PATTERNS OF SPECULATION
A STUDY IN OBSERVATIONAL ECONOPHYSICS

The collective behavior of economic agents during speculative episodes provides the foundations of this book. Such moments are marked by a special atmosphere of optimism and confidence in the future, which permeates the entire market and society as a whole. Exuberance, ebullience, and bullish are some of the expressions used to describe the up-going phase; whilst words such as uncertainty, fear, contraction and bearish characterize the subsequent down-going phase.

Much as Newton's discovery of universal gravitation could not have derived solely from observing falling apples (despite anecdotal evidence to the contrary), speculative bubbles also require the study of various episodes in order for a comparative perspective to be obtained. The analysis developed in this book follows a few simple but unconventional ideas. Investors are assumed to exhibit the same basic behavior during a speculative episode whether they trade stocks, real estate, or postage stamps. This idea is crucial for setting up a comparative approach. The main objective of this book is to show that behind the bewildering diversity of historical episodes it is possible to find hidden regularities, thus preparing the way for a unified theory of speculation. A theoretical framework is presented in the final chapters, which show how some basic concepts of dynamical system theory, such as the notions of impulse response, reaction times, and frequency analysis, play an instrumental role in describing and predicting various forms of speculative behavior.

Much of the text is written at a level that does not require a background in the technical aspects of economics, finance, or mathematics. It will therefore serve as a useful primer for undergraduate and graduate students of econophysics, and indeed for any reader with an interest in economics as seen from the perspective of physics.

A theoretical physicist by education, Bertrand M. Roehner has been investigating social and economic phenomena during the past 15 years. He is the author of *Theory of Markets* (1995), which explored the space-time structure of commodity prices, and also of *Hidden Collective Factors in Speculative Trading* (2001). The approach used in these books demonstrates how the observational strategy invented by physicists, and successfully applied in astrophysics and biophysics, can be fruitfully applied in the social sciences as well. Professor Roehner has been a visiting scholar at the Harvard Department of Economics (1994 and 1998) and at the Copenhagen Institute of Economics (1996), and he currently serves on the physics faculty of the University of Paris VII.

The great progress in every science came when, in the study of problems which were modest as compared with ultimate gains, methods were developed which could be extended further and further. The free fall is a very trivial physical example, but it was the study of this exceedingly simple fact and its comparison with astronomical material which brought forth mechanics. It seems to us that the same standard of modesty should be applied in economics.

John Von Neumann and Oskar Morgenstern (1953)

Can economics be reconstructed as an empirical science?

Wassily Leontief (1993)

It is a capital mistake to theorise before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.

Sir Arthur Conan Doyle (1910)

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Preface

In the past four years econophysics has become a very popular field among young physics graduates. In discussions I have had with a number of them who visited me I was struck by the fact that for most if not all of them the main objective seemed to be the construction of a (possibly unified) theory. Usually my reaction was to point out that this is precisely what most economists have been trying to do in the past decades and that one of the reasons which may explain their little success was probably the meagerness and inadequacy of the body of evidence on which these theories were erected. In truth, the conviction of these students simply reflected what physics had become in the second half of the twentieth century, namely a highly successful but also strongly structured and more and more theoretically oriented science. It is symptomatic of that trend that some of the most advanced researches concern grand unification and string theories, that is to say two fields which have (so far) little connection with experimental evidence.

Fortunately the "first generation" of econophysics mostly came from statistical physics, a field in which there is a closer link between theoretical and experimental work. On average at previous econophysical conferences at least 80 percent of the models were compared to some kind of statistical evidence. Such a comparison can be made in different ways however. In the early days of thermodynamics a number of basic experiments (such as those by Joule or Boyle) provided firm guide lines and foundations for the establishment of that new science. However, for many advanced modern theories of critical phenomena the theory was developed in an autonomous way and contact with experimental evidence was restricted to a small number of stylized facts. Not surprisingly, a similar methodological divide is also to be found in econophysics.

