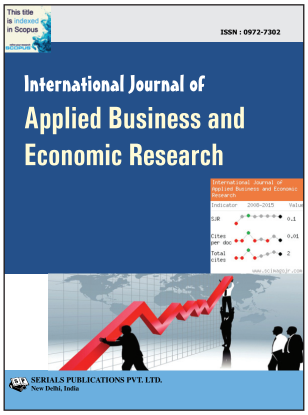

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Agent-based Simulation of an Artificial Financial Market

Effect of Short Selling on Market Stability

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ABSTRACT

In this paper we present a model of an artificial financial market withagents whose behavior is influenced by theirclosest neighbors regarding the investment decision to take. The model can generate the stylized facts of the real financial markets, specifically: excess volatility in the logarithmic returns, bubbles and crashes. We are interested in studying the effect of short selling prohibition; which is an Islamic principle, on the market stability and how it allows reducing the excess volatility in the logarithmic returns and the frequency of bubbles and crashes.

Keyword: Artificial financial market; Agent based modeling; Islamic finance principles.

1. INTRODUCTION

Since the beginning of the twentieth century, financial markets have resulted in a considerable amount of research, both fundamental and applied. Although these research fall within the general framework of finance, it is often interdisciplinary. This interdisciplinarity can be explained by the fact that markets are multifaceted: they can be seen as objects of purely financial studies (through the study of the economic stakes they represent), mathematics (through the study of the properties of the price series) or human (through the study of the psychology of the economic actors who participate in it). Yet none of these disciplines can today come up with a complete theory that would overcome the complexity of markets and fully understand them. This is probably due to the fact that they should propose a set of integrated theories, linking the microscopic aspects, that is to say, to account for the behaviour of individuals in all their heterogeneity, their characteristics, How they interact or are organized, to the macroscopic aspects of the financial system, such as how prices fluctuate.

Given this lack of unification between the different results on the microscopic and macroscopic levels, a new field of study emerged in the late 1990s: computational finance. This new discipline is at the crossroads of several areas of research: computer science, game theory and finance. It proposes a new framework for studying the financial markets: since it is so complex to study them in their real version, it is perhaps simpler to reproduce their functioning in virtual universes, perfectly controlled. These universes are reproduced by computer simulations called multi-agent simulations, which mimic the functioning of markets and investors, thus making it possible to test hypotheses or to test theories, freed from the constraints that would make these experiments materially impossible in reality.

This new field of investigation has given rise to strong results: Brian Arthur, for example, has shown, thanks to his El Farol Bar Problem [Arthur, 1994], that it is possible, using inductive agents (who make their decisions only by learning information from a historical), to elicit macroscopic dynamics close to an unknown theoretical equilibrium of the agents. This work, although carried out on a very simplified model, has inspired many advances in computational finance. Thus, it has been shown with the Santa-Fe Artificial Stock Market ([Palmer et. al., 1994]) that it is not necessary to assume that economic agents should have rational expectations to obtain realistic prices on a market, which runs counter to most of the theories admitted up to now in classical finance.

In this paper we propose a modelbased onVaga's coherent market hypothesis (Vaga, 1990) and Johansen, Ledoit, Sornette's model (Johansen et. al., 2002, Sornette, 2003), from now on denoted by JLS. However the major difference between our model and these authors' corresponding model is that the JLS model proposed an imitation mechanism between neighbours to determine the decision to buy or to sell, while ours aims to apply this imitation mechanism to determine the amount to trade, in order to allow the limitation of the selling decision to the held quantity of the asset and consequently the measure of its impact on the market stability .

In the first section of this paper we describe the used materials and methods. In the second section we give an overview of the JLS model. In the third section, we present the model structure and describe the way agents interact. In the subsequent section, we present simulations results. Simulation results verify the appearance of stylized facts of the real financial markets and howshort selling prohibition reduces them.

