Role of Behavioral Heterogeneity in Aggregate Financial Market Behavior: An Agent-Based Approach

Yasaman Kamyab Hessary, Mirsad Hadzikadic

Complex System Institute
College of Computing and Informatics
University of North Carolina at Charlotte, Charlotte, NC.
ykamyabh@uncc.edu, mirsad@uncc.edu

Abstract
In this paper, an agent-based model of stock market is proposed to study the effects of cognitive processes and behaviors of the traders (e.g. decision-making, interpretation of public information and learning) on the emergent phenomena of financial markets. In financial markets, psychology and sociology of the traders play a critical role in giving rise to unique and unexpected (emergent) macroscopic properties. This study suggests that local interactions, rational and irrational decision-making approaches and heterogeneity, which has been incorporated into different aspects of agent design, are among the key elements in modeling financial markets. When heterogeneity of the strategies used by the agents increases, volatility clustering and excess kurtosis arises in the model, which is in agreement with real market fluctuations. To evaluate the effectiveness and validity of the approach, a series of statistical analysis was conducted to test the artificial data with respect to a benchmark provided by the Bank of America (BAC) stock over a sufficiently long period of time. The results revealed that the model was able to reproduce and explain some of the most important stylized facts observed in actual financial time series and was consistent with empirical observations.

Keywords: Agent-based modeling, heterogeneity, decision-making, financial market, emergent property

1 Introduction

Solid understanding of the behavior of financial markets and its participants is extremely important to the general health and efficiency of an economy and plays a critical role in today’s societies. One of the key elements in studying the behavior of financial markets is determining and interpreting the origins of their statistical properties, otherwise known as stylized facts. This investigation makes it possible to analyze the influence of different trader’s characteristics on various market phenomena and their emergence.

The field of behavioral finance, which is rapidly expanding, observes finance from a broad social science perspective. Viewing financial market participants as boundedly rational, adaptive agents leads to a world of complexity. Agent-based modeling (ABM), which is the approach
followed in this work, is a flexible methodology for simulating such complex systems and their behaviors [13]. With ABM, financial markets can be modeled form bottom up, taking into consideration the evolution and interaction of the agents in an incremental fashion. Among the agent-based financial market models in literature, two-type models are the simplest kind with respect to heterogeneity. In such models, financial agents follow two general belief systems: fundamental and technical. Fundamentalists make decisions assuming that the price of an asset returns to its fundamental value in the long run, while chartists are mainly concerned about the trends and patterns observed in the past prices. Evidence for existence of these two types of traders in real markets can be traced back to the survey data gathered by Frankel and Froot [8]. The consistent findings from the data indicated that investors tend to use chartist trading rule at short horizons, while using fundamentalist approach at longer horizons.

Zeeman’s model [15] was one of the first agent-based models of stock market with fundamentalist and chartist traders, and a large number of literature was developed following the lead of him. He proposed a qualitative description of the stylized facts observed in short-term bull and bear markets. Although the model included several behavioral elements that are used as base for other financial market modelings, it lacked micro details. The study done by Gilli and Winker [9] showed that to have a better characterization of financial markets models, traders should be able to switch between different trading strategies than to simply assuming that the ratio of fundamentalists over chartists remains constant over time. The approach of stressing evolution and switching between fundamentalists and chartists, taken by Hommes [2], Lebaron [10] and Westerhoff [14], has proven to be quite successful. Although being able to reproduce some of the most important stylized facts of financial markets, they do not consider local interactions and heterogeneity within the two general belief systems.

The aim of this study is to investigate the effects of rational and irrational decision-making process and social interaction on overall market dynamics and the emergent of certain key stylized facts. In order to achieve this goal, a simple yet rich and flexible agent-based model of stock market is developed. In a first attempt to model this complex system, the methodology of two-type design suggested by Westerhoff [14] is followed. This method, being the simplest kind of heterogeneity, allows for a better tractability of the model’s parameters and a less complicated validation process. However, in order to gain additional explanation power and a closer representation of real financial markets, further heterogeneity is incorporated as the model proceeds. The objective is to satisfy the two essential agent design principals, simplicity and heterogeneity by a well-defined scheme and parameter space.

The proposed model differs from the original model and other related works in the approach that is taken to model heterogeneity, interaction and learning behavior of the agents. Related research limits heterogeneity through only a few elements of two general agent types, fundamentalists and chartists. They also capture learning and interaction through switching mechanism, in that the overall population of fundamentalists and chartists is set due to the realized profit associated with their forecasting rules. On the other hand, the novelty of the approach used in this work is that, while consistent with other two-type design frameworks, it builds heterogeneity into different aspects of agent design, making each fundamentalist and chartist unique within the two general types. Also, the method to model learning and evolution is through local interactions. At each time step, financial agents exchange information with their surrounding neighbors. They either compare strategy profits and change their tactic accordingly, or blindly choose to follow the most popular trading decision in their neighborhood, regardless of its utility and their own private information. This method helps gaining a broader global insight to trading strategies and evolution of the agents.

In this work, heterogeneity is modeled through several key parameters: a) Agents with dif-
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