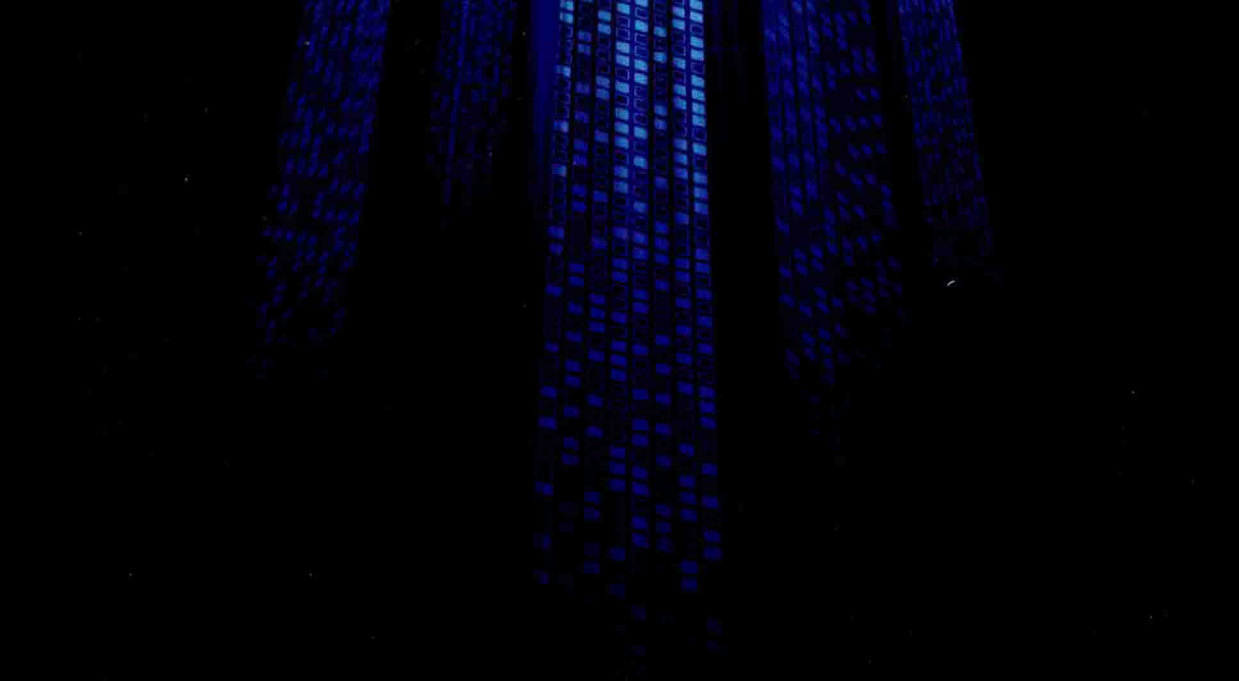

Econophysics and Companies

Statistical Life and Death in Complex Business Networks

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Econophysics and Companies

Econophysics is an emerging interdisciplinary field that takes advantage of the concepts and methods of statistical physics to analyse economic phenomena. This book expands the explanatory scope of econophysics to the real economy by using methods from statistical physics to analyse the success and failure of companies. Using large data sets of companies and income-earners in Japan and Europe, a distinguished team of researchers show how these methods allow us to analyse companies, from huge corporations to small firms, as heterogeneous agents interacting at multiple layers of complex networks. They then show how successful this approach is in explaining a wide range of recent findings relating to the dynamics of companies. With mathematics kept to a minimum, the book is not only a lively introduction to the field of econophysics but also provides fresh insights into company behaviour.

HIDEAKI AOYAMA is Professor of Physics at Kyoto University, Japan.

YOSHI FUJIWARA is Research Fellow at Advanced Telecommunication Research Institute International (ATR), Kyoto, Japan.

YUICHI IKEDA is Senior Researcher at Hitachi Ltd, Hitachi Research Laboratory, Japan.

HIROSHI IYETOMI is Professor of Physics at Niigata University, Japan.

