New Economic Windows

Ji-Ping Huang

Experimental Econophysics

Properties and Mechanisms of Laboratory Markets

Springer

Experimental Econophysics

New Economic Windows

Series editors

Marisa Faggini, Mauro Gallegati, Alan P. Kirman, Thomas Lux

Series Editorial Board

Jaime Gil Aluja
Departament d'Economia i Organització d'Empreses, Universitat de Barcelona, Barcelona, Spain
Fortunato Arecchi
Dipartimento di Fisica, Università degli Studi di Firenze and INOA, Florence, Italy
David Colander
Department of Economics, Middlebury College, Middlebury, VT, USA
Richard H. Day
Department of Economics, University of Southern California, Los Angeles, USA
Steve Keen
School of Economics and Finance, University of Western Sydney, Penrith, Australia
Marji Lines
Dipartimento di Scienze Statistiche, Università degli Studi di Udine, Udine, Italy
Alfredo Medio
Dipartimento di Scienze Statistiche, Università degli Studi di Udine, Udine, Italy
Paul Ormerod
Directors of Environment Business-Volterra Consulting, London, UK
Peter Richmond
School of Physics, Trinity College, Dublin 2, Ireland
J. Barkley Rosser
Department of Economics, James Madison University, Harrisonburg, VA, USA
Sorin Solomon Racah
Institute of Physics, The Hebrew University of Jerusalem, Jerusalem, Israel
Pietro Terna
Dipartimento di Scienze Economiche e Finanziarie, Università degli Studi di Torino, Torino, Italy
Kumaraswamy (Vela) Velupillai
Department of Economics, National University of Ireland, Galway, Ireland
Nicolas Vriend
Department of Economics, Queen Mary University of London, London, UK
Lotfi Zadeh
Computer Science Division, University of California Berkeley, Berkeley, CA, USA

More information about this series at http://www.springer.com/series/6901

Ji-Ping Huang

Experimental Econophysics

Properties and Mechanisms of Laboratory Markets

Springer

Ji-Ping Huang
Department of Physics
Fudan University
Shanghai
China

ISSN 2039-411X ISSN 2039-4128 (electronic)
New Economic Windows
ISBN 978-3-662-44233-3 ISBN 978-3-662-44234-0 (eBook)
DOI 10.1007/978-3-662-44234-0

Library of Congress Control Number: 2014944720

Springer Heidelberg New York Dordrecht London

© Springer-Verlag Berlin Heidelberg 2015
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

I feel obliged to say something in the preface, in an attempt to help the reader love the book, regardless of whether he/she chooses to read the book fortunately or unfortunately. This preface contains five parts. Let me start in the first part about my beloved physics.

Physical Methods Make Physics Mature

From Aristotle (384–322 B.C.) to the time before G. Galilei (February 15, 1564–January 8, 1642), physics was developed mainly on the basis of empirical analysis (observations), which offered correlations (namely relationships involving dependence). Owing to G. Galileo, the situation was significantly changed because he brought controlled experiments into the research of physics. This approach directly reveals cause and effect, which represents a deeper understanding than the correlation brought by empirical analysis. Next, it was I. Newton (December 25, 1642–March 20, 1726) who realized the necessity of introducing the tool of theoretical analysis (based on mathematics) to generalize the results obtained from both empirical analysis and controlled experiments. As a result, physics developed much faster than before, and currently physics has already become a mature discipline.

