groups and also the Pareto tail for distribution for the riches in their random saving gas model during the period 1995-2005.

Under the banner of **Econophysics, Kolkata**, he has been organising annual international workshops at the SINP, since 2005. Due to his influence, international workshops are conducted by JNU and Delhi Universities, national conferences are organised in Chennai, Rourkela, Khajuriakata, Dhenkanal, etc. Many scientists from SNBCBS, Kolkata, Calcutta University, IISER Kolkata, ISI Kolkata, TIFR Mumbai, IMS Chennai, PRL Ahmedabad, IISER Pune, IIM Kozhikode and many other Institutes are actively working in this field and it is also spreading to other Institutes. His student, Anirban Chakrabarty, is the first PhD holder in econophysics from India and is also a recipient of the Young Scientist award. Chakrabarti's work on the "Kolkata Paise Restaurant" problem is the first of its kind, which has been named after a city and has had some impact in the sphere of econophysics.

1.5.3.5 Complexity Theory

W. Brian Arthur (1946-)

Arthur was born in 1946, in *Northern Ireland.* He has acquired several degrees in various fields like engineering, mathematics and economics. He did Electrical Engineering at Queens University Belfast at undergraduate level, and holds an MA degree in Operational Research from Lancaster University, Lancaster, England, an MA in Mathematics from the University of Michigan, a PhD in Operations Research and he has also done postgraduate research in Economics at the UC, Berkeley.

He has a vast academic career. He has served at Stanford University as Morrison Professor of Economics and Population Studies and Professor of Human Biology.

Bio Box 1.37

Arthur at the World Economic Forum Annual Meeting, 2011
Field – Electrical Engineering, Mathematics, Operational Research, Economics
Alma mater – Queen's University Belfast, Lancaster University, England, University of Michigan, University of California, Berkeley
Institutes – Stanford University, Santa Fe, New Mexico
Award-Schumpeter Prize in 1990.

Arthur was the first director of the interdisciplinary Economics Programme at the *Santa Fe Institute*, *Santa Fe, New Mexico*, USA. The important contribution of Arthur, which is significant in technology-specific industries is:

"studying the impacts of positive feedback or increasing returns in economies, and how these increasing returns magnify small, random occurrences in the market place."

1.5.3.6 Prediction of Complex Systems

Didier Sornette (1957-)

Didier Sornette graduated from École Normale Supérieure in Physical Sciences (1977-81). He then joined the CNRS (French National Centre for Scientific Research) as a Research Scientist (1981-1990). He did his PhD at the University of Nice on the Statistical Physics of Interfaces (1985). He

Bio Box 1.38
Didier Sornette

Born	June 25, 1957
Fields	Physics, geophysics, complex systems, economics, finance
Institutions	Swiss Federal Institute of Technology Zurich, Swiss Finance Institute, UCLA
Alma mater	Ecole Normale Supérieure, University of Nice
Known for	Prediction of crises and extreme events in complex systems, physics of complex systems and pattern formation in spatio-temporal structures
Notable awards	Science et Défence French National Award, 2000 Research McDonnell award, Risques-Les Echos prize 2002 for Predictability of catastrophic events

became the Director of Research at the CNRS, France, in October 1990. He became Professor of Geophysics at UCLA, California (1996-2006), and the Chair of Entrepreneurial Risks at ETH Zurich (since March 2006). He has been Concurrent Professor of the East China University of Science and Technology (ECUST), Shanghai, China, since May 2004. He is the first Systems Analysis Group (SAG) Visiting Professor at the Washington University in St. Louis, Missouri, USA; SAG (2005-present), Director of Research in the X-RS research and development company in Orsay, France (1988-1995). He is adviser to aerospace industrial companies, banks, and investment and reinsurance companies (1991-present). He is

the recipient of the Science et Defence French National Award (1985) and Research McDonnell award 2000, studying Complex Systems, and the Scientific Prediction of Crises.

He received the Risques-Les Echos prize 2002 for the predictability of catastrophic events. He is on the committee of Risques-Les Cahiers de l'Assurance, 9 rue d'Enghien, 75010 Paris. He has authored and co-authored more than 350 research papers in refereed international journals. He is the editor of the reports of two international conferences and author of two textbooks and one monograph. He has guided nine students who have completed their PhD thesis and 20 post-doctoral students. Now he is working on social sciences, finance and economics: societal risks, bubbles and crashes, portfolio optimisation, trading strategies, insurance, macroeconomics, agent-based models, market microstructures, and the physics of complex systems and pattern formation in spatiotemporal structures, etc.

He is the Principal Investigator on a project called Future ICT Knowledge Accelerator and Crisis Relief System, a computing system working on *big datasets*. The core of the system is the Living Earth Simulator, a computing machine attempting "to model global-scale systems like technological developments, economies, epidemics, governments, cultural trends, agriculture, etc."

1.5.3.7 Social Force Model

Dirk Helbing (1965-)

Dirk Helbing has a formal education in physics and mathematics at the *University of Göttingen*. He was awarded a PhD degree on modelling social processes by means of game-theoretical approaches, stochastic methods, and complex systems theory from Stuttgart University. He is a professor of sociology and the head of the ETH, Zurich Competence Centre working on *The Physics of Socio-Economic Systems* and *Coping with Crises in Complex Socio-Economic Systems*.

His education in physics, traffic dynamics and optimisation helped him to model and simulate social problems and he is known for the *social force model* applying to self-organising phenomena in pedestrian crowds. Again in his "the slower-is-faster effect" he introduced the freezing-by-heating effect. Helbing is working on many social models like evolutionary game theory, optimisation of urban and freeway traffic, socio-inspired technology and techno-social systems, disaster spreading and crisis management, etc.

Bio Box 1.39
Dirk Helbing
Field – Physics, Sociology
Alma Mater – University of Göttingen, Stuttgart University
Institution – Dresden University of Technology
Known for – the social force model

1.5.3.8 J. Doyne Farmer (1952-)

Farmer was a student of Stanford University and worked in LANL during the eighties as head of the theoretical complex system group and later on in The Santa Fe Institute, USA. His research interests include complex systems, dynamic systems, theoretical biology, time series analysis and developing quantitative theories for financial markets. He has established a Prediction Company dealing with the quantitative trading firm. He was one of the research group of physics students on "chaos theory" of the UC Santa Cruz Dynamical Systems Collective.

Bio Box 1.40
J. Doyne Farmer

Born 1952 *U.S.*

Nationality American

Fields Physics, Finance

Institutions Santa Fe Institute, Los Alamos National Laboratory

Alma mater Stanford University, University of California, Santa Cruz

1.5.3.9 System and the modelling of financial risks

Jean-Philippe Bouchaud (1962-)

Jean-Philippe Bouchaud was born in France in 1962. He graduated and completed his PhD in Physics from the École Normale Supérieure, Paris. He worked on the dynamics of glassy systems and on granular media at the Service de Physique de l'Etat Condensé (CEA-Saclay). In 1991, he switched his interest to economics and theoretical finance and worked on agent-based simulations, extreme risk models, price formation, market microstructure, stock market fluctuations, the statistics of price formation, and the modelling of financial risks.

He is a critic of the standard concepts and models used in economics and in the financial industry like Black-Scholes models and market efficiency. He is a pioneer of econophysics.

Bio Box - 1.41
Jean-Philippe Bouchaud

Born	**1962 Paris**
Nationality	**French**
Fields	**Physics, finance**
Alma mater	**École Normale Supérieure**
Known for	**His work in the physics of a disordered system and the modelling of financial risks**
Notable awards	**Silver medal of CNRS**

He was the founder, in 1994, of the company Science & Finance that merged with Capital Fund Management in 2000. In addition, he is a professor at the École Polytechnique, teaching complex systems since 2008. He was the winner of the IBM young scientist prize in 1990 and the CNRS Silver Medal in 1996.

1.5.3.10 Inaugural Meeting on Econophysics

János Kertész

János, one of the pioneers of econophysics, works as a professor of physics at the University of Budapest, Hungary and his research interest is on complex networks and fractals. He organised the first ever conference on econophysics in Budapest in 1998.

János Kertész obtained his PhD from the Institute of Technical Physics (ITP) of the Hungarian Academy of Sciences (HAS) in 1980 and DSc from HAS in 1989. He has occupied many positions at ITP and became Professor of Physics at the Budapest University of Technology and Economics (BME) from 1993. From 1995-2007, he became Head of the Department of Theoretical Physics at BME and from 2001 the Director of the Institute of Physics at BME and then became Director of the Institute. He has a number of fellowships and is visiting professor at Cologne University. He visited Saclay (France), Naples (Italy), Boston (USA, several times), Duisburg (Germany), Cambridge (UK), and Jülich (Germany, several times).

Bio Box 1.42
János Kertész
Field – physics

Alma Mater – Eotvos University Budapest, Hungarian Academy of Sciences (HAS)
Institutions – ITP, BME
Awards – Novobátzky Award, Academy Award, Arnold Ipolyi Award, "Santa Chiara Prize", Albert Szent-Gyorgyi Award

He was a member of the Editorial Boards or Advisory Boards of the Journal of Physics A (1990-1994), Physica A (1990-), Fractals (1993-2003, 2008-) and Fluctuation and Noise Letters (2001-2003). He has a large number of publications in the field of econophysics in refereed journals.

1.5.3.11 Sitabhra Sinha

Sinha is Professor in Physics at the Institute of Mathematical Sciences (IMSc), Chennai. He received his PhD from ISI, Kolkata in 1998 on nonlinear dynamics and Post Doc from IISc, Bangalore and Cornell University, New York. He joined the faculty of IMSc, Chennai in 2002.

Bio Box 1.43
Sitabhra Sinha
Field – Physics
Alma Mater – Calcutta University, ISI, Kolkata, IISc, Bangalore, Cornell Univ., New York City
Institutes – IMSc, Chennai, NIAS, Bangalore

His research interests are in complex systems, nonlinear dynamics, and theoretical and computational biophysics. In addition, he works on the physics of social and economic phenomena, wealth distribution, price fluctuations in financial markets, electoral behaviour, and movie revenue distribution.

He has written two books, which are *Patterns in Excitable Media: Genesis, Dynamics and Control* published by CRC Press, Boca Raton, 2014 and *Econophysics: An Introduction* published by Wiley-VCH, Weinheim, 2010.

He was a participant during the Statistical Physics conference in Kolkata in 1995, during which the word "econophysics" was neologised by Prof. Stanley.

1.5.3.12 Quantum Finance

Bio Box 1.44
Belal E Baaquie

Field – Physics
Research Interests – QFT, Financial modelling based on techniques on quantum theory
Alma mater – Caltech, Cornell University
Institutes – Stanford University, Princeton, Harvard University, National University of Singapore

Belal E. Baaquie – Baaquie received his BS from the California Institute of Technology in 1972 and his PhD from the Theoretical Physics Department, Cornell University in 1976. He was Research Associate at Stanford University from 1976 to 1978 and is now working as Professor of Physics in NUS, Singapore, since 1984. His research interests include Quantum Field Theory and Financial modelling based on the techniques of quantum theory.

Prof. Baaquie is an authority and very much a specialist in quantum finance. He has written a number of books in this field like *Interest Rates and Coupon Bonds in Quantum Finance*, *Quantum Finance: Path*

Integrals and *Hamiltonians for Options and Interest Rates*. In these books, he has analysed interest rates and coupon bonds using quantum finance. In the second one, he shows how to approach problems related to financial markets with mathematical techniques that are traditionally used in quantum field theory. He has written many articles on general topics such as finance, education, history, economics and philosophy.

1.5.3.13 Manna Model

Subhrangsu Sekhar Manna – Having graduated from the Science College, Calcutta University, Manna did his PhD at the Saha Institute of Nuclear Physics in 1987. He joined IIT, Mumbai in 1992 and worked up until 1997. From 1998, he has been a faculty member at SNBNCS, Kolkata.

Bio Box 1.45
S. S. Manna
Field – Physics
Alma mater – Calcutta University, Saha Institute of Nuclear Physics, Kolkata
Institutes – IIT, Mumbai, SNBNCBS, Kolkata

His main areas of research interest are: Critical Phenomena in Complex Systems, Self-organised Non-equilibrium Critical Systems, Static and Dynamic Properties of Complex Networks. He is the originator of the "Manna Model" of stochastic self-organised criticality and also of the "Manna Universality Class" for dynamic critical behaviour and he is known for the "Chatterjee-Chakrabarti-Manna model of wealth distributions". He has published a large number of papers on complex networks.

1.5.3.14 Parongama Sen

Bio Box 1.46
Parongama Sen
Field – Statistical Physics
Alma mater – Calcutta University, SINP, Kolkata
Institutes – Delhi University, JNU, New Delhi, SINP, University of Cologne, S.N. College, Calcutta University
Research Interest - Dynamical phenomena in complex physical and social systems

Sen did her MSc at Calcutta University in 1986 and her PhD at the Saha Institute of Nuclear Physics, Kolkata in 1993. After that, she became a lecturer in the College of Applied Sciences, University of Delhi, a Research Associate at Jawaharlal Nehru University, New Delhi and SINP Kolkata. Then she was a post-doctoral fellow at the University of Cologne. Later she joined the S.N. College, Kolkata as a lecturer and she is now working in Calcutta University as a Professor.

Her research interests include Dynamical phenomena in complex physical and social systems. She has a number of publications in refereed journals on econophysics.

She has published a book *Quantum Ising Phases and Transitions in Transverse Ising models*, Lecture Notes in Physics M41, B. K. Chakrabarti, A. Dutta and P. Sen, Springer-Verlag, 1996.

1.5.3.15 Arnab Chatterjee

Chatterjee is an MSc from Calcutta University and has a PhD from SINP, Kolkata under the supervision of Bikas Chakrabarti on *Statistical Physics of Two Model Dynamical Systems: Magnets and Trading Markets*. He was a PDF at the *Condensed Matter and Statistical Physics Section, The Abdus Salam International Centre for Theoretical Physics (ICTP)*, Trieste, Italy, Oct 2007 - Oct 2010; *Centre de Physique Théorique*, Université de la Méditerrannée Aix Marseille II, Marseille, France (Nov 2010 - Oct 2011), a Research Scientist at the *ISI Foundation*, Turin, Italy (Nov 2011 - Feb 2012) and then a Research Scientist at *Aalto University*, Finland (since Feb 2012).

Bio Box 1.47
Arnab Chatterjee
Field – Physics, Econophysics
Alma mater – University of Calcutta, SINP, Kolkata
Institutes –ICTP, Trieste, Université de la Méditerranée Aix Marseille II, Marseille, ISI Foundation, Turin, Aalto Univ, Finland
Research Interest – **Statistical physics of socio-economic systems (Econophysics and Sociophysics)**

His main area of research is, basically, the applications of statistical physics to condensed matter and social sciences like the dynamic transition in ising systems, kinetic exchange models with quenched and

annealed disorder, statistical physics of socio-economic systems (econophysics and sociophysics), etc. He has a number of publications in the field of econophysics in refereed journals. He has co-authored and edited a number of books as detailed below.

1. Bikas K. Chakrabarti, Anirban Chakraborti, Satya R. Chakravarty, **Arnab Chatterjee**, *Econophysics of Income and Wealth Distributions*, Cambridge University Press, Cambridge (2012).
2. Sitabhra Sinha, **Arnab Chatterjee**, Anirban Chakraborti, Bikas K. Chakrabarti, *Econophysics: An Introduction,* Wiley-VCH, Berlin (2010); ISBN-13: 978-3-527-40815-3. It is used as a text book in the following courses:
   a. Econophysics in the Institute of Physics, Leiden University, Leiden, Netherlands.
   b. Econophysics in the Department of Mathematics and Statistics in the University of Bern, Bern, Switzerland.
   c. Mathematical Models in Economics and Finance (MMEF) in the Université Paris 1 Panthéon-Sorbonne, Paris, France.

The books edited by Arnab Chatterjee and others are:

1. **Arnab Chatterjee**, Sudhakar Yarlagadda, Bikas K. Chakrabarti (Eds.), *Econophysics of Wealth Distributions,* Springer-Verlag Italia, Milan (2005); ISBN: 978-88-470-0329-3.
2. **Arnab Chatterjee**, Bikas K. Chakrabarti (Eds.), *Econophysics of Stock and other Markets,* Springer-Verlag Italia, Milan (2006); ISBN: 978-88-470-0501-3.
3. Bikas K. Chakrabarti, Anirban Chakraborti, **Arnab Chatterjee** (Eds.), *Econophysics and Sociophysics,* Wiley-VCH, Berlin (2006); ISBN-10: 3-527-40670-0. (*Book review* in Journal of Artificial Societies and Social Simulation, Vol 10, Issue 4, October 2007).
4. **Arnab Chatterjee**, Bikas K. Chakrabarti (Eds.), *Econophysics of Markets and Business Networks,* Springer-Verlag Italia, Milan (2007); ISBN: 978-88-470-0664-5.

1.5.3.16 Deepak Dhar (1951-) Dhar works in the Department of Theoretical Physics, TIFR Mumbai as a Distinguished Professor. He obtained a Master of Science (Physics) from the Indian Inst. of Tech, Kanpur in 1972, and a PhD in Physics from the California Inst of Tech, Pasadena in 1978. To name just a few of his awards: in 1983, he received the Young Scientist Award; in 1991, the S. S. Bhatnagar award in Physical

Sciences; and in 1993, the J.R. Schrieffer Prize in Condensed Matter Physics. Prof. Dhar is a part of the Indian school of econophysics.

1.5.3.17 Hideaki Aoyama (1954 -)

Bio Box 1.48
Hideaki Aoyama
Born – 1954, Kyoto, Japan
Alma Mater – Kyoto University, Caltech
Institutes – Northeastern University in Boston, Harvard University, SLAC, Stanford, Kyoto University

Aoyama graduated from Kyoto University and did his PhD at Caltech, PDF at SLAC, Stanford University. Then he joined Northeastern University as a lecturer and was a visiting scholar at Harvard. Since 1988, he has been working at Kyoto University and is currently Professor of Physics in the Graduate School of Science.

He has published many books like *Classical Mechanics* (2005), *Pareto Firms* (2007), *Econophysics* (2008), and *Econophysics and Corporations*, and *Statistical Life and Death in Complex Business Networks* (forthcoming).

Prof. Aoyama was influenced by Hideki Takayasu, who had worked on mathematical modelling and simulation of the stock market in 1992. After that, the research of the Kyoto University econophysics group continued to the real economy and they published three books, two in Japanese and one

in English. Aoyama remarked that the potential for econophysics is very high in Japan and it will make a huge impact on economics through the application of physics. Prof. Aoyama and others have run four domestic econophysics conferences at the Yukawa Institute for Theoretical Physics at Kyoto University, in 2003, 2005, 2007 and 2009. Very recently they have analysed business cycles in Japan using the indices of industrial production (IIP), an economic indicator which measures the current conditions of production activities across the nation on a monthly basis.

1.5.3.18 Anirban Chakraborti

Bio Box 1.49
Anirban Chakraborti
Alma Mater – Calcutta University, SINP, Kolkata
Institutes – Ecole Centrale, Paris, BHU, India, Brookhaven National Lab, USA, JNU, Delhi.
Research Interests – Econophysics, Quantitative finance, Statistical Physics
Awards – INSA young scientist award, 2009

Chakraborti is a professor at JNU, Delhi. Before that, he was Associate Professor of Physics at the École Centrale, Paris. He has an MSc from Calcutta University and a PhD from SINP, Kolkata. He holds the first PhD in econophysics from India. He, along with collaborators, has introduced a self-organising model where agents trade with a single commodity with the money they possess and the role of money in the economic market is

then studied. They have made analyses of stock market data, both low-frequency (daily) and (intraday tick-by-tick) and have conducted empirical studies revealing the statistical properties of financial time series.

He is a referee of different journals like *PRL, PRE, EPJB, Physica A, Management Science, Mathematical Sciences, New Journal of Physics, Journal of Economic Behavior & Organization, Economics e-journal,* etc. In addition, he has convened a number of conferences and workshops and is a member of many scientific bodies. He has also co-authored and co-edited at least eight books so far. He has been invited to write many articles and reviews. He has a large number of publications in refereed journals.

1.5.3.19 Thomas Lux

Bio Box 1.50
Thomas Lux
Born - August 4th, 1962, Germany
Field – Economics
Alma mater – University of Wuerzburg, University of Bamberg
Institutions – Kiel University, Kiel Institute for the World Economy

Thomas, being an economist, has contributed a lot to the field of econophysics. He is considered among the 1000 most quoted economists

of the world. He has a number of publications in physics journals like *Nature, Physica A, European Journal of Physics B, International Journal of Modern Physics*, *Physical Review E,* etc. Some of his contributions in the field of econophysics are summarised below.

Some of his Shorter Contributions and Didactical Works are:

1. *Financial Systems: Ecology and Economics*, in: *Nature* 469, 2011, 303.
2. *Economics Crisis* (with F. Westerhoff), in: *Nature Physics 5*, 2009, 2-3.
3. *Worrying Trends in Econophysics* (with M. Gallegatti, S. Keen and P. Ormerod), in: *Physica A* 370 (2006), 1-6.

He is the editor of the following Special Issues and Contributed Volumes:

1. Alfarano, S., T. Lux and M. Milakovic (Guest editors), special issue on *Interdisciplinary Applications of Physics in Economics and Finance* of the *European Physical Journal*, Vol. 73, no.1, 2010.
2. Farmer, D. and T. Lux (Guest editors), special issue on *Statistical Physics Approaches in Economics and Finance* of the *Journal of Economic Dynamics and Control*, Vol.38, 2008.
3. Lux, T. S. Reitz and E. Samanidou, eds. *Nonlinear Dynamics and Heterogeneous Interacting Agents.* Lecture notes in *Economics and Mathematical Systems.* Berlin: Springer, 2005.

Here are some of his articles in refereed journals mainly related to econophysics:

1. *Parameter Estimation and Forecasting for Multiplicative Log-Normal Cascades* (with A. Leovey), *Physical Review E* (in press).
2. *Estimation of an Agent-Based Model of Investor Sentiment Formation* in *Financial Markets, Journal of "Forecasting Volatility under Fractality, Regime-Switching, Long Memory and Student-t Innovations"* (with L. Morales-Arias), *Computational Statistics & Data Analysis* 54, 2010, 2676-2692.
3. *Multifractality and Long-Range Dependence of Asset Returns: The Scaling Behaviour of the Markov-Switching Multifractal Model with Log-normal Volatility Components* (with R. Liu and T. di Matteo), *Advances in Complex Systems 11*, 2008, 1-16.

4. *Empirical Validation of Stochastic Models of Interacting Agents: A 'Maximally Skewed' Noise Trader Model* (with S. Alfarano and F. Wagner), *European Journal of Physics B* 55 (2007), 183-187.
5. *Agent-Based Models of Financial Markets* (with E. Samanidou, E. Zschischang and D. Stauffer), *Reports on Progress in Physics 70*, 2007, 409-450.
6. *Some New Results on the Levy, Levy and Solomon Microscopic Stock Market Model* (with E. Zschischang), *Physica A* 29, 2001, 563-573.
7. *Finite-Size Effects in Monte Carlo Simulations of Two Stock Market Models* (with E. Egenter and D. Stauffer), *Physica A* 268, 1999, 250-256.
8. *Scaling and Criticality in a Stochastic Multi-Agent-Model of a Financial Market* (with M. Marchesi), *Nature* 397, 1999, 498-500.

He has served as a referee for many journals related to physics, as well as economics journals: such as, *European Physical Journal B, Europhysics Letters, Journal of Statistical Mechanics, Journal of Wavelets, Nature, Physica A, Physica D, Physical Review E, Physical Review Letters, Proceedings of the National Academy of Sciences of the USA, Quantitative Finance, Statistical Papers, Review of Modern Physics,* and *Science*.

In addition, he has been invited to many econophysics conferences and workshops as a keynote speaker.

1.5.3.20 John Angle

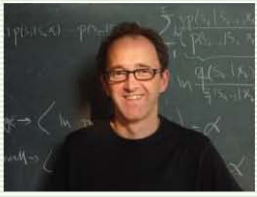
John was a statistical consultant to the Economic Research Service (ERS) of the US Department of Agriculture and then established The Inequality Process Institute LLC (TIPI). At TIPI, he works full time on research related to the Inequality Process. Professor Angle is a mathematical sociologist interested in income and wealth phenomena and is not, as such, an econophysicist.

Some Papers

1. Angle, John, 2011. *The particle system model of income and wealth more likely to imply an analogue of thermodynamics in social science*, *MPRA Paper* 28864, University Library of Munich, Germany.
2. Angle, John, 2010. *The Inequality Process vs. The Saved Wealth Model. Two Particle Systems of Income Distribution; Which Does Better Empirically? MPRA Paper* 20835, University Library of Munich, Germany.

3. John Angle, 2007. *The Macro Model of the Inequality Process and The Surging Relative Frequency of Large Wage Incomes, Quantitative Finance Papers* 0705.3430, arXiv.org.
4. Angle, John, 2006. *Not a Hollowing Out, a Stretching: Trends in US Nonmetro Wage Income Distribution, 1961-2003, MPRA Paper* 10111, University Library of Munich, Germany, revised 18 Aug 2008.

1.5.3.21 Matteo Marsili (1966-)



Matteo Marsili
Bio Box 1.51

Born in Rome, 4 January 1966. Italian citizen
Alma mater – University of Rome "La Sapienza" at SISSA, Trieste (1994)
Subject – Physics
Institutions – Abdus Salam ICTP, Trieste, SISSA, Trieste
Research Interests –
Interdisciplinary applications of statistical physics, including modelling socio-economic phenomena and financial markets, game theory, and biological networks.

Matteo, Abdus Salam ICTP (International Centre for Theoretical Physics), Trieste is principally a statistical physicist having a research interest in statistical physics, non-equilibrium critical phenomena, disordered systems, stochastic processes, complex networks, modelling socio-economic phenomena, financial markets, game theory and biological networks.

He has organised many conferences and workshops on socio-economic systems and finance, including:

1. Session on *Physics of Socio-Economic and Complex Systems* at the 22nd General Conference of the European Condensed Matter Division (EPS-CMD22) (Rome 27/08 - 1/09/2008).
2. Workshop *Complexity in Economics and Finance* (22-27 Oct 2007, Lorentz Center, Leiden NL).
3. Workshop *The Statistical Physics of Financial Markets* (ICTP Trieste, April 20-21, 2007).
4. Thematic Institute on *Networks, dynamics and socio-economics* and 7th Workshop on Economics with Heterogeneous Interacting Agents WEHIA 2002, (ICTP Trieste, 6 May - 1 June 2002).
5. *Application of Physics to Economic Modelling*, NATO advanced research workshop (Prague, 8-10 Feb. 2001).
6. Second School of Mathematical Economics (ICTP Trieste, 21 Aug-2 Sept 2000).