2. MATERIALS AND METHODS

Agent-based modelling is an approach for modelling the actions and interactions of single entities called agents, with a view to testing their effects on the system as a whole. Thereby, agents can be spatial patches representing traders. Thus, agent-based modeling has the inherent capacity to model social and human-environment systems from the bottom-up in discrete time steps by specifying their constituent parts. Here, we implemented an artificial financial market close to the one described by JLS. Accordingly, in the model, traders can randomly decide in each time step to buy or to sell where the amount to trade is based on two factors: there individual wealth (independent variable), and the decision of their reference group or neighbours (relative variable).

The model is implemented using Netlogo, an agent-based environment developed by Prof. Uri Wilensky at Northwestern University (Wilensky 1999). It is a simple yet flexible programming environment for simulating agent-based models.

3. JLS MODEL

JLS (2000) and Sornette (2003a) assume that a pool of irrational traders is connected into a network. Each trader is indexed by an integer $i = 1, \ldots, I$ and N(i) represents the number of agents who are directly connected to trader i in the network. JLS (2000) assume that each agent can have only two possible states si: "buy" ($si = +1$) or "sell" ($si = -1$). JLS (2000) suppose that the state of agent i is defined by the following Markov process:

$$si = \text{sign}\ (\text{K sum}(sj) + \sigma ei) \text{ where } j \text{ in N}(i)$$

Where the sign function sign(x) is equal to +1 if $x > 0$ and to −1 if $x < 0$, K is a positive constant, ei is an i.d.d normal random variable. In this model, K governs the tendency of imitation among traders, while σ governs their idiosyncratic behaviour. If K increases, the order in the network increases as well, while the reverse is true when σ increases. If order wins, the agents will imitate their close neighbours and their imitation will spread all over the network, thus causing a crash.

4. MODEL DESCRIPTION

Unlike the JLS model described above, the imitation mechanism used in our model is based on the amount to trade instead of the decision to buy or to sell. In this case the behaviour of a trader in a financial market can be described as following: the trader shall purchase or sell an amount of asset x based on two factors: his wealth, w, and the previous decision of his neighbours or reference group, xr. This would have the structure of a complex system as formulated in the equation below:

$$xi, t = f(wi, t, xr, t - 1).$$

As before, $xr, t - 1$ is the relative variable, while w is the independent variable.

In our model the f function is defined as:

$$f(wi, t, xr, t - 1) = (1 - \mu)\ wi, t + \mu \times xr, t - 1$$

$$xr, t - 1 = \text{sum}(xj, t - 1) \text{ where } j \text{ in N}(i)$$

N(i) represents the number of agents who are directly connected to trader i in the network, and μis a positive constant which governs the tendency of imitation among traders.

5.1. Model Structure

In attempt to highlight the benefits of short selling prohibition on the market stability, we consider a society of traders where each trader has the following properties:

- An initial amount of cash (uniformly distributed)
- An initial number of shares (uniformly distributed)
- A market sentiment: Each trader can have a positive sentiment (+1), in which case he is 'bullish', that is, he believes the market will rise or he can have a negative sentiment (−1) in which case he is 'bearish', that is, he believes the market will fall (randomly affected)
- An amount to trade (decision)
- Bankruptcy indicator