Physical Methods Might Help Econophysics to Grow Up

The historical route of developing physics sheds light on how to develop econophysics (even though econophysics is only a branch of physics, at least to physicists like me). In fact, if we compare physics with econophysics, we can find a similar route. In the mid-1990s, econophysics got its own name and started to board the stage of history as a new research direction (certainly, I also agree that researches within the scope of econophysics appeared much earlier than the mid-1990s, but at that time, the word "econophysics" was not yet coined). Since then, studies on econophysics have been mainly based on empirical analysis (as well as agent-based simulations, especially after the birth of the minority game in 1997 [1]; these simulations are used to understand empirical observations). Since the last decade, the situation has been updated by introducing controlled experiments into econophysics, say, the study of the minority game [2–4], political exchange for election outcome prediction [5, 6], the market-directed resource-allocation game [7–10], and a laboratory stock market [11]. In the early stage of introducing controlled experiments [2–4], controlled human experiments (which will be simply called "controlled experiments" throughout this book) were purely performed to yield new results. However, such human experiments often have unavoidable limitations such as specific subjects with specific identities in specific avenues at specific time. Thus, it becomes somehow difficult to generalize the results obtained from controlled experiments. To overcome these limitations and also to achieve more results (that cannot even be obtained from pure human experiments due to the lack of resources like time, money, and/or human subjects), since 2009 [7], my group has introduced a combination method of empirical analysis, controlled experiments, and theoretical analysis (based on agent-based simulations and/or analytical theory) [7–10] into the research of econophysics. Owing to the big success of the combination approach in physics, we expect more from the combination method in the field of econophysics. Because controlled experiments play the most important role in the combination approach, I call the econophysics related to the controlled experiments as *Experimental Econophysics*, which is the topic of this book.

To benefit the reader, a few well-known scholars have published several elegant English monographs on econophysics:

- R.N. Mantegna and H.E. Stanley, An Introduction to Econophysics, Cambridge University Press (2000);
- N.F. Johnson, P. Jefferies, and P.M. Hui, Financial Market Complexity, Oxford University Press (2003);
- J. Voit, The Statistical Mechanics of Financial Markets (3rd edition), Springer (2005);
- D. Challet, M. Marsili, and Y.-C. Zhang, Minority Games: Interacting Agents in Financial Markets, Oxford University Press (2005).

However, these monographs have not touched the field of experimental econophysics. So, the present book in your hand would be the first English monograph on *Experimental Econophysics*. I hope it will help to foster the development of econophysics, at least to some extent.

Peer Responses to Experimental Econophysics

What is experimental econophysics in the eyes of econophysicists? I prefer to answer this question as below.

From May 31 to June 2, 2014, I attended the International Conference on Econophysics (ICE2014) in Shanghai, China. During the ICE2014, I presented an invited talk, entitled "Experimental Econophysics: A laboratory market for modeling real stock markets." The talk presented both my key thoughts on experimental econophysics and the content of Chap. 3 of this book. Surprisingly, the audience appreciated this talk very much, and evoked much stronger repercussions than what I had expected. As a result, during or after my talk, many scholars (including Prof. R.N. Mantegna of the University of Palermo in Italy) had great interest to discuss with me the controlled experiments conducted by my group. In particular, on June 4, 2014, Prof. D. Sornette of ETH Zurich in Switzerland, who is both a chairman of ICE2014 and a leading worldwide expert in the field of econophysics, also emailed me:

> "I like very much your presentation at ICE2014. I would be glad if you could send me your presentation in pdf format. I would also appreciate receiving your papers that you listed, especially the ones on your lab experiments."

Such peer appreciation implies that experimental econophysics, coined by me, has had a good start. Nevertheless, a good start does not mean a good ending; to achieve the latter, we must do much better.

Who Should Read This Book?

One of my dreams, which are genuine dreams beyond reality, is to let this book attract a huge number of readers. So, the dream is as follows.

On one hand, everyone who has an interest in physics should read this book because it guides him/her to know how to develop statistical physics into the field of economics or finance.

On the other hand, everyone who has an interest in economics or finance should read this book because it helps him/her know of economic or financial problems from a different perspective.

The word "everyone" appearing in the above two paragraphs should include undergraduate students, graduate students, teachers in universities, and researchers in universities, institutes or industries, who are working in the field related to physics, economics/finance, complexity science, artificial intelligence, management science, sociology, ecology, or evolutionary biology.

Acknowledgments

First, I take this opportunity to express my gratitude to some of my group members for their great help in preparing some parts of the book. The details are as follows.

- Chapter 2: Mr. K.N. An, Mr. X.H. Li, Mr. C. Xin, and Mr. G. Yang;
- Chapter 4: Mr. C.G. Zhu, Mr. K.N. An, and Mr. G. Yang;
- Chapter 7: Dr. Y. Liang and Mr. K.N. An;
- Chapter 9: Mr. X.H. Li, Mr. G. Yang, and Mr. K.N. An;
- Chapter 12: Ms. L. Liu;
- Bibliography: Mr. G. Yang.