1.5.3.21 Victor Yakovenko (1961-)

Victor is one of the pioneers of econophysics. He is Professor of Physics, University of Maryland, USA. He completed his education in the USSR. He received his MS from the Moscow Physical-Technical Institute and his PhD in theoretical physics from the Landau Institute for Theoretical Physics, Moscow. He was a visiting professor to the Santa Fe Institute (2009) and Los Alamos National Laboratory, Santa Fe, New Mexico (2008) and to many other universities and institutes. His research interests are on unconventional superconductors, applications of statistical physics to economics and finance, photovoltaic conversion of solar energy, etc.

He has published invited review articles in the book *Encyclopedia of Complexity and Systems Science*, edited by R. A. Meyers, Springer (2009) and articles on econophysics in many other edited books. He has published many papers in refereed journals on econophysics, principally regarding the application of statistics to economics and finance, for example:

1. *Statistical mechanics of money.*
2. *Evidence for the exponential distribution of income in the USA.*
3. *Exponential and power-law probability distributions of wealth and income in the United Kingdom and the United States.*
4. *Statistical Mechanics of Money, Income, and Wealth: A Short Survey* with A. A. Dragulescu and many others.

Bio Box 1.52
Victor Yakovenko (Maryland University)

Place of birth – Donetsk, Ukraine
Citizenship – USA, since 2000
Field – Physics, Econophysics
Alma Mater – Landau Institute, Moscow, Moscow Technical Institute,
Institutes – University of Maryland, USA, Rutgers University
Awards and Honours
Fellow of the American Physical Society, Richard A. Ferrell
Distinguished Faculty Fellowship, Department of Physics, UMD, David and Lucile Packard Fellowship in Science and Engineering
Total award amount: $550,000
Soviet Youth League Prize in physics

Similarly, he has published many other papers on Stochastic Volatility Models for Stock Price Fluctuations. Many of his articles have attracted media interest and have been published in newspapers and periodicals written by reporters in *The American Scientist, The Australian Financial Review, The New Scientist, The New York Times Magazine,* etc.

He has refereed more than 292 articles in many physics and economics journals like *Nature, Physical Review Letters, Physical Review B, Physical Review E, American Journal of Physics, European Physical Journal B, Europhysics Letters, Journal of Physics Condensed Matter, Physica A, Journal of Economics, Journal of Economic Dynamics and Control Economic Modelling, Dynamics of Socio-Economic Systems, Journal of Mathematical Sociology*, etc.

1.5.3.22 Mauro Gallegati

Bio Box 1.53
Mauro Gallegati

Field – Economics
Alma mater – University of Ancona
Institute – Polytechnic University of Marche, Ancona
Research Interests – business fluctuations, nonlinear dynamics, models of financial fragility and heterogeneous interacting agents
Known for – developing the theory of asymmetric information and heterogeneous agents and their applications

Gallegati is Professor of Economics at the Polytechnic University of Marche, Ancona. He is visiting Professor in several universities and research institutes like the MIT, the Santa Fe Institute, Cambridge, Stanford and ETH, Zurich. His research interests include nonlinear dynamics, business fluctuations, heterogeneous interacting agents and models of financial fragility.

He has published papers in the top journals on economics, nonlinear mathematics, complexity, applied economics and econophysics. His research group studies agent-based models of economic phenomena. Professor Gallegati has been involved in several European projects since 2004 and the latest one is on financial crisis forecasting using the tools of complexity theory. Papers of Prof. Gallegati have more than 2168 citations. His work is mainly focused on *complexity, agent-based models, financial fragility* and *cycles and growth.*

1.5.3.23 Roberto Iglesias

Bio Box 1.54
J. Roberto Iglesias

Field – Physics, Economics
Institute – Institute de Fisica Campus do Vale UFRGS, Brazil
Research Interests – Statistical physics, Magnetism, Wealth distribution, Game theory

Iglesias is a professor and Head of the Applied Theoretical Physics Group, Instituto de Física - UFRGS.

His research activities include statistical physics applied to economics and social sciences, game theory applied to economic systems and in opinion dynamics, etc. The group develops models of economic and social organisations including the interactions between individuals and their capacities for learning and changing their behaviour and analysing the emergence of collective social behaviours. They also work in game theory as applied to economic systems and in opinion dynamics, i.e. the impact of authority, fashion, ethics and social influence, in general, on political, economic, cultural decisions and linguistics.

Alongside natural science and social science, he also has an interest in literature. He has written a book of short stories (in Portuguese).

He has many publications on physics applied to economics and social sciences, which have been published in *Physics A, Revista Mexicana de Física, The European Physical Journal B, The European Physical Journal – Special Topics, Journal of Statistical Mechanics*, etc.

1.5.3.24 Alan P. Kirman (1939-)

Bio Box 1.55
Alan P. Kirman (1939-)

Citizenship – British and French
Fields – Economics, Geography
Alma mater – Dulwich College (G.B.), Oxford University (Jesus College), Johns Hopkins School of Advanced International Studies, Bologna (Italy), Princeton University (USA)
Institutes – European University Institute, Florence. L'Université d'Aix-Marseille, à l'Université d'Aix-Marseille II, Warwick University, l'Université Libre de Bruxelles, Johns Hopkins University, Baltimore, Princeton University, University of Minnesota, Ratcliffe College, Leics
Awards and Honours – Elected Fellow of the Econometric Society, Alexander von Humboldt Stiftung Fondation Urrutia Prize for Economic Diversity

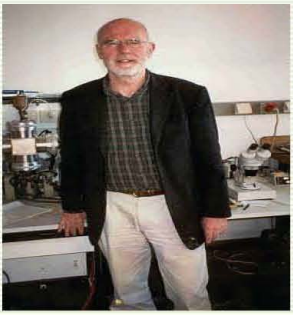
Alan P. Kirman is an economist and was Professor of Economics at Warwick University. In addition, he was Professor of Economics at the European University Institute, Florence and Professeur de Sciences Economiques à l'Université d'Aix-Marseille II.

He is a referee of many journals such as *The American Economic Review; Economic Journal; Econometrica; International Economic Review; Review of Economic Studies; Journal of Public Economics; European Economic Review,* etc. He has written and edited around 17 books like *Introduction to equilibrium analyses, Complex Economics: Individual and Collective Rationality,* etc. He has organised and has been invited to many conferences.

His view is that the representative agent disagrees with all individuals in the economy. His conclusion is that policy recommendations to improve the welfare of the representative agent would be illegitimate. He proposes that *Agent-based simulation models* dealing with many heterogeneous agents could be a possible alternative to the representative agent approach to economics.

1.5.3.25 Physical Economics

Jürgen Mimkes (1939-)



Bio Box 1.56
Jürgen Mimkes (1939-)

Country – Germany
Field – Metalurgist, Solid State Thermodynamics, Physical socio-economics
Alma Mater – University of Gottingen, Free University of Berlin, Technical University of Berlin
Institutes – University of Paderborn, Germany

Mimkes is a professor in the physics department at the University of Paderborn, Germany. Before that, he taught in many US universities and in Berlin. Since 1990, he has been working on social and economic systems. He calls his present field "physical economics", especially macro and microeconomics, and finance. He has difficulty in calling his field econophysics, as this only covers finance.

He has many publications, including *Society as a Many-Particle System* (1997), *Chemistry of the Social Bond* (2005) *Econophysics and Sociophysics (multi-authored*, 2006), and many others. Mimkes showed an *analogy* of segregation in populations to the miscibility gap in solutions and alloys in 1994. His first paper in this area was the *Binary Alloys as a Model for a Multicultural Society* in *The Journal of Thermal Analysis* in 1995. In 1996, his 110-page article on *Politics and Thermodynamics* was also published.

According to him, economic properties may be calculated in physical terms such as capital to *energy*, production to physical work, and GDP per capita to *temperature*, and production function to *entropy*. He considers production, trade, and banking to be compared with motors, heat pumps, and *refrigerators* as is evident from his article *Stokes Integral of Economic Growth*. In this article, he says that the "Carnot *process* of the *first law*" creates two levels in each *system*: buyer and seller, investor and saver, rich and poor, which, supposedly, have a correlation to "*hot* and *cold* in *physics*". He postulates that *efficiency* rises in proportion to the income difference between the rich and the poor, on the basis that *heat engine* efficiency increases as the temperature difference between hot and cold bodies increases.

Prof. Mimkes has published many papers on econophysics in diverse journals and has been invited to many conferences for talks.

1.5.3.26 Masanao Aoki (1931-)

Aoki is Emeritus Professor of Economics at UCLA. He works on areas such as:

1. Modelling and analysis of multi-agent models to investigate herding behaviour and return dynamics.
2. Modelling and analysis of multiple country models by state space time series technique.
3. Aggregation of the economy with heterogeneous agents by neural network methods.

Bio Box 1.57
Masanao Aoki

Professor Emeritus
UCLA, Department of Economics

He has written many books, reviews and publications.

1.5.3.27 IYETOMI, Hiroshi

Bio Box 1.58
IYETOMI, Hiroshi

Field- Condensed matter Physics, Econophysics
Institutes – Niigata University, Tokyo University

Iyetomi worked as Assistant Professor of Physics at the University of Tokyo (1984-1993) after receiving his PhD in Physics from the same University. During 1993-94, he worked on semiconductors at the Energy Research Laboratory, Hitachi, Ltd. From 1995-2012, he was Associate Professor and later Professor of Condensed Matter and Computational Physics at Niigata University. Now he is Professor of Mathematics at Niigata University, focusing on econophysics, network science, and multivariate analysis.

His research interests in econophysics are as follows. He adopts the statistical physics approach to obtain a new insight into macroeconomic phenomena, which are regarded as outcomes (collective motion) of interactions among a number of heterogeneous agents. Such an idea is analogous to that of the many-body problem in physics. The economic issues under study include business cycles, systemic risks (contagion of failure), and group structures in stock markets. In particular, he has so far focused on empirical analyses. He takes advantage of the random matrix theory to distinguish statistically meaningful information from random noises in complicated economic data and also applies network science methodology to elucidate structural and dynamical properties of large-scale economic systems.

1.5.3.28 Bertrand M. Roehner (1946-)

Roehner is Professor of Physics at the LPTHE, University of Paris. His research interests are stock price bubbles, real estate prices, speculative trading, sharp peak and flat trough patterns, price peaks, market integration, separatism and separatist uprisings, commodity prices, spatial propagation of price fluctuations, social bonds, social cohesion, military occupation, suicide, etc. He is the author of several books, for example *Theory of Markets* (published by Springer-Verlag), *Hidden collective factors by speculative trading* (published by Springer), *Patterns of speculation* (published by Cambridge University Press). He is a guest faculty member at many universities such as the Institute of Economics (Copenhagen, September 1996), the Harvard Department of Economics (Summer 1994, Fall 1998), and the Santa Fe Institute (2002). He was the co-organiser and invited speaker at the Prague 2001 NATO Conference on econophysics. He is a referee for various physical or economic journals including *International Regional Science Review, Physica A, Explorations in Economic History, Journal of Development Economics,* and *Journal of Economic Behavior*. He is a member of the editorial board of the main website devoted to econophysics: www.unifr.ch/econophysics.

1.5.3.29 Joseph McCauley

Bio Box 1.59
Joseph Mc Cauley

Institute – Houston University
Field – Physics, Econophysics

McCauley is Professor of Physics at Houston University, and at the same time, he also teaches econophysics. Now he works on econophysics and complexity: economics and finance. He has written many books including *Dynamics of Markets: the new financial economics* (2009), *Dynamics of Markets*, Cambridge (2004), etc. Besides, he has many papers in econophysics published in different journals such as *Response to Worrying Trends in Econophysics, Physica A* 369,343 2006; *Hurst Exponents, Markov Processes, and Nonlinear Diffusion Equations*, with K. Bassler & G. Gunaratne, *Physica A* 369, 343, 2006; and *How to make Mathematical Modelling Effective in Economics, Physica* 355A,1, 200ke.

1.5.3.30 Diego Garlaschelli (1977-)

Diego, from the Laboratory of Economics and Management, Sant' Anna School of Advanced Studies in Pisa, Italy, is the driving force behind Leiden econophysics. He was appointed as a tenure-track assistant professor, which meant that he had the opportunity to become a professor. Garlaschelli became the first professor of econophysics in April 2011 and started his lecturing career in May 2011 with a bachelor's course in econophysics for third-year students in the Lorentz Institute for Theoretical Physics, Leiden, Institute of Physics, University of Leiden. He did his PhD in Physics at the University of Siena (Italy), on *Statistical Physics Approach to the Topology and Dynamics of Complex*

Networks.

Bio Box – 1.60
Diego Garlaschelli (1977 –

Nationality – Italian
Fields – Physics, Econophysics
Known for – First Professor of Econophysics

He is the referee of many international journals like *Nature, Physical Review Letters, Physical Review E, New Journal of Physics, EuroPhysics Letters, European Physical Journal B, Physica A, Social Networks,* etc. He has been invited to many international conferences in econophysics as a speaker and has published many papers. He received an award for the best talk presented by young researchers at the Second International Conference on Frontier Science, *A Nonlinear World: The Real World*, Pavia (Italy), Collegio Cairoli in September 2003 and at Alessandria (Italy) in September 2004 in the conference "First Bonzenfreies Colloquium on Market Dynamics and Quantitative Economics".

1.5.3.31 Frédéric Abergel

Bio Box 1.61
Frederic Abergel

Alma Mater – University of Paris
Institute - Ecole Centrale Paris, Penn State University

Frederic is the Director of the laboratory of Mathematics Applied Systems at the Ecole Centrale Paris. He was a Consultant for BNP Paribas, Equity Derivatives from 1996 to 2001 and has worked in different capacities for many other financial institutions like Calyon, Paris Analytics, Barclays Capital, Natixis, etc. He specialises in financial modelling, electronic markets, trading, algorithmics and systems, risk management and management. He has a large number of publications and more than 675 citations. His papers on *Econophysics: Empirical facts and agent-based models, Econophysics review: II. Agent-based models* and *Econophysics review: I. Empirical facts* have many citations. He has many published papers mainly based on empirical properties and mathematical models of limit order books, quantitative finance, etc.

He is associated with the Econophysics Kolkata series of workshops.

1.5.3.32 Marcel Ausloos

Ausloos did his MSc in Physics at Brown University in 1970 and received his PhD from Temple University, Philadelphia, in 1973. Now, he is Professor of Physics at the University of Liège, Belgium, where his group works on applications of Physics in Economy and Sociology. In addition to fields like magnetism, superconductivity, optics, transport properties, phase transitions, fractals, evolution and growth, he has worked on econophysics and has published many papers. He has more than 350 published papers in various fields of theoretical condensed matter physics

and statistical physics. His recent papers on econophysics are quite interesting, for example:

1. *Econophysics of a religious cult: the Antoinists in Belgium [1920-2000],* Quantitative Finance Papers 1201.4841, arXiv.org, revised Jan 2012. Paulette Clippe & Marcel Ausloos, 2012.
2. *Benford's law and Theil transform of financial data.* Quantitative Finance Papers 1208.5896, arXiv.org. Janusz Miskiewicz & Marcel Ausloos, 2009.
3. *Has the world economy reached its globalization limit?* Quantitative Finance Papers 0910.3695, arXiv.org.

Bio Box 1.62
Marcel Ausloos

Alma Mater – University of Liège, Liège, Belgium, Brown University, Temple University, Philadelphia
Institute – Brown University, Temple University, Freie University, Berlin, University of Liège, Belgium
Field – Physics
Research Interests – magnetism, superconductivity, optics, transport properties, phase transitions, fractals, evolution, growth, econophysics...
Awards and Honours- Included in *WHO'S WHO IN THE WORLD,* 12th Ed.

1.5.3.33 Dietrich Stauffer (1943-) is a German theoretical physicist noted for his application of statistical physics and, in particular, computational physics to the areas of *econophysics* (since 1998) and *sociophysics* (since 2000). He did his MS in Physics in Munich in 1967. In 1970 he completed his PhD at Munich Technical University. Stauffer began researching biophysics in 1986, *econophysics* in 1998, *sociophysics* in 2000, and linguistics in 2004.

Bio Box 1.63
Dietrich Stauffer (1943-)

Field – Physics
Alma mater – Munich Technical University
Institutes – Munich (Germany), Urbana (IL), Atlanta (GA), and Saarbrucken (Germany), Saar State University, University of Cologne, Germany
Research Interests – Econophysics, Sociophysics, linguistics

Econophysics and sociophysics motivation – In regard to what stimulated Stauffer, a statistical physicist, to move into the study of econophysics and sociophysics problems, the seeds began when, as a graduate student, he became interested in the biological applications of condensed matter physics; and, in 1985, he began to simulate some biological models.

Being influenced by *Stanley*'s papers on the application of *econophysics* to percolation theory (Stauffer's speciality) to stock market fluctuations by

Cont and Bouchaud in 1997, he became interested in econophysics. He was also influenced by the physicist Kasia Sznajd's preprint on opinion dynamics which made Stauffer interested in this model to the effect that he would like to simulate war and peace.

The international conference on "Unconventional Applications of Statistical Physics: Physics of Random Networks, Econophysics, and Models of Biophysics and Sociophysics" was organised in honour of Stauffer's 60th birthday in 2003.

Stauffer's 2011 article *Statistical Physics for Humanities: A Tutorial* begins with an historical overview, contains sections such as "humans are neither *spins* nor *atoms*", "Schelling model for social segregation", on the work of *Thomas Schelling*, extols using an Ising model of the physics of *human behaviour* or choice, and concludes with a suggested outline for using Fortran to build computer simulations for a type of human statistical physics.

1.5.3.34 Manipuspak Mitra

Mitra, Professor of Economics at the Indian Institute of Statistics, Kolkata, works on econophysics as well as mainstream economics. He has published some papers in physics journals and book chapters on econophysics. His paper *Statistics of the Kolkata Paise Restaurant problem* jointly with Asim Ghosh, Arnab Chatterjee and Bikas K. Chakrabarti with a focus on Statistical Physics Modelling in Economics and Finance, was published in *The New Journal of Physics* 12(075033), (2010). Another paper, *The Kolkata Paise Restaurant problem and resource utilization* was published in *Physica A,* 388(12), 2420-2426 (2009) jointly with Anindya Sundar Chakrabarti, Bikas K. Chakrabarti and Arnab Chatterjee. Similarly, he has published book chapters on econophysics, for example *Cycle Monotonicity in Scheduling Models* and *Dominant Strategy Implementation in Multi-unit Allocation Problems* in *The New Economic Window Series*, published by Springer.

1.5.3.35 Satya R. Chakravarty: Chakravarty did his PhD at the Indian Statistical Institute, Kolkata and is Professor of Economics in the same institute.

Professor Chakravarty has worked as a visiting professor in many universities such as the Paris School of Economics, Paris, France, the Chinese University of Hong Kong (1998), the Bocconi University, Milan, Italy, the Yokohama National University, Japan, the University of British

Columbia, the University of Karlsruhe, Germany, the Bar Ilan University, Israel, and the Kagawa University, Japan.

Bio Box 1.64
Satya R Chakravarty

ISI, Kolkata
Field – Economics
Alma Mater – ISI, Kolkata
Institute – ISI, Kolkata
Research Interests – Welfare Economics, Public Economics, Mathematical Finance, Industrial Organization and Game Theory
Awards – **Mahalanobis Memorial Award**

He has over *80 publications* in prestigious scholarly journals and has edited volumes, covering topics such as inequality, poverty, tax progression, deprivation, size distributions of incomes and firms, mobility, polarisation, living standards, human development, migration, employment segregation, mathematical finance and voting games.

He has authored six books and also co-edited two books. In 1994, he received the ***Mahalanobis Memorial Award*** of the Indian Econometric Society. This is the most coveted award for an economist in India.

1.5.3.36 Yuji Aruka (1949-) Yuji Aruka is Professor of Economics at *Chuo University*, Tokyo, Japan. He is also a visiting professor to many universities like the Australian National University, Australia, the International School of Economic Research, University of Siena, Italy, the Institute for Market and Plan, Visiting Fellow at Clare Hall Cambridge, UK, etc. He did his Master of Economics degree at Waseda University in 1975 and a PhD in Economics at Kyoto University. He has many publications in physics journals as well as in economics journals.

Bio box 1.65
Yuji Aruka (1949) PhD Econ.

Field – Economics
Alma mater – Waseda University, Kyoto University
Institution – Chiba University of Commerce, Chuo University
Research Interests – Macroscopic microeconomics and heterogenous interacting agents under uncertainty, Social games, Econophysics and their interdisciplinary fields

His academic interests and teaching areas are macroscopic microeconomics and heterogeneous interacting agents under uncertainty, social games, econophysics and their interdisciplinary fields. He has been the editor of *The Journal of Economic Interaction and Coordination* since 6/2006. He was the chairman of ***IWSEP*** (International Workshop on Socio-and Econophysics) December 19-20, 2003, co-chairman, INSC08 (3rd International Nonlinear Science Conference) at Chuo University, March 13-15, 2008 and co-chairman, CS09 (The 9th Asia-Pacific Complex System Conference) at Chuo University, November 4-7, 2009. He is also the editor of the book *Complexities of Production and Interacting Human*

Behaviour, Physica Verlag [Springer Heidelberg], April 2011, 272pp. [ISBN: 978-3-7908-2617-3].

1.5.3.37 Fabrizio Lillo

Fabrizio Lillo has been Professore a contratto di Matematica Finanziaria, Research Professor in Mathematical Finance at the Scuola Normale Superiore di Pisa since January 2011. He did his PhD in Physics in 1999 at the University of Palermo and joined the same university as Assistant Professor of Physics. From 2009, he became a professor at Santa Fe. In 2007, he received the Young Scientist Award for Socio- and Econophysics from the German Physical Society. His research interests are on financial market microstructure, portfolio optimisation, high-frequency finance, systemic risk, application of Complex Systems and application of network theory to Finance.

Bio Box 1.66
Fabrizio Lillo

Field – Physics, Econophysics
Alma Mater – University of Palermo in 1999
Institution – Santa Fe, Palermo University, Italy,
Research Interests – financial market microstructure, high frequency finance, portfolio optimisation, and application of network theory to Finance.
Awards – Young Scientist Award for Socio- and Econophysics of the German Physical Society in 2007

1.5.3.38 Prasanta K. Panigrahi

Bio Box 1.67
Prasanta K. Panigrahi

Field – Physics
Alma Mater – Ravenshaw College, Utkal University, University of Rochester
Institutes – University of Hyderabad, PRL, Ahmedabad, IISER, Kolkata
Research Interests – Nonlinear dynamics, wavelet transforms, field theory

Panigrahi completed his MSc at Ravenshaw College, Cuttack, India and his PhD at Rochester University, USA. He worked at Hyderabad University and then at PRL, Ahmedabad. Presently, he has been working as Professor of Physics at IISER, Kolkata, since 2007. He is a referee for *PRL, Journal of Physics, Physical Review B, EPL, Pattern Recognition Letters, Pramana, Physics Letter A,* etc.

He has published many papers on wavelet transform and analysis of stock markets in *Journal of Quantitative Economics, Resonance, Phys. Rev. E, Pramana, Physica A, J. Phys. A,* etc.

1.5.3.39 Nivedita Deo

Nivedita Deo graduated from Delhi University and received her PhD from Purdue University, USA. She works on statistical physics, econophysics and finance. Under her guidance, many students are pursuing PhDs in econophysics. She has published many papers on econophysics. She has organised international conferences on econophysics in collaboration with

JNU and Kyoto Universities. She is a regular attendee of the Econophysics – Kolkata series.

Bio Box 1.68
Nivedita Deo

Field – Physics
Alma Mater – Ravenshaw College, Cuttak, Delhi University, Purdue University
Institutes – Delhi University, Santa Fe, I.I. Sc, **Bangalore,** Harvard University, etc.
Honours and Awards – Akeley Memorial Award for Theoretical Physics – Best Graduate 1987, Purdue University, USA, 1987, David Ross Fellowship, Purdue University, USA, 1984-1986,Radcliffe Fellow (Sept 1991-Aug 1992), Mary Ingraham Bunting Institute, Radcliffe College and Department of Physics, Harvard University, USA

1.5.3.40 Kimmo Kaski (1950-)

Kimmo Kaski is Professor of Computational Engineering and Academy Professor in Computational Science and Engineering. He was also the Director of the Centre of Excellence in Computational Complex Systems Research, in the Centre of Excellence Programme of the Academy of Finland for 2000-2005 and 2006-2011. As well as many awards and honours, he has been made a Fellow of the Institute of Physics, UK and granted the title of Chartered Physicist, 1998. He is a member of many professional organisations such as the American Physical Society (APS),

Bio Box 1.69
Kimmo Kaski

Field – Physics
Alma mater – Helsinki University of Technology (HUT); 1977: Licentiate in Technology, in Electron Physics, HUT; Oxford University
Institutes – Aalto University, Oxford University, Jyväskylä University, Temple University
Research Interests – Computational Science, Complex Systems, Complex Networks, Computational Systems Biology, High Performance Computing

Fellow of European Physical Society, etc. He is on the editorial board of *The International Journal of Modern Physics: Computers in Physics,* and he referees for APS journals, IOP journals, Institute of Electrical & Electronics Engineers (IEEE) (USA) journals, and IEE (UK) journals. He has supervised about 60 students through to their PhD degrees. His research has been covered by many news agencies including his work on econophysics and social science, for example *Story on computational social science* in *Nature News.* He has also published many articles in books. His papers on econophysics have been published in journals such as *Physical Review E, Physica A, European Physical Journal B,* etc.

1.5.3.41 Imre Kondor

Imre Kondor is a professor and the Head of the Department of Physics and Complex Systems Physics at Eötvös Loránd University, Budapest.

In 1980, he switched his research interest from physics to random systems, in particular to the field of theory of spin glasses. Now he applies the methods of statistical physics to problems in quantitative finance, and to the theoretical aspects of risk management and of financial regulation.

Bio Box 1.70
Imre Kondor

Field Physics
Alma Mater Eötvös University of Sciences, Hungarian Academy of Sciences, Budapest
Institutes – Eötvös University of Sciences, Raiffeisen Bank, Budapest, Institute of Finance, Corvinus University
Awards Brody Prize, Apaczai Csere Janos Prize and some others
Research Interests Application of the methods of statistical physics to problems in economics and finance, the theory of financial risk

He is a leader of the correlation heterogeneous network. His research areas include the application of the methods of statistical physics to economics, finance and financial risk.