WATARU SOUMA is Associate Professor of Physics at Nihon University, Japan.

About the authors

Hideaki Aoyama Professor of Physics, Kyoto University.

He received his PhD from the California Institute of Technology in 1982 and studied high energy physics at SLAC as a postdoctoral fellow, at Harvard University as a visiting scholar and at Northeastern University as a lecturer. He is an advising council for the Credit Risk Database (Tokyo) and a special advisor on physical sciences for the Renewable Energy Foundation (London).

Yoshi Fujiwara Research Fellow at Advanced Telecommunication Research Institute International (ATR) and Adjunct Lecturer at Kyoto University.

He received his PhD from the Tokyo Institute of Technology in 1992 and studied general relativity and quantum cosmology at the Yukawa Institute as a postdoctoral fellow, and at the Institute of Theoretical Physics, University of California at Santa Barbara as a visiting researcher. He was also engaged in research in econophysics at the Department of Economics, Università Politecnica delle Marche with Professor Mauro Gallegati.

Yuichi Ikeda Senior Researcher at Hitachi Research Laboratory, Hitachi Ltd.

He received his PhD from Kyushu University in 1989 and studied experimental high energy physics at the Institute of Nuclear Science, Tokyo University as a postdoctoral fellow, at Brookhaven National Laboratory as a collaborator on the project on Quark-Gluon plasma formulation. He also studied computational plasma physics at the University of California at Berkeley as a visiting industrial fellow. He worked as a senior researcher at Hitachi Research Institute from 2005 to 2008, and is currently seconded to the International Energy Agency (Paris).

Hiroshi Iyetomi Professor of Physics, Niigata University.

He received his PhD from the University of Tokyo in 1984 and continued to study strongly-coupled plasma physics as an assistant professor there. He worked at Hitachi Ltd as a researcher before moving to his current position. Also he studied condensed matter physics at Argonne National Laboratory as a research associate, at Louisiana State University as a visiting associate professor, and at Delft University of Technology as a visiting fellow.

Wataru Souma Associate Professor of Physics, Nihon University, Research Fellow at Advanced Telecommunication Research Institute International, and Visiting Associate Professor, Institute of Economic Research, Hitotsubashi University.

He received his PhD from Kanazawa University in 1996 and studied high energy physics at Kyoto University.

Hiroshi Yoshikawa (Foreword) Professor of Economics, University of Tokyo.

He received his PhD from Yale University in 1978. He served as president of the Japanese Economic Association in 2002 and is currently a member of the Council on Economics and Fiscal Policy in Japan. Among his several books, the latest is *Reconstructing Macroeconomics – A Perspective from Statistical Physics and Combinatorial Stochastic Processes* (Cambridge University Press, 2007).

Foreword

This book is one outcome of the new field of econophysics, and explains a wide range of recent findings relating to the dynamics of companies. While economics and physics each have long histories of their own, and their methods and purposes are obvious, econophysics, which has only a twenty-year track record, is still unfamiliar to many. Indeed, an emerging interdisciplinary approach in which the economy is studied with the tools of physics may provoke doubts as to whether the methods of a hard science can tell us anything about phenomena in which human beings are essential players. However, economics has in fact mimicked physics since the nineteenth century. This is particularly true of those who developed modern economics, the 'neoclassical' economists. The old masters such as Alfred Marshall and Léon Walras all drew inspiration from Newtonian mechanics. The fundamental concept of 'equilibrium', known to all students of the subject, is, of course, borrowed from physical science.

Thus, a moment's reflection shows us that the relation between physics and economics is long-standing and far closer than is commonly realised. Nevertheless, the recent development of econophysics represents a significant development. While traditional economics learned from classical mechanics, which analyses behaviours such as that of a ball thrown in the air or the motion of a weight at the end of a spring, econophysics looks to the statistical methods of the modern physicist.

