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Fractal markets: Liquidity and investors on different time horizons

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HIGHLIGHTS

- We propose an agent-based model of investors with different time horizons.
- The model shows the fractal structure provides liquidity in small time scale.
- The model reproduces the market fluctuation when the maximum horizon is exceeded.

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ABSTRACT

In this paper, we propose a new agent-based model to study the source of liquidity and the "emergent" phenomenon in financial market with fractal structure. The model rests on fractal market hypothesis and agents with different time horizons of investments. What is interesting is that though the agent-based model reveals that the interaction between these heterogeneous agents affects the stability and liquidity of the financial market the real world market lacks detailed data to bring it to light since it is difficult to identify and distinguish the investors with different time horizons in the empirical approach. results show that in a relatively short period of time fractal market provides liquidity from investors with different horizons and the market gains stability when the market structure changes from uniformity to diversification. In the real world the fractal structure with the finite of horizons can only stabilize the market within limits. With the finite maximum horizons, the greater diversity of the investors and the fractal structure will not necessarily bring more stability to the market which might come with greater fluctuation in large time scale.

1. Introduction

Financial markets are described as complex systems and the emergence of complexity could be spontaneous and the market crash might happen suddenly with no big changes of economy fundamental parameters. Efficient market hypothesis (EMH) asserts that the financial market is "informationally efficient". Over-reaction or under-reaction happens all the time and these noise traders must exist in the market to provide the necessary liquidity for the rational investors [1–3]. We have seen that empirical evidence shows that the capital markets are not well-described by the normal distribution and random walk theory [4–7]. The market fails at some time and the crash could happen suddenly with no shifts from economic fundamentals. Market price changes and volatility can be caused by the herding behavior which could be well-described by the complex system.

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To explain the above phenomena and the complexity of the financial market, the fractal market hypothesis (FMH) has many conceptual and quantitative advantages over the EMH through modeling and analyzing data. In FMH, financial markets are described as complex dynamical systems that the emergence of complexity could be spontaneous [8–10]. Benoît Mandelbrot's work on fractals showed that much complexity in financial market could be described by certain ubiquitous mathematical laws. Peters proposed FMH first [11], based on Mandelbrot's work [12] and using the fractal objects whose disparity parts are self-similar. FMH provides a new framework for the more precise modeling of the turbulence, discontinuity and non-periodicity that truly characterizes today's capital markets.

FMH provides a new visual angle of observation to explain the source of market liquidity. The market is stable when it consists of investors covering a large number of investment horizons which ensure that there is ample liquidity for the traders. The importance of information can be considered largely dependent on the investment horizon of the investor. There would be no liquidity, if information had the same impact on all investors [13,14]. For example, a day trader might have an investment horizon of several minutes while an institutional trader like a pension fund trades weekly or longer. Day trader who is currently long in the market encounters six standard deviations, for example, about 0.4 percent drop which is comparatively very small for the weekly traders with the standard deviation of more than 2%. The day trader could be wiped out if the fall continues while the weekly trader would probably believe the drop of the price is a buying opportunity and step in, buys stocks from day traders and creates liquidity which in turn stabilizes the market [11].

There is another side to the fractal market: if the heterogeneous structure shrinks, the market collapses easily. In general, market crashes happen when large numbers of agents place sell orders simultaneously creating an imbalance to the extent that market makers are unable to absorb the other side without lowering prices substantially. Most of these agents do not communicate with each other, nor do they take orders from a lead. In fact, most of the time they are in disagreement, and submit roughly the same amount of buy and sell orders. If an event occurs that has enough influence or puts the validity of fundamental information in question, long-term investors either withdraw completely or invest on shorter terms [15–18].

The idea of heterogeneous investors takes a new approach to investigate the liquidity and the "emergent" phenomena for financial market. The above phenomena weakens the foundation of EMH but can be explained by FMH. Yet EMH continues to be the backbone for the mechanics of the market while participants of mathematical analysis of FMH grow in numbers.

According to the published researches, agent-based model has not been implemented on fractal market with heterogeneous investors. Since it lacks necessary data to track the individuals' investment record and the investors might change their investment horizons, it is difficult to identify and distinguish the investors with different horizons in the empirical approach. However, the agent-based model can take it as preset parameters and simulate the market consisting of heterogeneous investors. In this paper, we proposed a new agent-based model which rests on FMH and agents with different investment horizons. Stochastic simulation provides us an efficient way to investigate various traders' behaviors with regard to the global statistics of the market [19–23], and this approach provides for a natural interpretation and an understanding of the structure of complex system and fractal market. In our agent-based model, it is assumed that agents adopt the same investment strategy and have different investment horizons, and a combination of Brownian motion and excessive demand/supply causes the fluctuation of the market.

In view of the current data and research essays, the fractal structure is regarded as the stabilizer of the market which might lose liquidity at some point and fall sharply or at least becomes unstable when the overall investment horizon of the market shrinks to a uniform level, in the market [11,13–16]. However, our experiments reveal that with finite maximum horizon even the fractal structure does not change, it could still be one of the main reasons for the "emergent" phenomenon and volatility clustering in financial market, and it cannot stabilize the market but becomes the source of the fluctuations when the maximum horizon is exceeded by market shocks or the price mildly rises for a long time. In the real market, no investors have the infinite investment horizons which might shrink to short term by event shock. Our model works with the limited numbers of investors and the fixed time horizons. Results indicate the "emergent" phenomenon happens when agents are herding and the market structure is fragmented. Using the technique of rescaled range analysis, we find that the maximum horizon divides the market into two fractal dimensions, the stable one in smaller time scale and the volatile one in larger ones. When a mild rise goes for a long time, or a shock hits the market and is big enough to change the aspects of most investors, it could implement the agreement of most investors with different horizons for the market trend and increase the possibility of a big crash. Rather than a liquidity provider, the fractal market fluctuates more seriously than the one caused by the shock itself.

2. Model

We construct a multi-agent model that consists of N investors, which could be classified by M ($M < N$) groups and adopt momentum strategy and buy stocks that have high returns or sell stocks with poor returns over a recent period of time T_i ($i = 1, 2, \ldots, M$). Agents in one group share the same time horizon. At a time step, agents determine the market trend (up/down) first, then buy/sell the stock with a fixed probability p. Different investor horizons lead to different trade decisions. In our model, the agents are designed to adopt this simplified momentum strategy: if the market rise/fall over a recent period of $0.1 \times T_i$, agents with the horizon T_i in group i will get confident for the trend and join the market (The agents could also adopt Gold/Dead cross signal instead and similar results are obtained.). When the stock fell for a long time, then rises moderately, with the prolonged downward fall still in memory, agents with a long time horizon would be short-sellers