Besides, I have completed the other chapters according to the articles published by my group. So, I must also thank all the other group members who coauthored these articles. In addition, all my current group members have also helped to look over the whole book and relay to me many constructive comments and suggestions, which are appreciated very much. Below is the name list of my current group members: Dr. X.W. Meng, Miss T. Qiu, Mr. G. Yang, Mr. X.H. Li, Miss L. Liu, Mr. C.G. Zhu, Mr. X.Y. Shen, Mr. G.X. Nie, Mr. H.S. Zhang, Mr. K.N. An, Miss Y.X. Chen, Mr. C. Xin, Miss F.F. Gu, and Mr. Q. Ji.

Second, for completing the book I have profited from valuable and stimulating collaborations and discussions with Prof. H.E. Stanley of Boston University, Prof. Y.-C. Zhang of Fribourg University, Prof. B.H. Wang of The University of Science and Technology of China, Prof. P.M. Hui of The Chinese University of Hong Kong, and Dr. Yu Chen of Tokyo University.

Third, I am so grateful to Prof. R.B. Tao and Prof. B.L. Hao of Fudan University for encouraging me to conduct econophysics in the Department of Physics at Fudan University. As the two professors are senior and experienced, their encouragement means a lot to me.

Fourth, I am indebted to my family members, especially two daughters (Ji-Yan Huang with the nickname of Qian-Qian and Ji-Yang Huang with the nickname of Yue-Yue), for their support when I spent many nights preparing the book, rather than accompanying them.

Last but not least, I acknowledge the financial support by the National Natural Science Foundation of China under Grant Nos. 11075035 and 11222544, by the Fok Ying Tung Education Foundation under Grant No. 131008, by the Program for New Century Excellent Talents in University (NCET-12-0121), by the Shanghai Rising-Star Program (No. 12QA1400200), and by Shanghai Key Laboratory of Financial Information Technology (Shanghai University of Finance and Economics).

Shanghai, China, June 2014 Ji-Ping Huang

Contents

Abstract

Experimental Econophysics describes the method of controlled human experiments, which is developed by physicists to study problems in economics or finance, namely stylized facts, fluctuation phenomena, herd behavior, contrarian behavior, hedge behavior, cooperation, business cycles, partial information, risk management, and stock prediction. Experimental econophysics along with empirical econophysics are two branches in the field of econophysics. The latter has been extensively discussed in the existing literature, while the former has been seldom touched. In this book, the author focuses on the branch of experimental econophysics. Empirical econophysics is based on the analysis of data in real markets using statistical tools borrowed from traditional statistical physics. Differently, inspired by the role of controlled experiments and system modeling (for computer simulations and/or analytical theory) in developing modern physics, experimental econophysics specifically relies on controlled human experiments in the laboratory (producing data for analysis) together with agent-based modeling (for computer simulations and/or analytical theory), with an aim to reveal the general cause–effect relationship between specific parameters and emergent properties of real economic/financial markets. This book covers the basic concepts, experimental methods, modeling approaches, and latest progress in the field of experimental econophysics.

Chapter 1
Introduction

Abstract In this chapter, I attempt to offer a general background of experimental econophysics, the theme of the book. For this purpose, I start by answering some fundamental questions. That is, why does physics need economics or finance, and vice versa? What are physical ideas or methods? Then, I introduce both the birth of econophysics and the two branches of econophysics (namely, empirical econophysics and experimental econophysics). Finally, I present the methodology of experimental econophysics.

Keywords Experimental econophysics · Physical idea · Physical method · Controlled experiment

It might be a kind of human inability that a single scientist cannot research on *all* the aspects of the nature and society. Owing to the human inability, science has been divided into many disciplines, e.g., mathematics, physics, chemistry, biology, economics/finance, and so on. As a result, specific researchers always work in the field of a specific discipline. For example, the researchers, under the name of physicists, work in the specific field of physics. After a longtime separation between physics and economics/finance, now the time is ripe for their combination, so that they could help each other to develop, at least to some extent.