He is a member of the editorial boards of *Fractals* and *Journal of Statistical Mechanics* and formerly review editor of *Journal of Banking and Finance*.

1.5.3.42 J. Barkley Rosser, Jr. (1948-)

Bio Box 1.71
J. Barkley Rosser, Jr. (1948-)

Nationality – American
Field – Economics
Alma Mater – University of Wisconsin–Madison
Institutes – James Madison University
Awards – Fellow of Economists for Peace and Security [2009]
Ouststanding Faculty Award from the State Council on Higher Education in Virginia [2011]

John Barkley Rosser, Jr. is a mathematical economist who received a BA in economics with a minor in mathematics in 1969, an MA in economics in 1972, and a PhD in Economics in 1976, all from the *University of Wisconsin–Madison*. He has been Professor of Economics at James Madison University in Harrisonburg, Virginia since 1988. His areas of interest are nonlinear economic dynamics including applications in the economics of catastrophe theory, chaos theory and complexity theory. He introduced the concepts of chaotic bubbles, chaotic hysteresis, and econochemistry into economic discourse. He is a pioneer of providing a mathematical model of the *period of financial distress* in a speculative bubble (1991, op. cit., Chap. 5). He was an editor of *The Journal of Economic Behavior and Organization,* from 2001–2010, and become co-editor in January 2011.

1.5.3.43 Tobias Preis (1981-)

Bio Box 1.72
Tobias Preis (1981-)

Country – Germany
Fields – Computational Finance, Complex Systems
Alma Mater – Johannes Gutenberg University of Mainz
Institutions – Warwick Business School, Boston University, University college of London, MIT
Known for – Identification of links between online behaviour and real world economic events

Tobias Preis did his MSc and PhD in Physics at the Johannes Gutenberg University of Mainz. Tobias Preis is an Associate Professor of Behavioural Science and Finance at Warwick Business School. His research area is the analysis and prediction of social and financial complexity. He has quantified and modelled financial market fluctuations. He and his colleagues have demonstrated that there is a relationship between the economic success and the online information-seeking behaviour of citizens of a country.

He has had many papers published on econophysics and his works have attracted a lot of media attention. He was the general secretary of the *"Physics of Socio-Economic Systems" Division* of the *German Physical Society (DPG)* from 2009 to 2011.

1.5.3.44 Scalas, Enrico

Scalas is an External Scientific Member of **BCAM** – the Basque Centre for Applied Mathematics, Spain. According to him, evidence-based financial mathematics is the core of contemporary financial mathematics consisting of the Black-Scholes theory for derivative valuation and the Markowitz method for portfolio selection.

He said that the problem of finding suitable stochastic models for price fluctuations in financial markets is still open and can be partially solved by means of interdisciplinary work involving experimental economics as well as statistics. He has published many papers on econophysics principally on financial time series and stylised facts.

Bio Box 1.73
Scalas, Enrico

Institution – BCAM - **Basque Centre for Applied Mathematics**

1.5.3.45 Marco Patriarca (1963-)

Bio Box 1.74
Marco Patriarca (1963-)
Nationality – Italian

Field – Physics
Alma Mater – University of Perugia,
Master's in Physics, University of Rome
Institutes – Instituto de Física Interdisciplinar y Sistemas Complejos,
University of the Balearic Islands

Patriarca did his PhD in Physics at the University of Perugia in 1993 and his master's in Physics at the University of Rome. Now he is a professor at the Instituto de Física Interdisciplinar y Sistemas Complejos IFISC (CSIC-UIB) Campus Universitat de les Illes Balears.

His current research activity mainly concerns Complex Systems and Statistical Mechanics, in particular:

- neuronal systems, specifically neuronal models of the wake-sleep cycle
- social dynamics (models of language competition and models of wealth distribution)
- diffusion problems (anomalous diffusion in periodic potentials, stochastic resonance, dimer diffusion in periodic force fields...).

His research activity focuses on some topics in fields like Brownian motion and Complex Systems. He has published many papers in refereed journals such as *Physica A, Quantitative Finance, EPJB,* etc.

In addition, he has diversified research interests such as Natural Sciences and Engineering, Physics and Technical Physics (diffusional processes, complex systems, material science, and computational physics).

1.5.3.46 Attilio Stella (1949-)

Bio Box 1.75
Attilio Stella (1949-)

Nationality: Italian
Field – Physics
Alma Mater – University of Padova, Katholieke Universiteit Leuven, Leuven, Belgium
Institutes – University of Padova, University of Bologna

Attilio Stella is Professor of Physics at the University of Padova. He did his PhD at the Katholieke Universiteit Leuven, Belgium. As well as this, he has held different positions in many other universities too. He is the author of about 110 papers in international refereed journals and has made about 20 contributions to reports and books. His research activity is in various fields of statistical physics.

1.5.3.47 Josep Perello

Josep Perello works in the University of Barcelona and researches econophysics as well as science communication and other areas. He has principally worked on stochastic volatility, risk analysis in hedge funds, stylised fact, Random walk formalism in financial markets and applications of thermodynamics to financial markets, etc. He has published more than 47 papers in refereed journals.

Bio Box 1.76
Josep Perello

Field – Physics
Research Interests – Science Communication, Econophysics, Art and Science
Institutes – Departament de Física Fonamental Universitat de Barcelona

1.5.3.48 Lorenzo Pareschi

Lorenzo Pareschi is a professor and Chair of the Mathematics and Computer Science department, Ferrara University. He did his PhD in Mathematics [1991-1995] at the University of Bologna, Italy.

His research interests include traffic flows, econophysics, sociology, and biomathematics in addition to mathematics and plasma physics. He has published many papers principally on *kinetic models for socio-economic dynamics of speculative markets* and game theory in different refereed journals.

Lorenzo Pareschi
Bio Box 1.77

Field – Mathematics
Alma Mater – University of Ferrara, University of Bologna, Italy
Institutes – University of Ferrara, CNRS Orleans, France
Research Interests – Econophysics, traffic flows, sociology, etc.

1.5.3.49 Giuseppe Toscani

Toscani is a full Professor of Mathematical Physics in the Faculty of Sciences, University of Pavia. His research interests include statistical mechanics, mathematical and numerical methods in the kinetic theory of rarefied gases, hyperbolic systems and applications, granular gases, mathematical modelling in socio-economic and related problems, diffusion equations, etc. He has chaired many international conferences such as the "Workshop on Analysis and Numerics of Kinetic and Hydrodynamic Modelling for the Environment and the Economy" (Castiglione della Pescaia, Italy, 2005), and the "Workshop on Kinetic and Macroscopic Modelling for Socio-Economic and Related Problems" (Vigevano, Italy, 2008). One of his edited books is *Mathematical Modeling of Collective Behavior in Socio-Economic and Life Sciences*, Birkhauser, Boston (2010). He has published many papers, two books and book chapters on econophysics in refereed journals and books.

Bio Box 1.78
Giuseppe Toscani

Citizen – Italy
Field – Mathematical Physics
Institute – University of Pavia
Research Interests - Mathematical modelling in socio-economic and

1.5.3.50 Rama Cont

Rama Cont is the Director of Research at the CNRS, *Laboratoire de Probabilités et Modèles Aléatoires*, Université Paris VI-VII. He did his PhD in theoretical physics at the University of Paris XI (Orsay) in 1998. His research interests are computational finance, stochastic modelling of financial markets, *Lévy* processes and applications, interest rate and credit risk modelling, modelling of social networks and *ill-posed inverse problems*. He received the "Best paper award in Mathematical Finance 2006", Europlace Institute of Finance. He has written books on Quantitative Finance. He has published many papers in refereed journals on stochastic analysis, systemic risk, complex networks, limit order markets, etc.

Bio Box 1.79
Rama Cont

Born – Tehran, Iran.
Field – Physics
Alma Mater – University of Paris, Ecole Normale, Paris
Institutes – CNRS, University of Paris, Columbia University
Research Interests – Stochastic modelling of financial markets, Credit risk and systemic risk, etc.
Awards – Grand Prix Louis Bachelier (French Academy of Sciences, SMAI and Natixis Foundation), 2010 and others

1.5.3.51 Neil Johnson (1961-)

Neil Fraser Johnson is Professor of physics at Miami University and heads the team of Complexity in the Department of Physics. Neil did his BA at Cambridge and a PhD at Harvard University. His research interests include complexity theory and complex systems, spanning quantum information, econophysics, and condensed matter physics. His group works on projects like Physical Complexity, Biological Complexity, and Social Complexity. He has two books to his credit, *Simply Complexity: A Clear Guide to Complexity Theory* and *Financial Market Complexity* (Oxford University Press, 2003). He is the editor of the Physics Section for the journal *Advances in Complex Systems* and associate editor for *Journal of Economic Interaction and Coordination*. Neil was a founder member of CABDyN (Complex Agent-Based Dynamical Systems) which

is Oxford University's interdisciplinary research centre in Complexity Science.

Bio Box 1.80
Neil F. Johnson (1961-

Field – Physics
Alma Mater – Cambridge University (U.K.), Harvard University
Institute – University of Miami, Oxford University
Research Interests – complexity theory and complex systems, econophysics, etc.

1.5.3.52 Vasiliki Plerou

Vasiliki Plerou graduated from Boston University in 1996 and also received her PhD in Physics in 2001. She received the young scientist award for socio- and econophysics from DGP, AKSOE in 2003.

Plerou has made a contribution to a wide range of phenomenological problems in econophysics. She contributed to the discovery of the half-cubic law of volumes, which have been found to be universal patterns of financial fluctuations and to the discovery of the inverse cubic power law for the stock return distribution. She was one of the first researchers who applied random matrix theory, a powerful tool in diverse fields of theoretical physics, to investigate the correlation between stock returns. Furthermore, she made successful attempts to apply these ideas and results to the more pragmatic problem of portfolio optimisation. She has been

instrumental in initiating a lot of new research during the past years, to the advantage of the field of socio- and econophysics for her empirical findings on modelling the stock market. She has 92 publications in many refereed journals and more than 1952 citations.

Bio Box 1.81
Vasiliki Plerou
Field – Physics
Alma Mater – Boston University
Institution – Boston University
Research Interests – Chemical Physics and Material Physics, Statistical Physics, Mathematical and Quantitative Methods
Awards – Young Scientist Award for Socio- and Econophysics from the AKSOE", 2003

1.5.3.53 Xavier Gabaix (1971-)

Gabaix is an economist and is currently Professor of Finance at the New York University Stern School of Business. He graduated in Mathematics and did his PhD in Economics. His research interests include asset pricing, origins and consequences of scaling behaviour, etc. He has received a number of prizes and awards, some of which are the Lagrange Prize for research on complex systems, 2012 (CRT Foundation), the Rising Star in Finance Award, 2012, the Best Young French Economist Prize, 2011, the Fischer Black Prize, the Bernacer Prize for best European economist under 40 working in macroeconomics/finance, and the Young Scientist Award for socio- and econophysics, 2006. He has publications in both economics and physics journals and has more than 2000 citations.

Bio Box 1.82
Xavier Gabaix (1971-)

Field – Economics
Alma Mater – Harvard University, Ecole Normale Supérieure
Institute – New York University
Research Interests – Asset Pricing, Behavioural economics, Executive compensation, Macroeconomics, Origins and consequences of scaling behaviour
Awards – Lagrange Prize for research on complex systems, 2012 (CRT Foundation) Rising Star in Finance Award, 2012, Fischer Black Prize, Best Young French Economist Prize, 2011, Bernacer Prize for best European economist under 40 working in macroeconomics / finance, Young Scientist Award for Socio- and econophysics, 2006

1.5.3.54 Sidney Redner (1951-)

Sidney Redner is a Professor of Physics and Departmental Chair of Physics at Boston University. He graduated from the University of California at Berkeley and received a PhD from MIT. His research interests include condensed matter and statistical physics; stochastic processes; first-passage processes; chemical kinetics; transport in disordered media; dynamics of social systems and the structure of complex networks. He has more than 240 publications in refereed journals and book chapters and one monograph, *A Guide to First-Passage Processes* (CUP, 2001). He is on the editorial board of *Journal of Statistical Physics, EPJB, J. Informetrics, J. Stat. Mech., American*

Journal of Physics, Journal of Physics A, and *Physical Review E*. Also, he was on the Advisory Panel of the Institute of Physics Publishing from 2001-09 and was Chair of APS Topical Group on Statistical and Nonlinear Physics from 2008 to 2009. He was Ulam Scholar at the Center for Nonlinear Studies at Los Alamos National Laboratory in 2004-05.

Bio Box 1.83
Sidney Redner

Field – Physics
Alma mater – MIT, University of California, Berkeley
Institute – Boston University
Research Interests – Condensed matter and statistical physics; stochastic processes, etc.

1.5.3.55 Yoshi Fujiwara

Fujiwara is Professor at Hyogo University in the Graduate School of Simulation Studies. His research interests are Theoretical Physics, Behavioural Economics, Macroeconomics, Complex Systems, and Complex Networks. He has 40 publications in journals like *Adv. Operations research, Physical Review E, Philosophy & Methodology of Economics e-Journal*. He has written a book entitled *Econophysics and Companies: Statistical Life and Death in Complex Business Networks*.

Bio Box 1.84
Yoshi Fujiwara
Fields – Physics, Econophysics
Institute – Hyogo University
Research Interests – Theoretical Physics, Behavioural Economics, Macroeconomics, Complex Systems, Complex Networks, Econophysics

1.5.3.56 Jun-ichi Inoue (1967-)

Inoue is working in the Graduate School of Information Science and Technology, Hokkaido University, in the department of Complex System Engineering. He works on information processing and econophysics applying Statistical Mechanics. He has published a number of papers in refereed journals and written chapters of different books on econophysics. His works are mainly based on "human collective behaviour at times of financial crisis by using stock-correlation", etc.

Bio Box 1.85
Jun-ichi Inoue

Fields – Physics, Econophysics
Institute – Hokkaido University
Research Interest – Statistical Mechanics: its application to information processing and econophysics

1.5.3.57 Taisei Kaizoji

Bio Box 1.86
Taisei Kaizoji

Field – Economics
Alma Mater – Waseda University, Tokyo Institute of Technology
Institutes – International Christian University, Tokyo
Awards - Fellowship of the Japan Society

Taisei Kaizoji is Professor of Economics at the *Department of Economics and Business*, *International Christian University*, Tokyo. He graduated from Waseda University in Business (1986) and completed his PhD at the Tokyo Institute of Technology in 1999. He was also a visiting professor to the University of Kiel, the Max-Planck Institute of Economics and the

ETH Zurich, Department of Management, Technology, and Economics. He has received numerous awards such as the "Fellowship of the Japan Society for the Promotion of Science for Japanese Junior Scientists, 1993-1994", "1999 Award for an original paper in Japan Society for Simulation Technology", etc. He is a member of the editorial board for *The Journal of Economic Interaction and Coordination,* Springer. He has a number of publications in physics journals like *Physica A, European Physical Journal B, Progress of Theoretical Physics Supplement,* etc. as well as in economics journals. His works are based on stock market studies. Many of his papers are co-authored by physicists.

1.5.3.58 Giulia Iori

Bio Box 1.87

Giulia Iori
Field – Economics, Physics

Alma Mater – *Università di Roma la Sapienza* Roma, Italy
Institutes – City University London, King's College London University of Essex
Research Interests – Market Microstructure Models, High frequency data analysis, Protein Folding

Iori did her PhD in Physics at the Università di Roma la Sapienza, Rome, Italy in 1993 and is now working as Professor of Economics at City University, London. Her previous appointments were as a reader in applied mathematics in King's College, London and a lecturer of finance at the University of Essex. Subsequently, her research interests have been quite diversified and include Protein Folding, Neuromagnetic Measures and Instrumentation, Spin Glasses in physics and Consumption behaviour, Market Microstructure Models, Inter-Bank Lending, Reserve Requirements

and Systemic Risk, Socio-Economics Networks, Securities settlement architectures, Genetic Algorithms in Financial Decision Making, High-frequency data analysis, and Option pricing and Hedging in economics and finance. She has organised at least three conferences on Nonlinear dynamics and econometrics, complex behaviour in economics, etc.

She has served as a referee for *PRL, PRE, Physica A, EPJ, Journal of Economic Behaviour and Organization, Advances in Complex Systems, Computational Economics, Quantitative Finance, Studies in Nonlinear Dynamics,* etc. She had been chosen for the outstanding referee award from the *Journal of Economics Dynamic and Control* in 2009. She has a number of publications on econophysics.

1.5.3.59 Jean-Pierre Nadal –

Bio Box 1.88
Jean-Pierre Nadal

Field – Mathematics, Sociology
Institute – CAMS, Ecole Normale Supérieure. France
Research Interests – Statistical Physics of Information Processing in Biological and Social Networks,
Computational neuroscience, Cognitive science, Complex systems in social sciences, etc.

Nadal is Director of Research at the CNRS and also works at CAMS (Centre of Analysis of Mathematical Sociology) and at the École Normale Superior, France. His main research interests are Statistical Physics of Information Processing in Biological and Social Networks and Computational neuroscience, Cognitive science, and Complex systems in social sciences. His papers on econophysics have been published in

physics journals like *PRE, EPJB, Condensed Matter and Complex Systems (EPJB), PRL* and other online journals like *arXiv* in the physics and society section. His papers are based on housing market dynamics, demand and supply in markets, electoral behaviour among urban voters, Computation in Neural Systems network, etc. His papers have more than 3706 citations. He has edited many books published by Springer. Moreover, he has published a book *Réseaux de neurones: de la physique à la psychologie* in French.

1.5.3.60 Sergei S. Maslov (1969-)

Bio Box 1.89
Sergei S. Maslov

Place of Birth – Moscow, **Nationality:** US citizen.
Alma Mater – State University of New York at Stony Brook
Institute – Brookhaven National Laboratory
Fields – Quantitative Biology, Physics, Econophysics
Awards – Presidential Early Career Award for Scientists and Engineers (PECASE), White House, Washington DC, T. A. Pond Award for the best results in comprehensive exams, Physics Department, SUNY at Stony Brook

Sergei S. Maslov is a group leader at the *Biology Department, Brookhaven National Laboratory* located on Long Island in New York state. He did his PhD in Physics at the State University of New York at Stony Brook and has held many other appointments. He has empirically studied the cross-correlations of stock indices in a diverse set of 37 countries all over the world and found that if the economy of a country is more globalised, then it is more strongly coupled to the world stock index. He came up with a simple model of a limit order driven market, where agents with equal probability trade stock at the market price or place limit orders, i.e.

instructions to sell (or buy) if stock price rises above (or falls below) a predetermined price level. He is on the Editorial Board of *Biology Direct* and is a reviewer on the NIH Panel for Technology Centres for Networks and Pathways. He has organised many international conferences on Quantitative Biology.

1.5.3.70 Ingve Simonsen

Bio Box 1.90
Ingve Simonsen
Field – Physics
Alma Mater – Norwegian University of Science and Technology
Institute – Norwegian University of Science and Technology
Research Interests – disorder systems, stochastic optics, and fractals; computational physics; complex systems, including econophysics and the study of complex networks; geophysics; high-energy physics

Ingve Simonsen holds a PhD degree in statistical physics from the Norwegian University of Science and Technology (*NTNU*). He works as a professor of physics at *NTNU* in *Trondheim*, Norway. He works on disorder systems, stochastic optics, and computational physics; fractals; complex systems, including econophysics and the study of complex networks, etc. He also works on random networks like the power transmission grid and the study and modelling of economic systems (econophysics). He has experience from both the analysis of empirical data and the construction and study of (toy) models used to identify and analyse specific mechanisms in the fields of econophysics and sociophysics.

1.5.3.61 Carl Chiarella

Carl works at the University of Technology, Sydney, as Professor of Quantitative Finance. He completed his PhD in applied mathematics at the University of New South Wales in 1969 with a thesis on nuclear reactor theory. He became a lecturer in 1971 at the School of Mathematical Science at the University of Technology, Sydney. Then he completed the MCom (Hons) in Economics at the University of New South Wales and took a PhD in Economics in 1987 from the same University for a thesis in economic dynamics. Carl works as a visiting professor at universities including the University of Kyoto, Nanyang Technological University, Hitotsubashi University, Tokyo Metropolitan University, the University of Bielefeld and the University of Urbino. He has authored more than 150 research articles in international and national journals and edited volumes and is the author or co-author of five books.

Bio Box 1.91
Carl Chiarella

Fields – Mathematics, Economics
Alma Mater – University of New South Wales
Institutes – University of Technology, Sydney.
Research Interests – Quantitative Finance, Nonlinear dynamics, Econometrics, etc.

1.5.3.62 Robert Savit

Robert Savit is Professor of Physics at Michigan University. He did his MS and PhD from Stanford University. His current research interests are in the areas of nonlinear and adaptive systems. His group works on nonlinear systems and the nature of adaptive competition for scarce resources and they explore its application in social systems.

Bio Box 1.92
Robert Savit

Field – Physics
Alma Mater – University of Chicago, Stanford University
Institute – University of Michigan
Research Interests – Theoretical Physics and Complex Systems

One of his publications is *Market Efficiency and Phase Transitions* (with R. Manuca and R. Riolo), *Phys. Rev. Lett.* 82, 2203 (1999).

1.5.3.63 Peter Richmond

Peter is a Theoretical Physicist and has wide experience in research, technology, innovation and management within both academic and commercial environments. He has taught solid-state physics in the Universities of Kent, UK and New South Wales, Australia. He developed a keen interest in colloid and surface science. In 1973, he joined Unilever where he applied his expertise to the worldwide detergents business. He also assisted with strategic activities relevant to the wider business activity.

Bio Box 1.93
Peter Richmond

Field – Physics
Alma Mater – Queen Mary College, Theoretical colloid and surface science, London
Institute – Universities of Kent, New South Wales, Trinity College, Dublin, Ireland, EPM Associates Ltd., Unilever, University of Loughborough
Research Interests – colloid and surface science, food biophysics and processing and biotechnology, econophysics

During the 1980s he built a new department concerned with the strategic science underpinning food processing at the Institute of Food Research at Norwich. After four years the department totalled 50 technical staff and was highly respected throughout the food industry and academia. In 1991 he was appointed Group General Manager, Technical Services for CWS Ltd, the largest Consumer Co-operative in Europe and owner of both the Co-operative Bank and the Co-operative Insurance Society, responsible for innovation as the business evolved from a manufacturer and wholesaler into a major UK retailer. He has published over 120 papers in technical literature. Since establishing EPM in 1996, he has consulted widely for universities in the UK and Ireland, the European Commission and major corporations concerned with food and other FMCG goods. He is an Executive Editor of *Journal for the Science of Food and Agriculture*. He has turned his attention to the new area of *econophysics* and has published a number of papers on the Pareto-Zipf Law in Non-stationary Economies, Heterogeneous Interacting Agents, Power Laws as disguised Boltzmann Laws, etc.

1.5.3.64 Wataru Souma

Wataru Souma is an Associate Professor at Nihon University. Before that he was a faculty member of integrated human studies at Kyoto University, Japan. His research interests include Chemical Physics and Material Physics, Statistical Physics, and Mathematical and Quantitative Methods. His publications are on wealth distribution in societies, distribution of labour productivity, the business cycle, etc. He has many publications with more than 2174 citations.

Bio Box 1.94
Wataru Souma

Institutes – Nihon University, Kyoto University
Research Interests – Chemical Physics and Material Physics, Statistical Physics, and Mathematical and Quantitative Methods

His papers have been published in journals like *Quantitative Finance, Journal of The Japanese and International Economies, Physical Review E,* etc. He has written some reviews in *Econophysics, agent-based models* and a book, *Econophysics and Companies: Statistical Life and Death in Complex Business Networks*.

1.5.3.65 Fulvio Baldovin

Baldovin is Professor of Physics at the University of Padova. His research interests are Statistical Physics, Condensed Matter Physics, Chemical Physics and Material Physics. His published work on econophysics has mainly been based on high-frequency financial market dynamics, thermodynamics and dynamics of systems with long-range interactions, noise-induced dynamical phase transitions in long-range systems, etc.

Bio Box 1.95
Fulvio Baldovin

Field – Physics
Institute – University of Padova
Research Interests – Statistical Physics, Chemical Physics and Material Physics, Condensed Matter Physics

His papers have been published in refereed journals like *Physical Review E, Physica A, Statistical Mechanics and Its Applications, Journal of Statistical Mechanics,* etc.

1.5.3.66 Jaume Masoliver

Jaume Masoliver is a professor in the Department of Physics at Barcelona University, Spain. His interest in research is mainly the application of statistical physics in stock market studies. He has had a number of papers published in many refereed journals like *Applied Mathematical Finance, Taylor and Francis Journals, The European Physical Journal B, Quantitative Finance, Journal of Economic Behavior & Organization,* etc. His papers are mainly based on scaling properties and the universality of first-passage-time probabilities in financial markets, First-passage and risk evaluation under stochastic volatility, multifractality in financial markets, etc. Five papers by this author were announced in NEP (New Economic Papers sponsored by the School of Economics and Finance of Victoria University in Wellington) and specifically in the following field reports:

NEP-ETS: Econometric Time Series (2), NEP-FIN: Finance (2), NEP-FMK: Financial Markets (1), NEP-RMG: Risk Management (3), *NEP-UPT*: Utility Models & Prospect Theory (1). He has more than 104 publications with more than 2432 citations.

Bio Box 1.96
Jaume Masoliver

Fields – Physics, Econophysics
Institute – University of Barcelona
Research Interests – Statistical Physics, Chemical Physics and Material Physics, Optics and Optoelectronics

1.5.3.67 Yi-Cheng Zhang

Bio Box 1.97
Yi-Cheng Zhang

Institute – Fribourg University
Research Interests – Physics, Information Science, and Complex Systems Science

Cheng is Professor of Physics at Fribourg University. His research interests are Physics, Information Science, and Complex Systems Science. He has published a large number of papers and they have more than 12456 citations. His paper *Dynamic scaling of growing interfaces*, published in *Physical Review Letters* 56 (9), 889-892 in 1986 has as many as 3451 citations. He has worked on multidisciplinary statistical mechanics, minority games, interacting agents in the financial market, and interacting individuals leading to Zipf's law, etc.