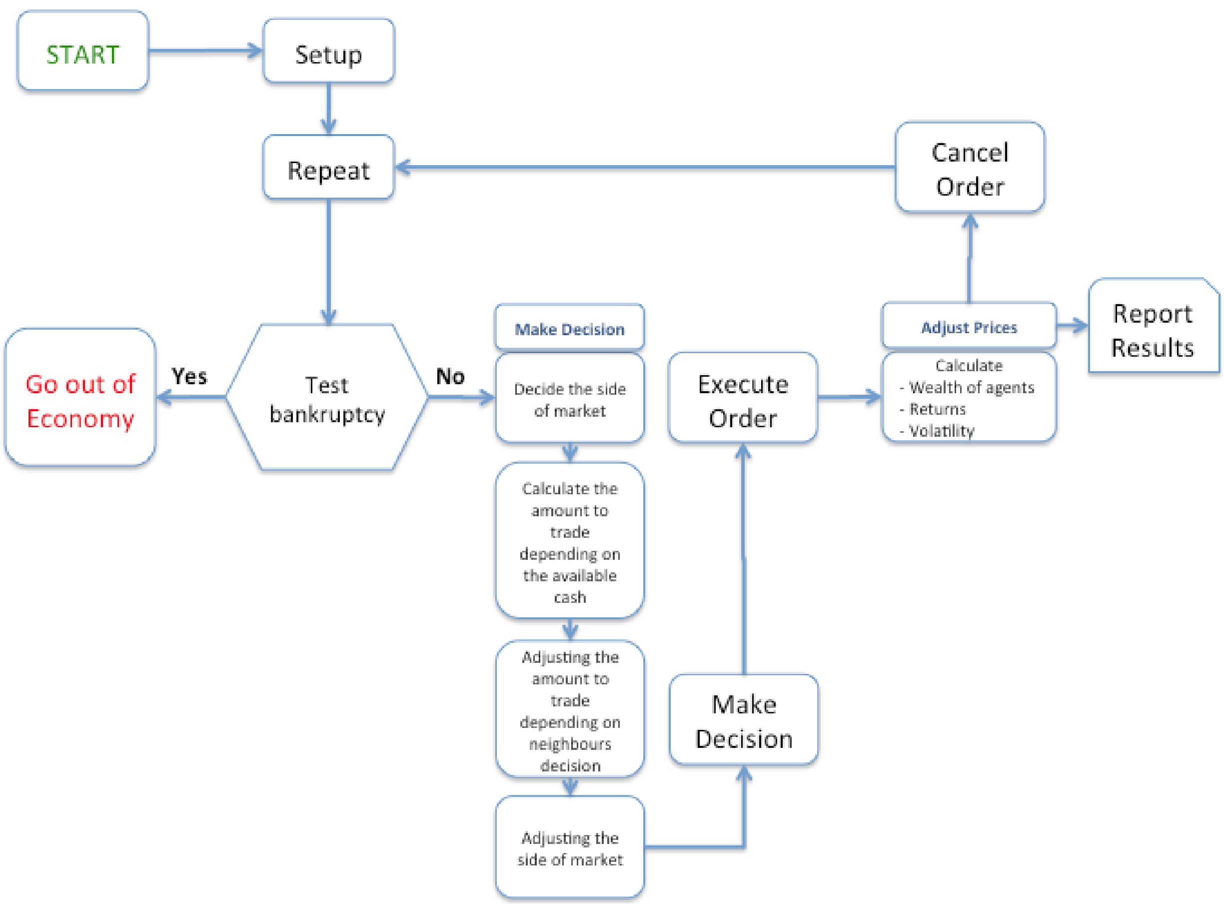
In each period, a market sentiment is affected randomly to each trader; the amount to trade is then calculated according to the model described in the 5^{th}section of the paper. The cash and the number of shares of traders are updated according to the occurred cash flows where the auctioneer fixes the price of the share.

Bankruptcy occurs when, at the end of a period, the wealth of a trader is equal to zero, it would reset all variables to zero, and the bankrupt agent is set out of the economy.

For buyer, the decision will depend on the available cash, while it will depend on the number of held shares for the sellers in the case where the short selling is not allowed. If short selling is allowed we consider that there is no limit for short selling.