When a stochastic model of stock price fluctuations is able to reproduce many of the statistical properties of actual price returns this is certainly of importance from the perspective of predictive econometric models, but it gives little information about the possible mechanisms of speculative price peaks. That point can be

illustrated by drawing on an analogy with meteorology. A stochastic description of the statistical properties of wind velocities would certainly be almost as difficult to build as one for stock prices, for in both cases there is a mix of short-term fluctuations and large but rare outliers. However, even if we assume that one is able to build a model that can satisfactorily describe the main statistical properties of high-frequency wind data, such a model would give us little understanding about the basic mechanisms that govern wind patterns, such as for instance the Coriolis effect (i.e. the deviation of wind directions to the right in the northern hemisphere). In order to unravel that facet of the phenomenon one would have to compare the pressure field with wind directions at several spatially separated locations. Once observation has established that wind directions are parallel (and not orthogonal) to isobars, one can set out to find a theoretical explanation for that puzzling fact. This, in a nutshell, is the approach that we use in the present book. In short, it should not be considered as a study in theoretical econophysics but rather as an investigation in what may be called "observational" econophysics. In that sense it complements previously published books in econophysics. I prefer the term "observational" to the term "empirical" because it conveys the idea that the objective is not just to collect statistical data but to conduct a series of investigations; in the words of Claude Bernard "the idea must lead the observation."

Needless to say, not all meteorological regularities are as simple and accurately verified as the Coriolis effect. Some effects (such as the formation of tornadoes) depend upon special circumstances, or even on the so-called "butterfly effect"; others are complex phenomena that can hardly be unravelled at a stroke. In the present study we will encounter the same difficulties. Very often it is by decomposing a complex phenomenon into simpler components that we are able to bring in some new light; that analytical methodology plays a crucial role in the present study.

In short, what our approach borrows from physics is a strategy regarding the way observational research should be conducted. Transposed to the social sciences that strategy has important implications: (i) all phenomena will be considered in a comparative perspective; (ii) great efforts will be devoted to find meaningful empirical regularities; and (iii) then, and only then, we will in the last chapters propose a theoretical framework.

Seen with the eyes of a physicist stock markets appear as one of the most tricky problems one can imagine. Indeed, stock price fluctuations result from a fairly complex set of interactions between a large number of agents, as illustrated by the following circumstances which make the problem particularly difficult: (i) There are several sorts of agents, e.g. market makers, short-term traders, and long-term investors, such as mutual fund shareholders, and each class is characterized by specific forms of behavior and characteristic times. There are even different sorts of stocks: growth stocks (for which capital gains are expected) and value stocks

(for which substantial dividends are expected) which may have completely different behavior patterns. Thus in 1999 American growth stocks outperformed value stocks by 27 percent, while in 2000 value stocks outperformed growth stocks by 30 percent. (ii) The range, characteristic time and other parameters of the interactions between agents are largely unknown. (iii) A substantial number of the statistical data that would be required are deemed confidential and are not made public. (iv) Stock markets are closely connected to other financial markets, such as the bond, exchange-rate, or real estate markets.

In short, from the point of view of statistical physics, stock markets constitute an open, out of equilibrium system, which involves different sorts of particles and interactions. In addition, because the rules of the market change in the course of time, the whole system is structurally time dependent. This inauspicious picture can once again be illustrated by drawing on the parallel with meteorology. The undertaking is similar to the challenge faced by somebody who tries to build a global meteorological model without knowing the basic laws which govern the interaction of air and water masses – e.g. Boyle's law or the Navier–Stokes equations – and who would, therefore, have to derive them solely from meteorological observations.

When it comes to stock market bubbles the perspective for a theory is even less promising. For the sake of illustration one can consider an analogy with a flood in the Rhone valley. Several circumstances contribute to such a flood: how much snow there is in the Alps, how fast it melts, how much rain fell in the Massif Central, etc. All these factors are more or less unrelated and it is their conjunction which provokes major floods. This makes the construction of a causal theory very difficult. Now, replace water by money; more specifically look at the snow in the Alps as representing the quantity of money in pension funds. In this case the melting of the snow represents the regulation enacted in the United States in the 1970s, which made it easier for pension funds and insurance companies to invest in stocks. Using the same parallel, the rain in the Massif Central would represent venture capital raised in order to support a major technological breakthrough like the Internet. The overall result would be an outstanding stock market bubble. Because the previous factors are largely unrelated a causal theory would be very difficult to build. For coming years the prospect of equity markets depends considerably on whether the American administration will permit Social Security funds to be invested in stocks. This move was initiated in the late days of the Clinton administration, but whether or not it will be implemented is a question for the political scientist, not for the economist or econophysicist.

In short, although fascinating from a historical perspective, the question of stock market bubbles is largely an ill-defined topic for the purpose of scientific investigation, at least if one wants to answer the question "why?" (in this book we rather focus on the "how?" problem).