1.5.3.68 Tiziana Matteo

Bio Box 1.98
Tiziana Di Matteo

Fields Physics, Econophysics
Research Interests Econophysics, Application of methods from Statistical Physics to Finance, Complex Systems, Science of Networks

Tiziana is a Reader in Financial Mathematics at King's College, London. She completed her PhD in Physics at the Dipartimento di Física - Università di Salerno, Italy in 1999. She was Associate Professor (Level D), of Applied Mathematics at the Research School of Physical Sciences, Australian National University, Canberra, Australia. She works on Econophysics, Finance, Complex Systems, the Science of Networks, etc. Her works have been published in refereed journals like *Physica A, New Journal of Physics, Journal of Banking & Finance, Quantitative Finance, European Physical Journal B,* etc., primarily on financial market studies.

1.5.3.69 Janusz A. HoÃlyst

Bio Box 1.99
Janusz HoÃlyst (1955-)

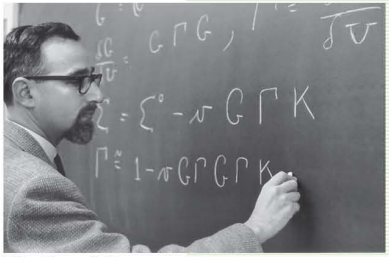
Nationality Poland
Field Physics
Interests Complex Systems, Physics in the economy and social sciences

HoÃlyst works as Professor of Physics at Warsaw University of Technology and is the head of the Centre of Excellence for Complex Systems Research. His research interests include models of emotions in cybercommunities, collective bankruptcies, economic and social networks, non-equilibrium statistical physics, collective opinion formation, cellular automata, self-organised criticality, etc. He is a pioneer of econophysics and is the Co-Founder and Chairman of the Section for Physics in Economy and Social Sciences of the Polish Physical Society. HoÃlyst has organised or co-organised 15 international interdisciplinary workshops or conferences on complex systems. Prof. HoÃlyst has worked as an adviser on the modelling of marketing and economic processes for the American Company *Bunge*.

1.5.3.70 Morrel Cohen (1927-)

Cohen received his PhD in Physics from the *University of California, Berkeley* in 1952. In 1960, he became Professor of Physics at James Frank Institute, *University of Chicago*. From 1968 to 1972 he was Professor of Theoretical Biology at the *University of Chicago* and from 1972 to 1981 he was the Louis Block Professor of Physics and Theoretical Biology in the *University of Chicago*. Presently, he is a distinguished scientist at Rutgers University. He has been engaged in the study of economics since 1975. One of his papers, *Econophysical visualization of Adam Smith's invisible hand* written with Iddo I. Eliazar was published in *Physica A* 392 (2013) 813–823. In it they extend the general connection beyond entropy to a concept analogous to that of the free energy of statistical thermodynamics and this extension allows them to introduce into general

non-physical contexts the concept of a deterministic or systematic "intrinsic force" which is analogous to a physical force.



Bio Box 2.0
Morrel Cohen [1927 -]

Nationality – USA
Field – Physics
Research Interests – Condensed matter physics, complexities of many body problems

1.5.3.71 Other Contributors in the field of econophysics

There are many other physicists, mathematicians and economists who have made valuable contributions in this emerging field of "econophysics". Their contributions are in no way less important than the scientists listed in the previous pages. They have published a number of papers in refereed journals and some of them have written books on econophysics, which will be discussed in other chapters. Moreover, we can regularly find people working in this field from different parts of the world like , Sonia R Bentes from Portugal; Yuichi Ikeda, Naoya Sazuka, and Aki Hiro Sato from Japan; R. Kitt and J. Kalda from Estonia; Tongkui Yu and Honggang Li from China; E. Heinsalu from Spain; Janusz Miskiewicz from Poland; Stefano Balietti from Hungary; Giorgio Israel, G. D. Maldarella, Paolo, Silvio Fra, and Damien Challet from Italy; P.L. Krapivsky and Gopikrishnan from Boston, USA, Juan C. Ferrero from Argentina; Raj Kumar Pan and Kausik Gangopadhyaya from India; Marc Potters from France; and D. Brockmann from England.

Declaration – In this chapter, I have mentioned many scientists. The order in which they have been placed is random and without any consideration as regards the weight of their contribution.

CHAPTER TWO

BRIDGING THE GAP

2.1 Introduction

Many people have tried, in different ways, to bridge the gap between natural science and social science and to adopt the principles and laws of natural science into social science. Institutions of an interdisciplinary nature have been established, researchers have worked in interdisciplinary subjects, new courses have been started, and books of an interdisciplinary nature have been published. Similarly, workshops, conferences and seminars have also been organised in different parts of the world. At such events, speakers from both the natural sciences and the social sciences are invited to deliver their talks, which helps the interaction between the two communities. Journals publishing papers on physics have started publishing papers on econophysics. In this chapter, we will deal with those things which have helped to bridge the gap between natural sciences and social sciences. These include:

- Institutes
- Books
- Workshops, Conferences and Seminars
- Journals publishing papers on econophysics
- Courses offered
- Awards in econophysics

2.2 Institutes

2.2.1 The Indian Statistical Institute

The brainchild of Prasanta Chandra Mahalanobis, the Indian Statistical Institute (ISI) was first set up by him in Presidency College in Kolkata. It was registered as a non-profit-making learned society in 1932 for the advancement of statistics in India. Research on samples of agricultural surveys and the socio-economic after-effects of the 1943-44 Bengal famine brought the Institute recognition across the world in a short period.

Now it is one of the foremost institutes for research and training in the interdisciplinary fields of social and natural sciences under the leadership of Prasanta Chandra Mahalanobis.

The ISI can be considered as the first such institute in the world which brings together natural and social sciences, mediated by statistics.

Fig. 2.1 Prasanta Chandra Mahalanobis

The major objectives of the Institute in its Memorandum are as follows:

(a) to promote the study and dissemination of the knowledge of statistics, to develop statistical theory and methods, and their use in research and practical applications generally, with special reference to the problems of the planning of national development and social welfare;
(b) to undertake research in various fields of natural and social sciences with a view to the mutual development of statistics and these sciences;
(c) to provide for and undertake the collection of information, and to carry out investigations, projects and operational research for the purposes of planning and the improvement of efficiency of management and production.

Besides its headquarters in Kolkata, the ISI has two major centres in Delhi and Bangalore and a branch in Giridih. The Institute has many people among its scientific staff who are well-known statisticians, mathematicians, computer scientists, economists and scientists in other fields, and among whom are fellows of the Indian National Science Academy, the Indian Academy of Sciences, the Institute of Electrical & Electronics Engineers (IEEE), recipients of the S.S. Bhatnagar Prize, G.D. Birla Award for

Scientific Research, Mahalanobis Memorial medals and fellows of many other distinguished scientific societies in India and abroad.

Since 1950, the Institute has been engaged in the collection and analysis of information on social, economic and demographic characteristics in India through the National sample surveys. Professor Mahalanobis and the Institute were entrusted with the responsibility of preparing the draft second Five-Year Plan of the country by Pandit Jawaharlal Nehru, the first Prime Minister of India in 1954. During these years, eminent economists such as Oscar Lange, Joan Robinson, Charles Bettelheim, Jan Tinbergen, Nicholas Kaldor, Simon Kuznets, many of whom were Nobel Laureates, visited the Institute and interacted with Professor Mahalanobis. Professors Amartya K. Sen, Sukhamoy Chakravorty and Pitambar Panth, then promising economists, have also participated in this fruitful interactive process. Sir Ronald A. Fisher was a frequent visitor. J. B. S. Haldane worked in this institute for several years from the late 50s onwards. Other luminaries to have visited the Institute were Frédéric and Irene Julio Curie, Neils Bohr, Frank Yates, A.N. Kolmogorov, P.M.S. Blackett, Jerzy Neyman, Norbert Wiener, J.D. Bernal and Harold Hotelling.

Fig. 2.2 Indian Statistical Institute, Kolkata

During the 1950s, the interdisciplinary nature of teaching in the Institute evolved through the guidance of stalwarts such as Sir Ronald A. Fisher, Professor P.C. Mahalanobis and Professor J.B.S. Haldane, with the encouragement of Professor Satyendra Nath Bose (Physics) who was the President of the Institute for a long time. The Parliament of India enacted the Indian Statistical Institute Act, declaring it an Institution of National Importance in 1959. The B.Stat (Hons.) and the M.Stat degree programmes in statistics were introduced in 1960 with a motto of bridging the gap between social and natural sciences. Research programmes leading to the award of PhD degrees were also introduced. In 1981, the Institute offered the first M.Tech course in computer science in India.

The ISI is regarded as the pioneer of the scientific quality control movement in India. It is also credited with introducing a formal Post Graduate Diploma course in Statistical Quality Control (SQC) and Operations Research (OR) in India in the 1960s which was the first of its kind. At present, the SQC and OR divisions of the Institute have a network engaged in guiding industries, located within and outside India, in developing the most up-to-date quality management systems (ISO 9000, QS 9000, TQM, Six Sigma, etc.).

The Master of Science degree in quantitative economics [MS (QE)] was introduced in 1996.

The Institute is engaged in significant research activity in many other disciplines, such as population studies, physics, agricultural and ecological sciences, geology, biological anthropology, human genetics, linguistics, psychometry, sociology and information science. In all these disciplines, much emphasis is placed on interdisciplinary research and collaborative work with the statisticians of the Institute. The Institute thus conjures up a symbiosis of pure, applied and interdisciplinary research involving various areas of statistics, mathematics, quantitative economics, etc. This symbiosis has been systematically reflected in the teaching and training programmes of the Institute.

The ISI can thus be considered as a pioneering institute in the world introducing interdisciplinary subjects probably on an experimental basis and this has proved to be successful.

2.2.2 The Santa Fe Institute

During the mid-80s, interdisciplinary scientific research started taking place on a global level. Many famous scientists from physical and social sciences started the Santa Fe Institute in the USA in 1984, where several Nobel Laureates in physics, biology and economics joined as adjunct faculties.

The Santa Fe Institute, founded in 1984 by Cowan, Gell-Mann, Anderson Metropolis, Stirling Colgate, etc, is a non-profit research institute located in Santa Fe, United States and is dedicated to the study of complex systems including physical and social systems. [Ref – Science & Culture Vol. 76 no 9 and 10, editorial, B.K. Chakrabarti & A. Chakraborti].

History

The research on complexity science began at the Santa Fe Institute more than three decades ago. Researchers are trying to find answers to some of the world's most intriguing questions like, "What are the best ways to head off global climate change?", "How can we understand and predict stock market behaviour?", "Is cooperation just as important as aggression in human evolution?", "Can computers behave more like living systems?" and so on.

Nowadays the Institute's research into these problems is firmly grounded using quantitative methods of physics, chemistry, and biology.

Early Founding Members

The idea of forming the Santa Fe Institute in the early 1980s was due to some serious scientists like Richard Slansky, George Cowan, Stirling Colgate, Herb Anderson, Nick Metropolis, Darragh Nagle, Peter Caruthers, Louis Rosen, and Ed Knapp from LANL. The Nobel Prize winner, Murray Gell-Mann, who discovered quarks, offered to lend his support along with the renowned physicist, David Pines and mathematician, Gian-Carlo Rota.

The State of New Mexico approved the articles of incorporation of the Institute under the name the "Rio Grande Institute" in 1984. The Institute's first president was Cowan, and Gell-Mann was elected chairman at the first meeting.

In November 1985, it was re-named as the "Santa Fe Institute". It convened its first science meeting on superstring theory in that month, in an attempt to describe all of the particles and fundamental forces of nature in one theory. In 1986, a workshop on complex adaptive systems was organised which began to define the Institute's scientific realm.

Concept Converted into Reality

Being frustrated with his own economists' past failures to foresee market catastrophes, Citicorp CEO, John Reed invited a small group of Institute researchers and economists to meet in Santa Fe in August 1986. The meeting helped in the growth of the SFI's programme of economics as a complex system with the help of Reed's monetary support.

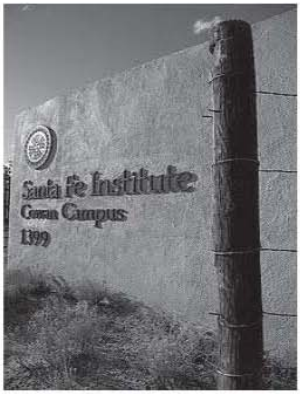


Fig 2.3

Different agencies started pouring funds into the Institute, such as unrestricted funding from Citicorp, from philanthropists and private foundations, from federal agencies and other sources. The Institute moved to the Cowan Campus on Hyde Park Road northeast of and high above Santa Fe in 1994.

Transition to Acceptance

The Institute was initially not accepted by people from mainstream science because of its transdisciplinary approach. But their views changed gradually, as greater numbers of scientists participated in the Institute's workshops. People started realising that, "there was at least something interesting going on in Santa Fe".

The Institute hosted workshops in the 1980s, which were among the world's first to explore topics on biological complexity, theoretical immunology, evolutionary economics, computational approaches to artificial life, evolutionary biology, global stability, theoretical ecology, and molecular evolution from the perspective of complex systems. The SFI expanded its research portfolio during the 1990s. Programmes in biology expanded as well, exploring new territory in genomics, viral dynamics, neurobiology, biochemical networks, complex systems in ecology and learning and memory in the immune system.[1]

[1] Ref- *Econophysics of Agent-Based Models*, edited by Frédéric Abergel et al. (Springer, 2013), pp. 273. Author- Kishore C Dash.

Methods Pioneered at SFI

This is a list of some of the most important and widely used methods developed at the Santa Fe Institute over the last 25 years.

1. Agent-based Models
2. The Science of Networks
3. Mathematical Immunology
4. The Physics of Markets
5. Adaptive Landscapes for Biology and Technology
6. Genetic Algorithms
7. The Physics of Computation
8. Computational Chemistry and Combinatorial Drug Discovery
9. Machine Learning
10. Molecular Computation

Critical Concepts Developed at SFI

These are a few of the organising concepts that integrate the many research projects of the Santa Fe Institute.

1. Complexity Measures
2. The Theory of Robust Systems
3. Principles of Innovation
4. Emergence
5. Scaling in Biology and Culture
6. The Connection between Energy and Information
7. Intelligence in Nature
8. The Theory of Risk
9. Chaos
10. Game Strategies and Conflict
11. Evolvability and Open-Ended Change
12. Quantitative and Meta-history
13. Economic Positive Returns
14. Criticality and the Edge of Chaos
15. Evolutionary Economics
16. Quantum Cosmology

Core SFI Projects

These are the ongoing research projects currently funded and generating peer-reviewed papers and monographs.

1. The Origin of Life
2. The Evolution of Information (genes, languages, computers)
3. The Evolution and Devolution of Society
4. The Dynamics of Financial Markets
5. The History of Languages
6. The Prediction and Management of Conflict
7. The Growth of Cities and Intellectual Capital
8. The Structure of Food Webs
9. Distributed Decision Making and Cognition
10. Efficient Algorithm Design for Network Science
11. Measuring Biological and Technological Innovation

SFI Focus Areas

1. Risk, Markets and Innovation (Organised by J. Doyne Farmer)
2. The Multiple Scales of Conflict (Organised by Jessica Flack)
3. Cities, Scaling and Sustainability (Organised by Luis Bettencourt and Geoffrey West)
4. Emergence in Decision-making and Cognitive Systems (Organised by David Krakauer)
   [The literature has been taken from the Institute's website http://www.santafe.edu].

2.2.3 The Inequality Process Institute

The Institute's Programme

The Inequality Process is a mathematical model that mimics the dynamics of individuals' wealth and income at micro level and the distribution of wealth and income at macro level. The Inequality Process is a stochastic interacting particle system, similar in some respects to that of the kinetic theory of gases. The Inequality Process is a statistical law like those in the natural sciences.

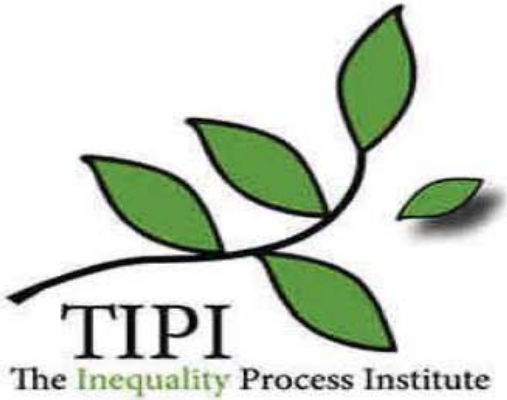


Fig. 2.4

The paper by John Angle in 2008, *Not a Hollowing Out, A Stretching: Trends in US Nonmetro Wage Income Distribution, 1961-2003* demonstrates that many of the implications of the macro model of the Inequality Process as regards how the distribution of wage income changes are evident in a time-series of two simple descriptive statistics: the dispersion of wage income, and relative frequency in a particular range of large incomes. The time-series of these statistics has been widely misinterpreted as evidence of galloping growth in wage income inequality and even the "hollowing out" of the distribution of wage income.

John Angle, a mathematical sociologist, is the founder of The Inequality Process Institute (TIPI). All his papers are based on wealth distribution in society, among black and whites, in urban and rural areas and so on, which are based on statistical mechanics. He is a true follower of Auguste Comte.

Citing the works of the TIPI, economist Thomas Lux (2005) pointed out that the findings of income distribution presented in multiple papers at the conference had been anticipated 20 years earlier in the first paper on the

Inequality Process presented to an international conference of econophysicists at SINP, Kolkata. One can say that "econophysics" and "sociophysics" are extensions of the field of statistical mechanics in physics into the social sciences. The distinction between sociophysics and econophysics is fluid and nearly meaningless.

In 2006, John Angle published an introductory review and extension of the Inequality Process for econophysicists in *Physica A: Statistical Mechanics and Its Applications*.

Some economists, such as Lux, University of Kiel (Germany), have crossed the disciplinary divide between economics and econophysics to the enrichment of both. Sociologists were invited by Professors B. K. Chakrabarti and A. Chatterjee, conference organisers, to attend Econophys-Kolkata III (see *www.saha.ac.in/cmp/econophys3.cmp*) in 2007. Lux delivered a talk at Econophys-Kolkata I at the Saha Institute of Nuclear Physics, India in 2005.

There is potential for collaboration between sociologists and interdisciplinary physicists in pursuing Comte's vision based on complementary skills. According to John Angle, there is no difference in meaning between *sociophysics* as used today by statistical physicists and *sociology* as coined by Comte almost two centuries ago.

2.2.4 The Institute for New Economic Thinking (INET)

This is a non-profit foundation based in New York and started by George Soros in 2009. The INET consists of new economic thinkers and has Nobel Laureates in economics, and teachers and students from different parts of the world. The 2008 global financial crisis has demonstrated the deficiencies in our outdated economic theories and has paved the way for new economic thinking. A number of leading economists, business leaders and policymakers have called for a fundamental rethink in economics after the 2008 financial crisis. On 12th April 2012 in Berlin, the Oxford Martin School and the INET announced that they had joined forces to create INET@Oxford, a major new interdisciplinary research centre at the University of Oxford. INET at Oxford brought together many people from across academic disciplines in its approach to economics. This is a centre in which economists, physicists, psychologists, biologists, anthropologists and others across the physical and social sciences work together. The Centre engages leaders from government and business. The mission of the Centre is to focus on addressing some of the greatest economic challenges

we face, ranging from avoiding future financial crises to ensuring that the positive potential of globalisation is realised, and its risks mitigated. The Centre is dedicated to working on Economic Modelling, Complexity Economics, Ethics and Economics, Global Economic Development, Employment and Equity, New Models of Economic Growth, Curriculum and Teaching Development.

2.3 Books Published on Econophysics

1. *Introduction to Econophysics: Correlations and Complexity in Finance* by *Rosario N. Mantegna* (Jul 16, 2007)
2. *Econophysics: An Introduction (Physics Textbook)* by *Sitabhra Sinha* Anirban Chakraborti, Bikas K. Chakrabarti (Dec 14, 2010)
3. *Patterns of Speculation: A Study in Observational Econophysics* by *Bertrand M. Roehner* (Jul 14, 2005)
4. *The Second Law of Economics: Energy, Entropy, and the Origins of Wealth (The Frontiers Collection)* by *Reiner Kümmel* (Jun 28, 2011)
5. *Dynamics of Markets: Econophysics and Finance* by *Joseph L. McCauley* (Apr 23, 2007)
6. *The Statistical Mechanics of Financial Markets (Theoretical and Mathematical Physics)* by *Johannes Voit* (Nov 19, 2010)
7. *Finitary Probabilistic Methods in Econophysics* by *Ubaldo Garibaldi* (Oct 18, 2010)
8. *Econophysics of Order-driven Markets (New Economic Windows)* by Frédéric Abergel, Bikas K Chakrabarti, Anirban Chakraborti and Manipushpak Mitra (Mar 9, 2011)
9. *Classical Econophysics (Routledge Advances in Experimental and Computable Economics)* by Allin F. Cottrell, Paul Cockshott, Gregory John Michaelson and Ian P. Wright (Jul 8, 2009)
10. Usa Monetary Policy Decomposition-Al And Unemployment Spillover Affects, Volume 7: Econophysics of EUROS, Predictions to Year 2100: Lectures: Excerpts by Michael Patrick Amos (Jan 10, 2012) – Kindle eBook
11. *New Directions in Statistical Physics: Econophysics, Bioinformatics, and Pattern Recognition* by Luc T. Wille (Dec 8, 2010)
12. *Econophysics and Companies: Statistical Life and Death in Complex Business Networks* by Hideaki Aoyama, Yoshi Fujiwara, Yuichi Ikeda and Hiroshi Iyetomi (Sep 15, 2011)

13. *Econophysics and Sociophysics: Trends and Perspectives* by Bikas K. Chakrabarti, Anirban Chakraborti and Arnab Chatterjee (Dec 25, 2006)
14. *Practical Fruits of Econophysics: Proceedings of the Third Nikkei Econophysics Symposium* by Hideki Takayasu (Nov 19, 2010)
15. *Econophysics & Economics of Games, Social Choices and Quantitative Techniques (New Economic Windows)* by Banasri Basu, Bikas K. Chakrabarti, Satya R. Chakravarty and Kausik Gangopadhyay (Jan 22, 2010)
16. *Econophysics of Markets and Business Networks (New Economic Windows)* by Arnab Chatterjee and Bikas K. Chakrabarti (Oct 23, 2007)
17. *Econophysics Approaches to Large-Scale Business Data and Financial Crisis: Proceedings of Tokyo Tech-Hitotsubashi Interdisciplinary Conference + APFA7* by Hideki Takayasu, Misako Takayasu and Tsutomu Watanabe (Jul 7, 2010)
18. *The Complex Networks of Economic Interactions: Essays in Agent-Based Economics and Econophysics (Lecture Notes in Economics and Mathematical Systems)* by Akira Namatame, Taisei Kaizouji and Yuuji Aruka (Jan 23, 2006)
19. *USA Monetary Policy Decomposition-AI & Unemployment Spillover Affects, Vol. 7: Econophysics Of EUROS, World Common Currency Areas in Year 2011, and Predictions to Year 2100* by *Michael Patrick Amos* (Feb 13, 2012)
20. *The Complex Dynamics of Economic Interaction: Essays in Economics and Econophysics (Lecture Notes in Economics and Mathematical Systems)* by Mauro Gallegati, Alan P. Kirman and Matteo Marsili (Jan 22, 2004)
21. *Noise and Fluctuations in Econophysics and Finance (Proceedings of SPIE)* by Derek Abbott, Jean-Philippe Bouchaud and Xavier Gabaix (May 30, 2005)
22. *Handbook of Modeling High-Frequency Data in Finance (Wiley Handbooks in Financial Engineering and Econometrics)* by *Frederi G. Viens* (Dec 20, 2011)
23. *Application of Econophysics: Proceedings of the Second Nikkei Econophysics Symposium - Application of Econophysics* by Hideki Takayasu (Nov 6, 2003)
24. *Theory of Financial Risk and Derivative Pricing: From Statistical Physics to Risk Management* by *Jean-Philippe Bouchaud* (Mar 2, 2009)

25. *Quantitative Finance for Physicists: An Introduction (Academic Press Advanced Finance)* by *Anatoly B. Schmidt* (Dec 28, 2004)
26. *Why Stock Markets Crash: Critical Events in Complex Financial Systems* by *Didier Sornette* and *D. Sornette* (Feb 23, 2004)
27. *Stochastic Methods: A Handbook for the Natural and Social Sciences (Springer Series in Synergetics)* by *C. W. Gardiner* (Nov 19, 2010)
28. *Econophysics of Stock and other Markets: Proceedings of the Econophys-Kolkata II (New Economic Windows)* by Arnab Chatterjee and Bikas K. Chakrabarti (Feb 1, 2007)
29. *Correlation Analysis of Housing Prices and Economic Indicators: An application of econophysics to housing prices* by Levent Kurnaz (Oct 14, 2009)
30. *Econophysics of Wealth Distributions: Econophys-Kolkata I (New Economic Windows)* by Arnab Chatterjee, Sudhakar Yarlagadda and Bikas K. Chakrabarti (Sep 14, 2005)
31. *Consumer, Firm, and Price Dynamics: An Econophysics Approach: Modeling by Economic Forces* by Matti Estola (Dec 5, 2008)
32. *Relation Of Economics To Other Disciplines, including: Economic Anthropology, Econophysics, Economic Sociology, Philosophy And Economics, Economic ... Kinetic Exchange Models Of Markets* by Hephaestus Books (Sep 2, 2011)
33. *Empirical Science of Financial Fluctuations: The Advent of Econophysics* by Hideki Takayasu (Dec 7, 2001)
34. *Introduction To Econophysics by Mantegna, Rosario on 13-Nov-1999* (Nov 13, 1999)
35. *Essentials of Econophysics Modelling Ha* by Frantisek Slanina (Jan 2011)
36. *Classical Econophysics* by Allin F. Cottrell, Paul Cockshott, Gregory John Michaelson and Ian P. Wright (Aug 11, 2011)
37. *Introduction to Econophysics Correlations Complexity in Finance Vvedenie v ekonofiziku Korrelyatsii i slozhnost v finansakh* by R. N. Manten'ya (Jan 1, 2009)
38. *Physics and Economics. At the root of econophysics / Fizika i ekonomika. U istokov ekonofiziki* by Kuznetsov B.G. (2010)
39. *Econophysics of Systemic Risk and Network Dynamics (New Economic Windows)* by Frederic Abergel, Bikas K. Chakrabarti, Anirban Chakraborti and Asim Ghosh (Sep 17, 2012)