Obviously, economic phenomena are constituted from the actions of very large numbers of people and companies. In Japan alone there are over a hundred million people and several million companies, or, in the language of physics, the human population is of order 10^8 and that of companies 10^6. Although these are small numbers in comparison with the everyday quantities of the natural sciences, the Avogadro constant, $\sim 6.02 \times 10^{23}$ for example, it is already impossible to track the movements of all people and companies with any high degree of accuracy. Fortunately for economics, this is not a problem, for while, as individuals, we may be interested in a particular person or a particular firm, economics as a discipline deals with macro phenomena, such as the economy of Japan, or that of Europe as a whole.

In its approach to these macro problems, traditional economics attempts first to analyse the microscopic and then to understand the macro-economy by a process of scaling up. In other words, standard economics regards the macro-economy as a

homothetic enlargement of the representative micro-unit. Faced with similar problems in the natural world, statistical physics takes a very different route. Recognising that the micro-agents are too numerous to be followed individually, they simply abandon the attempt to capture micro behaviour in detail, and employ statistical methods instead. This is the fundamental concept advanced by Maxwell, Boltzmann and Gibbs.

Notwithstanding this precedent, some may still wonder whether it can *in principle* be meaningful to conduct statistical analysis on social phenomena arising from the actions of individuals, each with an economic motive and a will. Are sophisticated human beings with brains, on the one hand, and inorganic molecules, on the other, really on an equal footing?

More than seventy years ago, when the majority of researchers were opposed to bringing physics into biology, Dr Torahiko Terada, the major force behind the attempt in Japan, remarked:

> When making a statistical analysis of a large number of human individuals we may properly regard it as a mere conglomeration of inorganic material, and altogether neglect individual free will. Indeed, it is now clear that pure physical problems, such as the density of particles in a colloidal matter, may with propriety be compared to statistics of a purely physical nature, such as the 'density' or 'average speed' of persons walking along the street... It is sheer folly to dismiss such insights as heresy simply because they are incompatible with the dogma that 'living creatures cannot be understood by Physics'. Such absurdities remind us that no ignorant amateur poses so serious a threat to progress as a scientist unaware of the nature and goal of their discipline. Torahiko Terada, 'Groups of animals as inorganic groups', *Journal of Science*, Iwanami Shoten (1933)

The application of physics to biology is now an established discipline, biophysics, and the controversies of the past are quite forgotten. We can confidently expect, not least because of trail-blazing studies such as the current volume, that econophysics will soon seem an equally natural development.

Hiroshi Yoshikawa

Preface

Between their first explorations in econophysics and the writing of this book the authors have travelled a long and sometimes winding road. One of our earliest results was the landmark study of personal income distributions in 2000 (Aoyama *et al.*, 2000), which convinced us that thorough empirical study, or 'phenomenology' as it is called in physics, was essential for an understanding of society and economics.

Since then, we have carried out research with an emphasis on the real economy, that is, people (workers), companies (corporations), banks, industrial sectors and countries. We have also studied the various markets that play a vital role in the activity and prosperity of actual businesses. As a result we began to think of writing a book focused on the real economy and based on the analysis of very large quantities of empirical data. Such work has been largely ignored by economists because that discipline does not, unfortunately, value the empirical search for regularities. Yet, it is this observation-based approach that lies at the root of the success so evident in physics. Kepler's laws of planetary movement, for example, were extracted from the vast quantity of astronomical data collected by Tycho Brahe and others. There is every reason to expect laborious but ingenious analysis of economic data to lead to progress, perhaps not as dramatic as that of Kepler, but progress nonetheless.

We hope that this book will serve as a source-book for people like ourselves who want to move the field of econophysics over to the study of practical economics and companies, rather than the current focus on the application of statistical physics to financial risk.

We shall let our three Tuscans discuss the whole subject in the Prologue and the Epilogue, after giving the following sincere acknowledgements – needless to say, many people assisted in the research behind this book. High-accuracy, high-frequency data are a must for detailed study of various economic agents, and we would like to thank the Credit Risk Database Association and its president, Shigeru Hikuma, for general help and advice on the nature of the database, the Organization for Small and Medium Enterprises and Regional Innovation for help in relation to bankruptcy data, and Tokyo Shoko Research Ltd. for assistance relating to chain-bankruptcy.

