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EDITORIAL

Focus on statistical physics modeling in economics and finance

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Abstract. This focus issue presents a collection of papers on recent results in statistical physics modeling in economics and finance, commonly known as *econophysics*. We touch briefly on the history of this relatively new multi-disciplinary field, summarize the motivations behind its emergence and try to characterize its specific features. We point out some research aspects that must be improved and briefly discuss the topics the research field is moving toward. Finally, we give a short account of the papers collected in this issue.

Contents

1. Introduction

There is a long-standing relationship between physics and economics. Several analogies between physical and financial systems have been recognized and explored, although here we only reference a few well-known examples, namely the mechanical nature of the mathematical framework of general equilibrium theory, Bachelier's random walk theory and the Black and Scholes formula. Before the 1990 s the connections were, however, sporadic and occasional, until gradually physicists started analyzing financial data in a systematic manner. This movement is ongoing, with the number of participating scientists and related research papers showing continual growth; after 15–20 years of development, we can now conclude that this is not merely a fashion, but the emergence of a new sub-discipline, econophysics.

2. Why econophysics?

There are several, coinciding reasons for this change. From the point of view of physics, the spectacular results of statistical physics for interacting systems and the behavior of correlated variables have to be mentioned first. Furthermore, the flood of data, resulting from the extraordinary and improving speed and ubiquity of computers, provides an attractive playground for physicists.

The motivation also comes from the side of finance. As financial instruments have become increasingly complicated and mathematically demanding, new job opportunities have opened up for mathematicians and physicists, with some preference for the latter. The reason for this is that while physicists understand the mathematics needed, they are more flexible than mathematicians in its application; moreover, they are trained to model phenomena and to work in a continuous feedback process with data. These attractive properties resulted in the employment of a large number of physicists on Wall Street, where many of the quantitative analysts (known informally as 'quants') have an MSc or PhD in physics. Meanwhile, leading banks and other financial institutions in Europe also use physicists to analyze and model financial data.

In the mid-1990s some physics journals opened their pages to reports on financial data analysis, which had a catalyzing effect on the related activities. The field has since gone through a clarification process, and has now reached a certain level of maturity. At the same time, a considerable diversification of topics has taken place. While in the beginning most attention was directed at the statistics of stock returns and foreign exchange rates, the scope of research has gradually expanded to include many related topics, from all aspects of market microstructure, through agent-based modeling, to more sophisticated markets and products.

After 15–20 years of development, considering the impact of econophysics is justified. We think that it is fair to say that so far no breakthrough has come from the discipline. Many important mosaic stones have been identified, but the whole picture is far from clear. (It is perhaps not a cynical comment to say that many of the 'breakthroughs' of financial economics have turned out to be failures, and that the ongoing global crisis is just a painful proof of the lack of fundamental understanding in this area.) It is also important to mention that communication between the physics and economics communities is hampered by differences of language, culture and background. The situation is sometimes made worse by physicists' ignorance of the finance literature, leading to improper citation practice and even to rediscoveries. In spite of these, an increasing number of academic economists think that the new and fresh viewpoints, the unorthodox approach and the powerful techniques of physicists may be useful in attempting to understand the complex system of the economy.

3. Focus points

This focus issue is intended to provide examples of research studies for scholars of different disciplines interested in the cross-fertilization of their specific field. One aspect that needs to be emphasized to both econophysicists and economists is the specificity of the econophysics approach. What is the specificity of econophysics research? What is the cultural contribution that econophysics research can make to economics?

Our view is that the econophysics approach has aspects that have made it complementary to most traditional economics approaches. Econophysics aims to discover empirically and interpret in terms of models regularities in the temporal, spatial and social setting of economic and social phenomena. Most of the regularities are of a statistical nature, whereas the deterministic aspects are usually quite limited or absent. This peculiarity should not be surprising to any scholar interested in econophysics. In fact, many problems and systems at the core of physics are characterized by an unavoidable statistical description. Examples of this include stochastic processes, critical phenomena, dynamical systems and even classical areas of physics such as friction.

Econophysics is therefore looking for statistical regularities in real systems, which are not necessarily interpreted in terms of micro-founded economic models. In other words, we believe that the observation of real systems provides a large set of statistical regularities that can be observed, statistically validated against appropriate null hypotheses and then used as starting points for the development and falsification of models of economic and social systems. One key aspect of the discipline is the role played by the observation of real systems in the model building and development. A continuous feedback between empirical observations, which are statistically validated against an appropriate null hypothesis with conventional or unconventional statistical tools, and developed models is an essential trait of the discipline.

The statistical validation of the observed empirical regularities is therefore crucial for the discipline. Unfortunately, econophysics contributions are quite inhomogeneous with respect to this important aspect. We are convinced that, in general, econophysicists need to improve the rigor of the statistical validation of their results. Physicists traditionally work on empirical/experimental investigations of closed systems in fully controlled (or almost fully controlled) experimental settings. Only a few research areas, such as astrophysics or geophysics, are largely characterized by observational experimental procedures. In economic and social systems the reverse is true. Most of the empirical investigations are of an observational nature, and while experiments performed with full control of the setting are constantly growing in number, they remain quite limited. For this reason, physicists contributing to the modeling of economic and social systems need to develop a practice of statistical validation of their discovered empirical regularities. This practice needs to be much more advanced than that employed for the fully controlled experiments of traditional physics. The positive aspect of this challenge is that physicists can also contribute to the development of new approaches to statistical validations of empirical regularities.