40. *Energy and the Wealth of Nations: Understanding the Biophysical Economy* by Charles A. S. Hall and Kent A. Klitgaard (Oct 26, 2011)
41. *Dynamics of Markets: The New Financial Economics* by *Joseph L. McCauley* (Oct 12, 2009)
42. *Statistical Physics and Economics* by *Michael Schulz* and *Siegfried Walter Souci* (Apr 8, 2003)
43. *Stochastic Processes: From Physics to Finance* by *Wolfgang Paul* (Dec 10, 2010)
44. *Mathematical Modeling of Collective Behavior in Socio-Economic and Life Sciences (Modeling and Simulation in Science, Engineering and Technology)* by Giovanni Naldi, Lorenzo Pareschi and Giuseppe Toscani (Aug 30, 2010)
45. Sociodynamics - A Systematic Approach to Mathematical Modelling in the Social Sciences, in 2000 by W. Weidlich
46. Econophysics Background and Applications in Economics, Finance, and Sociophysics. Editors: Gheorghe Savoiu, Academic Press, 2012
47. Econophysics and Physical Economics by Peter Richmond, Jürgen Mimkes, Stefan Hutzler 2013
48. Econophysics & Economics of Games, Social Choices and Quantitative Techniques (New Economic Windows) 2016 by Banasri Basu and Bikas K. Chakrabarti
49. Macro-Econophysics: New Studies on Economic Networks and Synchronization (Physics of Society: Econophysics and Sociophysics), 2017 by Hideaki Aoyama and Yoshi Fujiwara
50. Limit Order Books (Physics of Society: Econophysics and Sociophysics) by Frédéric Abergel and Marouane Anane, 2016
51. Essentials of Econophysics Modelling, by Frantisek Slanin, 2013
52. Experimental Econophysics: Properties and Mechanisms of Laboratory Markets (New Economic Windows), by Ji-Ping Huang, 2016
53. Interactive Macroeconomics: Stochastic Aggregate Dynamics with Heterogeneous and Interacting Agents (Physics of Society: Econophysics and Sociophysics) by Corrado Di Guilmi and Mauro Gallegati, 2017
54. Econophysics of Agent-Based Models (New Economic Windows), by Frédéric Abergel and Hideaki Aoyama, 2013
55. Econophysics of Income and Wealth Distributions by Bikas K. Chakrabarti and Anirban Chakraborti, 2013

56. Econophysics and Capital Asset Pricing: Splitting the Atom of Systematic Risk (Quantitative Perspectives on Behavioral Economics and Finance), by James Ming Chen, 2017
57. Econophysics of the Kolkata Restaurant Problem and Related Games: Classical and Quantum Strategies for Multi-agent, Multi-choice Repetitive Games (New Economic Windows) by Bikas K. Chakrabarti and Arnab Chatterjee, 2017
58. Econophysics and Financial Economics: An Emerging Dialogue, by Franck Jovanovic and Christophe Schinckus, 2017
59. Methods in Econophysics (Arcler Press), by Nelson Boliva, 2018
60. Econophysics Approaches to Large-Scale Business Data and Financial Crisis: Proceedings of Tokyo Tech-Hitotsubashi Interdisciplinary Conference + APFA7, by Misako Takayasu and Tsutomu Watanabe, 2014
61. Stochastic Processes: From Physics to Finance, by Wolfgang Paul and Jörg Baschnagel, 2015
62. The Second Law of Economics: Energy, Entropy, and the Origins of Wealth (The Frontiers Collection), by Reiner Kümmel, 2013
63. Study guide for Introduction to Econophysics: Correlations and Complexity in Finance by Mantegna, Rosario N., 2013
64. Vol. 6. Euros' Exchange Rates Predictions to Year 2100: On Econophysics of EURO, by Dr Michael Patrick Amos, 2013
65. Newtonian Microeconomics: A Dynamic Extension to Neoclassical Micro Theory by Matti Estola, 2017

2.4 Special Issues Published by Journals on Econophysics

1. *Physica A* 269(1)
2. *International Journal of Theoretical and Applied Finance* 3(1)
3. *European Physical Journal B* 20(4)
4. *European Physical Journal B* 27(2)
5. *Physica A* 344(1)
6. *Physica A* 382
7. *European Physical Journal B* 55(1)
8. *Journal of Economic Dynamics and Control* 32(1)
9. *Complexity* 14(3)
10. *Science and Culture* 76(9-10)
11. *AUCO Czech Economic Review* 4(3)
12. *Advances in Mathematical Physics*

Courses Offered in Different Universities

2.5.1 Leiden University, Netherlands

Kick-off for econophysics [ref. Leiden University website]

Leiden physics is making a start on econophysics: an optional course for third-year bachelor's students began in May 2011, and the first assistant professor in the subject is Italian Dr Diego Garlaschelli. He has been appointed to a tenure-track and is in line to become Leiden's first professor of econophysics.

Insights from physics

Fig 2.5

The instigators of econophysics in Leiden are former Lorentz Institute staff member, Fernando Vos and Duyfken Trading Knowledge BV. One of the owners of this company is Reindert Stoffer, a Leiden alumnus in physics. Duyfken trades in bonds, options and futures on the basis of insights from physics, the aim being to ensure that this new research field takes root at Leiden University, which is why the company is offering financial support.

Broadening the programme

According to theoretical physicist, Dr Peter Denteneer, who has been involved in the new research field from the outset, econophysics fits in with Leiden's effort to broaden the physics programme. For instance, the bachelor's programme now also includes socially-oriented courses such as

The physics of energy, *The physics of modern technology* and *Magnetic resonance*, the principle behind medical MRI scans.

Empirical science

Econophysics – which incidentally has been around for a while in the US, France and Italy – aims to discover patterns and correlations in the development of, for instance, share prices, the price of gold or oil, or a country's GNP over a given period of time. This might be a period of a single day ("I think the share prices are refreshed every 30 seconds," says Denteneer) or a longer period of weeks, months or years. Physics is an empirical science, as opposed to mathematics. Denteneer says, "Physics explains phenomena that take place in the environment. You can regard share prices as such a phenomenon. Predicting goes too far, this is about determining patterns and based on that, the likelihood of events and a reliable assessment of the risks."

Fig. 2.6 University lecturer Dr Diego Garlaschelli is in line to become Professor of Econophysics.

Crash

There are many parallels to be found between processes in the financial world and physical processes, says Denteneer. "A financial market crash can be compared to water reaching boiling point. The phase transition which takes place at such a point in time becomes apparent at a much

earlier stage in the form of various correlations. It might very well be that the same is true for financial markets. And there are also parallels between a crash and an earthquake." Other mathematical concepts that are much used in physics and also play an important role in econophysics are stochastic processes (probability), game theory and chaos theory. The students taking this optional course are also taught about the workings of stock markets and other related issues.

The Driver behind econophysics

Diego Garlaschelli, from the Sant' Anna School of Advanced Studies in Pisa, Italy, is the driver behind Leiden econophysics. He has been appointed as a tenure-track assistant professor, which means he has the opportunity to become a professor. His appointment is financed by Duyfkens. Garlaschelli started his lecturing career in May 2011 with a bachelor's course in econophysics for third-year students. The course structure is:

- Introduction to econophysics (historical background, an interaction between physics and economics, past and present aims of the field).
- Stochastic processes and time series.
- Stylised facts of single financial time series.
- Cross-correlations among multiple time series.
- Complex networks and interactions among economic agents.
- Network models of wealth distribution and market behaviour.
- International economic interactions: The World Trade Web.

The reference book for the course is *Econophysics: An Introduction (Physics Textbook)* by S. Sinha, A. Chatterjee, A. Chakraborti, B.K. Chakrabarti (Publisher: Wiley-VCH, 2010; ISBN: 978-3-527-40815-3).

Jan Tinbergen

The aim in Leiden is to link physics with history via econophysics: Jan Tinbergen studied theoretical physics in Leiden and defended his thesis in 1929 on the eve of the Great Depression, under renowned physicist Paul Ehrenfest. In 1969, Tinbergen was awarded the first Nobel Prize for Economics. "There are many physicists working in the financial world," says Denteneer. "They are popular in the world of finance because they are able to reduce enormous databases to a small number of crucial figures. I am convinced that physicists will play a healthy role in offering insights into the risks of the financial world."

Fig. 2.7 First Nobel Prize winner in Economics (1969) Jan Tinbergen, also a theoretical physicist.

2.5.2 University of Houston

The Econophysics course at the University of Houston is as follows:

Second Year

- Phys 6397: Introduction to Econophysics
- Phys 6350 (& 6150): Computational Physics I

Third Year

- Phys 7397 Simulation of Economic Systems
- Fina 7338 Financial Engineering and Derivatives

Fourth and Fifth Years

- Phys 7397: Advanced Data Analysis Techniques
- Fina 7366: Investments
- Fina 8397: Seminar on Derivatives
- Fina 8378: Seminar on Financial Markets in Institutions

Econophysics - Faculty

- **Kevin E. Bassler**
  Assistant Professor
  Department of Physics
  University of Houston

- **David R. Criswell**
  Director - Institute for Space Systems Operations
  Gemunu H. Gunaratne
  Associate Chairman
  Department of Physics
  University of Houston
- **Joe McCauley**
  Professor
  Department of Physics
  University of Houston
- **Donald J. Kouri**
  Professor
  Department of Physics
  University of Houston
- **Lawrence S. Pinsky**
  Professor and Chair
  Department of Physics
  University of Houston
- **Miguel Castro**
  Adjunct Professor
  Quantitative Research Scientist and Project Manager
  Quantlab Financial, LLC
  Houston, Texas
- **Valery A. Kholodnyi**
  Adjunct Professor
  Director of Quantitative Analysis
  Quantitative Analysis
  Quantitative Modelling Group
  Reliant Energy
  Houston, Texas

2.5.3 The University of Silesia

The undergraduate (6 semesters) and postgraduate (4 semesters) programme in *Econophysics* was launched in the academic year 2009/2010 in the University of Silesia as the only programme of its kind in Poland. The undergraduate programme allows students to learn the foundations of physics, mathematics, computer science and economics, and acquire specialist knowledge in the field of financial engineering, risk management and quality engineering.

The postgraduate programme covers a unique selection of courses in modern physics, mathematics, economics and statistics, with special emphasis on applications and practical aspects. To complete the programme, students write and defend a master's thesis, which enables them to receive a master's degree in *Econophysics*.

2.5.4 Econophysics Teaching at the University of Wrocław

With the cooperation of the Department of Physics and the Department of Economic Sciences, a new undergraduate course in econophysics has been established at the University of Wrocław.

2.5.5 MMEF Course at the University of Paris

Mathematical Models in Economics and Finance (MMEF).

First Year of Graduate Studies:

Mathematical Methods in Economics and Finance is a one-year, full-time, international programme taught in English. The course is designed for students to use mathematical models in finance and economics like optimisation models, stochastic models, mathematical finance, mathematical economics, etc.

Theory of Finance 2

Number of Credits: 4 ECTS Credits, 3 hours per week for 14 weeks, 42 hours total including tests.

Course Objective: Introduction to theories of financial markets inspired by complex-system science (especially Statistical Physics).

The aim of this course is to give an introduction to the dynamics of financial markets via the powerful tools that Mathematical Physics can offer. Topics include critical phenomena, Brownian motion, market phase transitions and self-organised criticality.

2.5.6 Some Important Centres of Econophysics Research:

1. Boston University USA.
2. Santa Fe Institute USA.
3. SINP, Kolkata, India.

4. École Centrale Paris, France.
5. University of Maryland, USA.
6. University of Palermo, Italy.
7. Kyoto University, Japan.
8. Leiden University, Netherlands.

2.6 Awards for social scientists: Sibal

Fig. 2.8 Kapil Sibal

The Human Resource Development Ministry has proposed an award for social scientists along the lines of the Bhatnagar awards for scientists. HRD Minister Kapil Sibal made this announcement while speaking at a conference organised by the Indian Council of Social Science & Research. "For scientists we have the Bhatnagar awards, but nothing for social scientists. We have proposed ten annual awards to recognise advancement in the field of social science. I hope that due recognition to social scientists and their contributions would spur thousands of aspiring scholars in the future. These awards will be known as the Amartya Sen Awards." (Sibal. Feb 29, 2012)

2.7 Awards in Econophysics

People are becoming attracted to the mathematical and computer simulation of social and economic systems. Scientists from sociology, economics, physics, biology, computer science and engineering are being recruited to work in the field of complex systems.

The division for "Physics of Socio-Economic Systems" (Φ·SOE, previously AKSOE/AGSOE) organises a spring conference and features outstanding international speakers not only from socio- and econophysics but also from sociology and economics. Furthermore, scientists are awarded for outstanding innovative work in this field.

Young Scientist Award in the field of Econophysics and Sociophysics

2002 - Damien Challet

2003 - Vasiliki Plerou received the Young Scientist Award for Socio- and Econophysics from the AKSOE

2004 - Illes Farkas received the Young Scientist Award for Socio- and Econophysics from the AKSOE

2005 - Reuven Cohen received the Young Scientist Award for Socio- and Econophysics from the AKSOE

2006 - Xavier Gabaix received the Young Scientist Award for Socio- and Econophysics from the AKSOE

2007 - Dr Katarzyna Sznajd-Weron (Wrocław, Poland) for her outstanding original contributions to a better understanding of open problems in socio-economic systems by means of physical methods

2008 - Dr Frabrizio Lillo (Palermo, Italy) for his outstanding original contributions to a better understanding of open problems in socio-economic systems by means of physical methods

2009 - Duncan Watts received the Young Scientist Award 2009

2010 - Dirk Brockmann received the Young Scientist Award 2010 (*Poster* Presentation)

2011 - Santo Fortunato received the Young Scientist Award 2011

2012 - Arne Traulsen received the Young Scientist Award 2012

2013 - Vittoria Colizza received the Young Scientist Award 2013

2014 - Roger Guimera received the Young Scientist Award 2014

2015 - Matjaz Perc received the Young Scientist Award 2015

2016 - Mason Porter received the Young Scientist Award 2016

2017 - Francisco C. Santos received the Young Scientist Award 2017

2018 - Martin Rosvall received the Young Scientist Award 2018.

2.8 Journals Publishing Econophysics Papers

After it was institutionalised, papers on econophysics started to be published in physics journals like *Physical Review Letters, Physical Review, Physica A, The European Physical Journal, Science, International Journal of Modern Physics C, Nature,* and *The European Physics Communications*. Similarly, journals publishing economics and financial mathematics papers also started publishing papers on econophysics. Such journals are *Quantitative Finance,* and *The Journal of Economic Behaviour & Organization*. We can now find many papers in arXiv also.

2.9 Workshops, Conferences and Seminars

In 1998, the inaugural conference on Econophysics was organised in Budapest. At present, a number of regular meetings/workshops/conferences are conducted in different parts of the world e.g. in Kiel, Germany, APFA, ESHIA/WEHIA, Dublin *econophysics conference*, ECONOPHYS-KOLKATA, Asia-Pacific *Econophysics Conference, World Econophysics Conference* in Canberra, Australia, *The International Conference on Econophysics* (ICE), China, etc. From 2004, the Econophysics Colloquium has been conducted as an annual event.

The Hyperion University in Bucharest, Romania, organises a conference under the banner of ENEC ("Econophysics, New Economics and Complexity"). The Conference provides an opportunity for scientists and researchers to present original papers and new ideas in the area of complex systems.

Prof. Bikas K. Chakrabarti organised a workshop under the banner of econophysics every year from 2005 to 2014. After that, the international conference on econophysics has been conducted by Anirban Chakraborti at JNU, New Delhi in collaboration with the École Centrale, Paris and Kyoto University, Japan.

There was also a dedicated Computing for Finance conference held at CERN on 21 November 2007, which was specifically aimed at how to use the grid for financial computing.

CHAPTER THREE

MAJOR RESEARCH TOPICS

3.1 Introduction

In this chapter, I will deal with some breakthrough research topics which cleared the path for neologising econophysics. I have already discussed at length how econophysics was very much present in the pre-classical and classical era and I do not want to repeat those. So here, I want to mainly discuss the developments just prior to the modern era and the happenings after econophysics was institutionalised. I feel it right to start from Osborne's log-normal distribution, which, in the opinion of some scientists, can be considered as the origin of econophysics.

3.2 Brownian Motion in the Stock Market

> "The logarithms of common-stock prices, and the value of money, can be regarded as an ensemble of decisions in statistical equilibrium, and that this ensemble of logarithms of prices, each varying with time, has a close analogy with the ensemble of coordinates of a large number of molecules" – suggested by Osborne, as is clear from the abstract of his paper shown below.

He derived a probability distribution function for a particle in **Brownian motion** using this function and the prices of some random stock choice at random times. He has shown in his paper that prices in the market vary in the same way as molecules in Brownian motion. According to *Professor Joseph L. McCauley* (University of Houston), Osborne first introduced the log-normal stock pricing model in 1958 and opined that he should be honoured as the first econophysicist.

Operations Research

March–April 1959

BROWNIAN MOTION IN THE STOCK MARKET†

M. F. M. Osborne

U S Naval Research Laboratory, Washington 25, D C

(Received February 6, 1958)

It is shown that common-stock prices, and the value of money can be regarded as an ensemble of decisions in statistical equilibrium, with properties quite analogous to an ensemble of particles in statistical mechanics If $Y=\log_e[P(t+\tau)/P_0(t)]$, where $P(t+\tau)$ and $P_0(t)$ are the price of the same random choice stock at random times $t+\tau$ and t, then the steady state distribution function of Y is $\varphi(Y)=\exp(-Y^2/2\sigma^2\tau)/\sqrt{2\pi\sigma^2\tau}$, which is precisely the probability distribution for a particle in Brownian motion, if σ is the dispersion developed at the end of unit time A similar distribution holds for the value of money, measured approximately by stock-market indices Sufficient, but not necessary conditions to derive this distribution quantitatively are given by the conditions of trading, and the Weber-Fechner law A consequence of the distribution function is that the expectation values for price itself $\mathcal{E}(P)=\int_0^\infty P\,\varphi(Y)(dY/dP)\,dP$ increases, with increasing time interval τ, at a rate of 3 to 5 per cent per year, with increasing fluctuation, or dispersion, of P This secular increase has nothing to do with long-term inflation, or the growth of assets in a capitalistic economy, since the expected reciprocal of price, or number of shares purchasable in the future, per dollar, increases with τ in an identical fashion

3.3 Income and wealth distribution; Price Changes in financial markets do not follow a Gaussian Distribution

Research on wealth distribution in society has been going on for some time. It has been observed that 20 per cent of the people have 80 per cent of the wealth. The rich are getting richer and the poor are getting poorer, broadening the gap. This is not only true in business, but the 80-20 rule is also applicable for wealth distribution, personal finance, spending habits, etc. It looks as if there is some physical or mathematical rule governing the distribution of wealth in the world.

The study of the 80-20 rule started by Pareto almost a century ago is still in focus and has currently been taken up by a small group of econophysicists to mathematically show the pattern of wealth distribution in societies. Econophysicists generally study an economy using the many-body physical system such as a gas. Random collisions between gas molecules give rise to macroscopic properties such as temperature and pressure, similarly, random encounters between individuals in an economic system might determine large-scale phenomena such as the distribution of wealth. Analysing the income data from the US Internal Revenue Service from 1983 to 2001, Physicist Victor Yakovenko of the University of Maryland in College Park, US and his colleagues observed that Pareto's law is true for only three per cent of people and the incomes of the other 97 per cent fitted a different curve, resembling one that also describes the spread of energies of atoms in a gas. From 1995-2005, Bikas Chakrabarti and his group from SINP, Kolkata, India found both the initial gamma/log-normal distribution for the income distribution of poor and middle-income groups and also a Pareto tail for the distribution of the riches in their random saving gas model. The work of Mandelbrot showed that income distribution, wealth distribution, etc. follow an inverse power law similar to that of Pareto.

According to Bachelier, the change in market prices followed a Gaussian distribution, one of the foundations of modern statistics. If economic features followed a Gaussian distribution, then many mathematical techniques could be applied to economics. With Bachelier's work and some modern reinforcement, a new era in economics was born and accepted by economists.

In his book, *The (Mis)behaviour of Markets,* Mandelbrot pointed out that "the market behaviour does not reflect the well-behaved Gaussian models proposed by economists in the 1970s and 1980s, rather it reflects a complex system and fractal mathematics". Mandelbrot argues that fractal techniques may provide a powerful way to analyse risk and it was accepted. He argued that for a 1-day pattern, distribution is close to Gaussian but not for a long period of time.

3.4 Inverse Quartic Power Law

In the late 1990s, Parameswaram Gopikrishnan and Vasiliki Plerou, who were then graduate students working at Boston University in the US, decided to analyse every transaction of every single stock item in the major US markets. The analysis of such huge data sets was not so easy, so

the university's computer system was upgraded to complete the task. Using these computers and analysing big data sets, Gopikrishnan and Plerou found that the tail of their histogram is not Gaussian but follows an "inverse quartic power law". This law means that if there is a probability p of, say, a \$5 price change occurring, then the probability of a \$10 price change is $p/2^4$, i.e. $p/16$. This inverse quartic law excels at describing the probability of very rare events, such as those occurring once every few decades. Events corresponding to 100 standard deviations, for example, have a probability of about 10^{-350} with a Gaussian model, but a far more realistic likelihood of 10^{-8} with the inverse quartic law.

[Ref - P. Gopikrishnan, M. Meyer, L. A. Nunes Amaral, and H. E. Stanley, Eur. Phys. J. B 3, 139 (1998).]

3.5 Economic Inequality: Is it Natural?

In their above paper, Arnab Chatterjee, Sitabhra Sinha and Bikas K. Chakrabarti have studied and reported that the income and wealth distribution of various countries clearly establishes a robust feature: Gamma (or log-normal) distribution for the majority (almost 90-95%), followed by a Pareto power law for the richest (5-10% of the population). They have shown that this "natural" behaviour of income inequality comes from a simple "scattering picture" of the market when the agent in the market has a random saving propensity like the kinetic theory of gases model.

3.6 Exponential Distribution of Income

In the paper, *Evidence for the exponential distribution of income in the USA* published by EPJB, v.20, pp585-589 (2001), A. A. Dragulescu and V. M. Yakovenko show that the distribution of individual income in the USA is exponential. They calculated the Lorenz curve without fitting parameters and found that the Gini coefficient 1/2=50% corresponds well with the data. From the individual income distribution, they have derived the distribution function of income for families with two earners and have shown that it also corresponds well with the data, which fits the Lorenz curve and Gini coefficient 3/8=37.5% calculated for two-earner families using family data gathered during the period 1947-1994.

3.7 "Thermal" and "Super Thermal" Income Classes

Temporal evolution of the 'thermal' and 'super thermal' income classes in the USA during 1983-2001 by A. C. Silva and V. M. Yakovenko.

Published by: *Europhysics Letters, v. 69, pp. 304-310 (2005)*

In the USA, Personal Income distribution has a well-defined two-class structure. 1-3 per cent of the population (rich) correspond to a Pareto power-law ("superthermal") distribution and the rest, the 97-99 per cent of the population, who are governed by the exponential Boltzmann-Gibbs ("thermal") distribution are poor people. By analysing income data for the time period 1983-2001, the authors have shown in this paper that the "thermal" part is stationary in time, and the "superthermal" tail shrinks and swells following the stock market. Based on the principle of maximal entropy, they quantitatively show that the concept of equilibrium inequality applies to the majority of the population.

3.8 Comparison between the probability distribution of returns in the Heston model and empirical data for stock indexes by A. C. Silva and V. M. Yakovenko.

Published by: *Physica A 324, 303-310 (2003).*

Comparing the probability distribution of returns for the stock market indices of Nasdaq, S&P500 and Dow-Jones with an analytical formula derived by Dragulescu and Yakovenko for the Heston model with stochastic variance, they found a very good agreement between the theory and the data for a wide range of time lags from 1 to 250 days during the period 1982-1999. However, there were deviations for the data for 2000-2002 due to the major change in the market from a positive growth rate in the 1980s and 1990s to a negative rate in 2000s.

3.9 Multi-agents' Games, Financial Markets and Econophysics

The Minority Game – The Basic Minority Game was formulated by physicists Damien Challet and Yi-Cheng Zhang in 1997. Agents exchange goods in the market. They sell what they have in excess and buy what they need or prefer. The market becomes a Minority Game, considering transactions of different agents. There is no production of new wealth and

no consumption, there is only an exchange of assets. So, wealth is considered as a conserved quantity, like energy or momentum. Thus, a person becomes richer only if another becomes poorer.

When the process is repeated many times, shrewder traders do well in the long run. But if everyone is equally skilful, there is a 50-50 chance of winning. In the long run, all the wealth winds up in the hands of one person.

This condensation of all property into the hands of one individual is an economic catastrophe—something like the formation of a black hole in astrophysics. Although you have all the riches in the world, you can't buy a thing, because no one else has goods to sell. And you can't sell anything either, because no one has money to buy anything. The whole economy is frozen. Two groups of physicists have published work on related themes. In France, Jean-Philippe Bouchaud of the Centre d'études de Saclay and Marc Mézard of the École normale supérieure have described "wealth condensation" in a somewhat different model. And Adrian Dragulescu and Victor M. Yakovenko of the University of Maryland have written on "the statistical mechanics of money".

The publications on asset-exchange models describe many more variations. Dragulescu and Yakovenko have assumed three different models which differ in the amount of money to be transferred, for example a small fixed amount of money, in the second case a random fraction of the trading pair's average wealth and in the third case, the amount is a random fraction of the average wealth of the entire population. To avoid putting traders into debt or bankruptcy, Dragulescu and Yakovenko apply the meta-rule that if the loser cannot pay, the entire transaction is cancelled. Equilibrium distribution has an exponential form in all these models and there is no economic collapse.

However, Chakraborti's savings model allows traders to hold back some of their capital from the market. In this case, the minimum wealth of a person does not reach zero level, but the dynamics of the model remain the same. This model slows the collapse, but all the wealth goes into one pair of hands at the end of the game.

The model of Bouchaud and Mézard (which includes investment earnings as well as trade) yields a Pareto-like power law for wealth distribution. But the models drawn most directly from the kinetic theory of gases predict an exponential distribution of wealth. Dragulescu and Yakovenko argue that

the middle part of the actual wealth distribution is indeed exponential, with a "Pareto tail" in the highest tax brackets. All the computational models are so crude, however, and the empirical measurements are so uncertain, that the curve-fitting inspires little confidence.

Microeconomic formulation of Kinetic theory models: In 2009 Chakrabarti and Chakrabarti studied the framework based on microeconomic theory, from which the kinetic theory market models could be addressed. They derived the moments of the model from their work of 2000 and used the equations in the savings model. In the framework considered, the utility function deals with the behaviour of the agents in an exchange economy.