4.2. Simulation Chart Flow

Short selling allowed

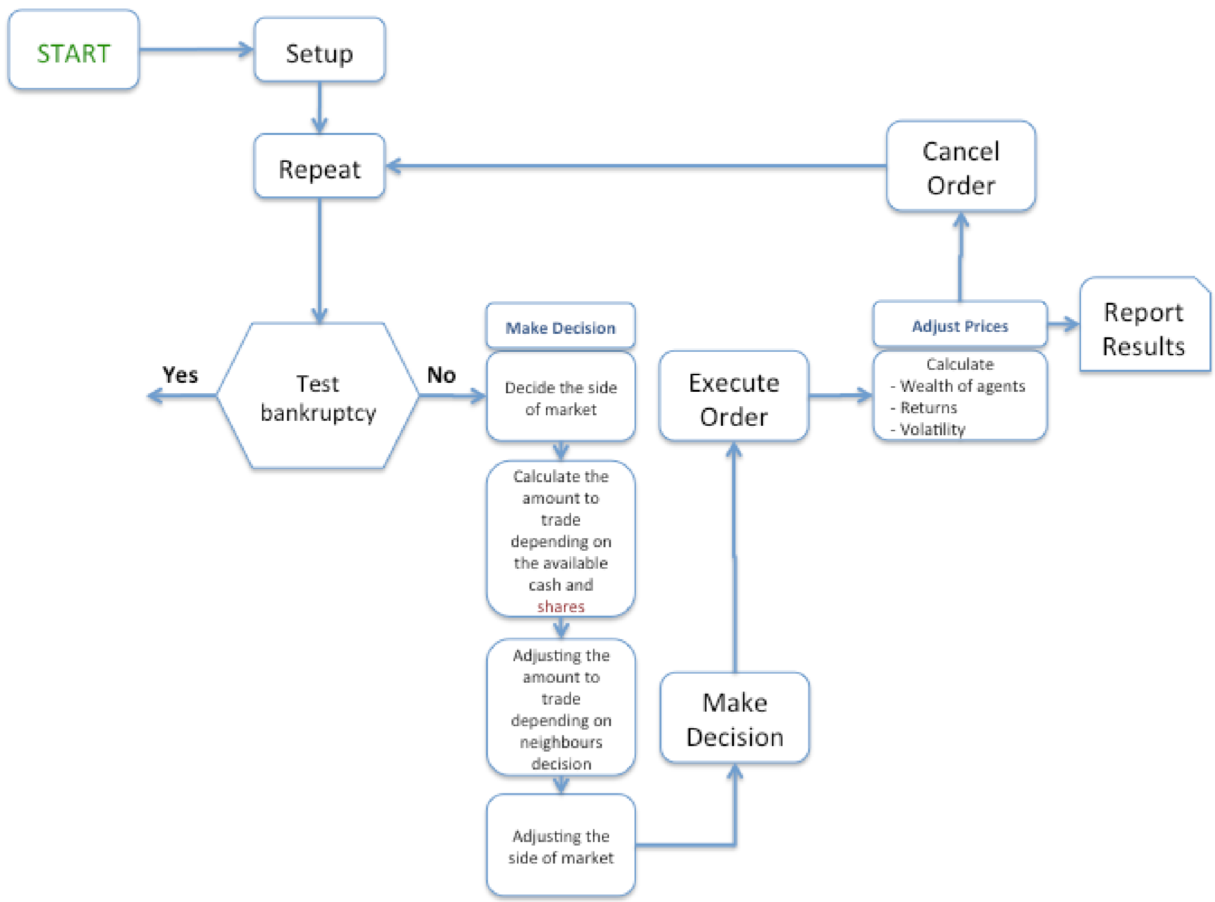


4.3. Simulation Input Parameters

User in Netlogo interface sets these parameters:

- μ : The constant which governs the tendency of imitation among traders (interval: [0, 1])
- Allowing short selling: Boolean

Short selling not allowed



4.4. Simulation Outputs

We consider the same outputs as Carlos Pedro Gongalves used in his "Artificial Financial Market Model":

- The chart of the logarithm of the price
- The chart of the logarithm of the returns
- The volatility indicator.

The main information that can be obtained from the logarithm of the price chart is information regarding bubbles and crashes and, more importantly, states of the market that were identified by Vaga, we can at least identify three: the random walk state; the coherent bull markets state, the coherent bearish market state. These are the most visible in the chart.

The second chart is perhaps one of the most important, since for a range of parameters, it shows the dynamics usually present in the actual financial markets, like excess volatility, jumps, successive jumps, correctional movements, all evidence that, following Shleifer (2000), goes against the Efficient Market Hypothesis.

The third chart is the representation of a volatility indicator, specifically, the absolute returns. This indicator has been considered to be a more accurate measure of the volatility process than the squared returns (Guillaume, Dominique in Trippi, 1995, Ding, Granger, Engle, 1993).