1.1 Why Physics Needs Economics or Finance?

If one counts from G. Galilei (February 15, 1564–January 8, 1642), physics, the study of nature, has been developing for 400 years or so. This duration is not very long compared to the millions of years for which humans have lived on earth. However, everyone has witnessed the significant changes in human life brought about by physics, such as electricity, computers, mobile phones, artificial satellites, utilization of nuclear energy, and so on. All of these changes are an outcome of the physical knowledge of the natural world. According to this fact, it is no doubt that the ideas and methods of physics are useful to handle the natural world. Here, the natural world means it contains non-intelligent units that have no adaptability due to the lack of learning ability. For example, such non-intelligent units are electrons, atoms,

J.-P. Huang, *Experimental Econophysics*, New Economic Windows,
DOI 10.1007/978-3-662-44234-0_1

molecules, colloidal particles, and so on. In sharp contrast to the natural world, the social world is full of intelligent units, which have adaptability due to the existence of learning ability; such intelligent units involve humans, companies (containing many humans), countries, and so on.

Science is always driven by curiosity, and physics is no exception. Inspired by the success of physics in handling the natural world, one might curiously ask whether the ideas and methods originally developed from physics for treating the natural world are also useful for the social world. The answer is definitely in the affirmative. But, the reader might proceed to ask: "what do you mean by saying the ideas and methods originally developed from physics for treating the natural world?" or "what are physical ideas and methods?"

1.1.1 What Are Physical Ideas?

1.1.1.1 Extracting Reasons Should be Coarse-Grained

Let me take the freely falling object as an example. The number of reasons determining falling height could be based on N: time, air resistance, atmospheric pressure, humidity, etc. However, G. Galilei (February 15, 1564–January 8, 1642) neglected the $N-1$ reasons and considered only the relation between falling height (h) and time (t), yielding $h = (1/2)gt^2$. Here, g is acceleration (a constant). As a result, he established the law of free fall, which helped I. Newton (December 25, 1642–March 20, 1726) to successfully establish classical mechanics in the discipline of physics. Based on this law, the first idea of physics comes to appear: one should extract crucial reasons, or equivalently *extracting reasons should be coarse-grained*.

1.1.1.2 Results Obtained Should Be Universal

After Galilei's $h = (1/2)gt^2$, I. Newton (December 25, 1642–March 20, 1726) revealed his second law, $F = ma$, where F is force, m is mass, and a is acceleration. This second law helps to explain not only the freely falling object on the earth (by setting $a = g$ and seeing F as gravity), but also the planetary motion in the sky (that had been empirically summarized in the laws of planetary motion by J. Kepler (December 27, 1571–November 15, 1630)). Besides, Newton's second law can even be used to predict new phenomena. For example, on August 31, 1846, U. Le Verrier (March 11, 1811–September 23, 1877) first predicted the existence and position of Neptune using Newton's second law plus Newton's law of gravity; Neptune was subsequently observed on September 23, 1846, by J. G. Galle (June 9, 1812–July 10, 1910) and H. L. d'Arrest (August 13, 1822–June 14, 1875). The success of Newton's second law indicates the second idea of physics, which is "results obtained should be universal." Here, "universal" means that the results should not only help to explain the existing phenomena, but also help to predict the future or unknowns.

1.1.2 What Are Physical Methods?

1.1.2.1 Empirical Analysis

From Aristotle (384–322 BC) to J. Kepler (December 27, 1571–November 15, 1630), physicists first observed the natural world and then analyzed the observations, yielding many empirical results, such as Kepler's laws of planetary motion. Such analysis is simply empirical analysis, which is based on existing data in nature.

Advantages of empirical analysis: reliability and huge data. Here, "reliability" means that according to the data collected from nature itself, any results obtained from the data should be reliable; "huge data" means that the number of data in nature is huge, which is definitely helpful for understanding the natural world.

Disadvantages of empirical analysis: uncontrollability (correlation) and non-formatting. Since the data are collected from nature, they are always uncontrollable. Then, what empirical analysis can produce is correlation but not causality. Clearly, causality represents a deeper understanding than correlation. Regarding "non-formatting," it is easy to understand that: the format of data existing in nature is not fixed but dependent on how people collect them. The non-formatting of data causes trouble for people to investigate.