Agent-based Modelling Based on Games

A. Minority Game models

1. El Farol Bar Problem

In 1994, Arthur introduced the "El Farol Bar" problem as a paradigm of complex economic systems. In this problem, a population of agents have to decide whether to go to the bar opposite the Santa Fe every Thursday night. Due to a limited number of seats, the bar cannot entertain more than X% of the population. If less than X% of the population go to the bar, the time spent in the bar is considered to be satisfying and it is better to go to the bar rather than stay at home. But if more than X% of the population go to the bar, then it is too crowded and the people in the bar have an unsatisfactory time. In this second case, staying at home is considered to be a better choice than attending the bar. So, each agent has to predict what everybody else will do.

Arthur was also interested in agents who have bounds on "rationality", i.e. agents who:

- do not have perfect information about their environment; in general they will only acquire information through interaction with the dynamically changing environment;
- do not have a perfect model of their environment;
- have limited computational power, so they cannot work out all the logical consequences of their knowledge;
- have other resource limitations (e.g. memory).

In order to take these limitations into account, each agent is randomly given a fixed menu of models potentially suitable for predicting the number of people who will go the bar, given past data (e.g. the same as two weeks ago, the average of the past few weeks, etc.). Each agent evaluates these models against the past data, each week. He chooses the one that was the best predictor of this data and then uses it to predict the number of people who will go to the bar this time. If this prediction is less than X, then the agent decides to go to the bar as well. If its prediction is more than X, the agent stays at home. Thus, in order to make decisions on whether to attend the bar, all the individuals are equipped with a certain number of "strategies", which provide them with predictions of the attendance in the bar in the coming week, based on the attendance in the last few weeks. As a result, the number who go to the bar oscillates in an apparently random manner around the critical X% mark. This was one of the first models that led to a way that was different from traditional economics.

2. Basic Minority Game

The "Original Minority Game" or the "Basic Minority Game" was formulated by Challet and Zhang (1997). As in the El Farol Bar problem, unlike most traditional economic models, which assume agents are "deductive" in nature, here too a "trial-and-error" inductive thinking approach was implemented. The minority game models could produce some macroscopic features observed in the real financial markets. Challet and Zhang (1998); Challet et al. (2000) failed to capture or reproduce the most important stylised facts of the real markets. However, in the physicists' community, it has become an interesting and established class of models where the physics of disordered systems facilitates a large number of physical insights (Savit et al. (1999); Martino et al. (2004)). Since a Hamiltonian function could be defined and analytic solutions could be developed in some regimes of the BMG model, the model was viewed as a more physical picture. In fact, it is characterised by a clear two-phase structure with very different collective behaviours in the two phases, as in many known conventional physical systems (Savit et al. (1999); Cavagna et al. (1999)). Besides these collective behaviours, physicists also became interested in the dynamics of the games, such as the crowd vs anti-crowd movement of agents, periodic attractors, etc. (Johnson et al. (1999a, b); Hart et al. (2001)). Thus, the Minority Games serve as a good tool for physicists in viewing and analysing the underlying dynamics of complex evolving systems such as the financial markets.

B. The Kolkata Paise Restaurant (KPR) problem

The KPR problem (Chakrabarti et al. (2009); Ghosh and Chakrabarti (2009); Ghosh et al. (2010a, b)) is a repeated game, played among N non-interacting agents, N being large. In this model, customers (agents) choose from N restaurants each evening simultaneously, where N is constant. The restaurants are of different rank but the price per meal is the same and can serve only one customer any evening. Customers usually wish to go to the restaurant with the highest possible rank while avoiding the crowds so as to be able to get dinner there. If more than one customer arrives at any restaurant on any evening, one of them is randomly chosen to be served. The others do not get dinner that evening. Daily labourers visit very cheap and fixed-rate "Paise Restaurants" in Kolkata. The labourers used to walk to one of these restaurants and would miss lunch if the restaurant was crowded. The best solution to the KPR problem is to make a queue and then each one is directed to visit a restaurant with a rank matching the person's place in the sequence of the queue on the first evening. Then the following evening, each person is told to go to the next ranked restaurant. This shift continues for successive evenings. This is one of the most efficient solutions and the system arrives at this solution immediately. However, in reality, this cannot be the true solution of the KPR problem, where each agent decides on his own every evening, based on complete information about past events. In this game, the customers try to evolve a learning strategy to eventually get dinners at the best possible ranked restaurant, avoiding the crowd. It can be seen that the evolution of these strategies takes considerable time to emerge and even then, the eventual utilisation fraction is far below unity.

The KPR problem has similarities with the Minority Game Problem (Arthur (1994); Challet et al. (2004)) as, in both games, herding behaviour is punished and diversity is encouraged. Also, both involve the agents learning from past successes, etc. However, KPR has some simple exact solution limits, some of which are discussed here. The real challenge is, of course, for the agents to design algorithms of mixed strategies for learning (e.g., from the pool discussed here) so that the fair social norm emerges eventually (in N_0 or lnN order time) even when everyone decides on the basis of their own information independently. This observation is in agreement with earlier observations in minority games (see e.g. Satinover and Sornette (2007)).

3.10 An Increase in Income Inequality

Banerjee and Yakovenko, in their paper "Universal patterns of inequality" *New J. Phys.* **12** 075032, 2010, construct a model that explains both the exponential and power-law regions of income distribution, and show that the increase of income inequality in the United States originates primarily in the increase of the income fraction going to the upper tail, which now exceeds 20% of the total income. They have studied probability distributions of money, income, and energy consumption per capita for ensembles of economic agents. Their result is in agreement with the empirical data for the USA, where income distribution oscillates between exponential at the low end and power law at the high end.

3.11 A Complex Multi-Agent Model

Westerhoff introduces a complex multi-agent model, which takes into account firm-firm interactions, socio-economic opinion dynamics and sales expectations depending on individual attitudes, in their paper, *An agent-based macroeconomic model with interacting firms, socio-economic opinion formation and optimistic/pessimistic sales expectations.* Published by *New J. Phys.* **12** 075035, 2010".

3.12 Kinetic exchange models of markets

For the last hundred years or more it has been a matter of interest among scientists (Social or Natural) to understand the distributions of income and wealth in an economy. Now it is one of the focused branches of econophysics.

J. Angle was the first to propose an elementary version of the stochastic exchange model. *A. Dragulescu* and *V. Yakovenko* first investigated such an exchange model. The assumption was that, in the short-term, an economy remains conserved in terms of income/wealth and any monetary transaction represents a redistribution of money from one agent to another. Such transactions lead to a *gamma distribution function* as in the *Chakraborti-Chakrabarti* model with uniform savings, and a gamma-like bulk distribution ending with a *Pareto tail* in the *Chatterjee-Chakrabarti-Manna* model with distributed savings. These results are very close to income/wealth distributions.

3.13 The Financial Bubble Experiment

On 2 November 2009, the Financial Bubble Experiment was launched within the Financial Crisis Observatory (FCO) at ETH Zurich (http://www.er.ethz.ch/fco/). The authors diagnosed the IBOVESPA Brazil Index, a Merrill Lynch corporate index, the gold spot price and announced three bubbles on three different assets in the initial report. On 23 December 2009, they added a diagnostic of a new bubble developing on a fourth asset (cotton futures). This report presents the four initial forecasts and analyses how they fared. They found that the IBOVESPA and gold showed clear signs of changing from a bubble regime to a new one within their forecast quantile windows; that the Merrill Lynch bond index changed from a strong bubble regime to one of more moderate growth just before their publication date; and that cotton was and still is in a bubble without showing a clear change of regime.

3.14 Sociological thermodynamics and economic thermodynamics

According to Jürgen Mimkes (a German metallurgist, solid-state thermodynamicist and professor of physical socio-economics), society is a Many-Particle System. One of his more notable conceptions was his 1990s phase diagram models of the integrations and segregations of cultures in society. In 1994, Mimkes began to consider the analogy of segregation in populations to the miscibility gap in solutions and alloys. His first paper was *Binary Alloys as a Model for a Multicultural Society* in *The Journal of Thermal Analysis* in 1995. In political thermodynamics, in 1996, Mimkes authored a 110-page article, *Politics and Thermodynamics.*

In the book *Econophysics and Sociophysics*, published in 2006, Mimkes has two chapters on *A Thermodynamic Formulation of Economics* and *A Thermodynamic Formulation of Social Science*. In his 2010 article, *Stokes Integral of Economic Growth,* on the subject of what he terms *econophysics*, Mimkes argues that economic properties may be calculated in physical terms: capital to *energy*, GDP per capita to *temperature*, production to physical work and production function to *entropy*.

3.15 The Contribution of Econophysics to the Economy

Econophysics has been contributing, roughly speaking, to four (of course, overlapping) areas of the traditional and modern economy:

(1) Financial markets,
(2) Industrial economics (e.g., companies' size distribution and growth rates),
(3) Wealth and income distribution in various societies,
(4) Networks analysis, since an almost common belief exists among econophysicists that universal empirical regularities can be discovered at least in the above-mentioned areas.

All studies in econophysics and sociophysics can be classified into three categories in respect of whether they are based on:

(i) statistical methods, including phenomenological thermodynamics of equilibrium and non-equilibrium states or the exotic (or non-Gaussian and non-exponential) statistical physics,
(ii) deterministic methods; this category is based, for example, on field theories or the theory of deterministic chaos, and
(iii) hybrid methods, where deterministic approaches are perturbed by different stochastic noises (Langevin type dynamics, which is supplied with a white noise, is a reference example here).

3.16 Stock Market Statistics and Its Analysis

Isaac Newton, the greatest scientist of all, notoriously sold early in the South Sea Bubble of 1720 after doubling his investment. Then he noticed that the price of stock was rising exponentially and he bought again at a higher price. Suddenly, he found there had been a crash in the market and he lost £20,000. It led him to remark that he could "calculate the motions of the heavenly bodies but not the madness of people."

Socio-economic systems are sensitive to different social, economic, natural or manmade disasters and to positive or negative news, which can go unnoticed unlike that of physical systems. However, it can be observed that the movement of stock prices rises or falls up to a certain level and remains almost stagnant with a small variation. From the stock market data, many people have done a statistical analysis for predicting the future of different stocks and stock indices. For example, some people say if there is a double peak in a chart of data, then it is expected that the stock price is likely to fall sharply. Similarly, if there is a double bottom, then it is expected that the price of the stock may rise. Didier Sornette, one of the leaders in the emerging discipline of econophysics, claims to detect log-periodic oscillations demonstrating a super-exponential trend in key long-term demographic, economic and financial series that, when extrapolated,

explode to infinity in about the year 2050. In short, he predicts the end of the world in or about the year 2050. If the physicists succeed in predicting the dynamics of stock prices considering different factors like social, economic, natural or manmade disasters and positive or negative news as different external forces, will it be the end of the problem? Probably not. Because, before the predicted crash, the real crash shall come and before the predicted peak, the real peak shall come. It will create one more problem and the Gaussian will have a narrow width and the difference is just like the difference in the excitement between a test match and a one-day match in cricket. If the correct prediction is made, in all probability, the real excitement of the market will be over and a doomsday market will soon be reached.

Physicists have modelled markets as a game played by similar players ("agents") that can only be won by a minority of the players ("minority game"). This sort of modelling is a synonym for the Boltzmann-Maxwell reduction of thermodynamics to elementary mechanics, modelling thermodynamic properties as the simple aggregate of many simple collisions between many similar billiard-ball molecules. Boltzmann's conclusion leads to the surprising Second Law of Thermodynamics—the irreversibility of time—when contemplating the aggregate of these time-reversible collisions and the econophysicists are reporting some surprising consequences of agent-based modelling in minority games.

Such agent models can replicate many of the "stylised facts" that characterise asset price evolution; they suggest that the market will fluctuate—the equilibrium they reach is dynamic as the price is expected to change even in the absence of new information. When markets reach what looks like a dynamic equilibrium, there remain exploitable patterns.

Agent-based modelling is just one approach the econophysicists have brought to a new level of sophistication. In another approach, Sornette finds parallels with many natural phenomena—specifically those phenomena with a large number of interacting parts with feedback, which typically can self-organise and perhaps make a sudden transition to a new state or phase (e.g., evolution, epidemics, earthquakes, ferromagnetism, weather, ecology, ruptures). He attempts to forecast these points of "self-organised criticality".

According to econophysicists, speculative markets are just another instance of a much more general phenomenon—game playing or some complex natural phenomenon. Their empirical emphasis has squeezed

some universal regularity out of the process of price evolution that has helped characterise the process of speculation. Sornette and others claim that data on many natural catastrophes are relevant to predicting stock market crashes or bubbles and they are just a different manifestation of the same underlying phenomenon.

Attempts to predict economic and market trends have been going on for a long time. The DJIA was originally developed to track the stock market to aid in the identification of market trends and cycles. Attempts have been made to predict the future of stock price from the study of charts, like technical, 200-day moving average, 100DMA, head, shoulders, candles, double peaks and double bottoms, etc. However, many of these techniques are not reliable and fail to predict bubbles and crashes. It is said, never buy stock on the advice of those who advise buying based on the study of different technical chart patterns. Professor Sornette argues that the market bubbles that lead to crashes have a characteristic log-periodic signature. In his book, Sornette says that bubbles do not always end in crashes, rather they terminate at a reasonable valuation after declining for a long period. During this period, shorting the market becomes less profitable as one cannot time the market. If everyone applies a mathematical technique, then the market will not show its natural behaviour leading to the destruction of the benefit of the technique. In such cases, the real crash may come before the predicted crash and the real peak may come before the predicted peak.

CHAPTER FOUR

WHAT DO THEY SAY?

4.1 Introduction

In this chapter, I will basically deal, in chronological order, with the reports, opinions, suggestions and criticisms given by different scientists (both natural and social), journalists, reporters, etc. on econophysics after it had been institutionalised. Essentially, this chapter is based on articles by different authors. It includes interesting reports on the power law of the growth rate of firms, the distribution of personal income in a society, the distribution of wealth, the kinetic exchange model, savings plans, unequal wealth distribution as a law of nature, comments on worrying trends in econophysics, game theory, predicting a financial crisis with the help of econophysics, etc. An interesting article, *Econophysicist Accurately Forecasts Gold Price Collapse*, is also included. Moreover, an analogy of financial markets and earthquakes is presented. Finally, there is a report on the physics of our finances.

4.2 Phillip F. Schewe and Ben Stein

In *Inside Science research – physics, Number 395* (Story #1), October 7, 1998, the authors reported that econophysics is the application of physics techniques to problems in economics. According to them, the economies of countries interact with each other just like electrons interact with each other, contributing to the global economy. The big data of the US gives an opportunity for statistical analysis to help our understanding of the behaviour of complex systems. Stanley et al., Nature, 29 Feb. 1996, had reported that the growth rate for a firm could be described with a single mathematical function for firms of all types and sizes. It was found that the probability distribution follows a "power law, such that the width is proportional to the firm size raised to a power of approximately 1/6". The same universal patterns and power laws for the fluctuations in the growth rates of the GDP of 152 countries from 1950-1992 were also found by Youngki Lee (Boston University Physicist) and economist David Canning (Harvard University) in *Physical Review Letters*, *Lee et al.*, 12 October

1998. These models raise the hope that complex human organisations can be studied with the methods and concepts developed in statistical physics.

4.3 Physicists' views on Wealth Distribution

Jenny Hogan reported in *New Scientist* on 12th March 2005 regarding wealth distribution among people in society with data and interpretation from different physicists and economists. According to her "the rich are getting richer while the poor remain poor". In 1979, the top 1% of the US population earned, on average, 33.1 times as much as the lowest 20%. In 2000, it became 88.5 times.

Physicists have been trying to understand the distribution of wealth based on certain physical laws and have found that inequality in market economies is here to stay. Economists met with physicists at SINP, Kolkata, India to discuss these issues of wealth distribution in March 2005 in the first ever "Econophysics" workshop. Sudhakar Yarlagadda, of the Saha Institute of Nuclear Physics (SINP) in Kolkata, says that it is still to be discovered whether there is some kind of social injustice behind this skewed distribution, as reported by Hogan. Victor Yakovenko, Physics professor of the University of Maryland, US, and his colleagues found that the income distribution among billionaires, which is only about 3% of the population follows Pareto's law, but for the poor, it fits another curve, which also describes the spread of energies of atoms in a gas. Again, he reported that the curve for the poor does not change significantly during inflation, but the income of the rich increases nearly five times during inflation. His study was based on US data from 1983-2000. Yakovenko, a speaker at the Kolkata conference, says that it would be very difficult to impose a policy to redistribute wealth, as reported by Hogan in *New Scientist* on 12th March 2005.

Bikas Chakrabarti et al., of the Saha Institute of Nuclear Physics, developed a better model in which they allowed people to save money in their gas model. This model predicts that both poor and rich classes exist, which Yakovenko also found. They have shown that changing the saving habits of people can make wealth distribution fairer than by taxing them. However, Makoto Nirei of Utah State University at Logan, US, a macroeconomist and a participant in the conference, is apprehensive of this model and says:

"This model seems to me to be not like an economic exchange process, but more like a burgling process. People randomly meet and one just beats

up the other and takes their money." Similarly, Economist Thomas Lux of Kiel University, Germany, says that "The models are too abstract."

But J. Doyen Farmer, a physicist from Santa Fe, US, is very much more hopeful about the model and comments that: "Many economic theories don't even come close to producing the wealth distribution we see, and if you can't produce that you're dead in the water," as reported by Jenny Hogan.

4.4 Workshop on Wealth Distribution in Kolkata

Christopher Shea reported in an issue of *The New York Times* on December 11, 2005, under the heading "Econophysics" that, according to Victor Yakovenko, current patterns of economic inequality are as natural, and unalterable, as the properties of air molecules in your kitchen. It is the same story as that reported by Jenny Hogan in *New Scientist*. Christopher remarked that although the application of physics in the field of economics is not new, the subfield of econophysics acquired legitimacy in March 2005, during the international conference on wealth distribution in SINP, Kolkata.

4.5 Worrying Trends in Econophysics

In *Physica A,* vol. 370, first issue, Mauro Gallegati, Steve Keen, Thomas Lux and Paul Ormerod expressed their concerns about econophysics as follows:

> "Our concerns are fourfold. First, a lack of awareness of work that has been done within economics itself. Second, resistance to more rigorous and robust statistical methodology. Third, the belief that universal empirical regularities can be found in many areas of economic activity. Fourth, the theoretical models which are being used to explain empirical phenomena."

In reply, Joseph L. McCauley of the Physics Department, University of Houston and Senior Fellow, **COBERA,** Department of Economics, J.E.Cairnes Graduate School of Business and Public Policy, NUI Galway, Ireland [01.06.2006] has responded to *Worrying Trends*..... in arXiv **0606002** in which he differs with the authors regarding some of their criticisms and their proposed remedy.

4.6 Predicting Economic Crises through "Econophysics"

Didier Sornette, a physicist at ETH Zurich in 2005, predicted bubbles in US real estate markets. It proved to be correct, despite the arguments of many economists that such bubbles could not exist. Afterwards, he also predicted the bursting of many other bubbles.

4.7 Quants and Phynance

> "If I had my life to live over again, I would elect to be a trader of goods rather than a student of science. I think barter is a noble thing." - Albert Einstein.

> "How could one describe and understand the movement of prices? Physics has always been concerned with dynamics, the way things change with time. It was the tried-and-true exemplar of successful theories and models. And physicists and engineers were jacks-of-all-trades, simultaneously skilled mathematicians, modellers, and computer programmers who prided themselves on their ability to adapt to new fields and put their knowledge into practice. Wall Street began to beckon them. In the 1980s, so many physicists flocked to investment banks that one head hunter I know referred to them as POW'S - Physicists on Wall Street." - Emanuel Derman from *My Life as a Quant - Reflections on Physics and Finance.*

Basically, physicists who have turned to quantitative finance are called "Quants". "Phynance" is a word, which is a combination of "Physics" and "Finance". This word had been tried earlier, probably to establish an interdisciplinary relationship between physics and finance before the word "Econophysics" was established. Quants apply the skills of the mathematics of complex systems to the stock market for making money.

Emanuel Derman applied his thinking to stock options after spending 20 years in the study of physics. According to him, option theory is very elegant and has the quality of physics. Besides being a professor of finance and risk management, he is a consultant with Prisma Capital Partners and Managing Director at Goldman Sachs. Wall Street is now flooded with physicists and a section for papers on finance has even been added to the physics website arXiv.org, where physicists post their papers. Dr Derman remarked in his book *My Life as a Quant: Reflections on Physics and Finance*, "In physics, there may one day be a Theory of Everything; in finance and the social sciences".

Physicists arrived on Wall Street in the late 1970s, in the midst of a financial revolution. Huge inflation made finances riskier and more complicated, so they tried to overcome such problems with their knowledge of computer programming and mathematical expertise. In the 1970s, the late Fischer Black, then at the University of Chicago, and *Myron S. Scholes* and Robert C. Merton, both then at MIT, worked out a way to guarantee profits from options. The so-called Black-Scholes model has been the Quants' gold standard ever since and is quite successful. It should be noted here that the Black-Scholes equation is quite similar to the differential equations used by physicists to represent heat diffusion and other random processes in nature.

CHAPTER FIVE

QUESTIONNAIRE

The author had some questions to ask of the pioneers and people who have been instrumental in bringing econophysics up to the level it has now reached and in response, they gave their well-considered replies, which are presented here.

Questions

1) What is your formal field of research: Physics, Economics, Mathematics, Computer Science, or ...? Do you identify yourself with econophysicists? What is the fraction of your research time/effort you put today into this kind of interdisciplinary research?

2) Do you think the studies under this econophysics banner have made any significant contribution either to physics or to economics, or to both? If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

3) Do you think an "Econophysics" forum/body should be formed, like other fields in physics, and should international conferences/workshops be conducted under its banner in different countries by rotation, annually or bi-annually?

4) Some universities have started offering optional graduate courses in econophysics; e.g.:

http://www.physics.leidenuniv.nl/edu/bachelor/courses_variatie/EF.asp

http://phys.uh.edu/research/econophysics/index.php

http://english.us.edu.pl/econophysics

http://www.sciencedirect.com/science/article/pii/S0378437104009616

and others like

(a)Trinity College Dublin, the University of Dublin, Ireland

(b) University of Munster, Germany

(c) University of Southern Denmark

(d) University of Ulm, Sweden

(e) University of Fribourg, Switzerland.

Do you think your university/institute should also offer such courses to their students? Have you written any textbook/research monograph on econophysics or in related fields? If not, do you intend to write one?

5) Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon? If so, by whom: physics or economics, or both? Do you think econophysics research will ever be recognised by a Nobel Prize? If so, in which discipline? Physics or Economics? And when?

5.1 John Angle

Reply from Professor John Angle, TIPI

The Inequality Process Institute, Pennsylvania, USA

Most of John's career has been as a statistical consultant to the Economic Research Service (ERS) of the US Department of Agriculture in Washington, DC. He is the founder of The Inequality Process Institute LLC (TIPI), an organisation that does both pure and applied research on personal income and wealth. At TIPI, he works full time on research related to the Inequality Process, a particle system model of personal income and wealth distribution, their dynamics, and the dynamics of income and wealth at micro level. John is a mathematical sociologist interested in income and wealth phenomena and is not an econophysicist. He has an outsider's interest in the natural sciences, particularly statistical physics, and envies the excitement of discovery among physicists.

Dear Professor Dash,

Thank you for your very kind email. I apologise for a slow response. I'm rushing to meet a number of due dates and the intrusive obligations that generate income for The Inequality Process Institute. I will respond in full to your questionnaire by early next month at the latest. In the meantime, perhaps the article I published in *Footnotes*, the monthly newspaper published by the American Sociological Association for its membership might be of interest. This article explains some of the histories of my venturing into a subject you kindly refer to as econophysics but I thought of as mathematical sociology when I began working on it. The two classifications are not mutually exclusive. Auguste Comte, the philosopher of science who in the 1930s coined the word "sociology" (sociologie in French), intended it to name a science of society, a science like a "social physics" (une physique sociale), sociophysics in current parlance. I draw almost no distinction between sociophysics and econophysics. Comte's challenge to find a science of society had an enormous resonance in the history of ideas and socio-political movements. I'm fairly sure that Karl Marx's economic theory began as a direct response to Comte's challenge. I haven't been able to find a document authored by Marx affirming my hunch.

The *Footnotes* article is at
http://www2.asanet.org/footnotes/feb07/fn9.html .

There are some comments on the *Footnotes* article at
http://members.asanet.org/Forums/view_forum.php?id=11.

Thanks for your interest,

Jack

John Angle, *angle@inequalityprocess.org*

Professor John Angle, TIPI, Pennsylvania, USA

Fig 5.1

Answers by Prof. Angle.

Ans. To Q.1 - My PhD is in sociology (University of Michigan, Ann Arbor).

I was initially employed as an assistant professor (University of Arizona). Most of my career since has been as a statistical consultant to the Economic Research Service (ERS) of the US Department of Agriculture in Washington, DC. I was employed in the Research Division, National Office, US Internal Revenue Service (IRS) (the income tax people in the US) in 1985 and 1986 as a mathematical statistician. While the task of the Research Division of the IRS was improving compliance with the US tax code, suggestions about new statistical techniques to identify noncompliance were not welcome. Statistical consulting at ERS included teaching econometrics in terms of matrix algebra to agricultural economists who had taken scalar variable econometrics in their youth. I also researched rural income issues at the ERS and served on the Federal inter-departmental Confidentiality and Data Access Committee. I took early retirement from the ERS to found The Inequality Process Institute LLC (TIPI), an organisation that does both pure and applied research on personal income and wealth. At TIPI I work full time on research related to the Inequality Process, a particle system model of personal income and wealth distribution, their dynamics, and the dynamics of income and wealth at micro level.

My papers on the Inequality Process began appearing in print in 1983. I did not refer to the model as a particle system until the late 1980s. It wasn't until 1990 that I published a paper discussing the similarity of the Inequality Process to the stochastic particle system model of the kinetic

theory of gases. So, I did not find the Inequality Process via statistical physics. The Inequality Process was abstracted from the verbal theory of the inequality of wealth over techno-cultural evolution in economic anthropology and sociology. I was delighted to find that some physicists were interested in this model and similar models. Thanks to Prof. Thomas Lux (Department of Economics, University of Kiel, Germany), I learned in 2005 of the work of Prof. Bikas Chakrabarti and his students as well as that of Prof. Victor Yakovenko and his students, and that of other physicists.