Many other collaborators have contributed to this book in direct and indirect ways at various stages of our research. Our thanks to all, particularly to the following:

Masanao Aoki (Los Angeles), Mauro Gallegati (Ancona), Corrado Di Guilmi (Ancona), Hiroyasu Inoue (Osaka), Taisei Kaizoji (Tokyo), Yasuyuki Kuratsu (Tokyo), Makoto Nirei (Tokyo), Hideaki Takayasu (Tokyo), Misako Takayasu (Tokyo), Schumpeter Tamada (Hyogo) and Hiroshi Yoshikawa (Tokyo).

We are also grateful to the Yukawa Institute for Theoretical Physics at Kyoto University for allowing us to use the computing facility for part of our numerical computation.

Thanks also to Nao-san for the illustrations, and to John Constable who has not only read the text in its entirety and brushed up and polished the English of our text, but also made many helpful comments.

Finally, we wish to thank Hitachi Ltd and Hitachi Research Institute, which have provided us with research funding for this project. The authors of a work on economics are perhaps more aware than most of just how important such support can be to labourers in the intellectual vineyard.

Prologue

I have for many years been a partisan of the Copernican view because it reveals to me the causes of many natural phenomena that are entirely incomprehensible in the light of the generally accepted hypothesis. (Galileo Galilei in a letter to Johannes Kepler)

SALVIATI: Greetings, Sagredo, Simplicio, my good friends. I can hardly believe that it was only yesterday that we resolved to meet and talk about this book. How the time drags when I am not in pleasant company such as yours.

SIMPLICIO: Greetings to you, most courteous Salviati, and well met, well met I say. My mind is already racing in anticipation. I have not forgotten, and could not forget, our wonderful discussions with Professor Galileo in Tuscany, and I am convinced that on this occasion too you have found something worth the labour of a *Dialogue* (Galilei, 1632).

SAGREDO: For my part I am also delighted to see you both again. In the company of two such philosophers as yourselves I never fail to find inspiration and illumination. Now, would you care to tell me the nature of the subject, Salviati?

SALVIATI: Certainly, certainly, shall I come to the point: I feel that a change is happening, just as it was when we met with Professor Galileo.

SIMPLICIO: *Change!* Ha!

SAGREDO: Now, now, Simplicio... Let's hear this out. The book is about a change, is it? But I don't understand even the title. What is this econophysics?

SALVIATI: You have gone right to the heart of the matter; econophysics is the name of an academic discipline, a name coined in 1995 by that most learned professor of Boston, Eugene Stanley. He means the word to describe the study of the economy or economics as seen through the eyes or analysed with the tools of exact science.

SAGREDO: Well that helps me a little, but I am still puzzled by the appearance of the word 'physics' in this new name. Can you explain that, Salviati?

SALVIATI: Well, that is simple indeed. The main driving force behind this new discipline is the natural science of physics. For, as you will shortly see, statistical physics has many concepts and principles that can be readily applied to phenomena

in economics. That is to say, just as economic systems are composed of many inhomogeneous agents, like people, companies and financial institutions, so the natural world studied so successfully by physicists consists of atoms and molecules in gases and condensed matter. The similarity is obvious, is it not?

SIMPLICIO: Well so you say, but I need hardly remind you that there is already a long-established and well-respected discipline studying these matters, namely economics. You should show a little more respect for that authority, for has not economics constructed an intellectual context in which economic observations can be placed; namely, the optimisation of utility by individual economic agents, the specification of the concept of equilibrium and the detailed delineation of the implications of the equilibrium model? Who needs this so-called econophysics?

SALVIATI: Alas, Simplicio, I fear you have erred in two ways.

SAGREDO: Only two? Simplicio's errors are legion and notorious, for example ...

