An Introduction to Econophysics

This book concerns the use of concepts from statistical physics in the description of financial systems. Specifically, the authors illustrate the scaling concepts used in probability theory, in critical phenomena, and in fully developed turbulent fluids. These concepts are then applied to financial time series to gain new insights into the behavior of financial markets. The authors also present a new stochastic model that displays several of the statistical properties observed in empirical data.

Usually in the study of economic systems it is possible to investigate the system at different scales. But it is often impossible to write down the 'microscopic' equation for all the economic entities interacting within a given system. Statistical physics concepts such as stochastic dynamics, short- and long-range correlations, self-similarity and scaling permit an understanding of the global behavior of economic systems without first having to work out a detailed microscopic description of the same system. This book will be of interest both to physicists and to economists. Physicists will find the application of statistical physics concepts to economic systems interesting and challenging, as economic systems are among the most intriguing and fascinating complex systems that might be investigated. Economists and workers in the financial world will find useful the presentation of empirical analysis methods and well-formulated theoretical tools that might help describe systems composed of a huge number of interacting subsystems.

This book is intended for students and researchers studying economics or physics at a graduate level and for professionals in the field of finance. Undergraduate students possessing some familarity with probability theory or statistical physics should also be able to learn from the book.

Dr Rosario N. Mantegna is interested in the empirical and theoretical modeling of complex systems. Since 1989, a major focus of his research has been studying financial systems using methods of statistical physics. In particular, he has originated the theoretical model of the truncated Lévy flight and discovered that this process describes several of the statistical properties of the Standard and Poor's 500 stock index. He has also applied concepts of ultrametric spaces and cross-correlations to the modeling of financial markets. Dr Mantegna is a Professor of Physics at the University of Palermo.

Dr H. Eugene Stanley has served for 30 years on the physics faculties of MIT and Boston University. He is the author of the 1971 monograph *Introduction to Phase Transitions and Critical Phenomena* (Oxford University Press, 1971). This book brought to a much wider audience the key ideas of scale invariance that have proved so useful in various fields of scientific endeavor. Recently, Dr Stanley and his collaborators have been exploring the degree to which scaling concepts give insight into economics and various problems of relevance to biology and medicine.

AN INTRODUCTION TO ECONOPHYSICS
Correlations and Complexity in Finance

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Contents

Preface

Physicists are currently contributing to the modeling of 'complex systems' by using tools and methodologies developed in statistical mechanics and theoretical physics. Financial markets are remarkably well-defined complex systems, which are continuously monitored – down to time scales of seconds. Further, virtually every economic transaction is recorded, and an increasing fraction of the total number of recorded economic data is becoming accessible to interested researchers. Facts such as these make financial markets extremely attractive for researchers interested in developing a deeper understanding of modeling of complex systems.

Economists – and mathematicians – are the researchers with the longer tradition in the investigation of financial systems. Physicists, on the other hand, have generally investigated economic systems and problems only occasionally. Recently, however, a growing number of physicists is becoming involved in the analysis of economic systems. Correspondingly, a significant number of papers of relevance to economics is now being published in physics journals. Moreover, new interdisciplinary journals – and dedicated sections of existing journals – have been launched, and international conferences are being organized.

In addition to fundamental issues, practical concerns may explain part of the recent interest of physicists in finance. For example, risk management, a key activity in financial institutions, is a complex task that benefits from a multidisciplinary approach. Often the approaches taken by physicists are complementary to those of more established disciplines, so including physicists in a multidisciplinary risk management team may give a cutting edge to the team, and enable it to succeed in the most efficient way in a competitive environment.

This book is designed to introduce the multidisciplinary field of econophysics, a neologism that denotes the activities of physicists who are working

on economics problems to test a variety of new conceptual approaches deriving from the physical sciences. The book is short, and is not designed to review all the recent work done in this rapidly developing area. Rather, the book offers an introduction that is sufficient to allow the current literature to be profitably read. Since this literature spans disciplines ranging from financial mathematics and probability theory to physics and economics, unavoidable notation confusion is minimized by including a systematic notation list in the appendix.

We wish to thank many colleagues for their assistance in helping prepare this book. Various drafts were kindly criticized by Andreas Buchleitner, Giovanni Bonanno, Parameswaran Gopikrishnan, Fabrizio Lillo, Johannes Voigt, Dietrich Stauffer, Angelo Vulpiani, and Dietrich Wolf.

Jerry D. Morrow demonstrated his considerable TEX skills in carrying out the countless revisions required. Robert Tomposki's tireless library research greatly improved the bibliography. We especially thank the staff of Cambridge University Press – most especially Simon Capelin (Publishing Director in the Physical Sciences), Sue Tuck (Production Controller), and Lindsay Nightingale (Copy Editor), and the CUP Technical Applications Group – for their remarkable efficiency and good cheer throughout this entire project.

As we study the final page proof, we must resist the strong urge to re-write the treatment of several topics that we now realize can be explained more clearly and precisely. We do hope that readers who notice these and other imperfections will communicate their thoughts to us.

Rosario N. Mantegna

H. Eugene Stanley

To Francesca and Idahlia