1.1.2.2 Controlled Experiments

Since empirical analysis helps to reveal correlation rather than causality, G. Galilei (February 15, 1564–January 8, 1642) started to perform experiments in the laboratory by purposefully tuning one or a few parameters/conditions (all the other parameters/conditions are fixed) in order to reveal cause–effect relationships (causality). His method was that of controlled experiments.

Advantages of controlled experiments: controllability (causality) and formatting. These are the inverse of the above-mentioned disadvantages of empirical analysis. Such experiments are controllable because one can tune a variable and see its effect (causality). As regards "formatting," it means the format of data could be conveniently organized during the experiment.

Disadvantages of controlled experiments: deviations and few data. Since such experiments are conducted in the laboratory, the experimental data may be different from their counterparts in nature. This difference is what we term as "deviations." On the other hand, the experimental data produced in the laboratory cannot be huge, as one can easily imagine. Thus, I indicate "few data" herein.

1.1.2.3 The Combination of Empirical Analysis, Controlled Experiments, and Theoretical Analysis

Due to the above-mentioned advantages and disadvantages of either empirical analysis or controlled experiments, I. Newton (December 25, 1642–March 20, 1726) combined both empirical analysis and controlled experiments; for instance, when he explained Kepler's laws of planetary motion (outcome of empirical analysis), he also explained Galilei's law of free fall (outcome of controlled experiments). The combination of empirical analysis and controlled experiments reserves their advantages, but removes their disadvantages. More importantly, Newton also realized that the combination of empirical analysis and controlled experiments can produce results only for specific areas: empirical analysis corresponds to the specific objects producing empirical data (e.g., Kepler's laws of planetary motion are only valid for planets); controlled experiments are related to specific laboratory samples/devices producing experimental data (e.g., Galilei's law of free fall specifically holds for the freely falling object in the laboratory). As a result, Newton utilized theoretical analysis (based on mathematics like calculus) to generalize the results (obtained from the combination of empirical analysis and controlled experiments) from specific areas to broad areas. For example, his second law ($F = ma$) helps to explain not only the motion of either planets (described by Kepler's laws of planetary motion) or freely falling objects (described by Galilei's law of free fall), but also the motion of many other objects, including a single molecule. Owing to the unprecedent success of this generalization (which is proved by the fact that physics has significantly improved human life), the method of combining empirical analysis, controlled experiments, and theoretical analysis has become the fundamental method for developing physics. Certainly, in reality, it is already enough for achieving some excellent results by using only one or two of empirical analysis, controlled experiments, and theoretical analysis. This fact depends on specific topics, for e.g., in modern condensed matter physics, where empirical analysis is hardly used. However, in modern astrophysics, controlled experiments are rare. It is not necessary for me to go into details here. In principle, the above-mentioned combination is an ideal, complete method.

So far, I have answered the question "what are physical ideas and methods?"

Last but not least, even though physics has helped to significantly improve human life due to the deep understanding of the natural world using the above-mentioned physical ideas and methods, it might be not suitable for people to immediately expect too much when physical ideas and methods are used to understand the social world. Why? Please note many of the above-listed applications brought about by physics are not a direct purpose of original research. For example, when M. Faraday (September 22, 1791–August 25, 1867) discovered the law that magnetism is able to produce electricity, he did not know whether it would be genuinely useful to humans. The reason he conducted the research was due only to curiosity. In fact, in history, the large-scale application of electricity only started at the end of the nineteenth century when Faraday had passed away for many years. This means people must be patient to wait for the application of a physical discovery as physicists need time to study.

In other words, the reason that physics needs economics/finance lies in the curiosity of physicists, which may broaden the realm of physics, especially statistical physics.

1.2 Why Economics or Finance Needs Physics?

Briefly speaking, economics is a discipline on how to allocate scarce resources efficiently. Since the time of A. Smith (June 5, 1723–July 17, 1790), economics has developed for more than 200 years. In the duration, mathematics was introduced into economics, thus causing economics to be a quantitative discipline. Because the subject discussed in the field of economics is human-activities-related phenomena in the social world, which is too complex, economics is still far from perfect. For example, existing economic theories fail to envisage even the possibility of a financial crisis like the recent one [12]. Thus, economics needs different ideas or methods in an attempt to perfect itself. Physics may be a candidate discipline for economics to absorb such ideas and methods. In this sense, economics needs physics so that people might scrutinize economic problems from a different perspective, thus yielding different insights. Certainly, economics can also resort to ideas or methods that are beyond physics, e.g., evolutionary biology.

