Physica A 419 (2015) 630–641

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Is there any connection between the network morphology and the fluctuations of the stock market index?

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HIGHLIGHTS

- Behavioral model to study market index fluctuations in several scenarios.
- Investigation of different trust network morphologies on the index oscillations.
- Remarkable effects due to complex network synchronization in anti-imitator scenario.
- Fluctuations of the stock market index are heavily biased by the network morphology.
- Mixing scenario enhances self-affine features of the stock market index.

ARTICLE INFO

Article history:
Received 16 January 2014
Received in revised form 11 August 2014
Available online 22 October 2014

Keywords:
Behavioral finance
Agent based models
Complex networks

ABSTRACT

Models which consider behavioral aspects of the investors have attracted increasing interest in the Finance and Econophysics literature in the last years. Different behavioral profiles (imitation, anti-imitation, indifference) were proposed for the investors, which take their decision based on their trust network (neighborhood). Results from agent-based models have shown that most of the features observed in actual stock market indices can be replicated in simulations. Here, we present a deeper investigation of an agent based model considering different network morphologies (regular, random, small-world) for the investors' trust network, in an attempt to answer the question raised in the title. We study the model by considering four scenarios for the investors and different initial conditions to analyze their influence in the stock market fluctuations. We have characterized the stationary limit for each scenario tested, focusing on the changes introduced when complex networks were used, and calculated the Hurst exponent in some cases. Simulations showed interesting results suggesting that the fluctuations of the stock market index are strongly affected by the network morphology, a remarkable result which we believe was never reported or predicted before.

1. Introduction

In the past decades, several interdisciplinary approaches led to the development of the field of Econophysics, which integrates knowledge from Economy, Statistical Physics, Computation, Mathematics, Sociology, and Psychology in order to quantitatively describe the actual behavior of the financial market [1–5]. Despite the intense debates in the literature opposing *graphists*, *fundamentalists*, *behaviorists* etc., which only express the residual reductionism from the specific fields of

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http://dx.doi.org/10.1016/j.physa.2014.10.026
0378-4371/

the researchers, the use of statistical physics tools, as fractal analysis or Fokker–Planck equations, and computational techniques, as agent-based models or numerical integration of differential equations, has greatly improved our comprehension of how the real market works [6–11]. Of particular interest, the temporal series of the stock market index is widely studied by means of analytical and numerical analysis [2,12], both qualitatively and quantitatively, but, for the moment, they still resist to be tamed.

Stock market indices are affected by a lot of situations which can cause fluctuations. Since the value of the index depends on the predominant choice of the investors in a given moment [13], it can be affected by a wide range of situations such as financial reports from companies, news on the media, and even by simply following the choice of an investor's best friend [14]! The development of the modern Game Theory in the mid of Section XX, from the seminal work of John von Newman [15] has demonstrated the importance of this subject to several areas, from Economics to Biology, passing by Psychology, Mathematics etc. [16]. Of particular interest for the Finance literature, Minority Games (MG) [17], Cooperative Games, Zero-Sum Games and Behavioral Models play a major role on the description and analysis of real market systems [3,9,18–20].

In recent years, hundreds of papers have demonstrated that most part of the features of real markets can be quantitatively and qualitatively described by computational models using Game Theory ideas combined with Statistical Physics tools. A particular attention has been devoted to agent-based models, due to its great applicability in the study of fluctuations in financial markets [7], which exhibit fascinating statistical properties [3]. In these models, it is common to observe the agents working on the lattice, with a local neighborhood, and several instances are proposed for the investors dynamics. The investors act like a crowd–anticrowd MG [21,22] by taking into account their psychological behavior (imitation or anti-imitation), which is fundamental for more realistic market games [23–26]. Minority Games can differ in the type of microscopic dynamics used (e.g. stochastic versus deterministic), in the definition of the information provided to the agents (real-valued versus discrete), in the agents decision making strategies, and also in the specific recipe used for converting the observed external information into trading actions [27]. Thus, a huge range of possibilities are open to explore combining Game Theory ideas, Statistical Physics tools and computational modeling.

A particular situation occurs when the investor's decision is based only on the behavior of his trust network. In this case, psychological tendencies arise from various processes [28], for instance, by spreading the information away and by social influence. Thus, sometimes the investors act in a completely irrational way, weakening the basic premise of the efficient market hypothesis [19,29]. Even if this kind of situation is not observed all the time, it is essential to the development of the so-called crisis of the financial markets [1].

Real markets exhibit several phenomena which can be associated to this irrational behavior of the investors, causing avalanches – large fluctuations of the number of investors buying or selling stocks – which are reflected in large oscillations of the stock market index [9], a mark of a period of crisis [1]. In the last decades, the statistical physics community has turned its attention to the task of extracting information from these index fluctuations using new theoretical approaches based on fractal geometry and chaos theory and, very frequently, by applying computational modeling [3,8,30,31]. The most used tool to quantify the stock index time series is the Hurst exponent [32,33], in particular, the detrended fluctuation analysis (DFA) [34,35] is widely employed.

Another interdisciplinary field which has experienced an increasing interest in last years, is the development of the, so called, Complex Networks. This multidisciplinary subject integrates computation, graph theory, statistical mechanics, sociology and economics [36–38] enhancing the potential power for prediction of crisis by combining several tools to analyze the data, providing a plethora of computational techniques which make possible the studying of economical systems by means of simulations. Initially motivated by the expansion of the internet and the need of understanding the properties of the www network, this subject migrates from mathematics and computation to biology and sociology when the researchers discovered that several social networks, as the sexual or postal ones [38], exhibit the same power law features as they observe in ecological or metabolic networks of living organisms [39]. Besides, networks are essential for the spreading of information, and play a central role on social relations [40]. Recently, some works aimed to investigate the topology of trust economical networks [41–45] but there is no comprehensive study on this subject yet.

In this paper, we have extended an agent based model [31,46] to study the behavior of the investors in the stock market focusing on the relation between the trust network of the investors and the stock market fluctuations. We considered different network morphologies for the investors trust network, and tested the dependence on the initial conditions for the state of the investors in each situation. Four scenarios of behavioral profile of the investors were considered, and we have studied the temporal evolution of the stock market index which was obtained in each scenario. We show that, for some scenarios, different network morphologies lead to completely different behavior on the fluctuations of the stock market index, and some results were totally unexpected. The paper is structured as follows: firstly, the networks used along the work are characterized and the model is presented; secondly, we show the results for the temporal evolution of the stock market index in each scenario studied. Finally, we close with our conclusions and perspectives, followed by the references.

2. Methodology

In this section we describe the techniques and models used in simulations. The algorithms considered to build the investors' trust network are discussed in the next subsection. Then, in the following subsection, we present the behavioral agent based model detailing the cellular automaton rules used and the scenarios investigated.