4. Content of this focus issue

This focus issue is, of course, not comprehensive with respect to the overall body of ongoing econophysics research. It provides a distinctive perspective, originally triggered by the issue's editors, and then shaped by the response of the colleagues and scholars invited to submit a paper presenting original research results. *New Journal of Physics* requires that papers contain a significant proportion of original results; accordingly, there are no reviews. Additionally, collection faces the challenge of being multidisciplinary in both the setting and in its contributors. Econophysics is a discipline at the interface between physics, economics and the social sciences. The development of the discipline therefore requires a multidisciplinary recognition of class of problems, concepts, methodologies and working languages, which need to be shared across the contributing major disciplines. This is problematical, because each discipline has its own paradigms, peer review customs, research communities, publication time horizons, procedures and presentation styles. In fact, in the preparation of the present issue, we have verified how difficult it is to harmonize the participation of scholars from different research communities in a common editorial project. We have invited research papers from scholars who are economists or professionals in the financial industry, but have obtained a lower number of such contributions than we were hoping for. Our impression as editors is that the main reason for this is probably the distance between peer review practice as it is followed in the different disciplines.

We now list the papers of this focus issue in brief. Ren and Zhou [1] present a careful statistical analysis of recurrence intervals on the Chinese stock market. Thurner *et al* [2] propose a simple quantitative model of Schumpeterian economic dynamics. Still and Kondor [3] approach the problem of portfolio optimization from the point of view of learning theory and consider instability due to portfolio size and due to budget constraint. Burda *et al* [4] apply random matrix theory to large generated covariance matrices. Ghosh *et al* [5] analyze the 'Kolkata Paise Restaurant' problem, and show that 'naïve' strategies sometimes lead to much better results than sophisticated ones. Banerjee and Yakovenko [6] construct a model that explains both the exponential and power law regions of income distribution, and show that the increase of income inequality in the United States originates primarily in the increase of the income fraction going to the upper tail, which now exceeds 20% of total income. Vaglica *et al* [7] show with a careful statistical analysis how splitting of large trades can be detected by hidden Markov models and discover a buy–sell asymmetry in 'hidden orders' submission as a function of the market state. Hardiman *et al* [8] study the long-range correlations in online betting and identify different mechanisms depending on the period of betting. de Lachapelle and Challet [9] study the stylized facts of individual traders investing in a financial market using a proprietary database of Swissquote Bank SA to provide empirical bases for agent-based modeling. Cantono and Solomon [10] construct an autocatalytic model of the economic crisis and analyze the interaction between the individual and collective levels. Aste *et al* [11] carry out a statistical analysis of the change in the stock correlations due to the 2008–2009 crisis using network tools. Westerhoff [12] introduces a complex multi-agent model, which takes into account firm–firm interactions, socio-economic opinion dynamics and sales expectations depending on individual attitudes. Hua *et al* [13] investigate the reaction of an emergent market to extreme price changes, as seen in the limit order book, and show the difference in the behavior of individual and institutional investors. Drodz *et al* [14] investigate several aspects of the foreign exchange market with a focus on multifractality. Allez and Bouchaud [15] discover several new stylized facts concerning the intraday seasonalities of stock return dynamics, while Pan and Sinha [16] investigate the process by which some movies made by the Indian film industry achieve success.

5. Near-future research perspectives

Our invitations for the focus issue were guided by different requirements. We have already discussed our intention to make this issue truly multidisciplinary. A second guideline was our personal view of the research problems that we expect to be relevant in the econophysics research of the future. Econophysics has already contributed much, and will certainly continue to contribute to the field of market microstructure. According to Joel Hasbrouck, ‘Market microstructure is the study of the trading mechanisms used for financial securities’ [17]. The term was introduced by Garman in 1976 [18]. He was commenting on the new word by saying ‘We depart from the usual approaches of the theory of exchange by (1) making the assumption of asynchronous, temporally discrete market activities on the part of market agents and (2) adopting a viewpoint, which treats the temporal microstructure, i.e. moment-to-moment aggregate exchange behavior, as an important descriptive aspect of such markets.’ These sentences make clear that the approach of market microstructure is naturally close to the approach of econophysics. In fact, market microstructure essentially considers the empirical nature of the granular interaction (in time and price) observed during price formation in real financial markets.

Another broad research area where economists and econophysicists share the same methodological tools is that of agent-based models. Econophysicists have contributed to this research area in the setting of models and in their investigations with both analytical and numerical tools. Recently, there have been efforts to make the agent-based modeling empirically grounded by investigating the trading profile of single institutions or even investors. Network theory is now a very important research area for statistical physics, and networks are naturally present in economic and social systems. Social scientists and economists have recognized their importance for social and economic problems for many years. Large networks can currently be characterized using different properties, ranging from topology to metric properties, and networks can be used as both descriptive and interpretative tools. Network modeling of social and economic complex systems is therefore a research area where econophysicists can interact productively with economists and social scientists. Due to the availability of datasets, it is possible to track economic and social activity down to the individual level. The analysis of these networks and, more generally, the analysis and modeling of individual choices, can be attempted by inferring the preferences, risk profile and the degree of information processing of single agents or individuals. In this way, the robustness and generality of key concepts of economic theory such as the representative agent and the fully rational agent can be compared with empirical evidence, and one can investigate their generality or, conversely, whether heterogeneity of social and complex systems is an essential and unavoidable trait of these systems. This is a fundamental question, and econophysics is expected to make major contributions to its clarification.

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