Far from being discouraging a clear assessment of the difficulty of the task has a number of positive implications for the present study: (i) Instead of restricting my investigation of speculative phenomena to stock markets, I will also consider other speculative markets, such as the markets for real estate, commodities, postage stamps, or antiquarian books. In many respects these markets are simpler than stock markets; for instance they are less open, less structurally time dependent, and involve only one or two types of investors. (ii) Instead of trying to develop a global predictive model I will focus on specific regularities which seem to shape speculative phenomena. By concentrating on the question "how?" the present study prepares the way for a more comprehensive theory of speculation. (iii) Because one is confronted to a multifaceted phenomenon, an important preliminary step is to subdivide it into simpler components. In our flood analogy they would, for instance, consist of studying the consequences for the water level in rivers of snow melting. In contrast to major floods, which are rare, the former process occurs every year and one is thus in a much better position to study it statistically. The approach based on the *separate investigation* of the building blocks composing a complex phenomenon will be further discussed in chapter 1.

There is currently a methodological gulf between econophysics and economics, but there is also a deep cultural divide between economics and sociology which goes back to the origins of the two disciplines. The founding fathers of sociology, such as Emile Durkheim (1858–1917) or Vilfredo Pareto (1848–1923), defined the objective of their field as the *comparative* study of *collective* social phenomena. No model of the individual man was presupposed. On the contrary, information about individual behavior was to be derived from the observation of (large-scale) social phenomena. In more recent times that line of research was continued by sociologists such as Karl Deutsch (1912–), Stanley Lieberson (1933–), or Charles Tilly (1929–). In contrast, by adopting as the cornerstone of the discipline the concept of an individual, rational economic agent, economics started with opposite premises. This had the following far-reaching consequences: (i) The primacy of model building over comparative empirical research. Indeed, since the economic agent was supposed "rational" any economic phenomenon could in principle be derived from a set of axioms. As an illustration it can be mentioned that it is almost impossible to publish an empirical paper in an economic journal (for financial journals the situation is less clear-cut). (ii) A lack of interest in collective phenomena which cannot yet be explained in terms of individual behavior. (iii) A tendency either to ignore or to belittle the connection between economic agents and the society in which they live and work.

By stressing the importance of empirical research, by ignoring the academic borderlines between sociology and economics, econophysicists have initiated a transformation which has been recurrently advocated by renowned economists,

such as Clive Granger, Wassily Leontief, or Anna Schwartz. As their recommendations largely fell on deaf ears it became obvious that economics could hardly be reformed from within.

The comparative approach advocated in this book has been used repeatedly in the past, but most often in a fairly unsystematic way. Today, however, thanks to the Internet and to the widespread use of English by statistical agencies all around the world, it has become far easier to collect statistical data from various countries. For instance, it is easy nowadays to download data ranging from real estate prices in Singapore, to office vacancy rates in Houston or assets of equity mutual funds. This represents an historic opportunity for the development of the comparative way in the social sciences. One can hope that in a couple of decades most (non-copyrighted) books will be digitized and made available on line, which would give access to many pre-Internet data as well. In short, the Internet represents a revolution in the social sciences of the same magnitude as observation based on space telescopes in astronomy. In both cases the field of observation is enlarged to unprecedented proportions.

This book summarizes a journey that led me from neutrino physics to the spatial analysis of grain prices, the investigation of Zipf's law, and eventually the study of speculative phenomena. Even if the former topics are only occasionally mentioned in the present book they have necessarily left their mark on my present approach. Even more pivotal was the realization that in economics the main obstacle was not so much the inadequacy of the theories as the lack of definite empirical patterns and regularities. This idea can be illustrated by a personal note. Sometimes colleagues in my department ask my opinion about the topics which should be included into an econophysics curriculum. I guess they expect me to mention the theory of stochastic processes or other subjects in financial mathematics. However, partly because it is my conviction and partly because I am curious to observe my colleagues' reactions, I usually answer: "Well, in my opinion there would be no better preparation to econophysics than to take a course in experimental physics" (as it happens there is indeed in our department an excellent course of that kind). The awareness that observations and facts have to be reshuffled and reorganized before they can be modeled mathematically has guided me throughout the present study.

"Patterns of speculation" could seem to be a vague, catch-all title, but it has the advantage of emphasizing fairly well both the ambition and the limits of my undertaking. The ambition is reflected in the fact that the title does not make any reference to a specific market (e.g. stocks, options, and so on); as a matter of fact my scope includes all markets for which speculative effects can be documented. In short this book argues that there are sufficient similarities between various manifestations of speculation to warrant an all-embracing study. Needless to say, the ultimate objective is to pave the way for a unified theory of speculation.

