Econophysics and Sociophysics

Trends and Perspectives

Edited by
Bikas K. Chakrabarti, Anirban Chakraborti, and
Arnab Chatterjee

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Preface

In a proverbial Indian story (Buddhist Udana 68–69), a few blind people touched different parts of an elephant: the trunk, tusk, leg, tail, etc., and interpreted them as different animate/inanimate objects following their own perceptions, ideas or experiences. We, the scientists: physicists, biologists, economists or sociologists, all tend to do the same. In all its manifestations, inanimate, biological or sociological, nature does perhaps employ the same elegant code, like the genetic code of the elephant, but suppressed partially and expressed differently for various parts of its body. We perceive them differently, depending on our training and background. Nature hardly cares whether our views are physical, biological, or sociological. The complexity studies aim to capture these universal codes, manifested differently in different parts of the same body of natural phenomena.

This grand unification search is at a very inspiring stage today and this book reports on a part of these interdisciplinary studies, developed over the last ten to fifteen years and classified mainly under the headings *econophysics* or *sociophysics*. It was not the success of the studies that motivated us to collect the authentic reviews on intriguing developments in this volume; but it was rather the promise and novelty of this research which has been our guide in selecting them.

The contents of this book may be divided into two parts. The first nine chapters can be broadly categorized as econophysics and the rest as sociophysics, although there are obvious overlaps between the two.

In the first chapter, J. Mimkes shows how exact differentials can be formed out of inexact ones, and then identifies and exploits the correspondences between such functions in thermodynamics and in economics. In the next chapter, R. Stinchcombe shows how limit-order financial markets can be faithfully modeled as nonequilibrium collective systems of “particles” (orders) depositing, evaporating, or annihilating, at rates determined by the price and market condition. After establishing a general “complex adaptive” framework, starting from simple games and well-known limiting cases, like minority games, D. M. D. Smith and N. F. Johnson show how “general managers” could be designed for the evolution of competitive multi-agent populations. In the following chapter, Y. Fujiwara et al. analyzed exhaustively the data for firm sizes and their growths in Europe and Japan, establishing the power-law regimes and the conditions for detailed balance in their growth dynamics. In the next chapter P. Richmond et al. briefly review the wealth/income distributions in various societies, and describe some of the successful statistical physics models, and the asset exchange model with random savings, in particular, to capture such intriguing distribution forms. In the next chapter, A. Kar Gupta concentrates on one class of such (random asset exchange) models, studying them using a transition-matrix approach, and identifies some correspondence in formalism with one-dimensional diffusion and aggregation of particles. Y. Wang et al. then discuss how such asset exchange models can be used to figure out the monetary circulation process and to improve the measurement of economic mobility. The mechanical modeling of the triangular arbitrage advantages in the foreign exchange market is described next by Y. Aiba and N. Hatano. M. Ausloos in the next chapter, describes the general features of the fluctuations in the stock and foreign exchange markets, emphasizing measuring techniques and subsequent statistical and microscopic-like models; including also the specificity of crash patterns.

In the tenth chapter, J. Mimkes extends the thermodynamical correspondence of free energy minimization to the corresponding optimization of "happiness" in society. C. Schulze and D. Stauffer next discuss the intriguing problem of growth and decay (due to competition and/or regional/global dominance) of languages and computer simulation models for such dynamics. In the following chapter, G. Weisbuch reviews the evolutionary dynamics of collective social opinions using cellular automata and percolation models. S. Galam, in the next chapter, describes how spread and decay of conflicting public opinion can be modeled using statistical physics. Next, he argues how social percolation of an extreme opinion (say, of terrorism) occurs, and identifies the global spread/percolation of such terrorism with the event of the September 11, 2001 attack on the USA. S. Sinha and R. K. Pan, in the next chapter, identify some robust features (e.g., log-normal form and bimodality) in the distribution and growth of popularity in several social phenomena, such as movies, elections, blogs, languages, etc. and describes how some agent-based models can capture these features. In chapter sixteen, A. Johansson and D. Helbing describe the unique features of dynamics of dense crowds under constraints, and review the various cellular automata and flow-like continuity equation models used to describe them. P. Sen, in the next chapter, describes the distinctive static and dynamic properties of social networks including those of the railway networks and citation networks. The emergence of "collective memory" in many such social phenomena, including games, are very characteristic and J.-I. Inoue, in chapter eighteen, describes the celebrated

Hopfield model for associative memory and its extension to (nonfrustrating) networks of plant cells for the emergence of "intelligence" in them. D. Helbing et al. describe in the next chapter, how some fluid/traffic-like flow models can be adopted for optimized production in various manufacturing industries. In the last chapter, S. Jain and S. Krishna describe how one can identify the effects of various innovations in the context of evolving network models.