5. SIMULATION RESULTS

Several simulations have been performed to understand the relationship between the different parameters.

As explained in the previous section, the outputs should allow us to assess the effect of short selling prohibition on the market stability, thus, lets run the simulation for these two cases:

5.1. Short Selling Allowed: Case 1

Input parameters:

- μ: 0 (no imitation mechanism)
- *Allowing short selling:* True
- *Traders number:* 10000 each owns initially 10 in cash and 10 shares

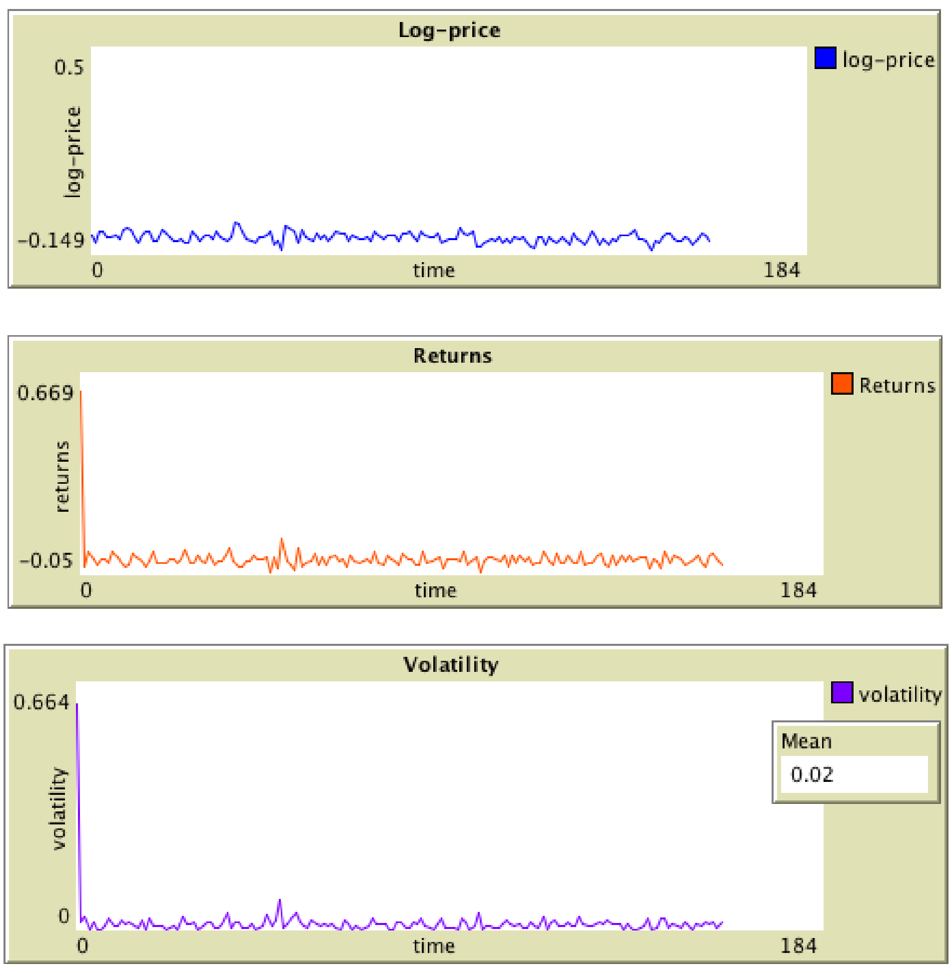


Figure 1

Outputs analysis: In the first chart of the Figure 1, we notice that dynamic of price is stable, in the second and third chart we notice that the returns are stables and the volatility remainss table in a low level of 2% during the time of the simulation.

These results were expected because of the absence of imitation mechanism and thus the herding behaviour that lead to a disorganized state of market.