The word "pattern," on the other hand, emphasizes the limits of the present work. It does not propose a theory of speculation, but if it can convince the reader that such a theory should be possible it will have met its objective. For this purpose we show that behind the bewildering diversity of speculative phenomena there are common regularities. This book describes a number of them, and, even though some are merely qualitative, they are nevertheless of interest in so far as they show that speculative phenomena were not fundamentally different in the nineteenth, twentieth, or twenty-first century. This observation is of fundamental importance, for, if one must propose a new theory every 50 years, economic analysis will be as endless (and hopeless) as the task of Sisyphus.

There are four main parts to this book which, although related, are fairly distinct. The first part presents the main ideas (as seen by the present author) on which are based the econophysical approach to economic phenomena. In particular I emphasize that this approach continues a century-long tradition in empirical and comparative analysis. Biophysics, astrophysics, neurophysics constitute three examples where the approach used by physicists was applied to other fields; as these cases have a much longer historical record than econophysics (biophysics, for instance began in the nineteenth century) it can be of interest to examine these cases more closely in order to identify the factors which brought about their fruitful development. The second and third parts aim to discover qualitative and quantitative regularities in the organization and evolution of speculative markets. The analysis emphasizes that all speculative bubbles are "rational," in the sense that the expectations of investors are consistent with the preconceptions and social climate that prevailed at that time. In other words, the rigid concept of rationality symbolized by the so-called homo economicus will be replaced by an extended concept of *social rationality*. If one looks at speculative bubbles by focusing on social behavior, deep similarities become visible beyond apparently distinct phenomena. In our analysis of qualitative regularities one of our main threads will be the theme of social productivity: many of the changes in the organization of markets came about as an attempt to perform the same function at a smaller social cost. The final part of the book proposes some elements for a theory of speculative price peaks.

The writing of this monograph was an exhilarating journey in the course of which I came to explore many different facets of speculative trading ranging from diamond or postage stamp markets to stock or bond markets. Maybe in some places I have erred; that is almost inevitable if one considers the diversity of the data that needed to be processed. Needless to say, I welcome notification of possible errors or omissions.

Another observation is in order regarding repetitions. Only a few readers will probably read this book throughout, from first to last chapter, and, accordingly,

some useful definitions or arguments have been purposely repeated in different chapters.

In an article published in *Europhysics News*, Peter Richmond (2000) wrote that econophysics "offers both the excitement and bewilderment that must have been felt by the pioneers of thermodynamics or quantum mechanics in previous centuries." This view certainly captures an essential aspect of econophysics, namely the enthusiasm of a small and closely knit community of researchers. From its very beginnings econophysics was, in R. Putnam's terms (2000), endowed with a high level of social capital.

For me this community was of vital importance. Thanks to my contacts with other econophysicists, what would otherwise have been a long and lonely voyage far away from home has become an exciting trip; to all I want to express my sincere gratitude. Together Rosario Mantegna, Luis Amaral, and Gene Stanley were the moving spirit behind many innovations and initiatives. Yi-Cheng Zhang and Sergei Maslov were liberal idea providers. Didier Sornette shared with me his enthusiasm and together with Thomas Lux worked at bridging the gap between econophysics and economics. Many thanks to Dietrich Stauffer for his perceptiveness, insight, and invigorating sense of humor. Together with his colleagues at Science et Finance, Jean-Philippe Bouchaud introduced many sophisticated mathematical models. Doyne Farmer provided an essential link between European econophysical centers and the Santa Fe Institute; moreover I much appreciated his lucid approach regarding simplicity versus complexity in economic systems. The views expressed in this book have also benefited from discussions with several colleagues to whom I express my gratitude; let me mention in particular James Feigenbaum, Peter Freund, Taisei Kaizoji, Vasiliki Plerou, Sorin Solomon, and Gilles Zumbach.

I am deeply indebted to several distinguished economists for their unfailing support and interest. Guy Laroque and Edmond Malinvaud have been a permanent source of stimulation since the early 1990s. The encouragements that over the years came from Milton Friedman, Clive Granger, Anna Schwartz, Richard Sylla, and Jeffrey Williamson were highly appreciated. The work of other renowned "comparativists," such as James Foreman-Peck, Gunnar Persson, and Graeme Snooks, convinced me that I might be on the right track after all.

I also express my gratitude to my colleagues at my institute for their daily help and good humor, and especially to Laurent Baulieu, Bernard Diu, Jean Letessier, Annie Richard, and Ahmed Tounsi.

This book is dedicated to Brigitte and Sylvain, my wife and son, whose cheerful encouragement and stimulating support was invaluable.

Bertrand Roehner
Paris, February 19, 2001