We sincerely hope that these wonderful and up-to-date reviews in such a wide landscape of emerging sciences of econophysics and sociophysics will benefit the readers with an exciting feast of relevant ideas and information. We are indeed thankful to our esteemed contributors for their efforts and outstanding co-operation. We are also grateful to Wiley-VCH for their encouragement and constant support in this project.

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1
A Thermodynamic Formulation of Economics

Juergen Mimkes

The thermodynamic formulation of economics is based on the laws of calculus. Differential forms in two dimensions are generally not exact forms (δQ), the integral from (A) to (B) is not always the same as the integral from (B) to (A). It is possible to invest little in one way and gain a lot on the way back, and to do this periodically. This is the mechanism of energy production in heat pumps, of economic production in companies and of growth in economies. Not exact forms may be turned into exact forms (dS) by an integrating factor T, $dS = \delta Q/T$. The new function (S) is called entropy and is related to the probability (P) as $S = \ln P$. In economics the function (S) is called production function. The factor (T) is a market index or the standard of living, GNP/capita, of countries. The dynamics of economic growth is based on the Carnot process, which is driven by external resources. Economic growth and capital generation – like heat pumps and electric generators – depend on natural resources like oil. GNP and oil consumption run parallel for all countries. Markets and motors, economic and thermodynamics processes are all based on the same laws of calculus and statistics.

1.1
Introduction

In the last ten years new interdisciplinary approaches to economics and social science have been developed by natural scientists. The problems of economic growth, distribution of wealth, and unemployment require a new understanding of markets and society. The dynamics of social systems has been introduced by W. Weidlich (1972) [17] and H. E. Stanley (1992) [15] has coined the term econophysics. A thermodynamic approach to socio-economics has been favored by D. K. Foley (1994) [4], J. Mimkes (1995) [10] and Drăgulescu and V. M. Yakovenko (2001) [3]. Financial markets have been discussed by M. Levy et al. (2000) [8], S. Solomon and Richmond (2001) [14], Y. Aruka (2001) [1] and many others. Many conferences have been held to enhance the communication between natural and socio-economic sciences with topics like econophysics, complexity in economics and socio-economic agent systems. In the first chapter, the mechanism of economic production is discussed on the basis of calculus and statistics. The two mathematical fields will be applied to economics in a similar way to thermodynamics, this is the thermodynamic formulation of economics.

1.2 Differential Forms

1.2.1 Exact Differential Forms

The total differential of a function $f(x,y)$ is given by (see, e.g., W. Kaplan [6])

$$df = (\partial f/\partial x)\,dx + (\partial f/\partial y)\,dy \tag{1.1}$$

The second (mixed) derivative of the function $f(x,y)$ is symmetric in x and y,

$$\frac{\partial^2 f}{\partial x\,\partial y} = \frac{\partial^2 f}{\partial y\,\partial x} \tag{1.2}$$

In the same way every differential form

$$df = a(x,y)\,dx + b(x,y)\,dy \tag{1.3}$$

is called total or exact, if the second derivatives

$$\partial a(x,y)/\partial y = \partial b(x,y)/\partial x \tag{1.4}$$

are equal. Exact differential forms are marked by the "d" in df. The function $f(x,y)$ exists and may be determined by a line integral,

$$\int_A^B df = \int_A^B \left(\frac{\partial f}{\partial x}\,dx + \frac{\partial f}{\partial y}\,dy\right) = f(B) - f(A) \tag{1.5}$$

The closed integral of an exact differential form is zero: The closed integral may be split into two integrals from A to B on path (1) and back from B to A on path (2). Reversing the limits of the second integral changes the sign of the second integral. Since both integrals depend on the limits A and B only, the closed integral of an exact differential is zero:

$$\oint df = \int_A^B df_{(1)} + \int_B^A df_{(2)} = \int_A^B df_{(2)} - \int_A^B df_{(2)} = 0 \tag{1.6}$$