The above conclusion also holds for finance. As regards finance, its relation to economics is similar to the relation between applied physics and basic physics. That is, finance focuses on application research, but economics focuses on basic research. For example, if a seller sells a pen at a price of 1 Chinese Yuan, the exchange behavior between me and the seller belongs to finance, but the reason that the pen costs 1 Chinese Yuan rather than 100 Chinese Yuan belongs to economics. Nevertheless, throughout this book, I do not sperate economics and finance distinctly because both are closely related to the trading behavior of humans.

1.3 Physics + Economics or Finance → Econophysics

Physics meets economics or finance, yielding econophysics (the wording "econophysics" first appeared in the literature as early as 1996 [13]). According to the above, econophysics is a branch of physics (at least in the eye of physicists like me), which uses physical ideas and methods (listed in Sect. 1.1) to analyze problems related to economics and finance. Loosely speaking, econophysics is what physicists do in the field of economics or finance since these physicists are naturally armed with physical ideas and methods. To briefly summarize the above, the aim of econophysicists could be at least twofold: first, to broaden the realm of traditional physics (throughout this book, the phrase "traditional physics" means the physics that is used to study nature with non-intelligent units like atoms, rather than the society with intelligent units like humans), especially statistical physics, second, to scrutinize economic or financial problems from a physical perspective.

1.4 Dividing Econophysics into Two Branches: Empirical Econophysics and Experimental Econophysics

In general, econophysics contains three methods: empirical analysis (starting from the articles by H. E. Stanley and coworkers in the mid-1990s, see for example Ref. [14]), controlled experiments (starting as early as 2003 by T. Platkowski and M. Ramsza [2]), and theoretical analysis (starting from the establishment of minority game in 1997 by Challet and Zhang [1]). Here, empirical analysis in the field of econophysics is based on existing data in real markets, and controlled experiments mean experiments conducted in the laboratory which produce data by tuning one (or few) variable(s)/condition(s). The theoretical analysis in the field of econophysics is based on agent-based modeling (or system modeling), which has two approaches: agent-based simulations (also called computer simulations) and analytical theory. Agent-based simulations have helped to develop econophysics significantly, which are an analog of molecular dynamics simulations [15], Monte Carlo simulations [16], or finite element simulations [17, 18] in traditional physics. According to traditional physics, for analytical theory, one needs to start from some common laws or principles that are often lacking in social human systems (the research object of econophysics). Thus, compared with agent-based simulations, analytical theory has not played a very important role in econophysics.

Since the birth of econophysics in the mid-1990s [13], empirical analysis has dominated the research community of econophysics till now, which forms a branch of econophysics called empirical econophysics. However, as a discipline, econophysics is still too young, with vast development space. As one knows, the maturity of traditional physics is mainly due to the role of controlled experiments in the laboratory. Accordingly, it seems unbelievable that in the future, econophysics without controlled experiments could be as mature as traditional physics. Thus, I believe that for developing econophysics in a healthy manner, econophysicists must resort to controlled experiments. In this sense, for the time being, to emphasize the importance of controlled experiments, I suggest a different branch in econophysics, i.e., experimental econophysics, which mainly focuses on controlled experiments in the laboratory. Accordingly, in this book, econophysics is divided into two branches: empirical econophysics and experimental econophysics.

Clearly, the above two branches are divided according to the two different methods. It is worth noting that in the above paragraph, I did not mention theoretical analysis. But, for physicists like me, these simulations must be used to understand either empirical data (in real markets) or experimental data (in laboratories). So, for understanding empirical data, theoretical analysis is only a supplementary tool in empirical econophysics. On the other hand, for mainly understanding experimental data, theoretical analysis serves as an additional tool in experimental econophysics.

The focus of this book is experimental econophysics [19]. Regarding empirical econophysics, I refer the reader to some excellent monographs [14, 20–22] and reviews [23, 24]. If the reader can read Chinese, I would also recommend him/her to read two relevant monographs in Chinese [25, 26].