SALVIATI: Piano, piano, Sagredo. Firstly, Simplicio, my dear fellow, undue or unconsidered respect for authority is a prison with invisible walls. Secondly, the context to which you refer is, as it turns out, not entirely suitable for the analysis of economic phenomena. Let me put it in this way: the grounding principle of econophysics, and this is much more important than the mere import of certain concepts from physical science, is the scientific approach itself, where hypotheses and possible theories are discussed freely in an open manner, tested against determinable facts and used to make predictions, though not necessarily in that order. And science is really about changing ourselves, our mind, our dearest views, even when we are comfortable and don't wish to be changed, or find alternative views almost impossible to hold in our minds. For example, the quantum theories, or relativistic theories, all of which are beyond our everyday realm – is that not so Simplicio!

SIMPLICIO: I am sure you mean no offence, but there is no need to raise your voice, Sagredo, I am listening carefully, though I am not sure yet that I understand your point.

SALVIATI: Forgive me my dear Simplicio, the subject is of very great importance to me. For you see, the most remarkable thing is that if physicists and economists clear their minds of constraints, they can work together in this discipline, and very fruitfully.

SAGREDO: So, you say that this book is about the scientific study of companies, firms and corporations?

SALVIATI: Yes, yes, the study of the real economy, as it is made up of people, companies, financial institutions – and all this through the lens of exact science. An acquaintance of mine, some sort of poet really, but we need not hold that against him, once said that:

> Science, ... is the north-west passage
> between cynicism and credulity.

Perhaps it is a little difficult to understand (poets!), but I think on reflection the matter is clear enough. The challenge before us is to find a way between, on the one hand, a credulous belief in the views of the establishment, whether that is the Church or in this case the academy, and, on the other, a bitter nihilism that tells us to abandon our endeavours because knowledge is impossible and the establishment does no more than reflect the structures of political power prevailing in its time. However, and wonderfully, the methods of science can and do break down the endless circular movement of constrained institutional thought, and, in spite of all the difficulties, these methods also build up a body of facts and understanding on which two or more minds can agree.

SAGREDO: Ah yes, I think I can accept this; the method yields understanding without the need to invoke any divine or ultimate foundations to knowledge.

SALVIATI: Precisely, but as yet in economics there is a lack of progress academically.

SIMPLICIO: Well! I'm not sure everyone would agree with that.

SALVIATI: Perhaps not, but you have to admit that economics is not a powerfully predictive or technological science yet.

SAGREDO: That would be difficult to dispute, sadly.

SALVIATI: But we need not despair; this book argues that there is a way through.

SAGREDO: That is most encouraging. I'll make a start straightaway; I hope it isn't too difficult.

SALVIATI: Certainly not. The authors told me that their aim is to speak clearly to a very wide range of readers, not just students of physics or economics, but of other fields too. Indeed they hope for many readers outside the world of universities, people in financial institutions and companies and businesses of all kinds and sizes. Everybody in fact who is interested in or practises economics, and that is, I hazard the guess, almost everybody.

SAGREDO: Is there much mathematics? It seems unavoidable.

SALVIATI: Well, you are right that there must be some, but the authors have designed their argument to make it accessible to those with only a basic mathematical training. Complicated mathematical formulae are placed in mathematical boxes, and these are indicated with the icon $\alpha\beta^2$.

SAGREDO: Ah, that will be useful for me; very considerate.

SIMPLICIO: I also notice that there are 'coffee break' boxes marked with the icon ☕, which seem to be tempting digressions from the main subject of the book. These look very interesting, though I still have my doubts about the main thesis of this work.

SALVIATI: Well, that is forgivable since you have yet to read it, and when you do I have no doubt that your mind will throw up many questions as you get to grips with the work. You may find that the dedicated support website for the book, www.econophysics.jp/books/ec, answers some of these. There is a great deal of additional information there, and of course you can contact the authors too.

SAGREDO: Splendid, then let us meet again when we have read the book, and formed our opinions of it. Salviati, Simplicio.

SALVIATI: But first, shall we remind ourselves of the ubiquity of economic activities in our daily lives by dropping in to this pleasant-looking inn and purchasing some refreshment before you return to your studies?

SIMPLICIO: For once, Salviati, you have said something with which I can wholeheartedly and completely agree. I do believe it is my turn, and fortunately I have my wallet with me.

Contents