I'd identify myself as a mathematical sociologist interested in income and wealth phenomena, not as an econophysicist. I have an outsider's interest in the natural sciences, particularly statistical physics, and envy the excitement of discovery among physicists. No meeting of the American Sociological Association has ever been characterised by a name anything like the "Woodstock of Sociology" (cf. the 1989 meeting of the American Physical Society meeting in which findings of high-temperature super-conducting were presented, called by The New York Times "the Woodstock of Physics" after a well-known rock music concert because of the excitement at the meeting about those findings). Neither has any seminar group of sociologists ever acquired the fame or historic significance of the Bonzenfreies colloquium.

Ans. To Q.2

Until econophysics models are shown to be relevant to the empirical phenomena that are the traditional subject matters of physics, I suspect that econophysics models will be little more than an avocation, a pleasant excursion into a novel subject area using familiar mathematical models, for physicists. My opinions about the subject matters of academic disciplines and their boundaries, i.e., departmental "turf" as US academics might say (to use American slang for the territory and sustenance of a violent gang denied to non-members) are much less energetic than those of academics. I am focused on explaining social and economic phenomena related to wealth in either its stock (assets) or flow (income) form in a pragmatic way that disregards the boundaries of academic disciplines, as well as their paradigms, jargon, and xenophobia. Except of course when it comes to writing up findings for a journal, most of which are imbued with a discipline's paradigm. I'm not interested in whether the Inequality Process is classified as economics or mathematical sociology. I think the statistical signature of the Inequality Process is all over data on income and wealth in the US. I suspect that the same will be shown with other

countries' data. If it is demonstrated that the Inequality Process is universal, findings about it are not going to fade away as academic fads do. The Inequality Process, if shown to be universal and ubiquitous in everyone's life, will become a permanent part of science, a new part that is rather difficult to distinguish from statistical laws in the natural sciences, a part, I hope that will eventually, beyond my lifetime, envelop and surpass the discipline of economics rather than vice versa.

Ans to Q. 3

Of course. The enlargement of knowledge requires ramification into increasingly specialised subject matter fields and the formation of an association of researchers in each new field as it buds off from the older discipline that once laid claim to have an explanation for the new field's subject. A colleague wrote to me to announce a new journal she was editing. Its title seemed to me so specialised that my initial impression was to wonder how so specialised a journal could exist. Then I realised that's what most people think about the first journal in a new area of knowledge at its inception, journals that often go on to become the oldest and most prestigious of their fields.

Ans to Q.4

I'm not in a position to give advice about the development of a curriculum for students of physics. I have discussed with colleagues, who are mathematical sociologists, syllabi for courses in mathematical sociology. I'd like to see the emergence of mathematical sociology as a viable subfield of sociology. I'm the initial (but not final) organiser of the Mathematical Sociology Section of the American Sociological Association. The book I'm working on is a monograph on the Inequality Process. It's not a textbook.

Ans to Q.5

Writing as a sociologist interested in the sociology of science, I would hypothesise that the likelihood of the emergence of econophysics as a course, or a programme within a physics department, or a joint programme between departments or a separate department of its own in a university is essentially a question of whether teaching and doing research in it is a financially viable activity. It is a question of demand for the knowledge it produces. So while national science funding agencies, such as the National Science Foundation in the US, might see promise in such an area of knowledge and provide "seed money" for a pioneering programme or

research institute (e.g., the Santa Fe Institute) in econophysics, the long-term and widespread viability of the field depends on how powerfully useful the knowledge it produces is.

If one can unify a useful econophysics model with established physical law (about the traditional subject matter of physics) in a novel and surprising way, then, I'd guess, depending on the scope of possibilities such a finding might open, a Nobel Prize in physics might not be out of the question for a PhD in Physics. The Nobel Prize in Economics is a more remote possibility. Economics is an insular and dogmatic field, in some ways more like a religion than a science, and more xenophobic than other social sciences. A Nobel Prize in Economics might be given for rebranding useful statistical law now classified as econophysics as traditional economics, a kind of theological re-interpretation rather than scientific discovery. Otherwise, the main prize that really good work in econophysics can expect to receive from a committee of elite economists will be, I'd guess, the disciplinary analogue of a referral of a Renaissance-era schismatic to the Counter-Reformation's Holy Office of the Inquisition, something of a negative prize.

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5.2 Prof. Bikas Chakrabarti

Answers from Prof. Bikas Chakrabarti, SINP, Kolkata

Chakrabarti did his MSc. in Physics at Calcutta University and PhD at the Saha Institute of Nuclear Physics, Kolkata. He was a post-doctoral fellow at the Department of Theoretical Physics, University of Oxford and the Institute for Theoretical Physics, University of Cologne. He has been working as a faculty member in the Saha Institute of Nuclear Physics since 1983 and retired as Director of SINP and Senior Professor.

1) What is your formal field of research: Physics, Economics, Mathematics, Computer Science, or ...? Do you identify yourself with econophysicists? What is the fraction of your research time/effort you put today into this kind of interdisciplinary research?

Ans-Physics.

2) Do you think the studies under this econophysics banner have made any significant contribution either to physics or to economics, or to both? If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Ans- Have not yet made any major impact in economics ... the (statistical) physics community has been more open and appreciative.

3) Do you think an "Econophysics" forum/body should be formed, like other fields in physics, and should international conferences/workshops be conducted under its banner in different countries by rotation, annually or bi-annually?

Ans- Yes, and there are a few such regular meetings worldwide.

4) Some universities have started offering optional graduate courses in econophysics. Do you think your university/institute should also offer such courses to their students? Have you written any textbook/research monograph on econophysics or in related fields? If not, do you intend to write one?

Ans -Together with my colleagues, I have written several. Our first book, *Econophysics: An Introduction,* S. Sinha et al., Wiley-VCH, 2010, has remained the only "literature" for the Econophysics course offered in Leiden University, since its start in 2012; see the latest 2017-2018e-prospectus:
https://studiegids.leidenuniv.nl/en/courses/show/69415/econofysica

5) Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon? If so, by whom: physics or economics, or both? Do you think econophysics research will ever be recognised by a Nobel Prize? If so, in which discipline? Physics or Economics? And when?

Ans -Not clear yet. However, until the economists can see and appreciate the success of the econophysics approaches, the subject will not get established.

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5.3 Prof. Sitabhra Sinha

Answers from Prof. Sitabhra Sinha, IMS, Chennai, India

Sinha is Professor of Physics at the Institute of Mathematical Sciences (IMSc) at Chennai, and adjunct faculty of the NIAS, Bangalore. His PhD work was on the nonlinear dynamics of recurrent neural network models completed at the Machine Intelligence Unit, Indian Statistical Institute, Calcutta (1994-1998). His postdoctoral research is on nonlinear dynamics of spatially extended systems at the Department of Physics, Indian Institute of Science, Bangalore (1998-2000 and 2001-2002) and Weill Medical College of Cornell University at New York City (2000-2001). He joined the faculty of IMSc in September 2002. His areas of research fall broadly under complex systems, theoretical and computational biophysics and nonlinear dynamics.

Ans to Q.1 My formal field of research is Physics, specifically Complex Systems theory. Yes, I identify myself as belonging to the community of physicists involved in analysing social and economic phenomena using techniques from statistical mechanics, nonlinear dynamics and computer simulations. I devote about a third of my research time/effort to exploring econophysics-related questions.

Ans. To Q. 2

Yes, I believe econophysics studies have already made significant contributions to economics, specifically in understanding the behaviour of financial systems and also in explaining the ubiquity of inequality distributions. From Bachelier onwards to Mandelbrot and Osborne, there have been many attempts to understand the nature and origin of fluctuations in economic variables, such as prices and indices. The careful empirical analyses of financial market data pioneered by Stanley, Bouchaud, et al. in the 1990s have revolutionised this area of economics. There has not been a critical contribution towards advancing physics as yet, although the advances made in econophysics to understanding the dynamics of interactions among agents may prove very useful in extending the reach of physics to studying biological and social systems.

Ans to Q. 3 Yes. To some extent, this has already been done for quite some time now. In India, we have had the annual series of meetings ECONOPHYS-KOLKATA and a few workshops on the subject in IMSc Chennai.

Ans. To Q. 4

Yes, I believe my Institute should offer an elective course in econophysics as part of the coursework that all physics graduate students have to undergo.

Yes, I have written a textbook in Econophysics (Sinha, Chatterjee, Chakraborti and Chakrabarti, *Econophysics: An Introduction,* Wiley-VCH).

Ans. to Q.5

Yes, econophysics will be recognised soon by both economics and physics. I believe econophysics research will be recognised by a Nobel Prize in the discipline of Economics in about a decade. I would guess that the work on understanding fluctuation phenomena in financial markets will most likely win the first Nobel Prize for econophysics. While the work on understanding inequality distributions is even more fundamental, I suspect that the real breakthrough discovery in this field is still in the future.

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5.4 Bertrand Roehner

Institute for Theoretical and High Energy Physics LPTHE, University of Paris 64 Place Jussieu, F-75005 Paris, France.
http://www.lpthe.jussieu.fr/~roehner.

Roehner is Professor of Physics at LPTHE, University of Paris. His research interests are speculative trading, price peaks, sharp peak, real estate prices, separatism and separatist uprisings, wheat prices, commodity prices, spatial arbitrage, spatial propagation of price fluctuations, social bonds, social cohesion, military occupation, resistance, suicide, apoptosis, intermarriage, mixed couples, white flight. He is the author of several books like *The Theory of Markets* (published by Springer-Verlag), *Hidden collective factors by speculative trading* (published by Springer), *Patterns of speculation* (published by Cambridge University Press), etc.

Questions-Answers

1)

Q: What is your formal field of research?

A: Particle physics

Q: Do you identify yourself with econophysicists?

A: Yes

Q: What is the fraction of your research time you put today in this kind of interdisciplinary research?

A: 100%

2) ***Q: Do you think the studies under this econophysics banner have made any significant contribution either to physics or to economics, or to both? If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?***

A: Yes. Particularly because it introduced the idea that models must be able to produce successful predictions instead of just describing past episodes. Describing former episodes without making any NEW testable prediction is just circular reasoning, isn't it?

For the second part of the question which is about the future, I have no idea.

3) *Q: Do you think an "Econophysics" forum/body should be formed, like other fields in physics, and should international conferences/ workshops be conducted under its banner in different countries by rotation, annually or bi-annually?*

A: I don't have any clear opinion on this point.

4) *Q: Do you think your university should offer econophysics courses to students?*

A: Yes.

Q: Have you written any textbooks on econophysics?

A: The books that I wrote were not intended as textbooks but I think that substantial parts of them can be used for that purpose. I have myself used them for teaching a course in econophysics at Beijing Normal University in 2011. By the way, this institution can be added to the list given in the questionnaire.

5) *Q: Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon?*

A: No, I don't think so. Economics has a strong political content. In the words used by my colleague, Jean-Philippe Bouchaud, in one of his papers, it is more a religion than a science. So, when econophysicists insist that the tenets and dogma accepted by economists should be tested, their wishes are not welcomed by the profession.

The Nobel Prize in Economics has been awarded to many economists for purely theoretical and untested research, something which (as far as I know), has never been done for the Nobel Prize in physics.

So, one cannot really say that the "Nobel" in economics is a scientific Nobel Prize.

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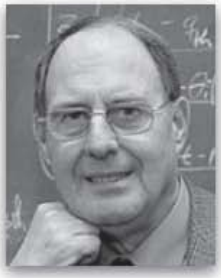
5.5 Reiner Kümmel

Reply from Prof. Kümmel, Universität Würzburg, Deutschland



Kümmel was awarded a PhD degree at the University of Frankfurt. He was DAAD Lecturer and Professor Asistente / Asociado at the Universidad del Valle in Cali, Colombia from 1970 to 1972. From 1974 to 2004 he was Professor of Theoretical Physics at the University of Würzburg. He retired from service in 2004. Since then he has been working as a lecturer in "Thermodynamics and Economics" at the University of Würzburg. Kümmel is noted for his 2011 book, *The Second Law of Economics: Energy, Entropy, and the Origins of Wealth,* in which he argues that we need to begin to incorporate *energy* and *entropy* thinking into *economics.*

Dear Dr Dash,

Thank you for your message and the interesting questionnaire. My answers come right in the questionnaire below. With very best wishes for your endeavour,

Reiner Kümmel *www.physik.uni-wuerzburg.de/~kuemmel*

Ans. to Q.1

Physics. I am a member of the econophysics branch of the German Physical Society. Before my retirement in 2004, I dedicated about one third of my time to econophysics. Now it is 100 per cent – see my homepage.

Ans. to Q.2

Probably yes. But there has not yet been much impact in either field.

If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Ans. - Yes

Ans. Q.3 - Yes. Bi-annual international conferences should complement the annual German econophysics conferences. An organisation like the "Association on the Study of Peak Oil", or the "International Society of Ecological Economics", would be helpful.

Ans. to Q.4

My University, the University of Würzburg, Germany, offers the course on "Thermodynamik und Ökonomie" (Thermodynamics and Economics), which is also announced on my homepage. The monograph, on which the course is based, is my book *The Second Law of Economics: Energy, Entropy, and the Origins of Wealth*.

http://www.springer.com/physics/complexity/book/978-1-4419-9364-9

Q.5) Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon?

Yes, it already is by the German Physical Society

If so, by whom: physics or economics, or both?

By physics

Do you think econophysics research will ever be recognised by a Nobel Prize? If so, in which discipline? Physics or Economics? And when?

Quite a few Nobel Prize winners in economics were physicists by training. But economists will never propose an active econophysicist for the prize. They prefer it for themselves and dislike econophysics anyway. If the NP will ever be awarded to an econophysicist, it will be after economic breakdowns have been predicted, and economic recoveries via actions suggested by econophysicists.

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5.6 Jürgen Mimkes

Reply from Prof. Mimkes, University of Paderborn, Germany

Mimkes is a professor in the physics department at the University of Paderborn, Germany. Before that, he taught in many US universities and Berlin. His main field is solid-state physics and thermodynamics. He has been dealing with the subject of the statistics and thermodynamics of social and economic systems since 1990. He calls his present field "physical economics", especially macro and microeconomics, and finance, and he has trouble calling his field econophysics, as this only covers finance. He has many works related to *sociological thermodynamics* and *economic thermodynamics* (we can say Econophysics) like *Society as a Many-Particle System* (1997), *Chemistry of the Social Bond* (2005) *Econophysics and Sociophysics* (multi-authored, 2006), and many others. Prof. Mimkes completed his BS in physics in 1963 at the University of Göttingen, his MS in physics in 1964 at the Free University of Berlin, and his PhD in 1967 at the Technical University of Berlin.

Ans. to Q.1

My background is physics and solid-state thermodynamics. My present field is "physical economics", especially macro and microeconomics, and finance. My time invested in this interdisciplinary work is 100%. I have trouble calling my field econophysics, as this only covers finance.

Ans. to Q.2

I think the studies have widened the scope of economics, moving from narrative social science to a more exact "natural science". In addition, econophysics has shown that physics is far more than a science of dead

matter. Physics is the base of natural science including economics and social sciences.

In my view, the present studies will succeed in the future as the basis of social and economic science if econophysics will include macroeconomic aspects.

Ans. to Q.3

We already have many international meetings on econophysics: the European COST meetings, the worldwide economic WEHIA meetings, the European Complexity meetings, The Indian meetings on Socio-Economics at the SAHA Institute in Kolkata, the annual meeting of members of Socio-Economic Systems by the German Physical Society, meetings in Japan, China, USA and Switzerland, to name a few.

These meetings are already linked by members in different meetings, but it would be beneficial to establish international meetings from all these groups.

Ans. to Q.4

I strongly support the idea to install the new field of econophysics as an interdisciplinary field in economics and physics.

I am presently writing a textbook on physical economics and econophysics to promote the knowledge of econophysics in different universities.

Ans. to Q.5

I believe that physical economics or econophysics will soon be recognised as a special field in natural science. If the field keeps contributing new ideas, a Nobel Prize in Economics should be possible. When? People like Nash had to wait many years for this prize!

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5.7 Prof. Chakravarty

Reply from Prof. Satya R. Chakravarty, Indian Statistical Institute, Kolkata, India

Chakravarty is Professor of Economics at the *Indian Statistical Institute*, Kolkata. His main areas of interest are Welfare Economics, Public Economics, Mathematical Finance, Industrial Organisation and Game Theory. His work spans theoretical, empirical and policy analysis. He has authored six books and co-edited two books *Quantitative Economics: Theory and Practice* (with D. Coondoo and R. Mukherjee), Allied Publishers, New Delhi, 1998 and *Econophysics & Economics of Games, Social Choices and Quantitative Techniques* (with Banasri Basu, Bikas K. Chakrabarti and Kausik Gangopadhyay), Springer-Verlag, Italia, 2009. He received the ***Mahalanobis Memorial Award*** from the Indian Econometric Society in 1994. This is the most coveted award for an economist in India.

Ans. to Q.1

Economics, a significant part of research time.

Ans. to Q.2

Likely to make significant contributions to economics.

Ans. to Q.3

Yes. Conference probably once every two years. I am associated with ECINEQ (Society for the study of economic inequality) and we arrange one conference every two years.

Ans. to Q.4

I believe some universities /institutes in India should offer such courses.

Answer to Q.5

I see some possibility in economics. My study of the literature shows that an economy can be regarded as a thermodynamic system and the distribution of income among economic agents can be identified with the distribution of energy particles in a gas. There may be other areas of overlap. In view of these, I see a high chance.

Satya R. Chakravarty

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5.8 Prof. Aoyama Hideaki

Answers from Prof. Aoyama Hideaki, Professor, Graduate School of Sciences, Kyoto University, Japan.

Hideaki is one of Japan's leading theoretical physicists. Though his interests span many areas, his current focus is on econophysics, the new field that hopes to move economics closer to being an exact science. Among his many publications are *Classical Mechanics* (2005), *Pareto Firms* (2007), *Econophysics* (2008), all in Japanese, and a new study forthcoming from the Cambridge University Press, *Econophysics and Corporations, – Statistical Life and Death in Complex Business Networks.* Prof. Aoyama with others have run four domestic econophysics conferences at the Yukawa Institute for Theoretical Physics at Kyoto University, in 2003, 2005, 2007 and 2009. Very recently they have analysed business cycles in Japan using the indices of industrial production (IIP), an economic indicator which measures the current conditions of production activities in the nation on a monthly basis.

Ans. to Q.1

My field of research is Physics. I identify myself as a Theoretical Physicist. I have been doing research in Particle Physics mostly, and in addition to that, I wrote papers in Linguistics, Economics (Econophysics), and Condensed Matter Physics. Economics and Econophysics work occupied 100 per cent of my research time last year, but it can change as my interest is broad.

Ans. to Q.2

Some works on the real economy have made an impact on Economics. Although there are many who still do not agree, mainstream economics with its utility function and classical Newtonian equilibrium has been shown to be inappropriate. The core of the thinking in Econophysics, the scientific study with emphasis on analysis of actual data and theoretical models with concepts borrowed from statistical physics, is gradually becoming the standard for the next stage of Economics.

Ans. to Q.3

Yes, to all. In every possible form, it should be discussed, the research results shared, and the young generation of academics should be exposed to its light.

Ans. to Q. 4

I wish we could have courses like that. But funding comes very slowly.

I and my colleagues published a book on Econophysics from Cambridge University Press and wish to publish another.

Ans. to Q.5

I am not sure if it is good to establish ourselves as "econophysicists", separating us from economists. Rather we need to convince them that our view, scientific view, is the view they should adopt, and create the next stage of the development of economics, contributing to a stable and happy global society.

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5.9 János Kertész

Answers from Prof. János Kertész, Director of the Institute of Physics, Budapest University of Technology and Economics.

János is a *physicist* from the University of Budapest, Hungary. He is one of the pioneers of *econophysics*, *complex networks* and the application of *fractal geometry* in physical problems. The inaugural meeting on Econophysics was organised 1998 in Budapest by János Kertész and Imre Kondor. János Kertész obtained his PhD from the ITP of the HAS in 1980 and his DSc from HAS in 1989. He has occupied many positions at ITP and became Professor of Physics at the Budapest University of Technology and Economics (BME) from 1993 and was also Deputy Director of the Institute of Physics at BME from 1992 to 2000. From 1995 to 2007 he was Head of the Department of Theoretical Physics at BME and from 2001 was the Director of the Institute of Physics at BME. He is the Director of the Institute of Physics in *Budapest University of Technology and Economics*, *Budapest*, Hungary.

Dear Dr Dash,

Thank you for your mail.

Please note, with Rosario Mantegna we wrote a somewhat detailed editorial preface to a focus volume of *New Journal of Physics* about some questions you posed, see *New Journal of Physics* 13 (2011) 025011, doi:10.1088/1367-2630/13/2/02501
Below are my brief replies.
Best regards,
János Kertész

Ans. to Q.1

My formal field: Physics

Econophysics is an important field of research, in my opinion.

30%

Ans. to Q.2

I think that econophysics has already achieved remarkable results in economics though there has not been a real breakthrough so far; however, I am confident that we are on a good track. (It is perhaps not a cynical comment to say that many of the "breakthroughs" of financial economics have turned out to be failures and that the ongoing global crisis is just the painful proof of the lack of fundamental understanding in this area.)

Ans. to Q.3

I think that there have already been such forums: APFA, ECCS, etc. Econophysics is massively represented in conferences on complex systems. The German Physical Society has a Division for the Physics of Socio-Economic Systems. I think that a similar, worldwide umbrella, which includes social systems too, would make a lot of sense.

Ans. to Q.4

I am in the process of introducing a related project in Budapest.

I have not written such a book and will not do so in the near future.

Ans. to Q.5

The goal of econophysics is to understand economics and finance, therefore recognition should also come from that direction. I am optimistic but this will take time. What helps is more respect for economics literature and ground-breaking results.

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5.10 Tiziana Di Matteo

Answers from Tiziana Di Matteo, Reader in Financial Mathematics, King's College London

Tiziana is a Reader in Financial Mathematics at King's College, London. She did her PhD in Physics in 1999 at the Dipartimento di Física - Università di Salerno, Italy. She was Associate Professor (Level D), of Applied Mathematics at the Research School of Physical Sciences, Australian National University, Canberra, Australia. Her research interests are Econophysics, Application of methods from Statistical Physics to Finance, Complex Systems, Science of Networks, etc. She has publications in refereed journals like *Physica A, New Journal of Physics, Journal of Banking & Finance, European Physical Journal B, Quantitative Finance,* etc.

Ans. to Q.1

It is Complex Systems and Econophysics.

Yes, I do, I identify myself as an Econophysicist. 80%.

Ans. to Q.2

I think they made several contributions and the main contribution so far has been the empirical analysis of real economic and financial data sets that have resulted in the so-called "stylised facts" that any model should reproduce.

Ans to Q. 3

We have already had some of these including the Genoa forum:

http://www.ge.infm.it/~ecph/index.php

the Econophysics forum:

http://www.unifr.ch/econophysics/

and regarding conferences, meetings and workshops, we have had many in the last few years including the Econophysics Colloquium started in Canberra in 2005 and now becoming an annual event:

http://www.econophysics-colloquium.org/

The next edition, the Econophysics Colloquium 2012, will be at ETH in Zurich and the 2013 edition in Korea and the 2014 edition in Japan.

Ans. to Q.4

Why not? I am personally teaching in my Financial Mathematics master's course some materials on Econophysics.

I have written some papers and contributed to some volumes in Econophysics.

Ans. to Q.5

I think it is already recognised as a research field mainly within the physics community.

When something very relevant to Economics will be discovered, a Nobel Prize in Economics to an Econophysicist is certainly possible.

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5.11 Hagen Kleinert

Answers from Prof. Hagen Kleinert, Professor of Theoretical Physics, Free University of Berlin, Germany

Hagen has been Professor of *Theoretical Physics* at the *Free University of Berlin*, *Germany* since 1968. He was awarded the *Max Born prize* in 2008 for his contributions to particle and solid-state physics. He has also won the *Majorana Prize*. His publications are both in physics and financial markets. He has authored many books on theoretical physics and financial markets.

Ans. to Q. 1

Theoretical Physics, Yes, 10%.

Ans. to Q. 2

No, Yes.

Ans. to Q.3

Yes.

Ans. to Q. 4.

Yes, I wrote a book, *Path integrals in quantum mechanics, statistics, polymer physics, and financial markets.*

Ans. to Q. 5)

Yes, Economics, Yes in Economics, Future.
Web: http://www.klnrt.de
http://www.worldscibooks.com/physics/7305.html

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5.12 Mauro Galegati

Reply from Prof. Mauru Galegati, Professor of Economics, Polytechnic University of Marche, Ancona

Gallegati obtained his PhD in Economics in 1989 at the University of Ancona and is Professor of Economics. Prof. Gallegati is on the editorial board of several economic journals. He has worked on nonlinear dynamics, business fluctuations, heterogeneous interacting agents and models of financial fragility. Mauro is well known from his widely cited work with Joseph E. Stiglitz, developing the theory of asymmetric information and heterogeneous agents and their applications. He has published papers in the top journals on economics, complexity and econophysics.

Ans. to Q.1

Economics
no
25%

Ans. to Q.2
yes
yes

Ans. to Q.3

yes

Ans. to Q. 4

yes
no
no

5) Ans. To Q.5

no
no

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5.13 Thomas Lux

Answers from Thomas Lux, Professor of Economics, CAU Kiel

Thomas is an economist, who has made a lot of contributions in the field of "Econophysics". He is *ranked among the 1,000 most often quoted economists within the decade 1990 - 2000*. He has a number of publications in physics journals like *Nature, Physica A, European Journal of Physics B, International Journal of Modern Physics, Physical Review E,* etc.

Questions

Ans. to Q. 1

Thomas Lux: My field of education and research is economics and finance. I hold a PhD in Economics and I am currently Professor of Economics at CAU Kiel. I have spent my entire career within economics departments. My education in physics is of a more informal nature. As a postdoc, I started studying material from statistical physics. My feeling

then was that stochastic models for interacting particle systems could be very useful as a methodological approach for the modelling of interacting agents in economics as well. I soon started to use such methods in my own research (since the early 90s). Since my first publications in this vein were received quite positively, from about the mid-90s most of my research output can be attributed to what has later been called "econophysics".

Ans. to Q. 2

Thomas Lux: I believe that at least certain branches of "econophysics" research have made significant and lasting contributions. In financial economics, for instance, the development of agent-based models of heterogeneous, interacting investors have demonstrated how the stylised facts (economics terminology) or universal statistical features can be explained via the tension between centripetal and centrifugal forces generated by different trading strategies. A large body of literature has (in my view) convincingly shown that features like fat tails and clustered volatility can be obtained in a robust way as emergent phenomena from microscopic models with a few basic ingredients. In contrast, mainstream finance has always treated the most prevalent features of financial data as "anomalies" – not a very convincing way to deal with empirical phenomena.

