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The effects of behavioral and structural assumptions in artificial stock market

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Abstract

Recent literature has developed the conjecture that important statistical features of stock price series, such as the fat tails phenomenon, may depend mainly on the market microstructure. This conjecture motivated us to investigate the roles of both the market microstructure and agent behavior with respect to high-frequency returns and daily returns. We developed two simple models to investigate this issue. The first one is a stochastic model with a clearing house microstructure and a population of zero-intelligence agents. The second one has more behavioral assumptions based on Minority Game and also has a clearing house microstructure. With the first model we found that a characteristic of the clearing house microstructure, namely the clearing frequency, can explain fat tail, excess volatility and autocorrelation phenomena of high-frequency returns. However, this feature does not cause the same phenomena in daily returns. So the Stylized Facts of daily returns depend mainly on the agents' behavior. With the second model we investigated the effects of behavioral assumptions on daily returns. Our study implicates that the aspects which are responsible for generating the stylized facts of high-frequency returns and daily returns are different.

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1. Introduction

Agent-based models of complex adaptive systems are attracting significant interest in many disciplines. An important area receiving much attention is agent-based computational finance (ACF), which gives a new approach providing deep insights into the dynamics of security markets [1]. Researchers in agent-based computational finance have built artificial stock markets (ASM) that reproduce characteristic behavior (stylized facts) of regular markets, such as heavy tails of the (unconditional) distribution of daily and hourly returns, excess volatility, volatility clustering, and volume/volatility correlation.

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However, Ghoulmie et al. [2] and Raberto et al. [3] have argued that most artificial stock markets are formulated in a complex manner and, due to their complexity, it is often not clear which aspect of the model is responsible for generating the observed stylized facts and whether all the ingredients of the model are indeed required for explaining empirical observations. Further, Raberto et al. [3] pointed out that no artificial stock market is yet able to explain all the known stylized facts of real-life markets.

Thus, further work is required to determine which aspects of the artificial markets are responsible for the stylized facts that emerge.

Recent literature [3–6] has led to the conjecture that the emergence of some stylized facts is mostly due to their microstructure. The dynamics of a stock market depends on the interaction between the trading mechanism and the behavior of the participants. The trading mechanism defines the rules of the market, which specify how orders are placed and filled and how the price changes. The behavior of the participants is the outcome of their trading strategies, which include how they form expectations or interpret signals. Li Calzi and Pellizzari [4] believe that the first generation of agent-based simulations of stock markets has explored a very rich set of behavioral assumptions, but has paid comparatively little attention to structural assumptions.

Cincotti, Focardi, Marchesi and Raberto [5–7] developed the Genoa artificial stock market (GASM, which has a detailed microstructure similar to the real stock market. They found that both cleaning house and continuous double auction structures can produce heavy-tailed distribution of returns even with a market populated by zero-intelligence agents. LiCalzi and Pellizzari [4] presented a structurally detailed model with a minimal set of behavioral assumptions that also produced a heavy-tailed distribution. Their results supported the conjecture that heavy-tailed distribution is mostly due to the microstructure.

However, more research with ASMs, including the pioneering work done at the Santa Fe Institute [8,9] and our previous work [10,11] reproduced the stylized facts of markets without consideration of their detailed microstructures.

So, we believe that it is desirable to pay attention to investigate the effects of behavioral and structural assumptions in artificial stock markets.

In this paper, we present two artificial stock markets and use them to explore how both the behavior and microstructure features impact the stylized facts of market performance.

The paper is organized as follows. Section 2 presents a simple model with zero-intelligence agents and a clearing house mechanism, which is used to study the effects of the microstructure on high-frequency fluctuations of intraday trading. Section 3 presents an artificial stock market based on Minority Game, by which we study the effects of behaviors on daily returns; Section 4 describes the conclusions from these studies.

2. The effects of microstructure mechanisms

Researchers [4–6] have developed models with detailed microstructures and shown that with a minimal set of behavioral assumptions even zero-intelligence agents suffice to generate leptokurtosis. A possible conclusion could be that the fat tails phenomenon may depend mainly on the market microstructure. Does the market microstructure play a so important role? And how does microstructure generate this phenomenon? We will build a simple zero-intelligence agents model to answer these questions.

2.1. The model

Economic environment: there is only one virtual asset (stock) where the fundamental value is unknown, because we are nor concerned with whether the price converges to or diverges from the fundamental value. Each day, each agent decides to buy or sell a share of stock randomly. He issues an order with limit price based on exogenous information. Each trading day is subdivided into T elementary time steps with the market clearing at each time step.

Behaviors of agents: there are N agents with zero intelligence. At a given time step t, agent i issues an order. The order is either a bid or an ask, each with probability 50%. The limit price of the bid or ask is based on $\varepsilon_i \sim \mu(0, \sigma^2)$, where ε_i is a random draw by agent i from a Gaussian distribution with constant mean $\mu = 0$ and standard deviation σ. We assume that the limit price associated with the buy order is given by $p_i^B = \varepsilon_i$, and the limit price associated with the sell order is given by $p_i^A = \varepsilon_i$. The price p_i^A or p_i^B is logarithmic return.

Price formation: every order will be stored in the book if it is not traded. At the end of the trading day, the book will be emptied. The principles of clearing are: 1. the clearing price must generate the maximum trading volume; 2.