There is also quite a broad area of research on topics in quantitative finance (option pricing, risk management, etc.) in which research contributed under the banner of "econophysics" mingles with research conducted by statisticians, mathematicians and others without there being much recognisable difference in scope and methodology. A certain blind spot still exists in macroeconomics, despite some innovative and interesting work like that by Mauro Gallegatti, Domenico delli Gatti and some others. Macroeconomics would certainly benefit from adopting more of a view of the economy as an adaptive dynamic system with dispersed activity rather than the dominating representative agent approach.

Ans. to Q. 3

Thomas Lux: There have been quite a number of annual conference series (like Econophysics Colloquium, APFA, the econophysics meetings at Kolkata and others) most of which were initiated at least ten years ago. Certainly, such focused events are very important for the development of the field. Similarly important are conferences in which "econophysicists" meet and interact with open-minded economists without a physics

background. The annual meetings of the Society for Economics with Interacting Heterogeneous Agents and the Society of Computational Economics have usually attracted a large number of colleagues with an interdisciplinary background.

Ans. to Q. 4

Thomas Lux: Certainly, courses providing an overview of econophysics literature should be very welcome. After all, it has been a very active field of research and, as I see it, has produced some significant insights. However, I don't see a clear "econophysics" curriculum emerging. Existing courses and textbooks are often pretty idiosyncratic and governed by the particular research interest of the persons in charge. In my view, a major contribution of such programmes should be to bring students from economics into contact with the approach and methodology of research in physics which has many important tools to offer and is altogether of a much more practical hands-on nature than the inherited research style in economics (with its leaning towards rigorous mathematical proofs rather than practical data analysis). I myself am offering a course on agent-based modelling (including statistical physics methodology to deal with such systems) in our PhD programme and have authored a few surveys on econophysics research.

Ans. to Q. 5

Thomas Lux: Right now, it seems quite unthinkable. There is obviously a lot of resistance from both mainstream economics and traditional quarters in physics. While some physicists do not consider research on social and economic phenomena as an appropriate research topic for their colleagues, the attitude of some economists seems to be more that of shyness with strangers who use concepts and terminology they have not encountered before. Often it is also an outrage that some concepts dear to economists like rationality and utility maximisation are altogether ignored by econophysicists. And last but not least there is vested interest in the value of one's human capital that might be tied to particular tools and methodological approaches and gets endangered by new developments. Nevertheless, economics has seen many "scientific revolutions" and the once heavily rebuked fields of behavioural and experimental economics have meanwhile also been honoured with Nobel Prizes. So, in the end, solid research will always be recognised sooner or later.

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5.14 Prof. Victor Yakovenko

Answers from Prof. Victor Yakovenko, University of Maryland, USA

Victor is one of the pioneers of "econophysics". He is Professor of Physics, University of Maryland, USA. He was educated in the USSR. He received his MS from the Moscow Physical-Technical Institute and his PhD in theoretical physics from the Landau Institute for Theoretical Physics, Moscow. His research interests are in unconventional superconductors, Andreev bound states in superconductors, Strongly correlated materials close to a metal-insulator transition, Physical effects of high magnetic fields, the quantum Hall effect, Applications of statistical physics to economics and finance, etc. He has written a book entitled *Classical Econophysics* with A. F. Cottrell, P. Cockshott, G. J. Michaelson, and I. P. Wright, published by Routledge (2009). Many of his articles have attracted media attention and have been published in newspapers and periodicals written by reporters in *American Scientist, Australian Financial Review, New Scientist, The New York Times Magazine,* etc.

Questions

Ans. to Q. 1

Ans - Physics

Do you identify yourself with Econophysicists?

Yes

What is the fraction of your research time/effort you put today into this kind of interdisciplinary research?

About 50%

Ans. to Q. 2

Yes, to both

If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Even more potential in the future

Ans. to Q. 3

Yes

Ans. to Q. 4

It is not going to happen at my university any time soon.

I am considering writing a book but never have time.

Ans. to Q. 5

Econophysics is already in the Physics and Astronomy Classification Scheme (PACS) classification, but not in the economics classification.

There is no Nobel Prize in Economics. Alfred Nobel was against it. After his death, the Bank of Sweden established a pseudo-Nobel Prize to promote its political agenda. Given these controversies, I don't think a Nobel Prize in econophysics would be awarded any time soon, but it does not matter.

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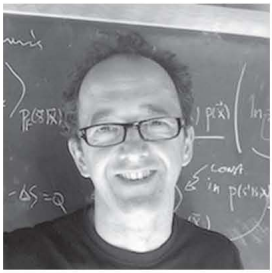
5.15 Matteo Marsili

Answers from Matteo Marsili, Abdus Salam ICTP, Triste



Matteo is basically a statistical physicist having research interests in statistical physics, non-equilibrium critical phenomena, disordered systems, probability interests theory and stochastic processes, complex networks, interdisciplinary applications of statistical physics, including modelling socio-economic phenomena and financial markets, game theory, and biological networks. He has organised many conferences and workshops on socio-economic systems and finance.

Questions

1) What is your formal field of research? Physics.

Do you identify yourself with Econophysicists? No, I don't think the word makes any sense.

What is the fraction of your research time/effort you put today into this kind of interdisciplinary research? 40%

Ans. to Q. 2

No.

Ans. to Q. 3

No, I don't think "Econophysics" makes sense. There is no "physics" in "economics". Quantitative training is helpful, but those who study economics should have proper training in microeconomics, game theory, macroeconomics, etc. There are already a lot of conferences in "Econophysics".

Ans. to Q. 4

Do you think your university/institute should also offer such courses to students? No.

Have you written any textbook/research monograph on econophysics or in related fields? I wrote a book on Minority Games plus a couple of preceding volumes.

If not, do you intend to write one? Maybe.

Ans. to Q. 5

No, I don't.

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5.16 Diego Garlaschelli

Answers from Diego Garlaschelli

Diego Garlaschelli is an Italian Associate Professor of Theoretical and Applied Physics at the IMT Advanced School, Lucca and at Leiden University. He is the first Professor of Econophysics at Leiden University where physicist Jan Tinbergen had received the first Nobel Prize in Economics.

1) What is your formal field of research: Physics, Economics, Mathematics, Computer Science, or ... ?

Physics.

Do you identify yourself with Econophysicists?

Yes.

What is the fraction of your research time/effort you put today into this kind of interdisciplinary research?

70%.

2) Do you think the studies under this econophysics banner have made any significant contribution either to physics or to economics, or to both? If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Yes. Curiously, more recent results in econophysics about systemic risk in interbank networks appear to have had a stronger impact on economics literature than the early studies of economics about financial time series.

If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Yes.

3) Do you think an "Econophysics" forum/body should be formed, like other fields in physics, and should international conferences/ workshops be conducted under its banner in different countries by rotation, annually or bi-annually?

Yes, even if regular events already exist (Econophysics Colloquium, WEHIA).

Ans to Q.4

My university is actually the first one on your list, and I do teach that course!!!

I have not written a textbook (I use the recent one by Sinha et al. in my course), but I prepare my own teaching materials (slides and exercises) and I wrote an early review paper *Emergence of complexity in financial networks.*

5) ***Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon?***

I hope so.

If so, by whom: physics or economics, or both?

More likely by physics, I guess. Most econophysics experts are hired in physics departments. However, there is one exception I know (and probably more): IMT in Lucca (Italy) does research in economics (not in physics), yet it hires physicists with the express purpose of doing research in econophysics.

Do you think econophysics research will ever be recognised by a Nobel Prize? If so, in which discipline? Physics or Economics? And when?

I have no idea. But consider that the first ever Nobel Prize in Economics was awarded to Jan Tinbergen, who was a theoretical physicist by training. And similarly with Koopmans.

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5.17 K.C Mishra

Answers from Prof. K.C Mishra, Vice Chancellor, Sri University, Odisha, India

Prof. Mishra joined Utkal University as a lecturer in Physics but later on switched to management. After teaching management in many universities in India and abroad he is now working as Vice Chancellor of Sri University, Bhubaneswar.

1) What is your formal field of research: Physics, Economics, Mathematics, Computer Science, or ...? Do you identify yourself with Econophysicists?

Management, Financial technology, value measurement.

What is the fraction of your research time/effort you put today into this kind of interdisciplinary research?

All my personal and scholar-centred research is multi-disciplinary.

2) Do you think the studies under this econophysics banner have made any significant contribution either to physics or to economics, or to both? If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

My tryst with concepts like preference dynamics theory, opportunity loss elasticity, quantum entanglement of economic behaviour, multiverse utility theory, superimposition inflation function and entropy of market excitement has veered me towards the conviction that econophysics can be the scientific and rational basis of most economic concepts without having to hover around confusions like "on one hand ---- and state just the contrary on the other hand -----" making economists and economics a laughing stock with popular politicos. Conversely, as physicists move from material concepts to astral concepts to causal concepts, it may be conceived in the intellectually reflexed mind of the physicist but often they miss the explanatory verve. An analogy is the best way to disseminate created knowledge. Visible economic trends can be used as a good analogy to explain astral and causal concepts in physics. Big crunch or big chill as concepts of physics can neither be actually realised in the next several conceivable human lifetimes nor be simulated in a reciprocal hadron collider but can be causally extrapolated from economic crunch and chill phenomena occurring at lifetime intervals.

3) Do you think an "Econophysics" forum/body should be formed, like other fields in physics, and should international conferences/ workshops be conducted under its banner in different countries by rotation, annually or bi-annually?

Econophysics is in a stage of conceptualisation where it has to be sold, not bought, easily. Selling requires a lot of algorithmic exercises. A greedy and randomised algorithm to produce approximate buy-in would be efficient. Experiments on both the synthetic and real-world environment demonstrate the effectiveness and efficiency of the proposed greedy algorithms. A greedy algorithm for optimal target planning through promotional effort selection and audience *selection is* basically an optimising process. In econophysics, that formula has to be increasingly tested by fast-paced, algorithmic bidding systems that target individual learners and researchers rather than the aggregate audience seminars serve up. In the world of "programmatic research" technologies and context matter less than tracking those research carriers wherever they go. And that kind of algorithm is the reason that econophysics should follow the participants whether they are on a physics or on an economics gathering –

virtual or actual.

4) Some universities have started offering optional graduate courses in econophysics. Do you think, your university/institute should also offer such courses to students? Have you written any textbook/research monograph on econophysics or in related fields? If not, do you intend to write one?

Our university has not yet started either an economics or a physics course which may be a convenient pre-condition for starting an econophysics module. But in this university, participants are permitted to conduct econophysics research for a doctoral degree.

My Postdoctoral work was 60% econophysics. I have a few published papers singly and jointly in the area.

5) Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon? If so, by whom: physics or economics, or both? Do you think econophysics research will ever be recognised by a Nobel Prize? If so, in which discipline? Physics or Economics? And when?

Biophysics and Geophysics have better association analysis results which can be conceived intuitively by being inclusive disciplines of natural science but econophysics is a value judgement cross association between natural science and the liberal arts. Such associations are ordinal like "Time is money" or "Knowledge is power". Acceptance takes time till kinship syndrome sets in. Algorithmic associations are easier in parallel than cross disciplines; for example, in an economics context, political-economics, business-economics, behavioural economics and econometrics contexts, and similarly in a physics context, biophysics, geophysics, high-energy-physics, minute-physics or quantum-physics, etc. Even though the association between physics and economics can be tested in a large basket of data, there are two key confounding issues. Firstly, discovering conceptual congruence of two cross data sets where the analysis champion is not acquainted with at least one set. Secondly, some of the economics data patterns are either spurious or transmutable seemingly happening by chance not consistently. It will require a good amount of robust defence to associate the learning baskets strategically. But metaphysically speaking, the longest journey begins with a single step. Start it.

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5.18 Prasanta Panigrahi

Answers from Prasanta Panigrahi, Professor of Physics, IISER, Kolkata

Prof. Panigrahi, after completing an MSc at Ravenshaw College, entered into IOP, Bhubaneswar for a predoctoral course and then did his PhD at Rochester University. After doing a postdoc, he came back to India and joined Hyderabad University, PRL Gujarat and is now working as a Prof. of Physics at the Indian Institute of Science Education and Research, Kolkata.

Dear Kishore, excellent idea. I certainly think our universities, IITs and IISERs should offer this course. I know in IIT Kanpur, there is a strong interest in Economics and Mathematics. In many universities abroad, MS programmes on Financial Mathematics are being offered (e.g., Columbia University). The only thing is that the book needs careful editing and a smooth amalgamation of chapters, with methods and applications carefully presented. Best, Prasanta

Analysis of Answers

Answers to Q.1

a. **Your Formal Field of Research**

Physics – 60.5%

Economics & Sociology – 32.6%

Econophysics - 6.9%

b. **Do you identify as an Econophysicist?**

Yes – 44.2%, No - 32.5%, Unclear – 23.3%

c. Fraction of Time you put into econophysics research

Ans. 100% - 31%

More than 50% - 33.3%

Less than 50% - 33.3%

Q.2 a. Do you think the studies made generally under the econophysics banner have made any significant contribution?

Yes – 80%, No - 13.37%

b. If so, to Physics or Economics, or both?

Physics – 0%, Economics – 60%, Both – 6.7%, Not in either field – 20%

c. If not yet at a satisfactory level, do you think these studies have any potential to succeed in the near future?

Yes – 33.3%, No – 7.7%

Q.3 a. Do you think an "Econophysics" forum/body should be formed like other fields in physics?

Yes – 84.6%, No-0%, Already existing – 7.7%, No clear idea – 7.7%

b. Should international conferences/workshops be conducted under its banner in different countries by rotation?

Yes – 80%, No-6.7%, Already existing – 6.7%, No clear idea – 6.7%

Q. 4. a. Do you think, your university/institute should also offer econophysics courses to students?

Yes - 80%, No – 20%

b. Have you written any textbook/research monograph on econophysics?

Yes – 69.7% No -31.3%

c. If not, do you intend to write one?

Yes – 20%, No – 15.4%

Q.5a. Do you think, just as in many other interdisciplinary fields like biophysics, geophysics, etc., "econophysics" will be recognised as a natural one soon? If so, by whom: physics or economics, or both?

Yes – 53.3%, No – 26.7%, No clear idea – 20%

b. Do you think econophysics research will ever be recognised by a Nobel Prize?

Yes – 46.6% No – 26.7%, No Clear idea – 26.7%

c. If so, in which discipline? Physics or Economics?

Physics – 0%. Economics – 46.7%, No Clear idea/does not matter, etc. – 53.3%

d. When?

Near Future – 0%

Later – 46.7%

Never – 26.7%

Conclusion

I had sent e-mails to about 43 esteemed Professors around the globe. I only received 18 replies. The response percentage was just 39.5, which is not encouraging. Among those who replied, it was a mixed bag of physicists (60.5%), economists (32.6%) and econophysicists (6.9%). Altogether, 46% identify themselves as econophysicists. It is encouraging to note that 31% are fully dedicated to econophysics research, whereas 33.3% devote more than 50% of their time to econophysics research. Interestingly 80% of them believe that studies made under the econophysics banner have made significant contributions and 60% agree it has contributed to economics and 0% say it has contributed to physics. In total, 84.6% want to form an econophysics forum/body and 80% want international conference/workshops conducted under its banner in different countries by rotation. It is certainly big news that 80% are interested in offering courses on econophysics in their universities. 53.3% believe that "econophysics" will be recognised in the same way as biophysics and geophysics soon and even 46.6% expect econophysics research to be recognised with a Nobel Prize sooner or later in economics, but not in physics (0%).

Although this is a preliminary study and the responses that I have received are not significant in number, I believe that econophysics certainly has made some impact among natural as well as social scientists and is stepping forward to establish itself as a new field in the interdisciplinary field of science. My previous article *Evolution of Econophysics* also establishes the same fact. The frequency of the word "Econophysics" in different articles and papers is continuing to increase.

CHAPTER SIX

THE LAST PAGE

I would like to highlight the need for the establishment of an institution as suggested by Bikas K Chakrabarti during the concluding session of the Joint International Conference entitled "Econophys-2017 & Asia-Pacific Econophysics Conference (APEC)-2017", held in JNU and DU, New Delhi from 15-18 November 2017. I am presenting parts of his article from arXiv with due permission from him. Springer will publish a version of this article along with the papers presented in the above-mentioned conference.

The draft proposal on *An International Centre for Social Complexity, Econophysics & Sociophysics Studies: A Proposal by Bikas K. Chakrabarti* [Saha Institute of Nuclear Physics, Kolkata 700064, India; S. N. Bose National Centre for Basic Sciences, Kolkata 700106, India; and the Economic Research Unit, the Indian Statistical Institute, Kolkata 700108, India], posted on the free online site, arXiv (number 1805.05586) is indeed extremely interesting and relevant to the main focus of this book. With Chakrabarti's kind permission, I reproduce here some selected parts of his draft proposal.

In the introduction for the proposal, Chakrabarti writes: "More than twenty years have passed since the formal coining of the term and hence the launch of econophysics as a research topic (since 1995; see the entry by Barkley Rosser on Econophysics in 'The New Palgrave Dictionary of Economics').

[1]: Econophysics: According to Bikas Chakrabarti (2005), the term 'econophysics' was neologised in 1995 at the second Statphys-Kolkata conference in Kolkata (formerly Calcutta, India) by the physicist H. E. Stanley). Soon, econophysics had been assigned the PACS number 89.65Gh by the American Institute of Physics. According to Google Scholar, typically today more than a thousand papers and documents containing the term 'econophysics', are published each year (many more research papers are, in fact, published today on the topic without ever

calling it econophysics) in almost all physics journals covering statistical physics, general science journals and a few economics journals. More than 15 books on econophysics (with the word econophysics in the title of the book), including some textbooks and monographs, written by pioneers and active researchers in the field, have already been published by Cambridge University Press, Oxford University Press, Springer and Wiley. Many more edited books and conference proceedings are published (a search of 'econophysics' titles in the 'amazon.com: books' today gives more than 140 entries; with some double counting of course!) It has been a similar story for 'sociophysics'. Regular interactions and collaborations between the communities of natural scientists and social scientists, however, are rare even today!"

He then continues:

> "Though, as mentioned already, interdisciplinary research papers on econophysics and sociophysics are regularly being published at a steady and healthy rate, and a number of universities (including the Universities of Bern, Leiden, London, Paris and Tufts University) are offering interdisciplinary courses on econophysics and sociophysics. Not many clearly designated professor positions, or other faculty positions for that matter, are available yet (except for econophysics in the Universities of Leiden and London). Neither are there designated institutions in these interdisciplinary fields, nor separate departments or centres of studies for instance. We note, however, happily in passing, a recently published highly acclaimed ('landmark' and 'masterful') economics book [2] by Martin Shubik (Seymour Knox Professor Emeritus of Mathematical Institutional Economics, Yale University) and Eric Smith (Santa Fe Institute) which extensively discusses econophysics approaches and in general on the potential of interdisciplinary researches inspired by the developments in natural sciences. Indeed, this massive 580-page book can also serve as an outstanding 'white-paper' document in favour of our intended proposal."

And to summarise some of the notable impacts of such studies and research so far, Chakrabarti writes: "Though the inter-disciplinary interactions have not grown much, some sure signs of positive impact for the research achievements in econophysics and sociophysics have been documented in the literature. The precise characterisations of stock market fluctuations by Mantegna and Stanley [3] have already made a decisive mark in financial economics and all the related subjects (with more than 4000 citations already for the book [3]; Google Scholar). In the section on 'The position of econophysics in the disciplinary space' in the book *Econophysics and Financial Economics* [4], the authors write (pp. 83,

178): 'To analyse the position of econophysics in the disciplinary space, the most influential authors in econophysics were identified. Then their papers in the literature were tracked by using the Web of Science database of Thomson-Reuters ... The sample is composed of Eugene Stanley, Rosario Mantegna, Joseph McCauley, Jean-Philippe Bouchaud, Mauro Gallegati, Benoit Mandelbrot, Didier Sornette, Thomas Lux, Bikas Chakrabarti, and Doyne Farmer.' The book [2] by Shubik and Smith noted (pp. 75-76) that while a simple kinetic exchange market model (see e.g., [5]) leads to exponentially decaying distributions, 'it was shown in [6] that the uniform saving propensity of the agents constrains the entropy maximizing dynamics in such a way that the distribution becomes gamma-like, while the (quenched) nonuniform saving propensity of the agents leads to a steady-state distribution with a Pareto-like power-law tail [7]. A detailed discussion of such steady-state distributions for these and related kinetic exchange models is provided in [8]'. Shubik and Smith [2] also noted the important contributions by physicists in the study of multi-agent iterative (and collective) learning game models for efficient resource sharing ([9] for binary choice iterative learning games and [10] for multi-choice iterative learning games). This book [2] also discusses in detail the impact of the pioneering work by physicist Per Bak and collaborators in the context of the self-organising dynamics of complex markets. The Econophysics course offered by Diego Garlaschelli in the Physics department of Leiden University, where the first economics Nobel Laureate (statistical physicist Jan Tinbergen) came from, follows exclusively the book *Econophysics: An Introduction* [11] since its inception in 2011 (see e.g., [12] for the 2017-2018 and 2018-2019 e-prospectuses).

Discussions on the further impact of econophysics [3, 4, 13, 14] and sociophysics [15-18] research will be continued later."

Following discussions about some earlier attempts for initiating such an institute, the brief proposal, as presented by Chakrabarti (in arXiv:1805.05586) is reproduced as below:

> "In view of all these, it seems it is time to try for an international centre for interdisciplinary studies on complexity in social and natural sciences; specifically, on econophysics and sociophysics. The model of the Abdus Salam ICTP, Trieste (funded by UNESCO and IAEA), could surely be helpful to guide us here. An ICTP-type institute could be initiated for research on econophysics and sociophysics (see also [19]). We note that Dirk Helbing (ETH, Zurich) and colleagues have been trying for a European Union funded 'Complex Techno-Socio-Economic Analysis

> Centre' or 'Economic and Social Observatory' for the last six years (see Ref. [20] containing the White Papers arguing for the proposed centre). We are also aware that the Indian Statistical Institute had taken a decision to initiate a similar centre in India (see 'Concluding Remarks' in [21]). Siew Ann Cheong (Nanyang Technological University, Singapore) had tried for a similar Asian Centre in Singapore [22]. In view of some recent enthusiasms at the Japan-India Heads of States or Prime Minister level, and the signing of various agreements (predominantly for business deals, infrastructure development, technical science and also cultural exchanges) by them, the possibility of an Indo-Japan Centre for studies on Complex Systems is also being explored, including the possibility of a centre in Tokyo with private support [23]. There are several other similar initiatives (e.g. [24])."

It then continued:

> "These proposals are or had been, for regular research centres on such interdisciplinary fields, where regular researchers are expected to investigate such systems. In view of the extreme interdisciplinary nature of econophysics and sociophysics, such efforts may be complemented by another visiting centre model. Unlike the above-mentioned kind of intended centres, this proposed centre may be just a visiting centre where natural and social scientists from different universities and institutions of the world can meet for extended periods to discuss and interact on various interdisciplinary issues and collaborate for such researches, following the original ICTP model. Here, as in ICTP, apart from a few (say, about ten to start with) promising young researchers on econophysics and sociophysics as permanent faculty who will continue active research and active visiting scientist programmes (in physics, economics and sociology), etc. can be pursued. The faculty members, in consultation with the advisers from different countries, can choose the invited visitors, and workshops or courses, on economics and sociological complexity issues, can be organised on a regular basis (as for basic theoretical sciences in ICTP or in Newton Centre, Cambridge, etc.). In two short communications [25], Martin Shubik (Yale University, New Haven) supported the idea very enthusiastically and encouraged us with some very precise suggestions. He also noted that such a centre can play a much more inclusive role for the whole world (as is being done by the ICTP), compared to what the Santa Fe Institute has been successful in doing for the US. Gene Stanley (Boston University, Massachusetts) supported enthusiastically [26] such a proposal ('... you already thought of all the ideas I might have had... I will continue to think ...')."

In concluding the proposal (arXiv:1805.05586) Chakrabarti writes:

> "We think it is an appropriate time to initiate such a project for the healthy growth of this 'Fusion of Natural and Social Sciences', through active dialogue among the students and experts from different disciplines (e.g., physics, computer science, mathematics, economics and sociology), engaged in researches in their respective disciplines and institutions, from all over the world. We find both the experts in the related disciplines, as well as the researchers already initiated in such interdisciplinary researchers, have deep feelings about the urgent need for such a centre, where short and long-term visits would be possible and enable them to participate in interdisciplinary schools, workshops, and research collaborations."

The references cited in the above portions reproduced here (from arXiv:1805.05586) are as follows:

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In my questionnaire, I had asked a question about whether an international forum is needed for econophysicists. However, Bikas Chakrabarti, who is a pioneer of econophysics, is already one step ahead and proposes an institution of the ICTP, Trieste type to be used by natural and social scientists. We have seen in Chapter One of this book that people from the fields of Physics, Mathematics, Physiology, and Engineering have jumped

to Economics. Similarly, some of the social scientists have appreciated the work done by the natural scientists in the field of social science and even worked under them leading to their PhD degree. Some physical scientists have been awarded the Nobel Memorial Prize in Economics and some social scientists have been awarded the Nobel Prize in Economics working on the principles of natural sciences. These are the developments which laid a foundation stone for the new branch, "Econophysics". Even the word "Phynance" has appeared, which is a combination of Physics and Finance and could not stick. The name "Econophysics" was coined by H. Eugene Stanley, in Kolkata, India, in 1995. After 1995, Econophysics has struggled to find its place in natural science. It is heartening that in India, social science is now proposed to be considered as a part of natural science by the INSA, and social scientists can be selected for the Shanti Swaroop Bhatnagar award. In these circumstances, scientists, both from natural and social sciences, are required to sit under the same roof for the benefit of society. Now the question is about funding. I think different stakeholders like financial institutions, insurance and banking organisations, housing finance companies, etc. should come forward for funding. This is an ambitious project proposed by Bikas Chakrabarti and as such, "he likes to see changes and really makes something happen" (said by H. E. Stanley during an interview with Kausik Gangopadhyay of IIM, Kozhikode, India; *https://doi.org/10.1177/2277975213507763*). Let us keep our fingers crossed and be hopeful for the establishment of such an extremely timely and desirable international institution.