5.2. Short Selling Allowed: Case 2

Input parameters:

- µ: 0.33
- *Allowing short selling*: True
- *Traders number*: 10000 each owns initially 10 in cash and 10 shares

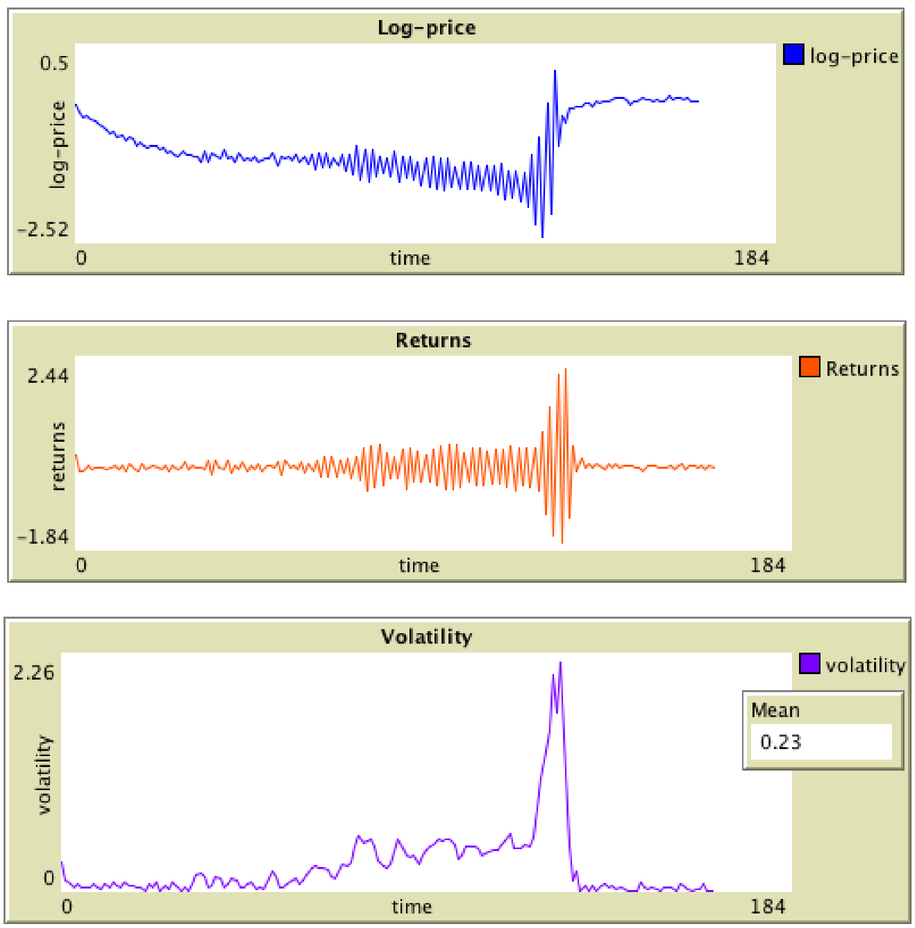


Figure 2

Outputs analysis: In the first chart of the Figure 2, we notice that bubbles followed by crashes happen after 100 periods. This is due to herding behaviour, as the tendency of imitation among traders is now set to 0.33 instead of 0. The volatility chart shows that the imitation mechanism leads to more frequent and more extreme herding behaviours and to higher volatility (> 25%). It means that if the markets were efficient, volatility would not change with time.

Now, this simulation also allows the understanding of a mechanism behind the volatility phenomena. Indeed, the volatility clusters and the jumps come from the fast phase transitions occurring in traders herding behaviour. Therefore, our model shows that the volatility phenomena in actual markets may emerge as a consequence of deviations to Efficient Market Hypothesis, and that it can be a consequence of the dynamics of herding.

5.3. Short Selling not Allowed

Now, in order to verify if the short selling prohibition allows more stability of markets and reduces the volatility phenomena highlighted in the previous simulation, lets run the program with the same parameters but with the Allowing short selling parameter set to False.

Input parameters:

- μ: 0.33
- *Allowing short selling*: False
- *Traders number*: 10000 each owns initially 10 in cash and 10 shares

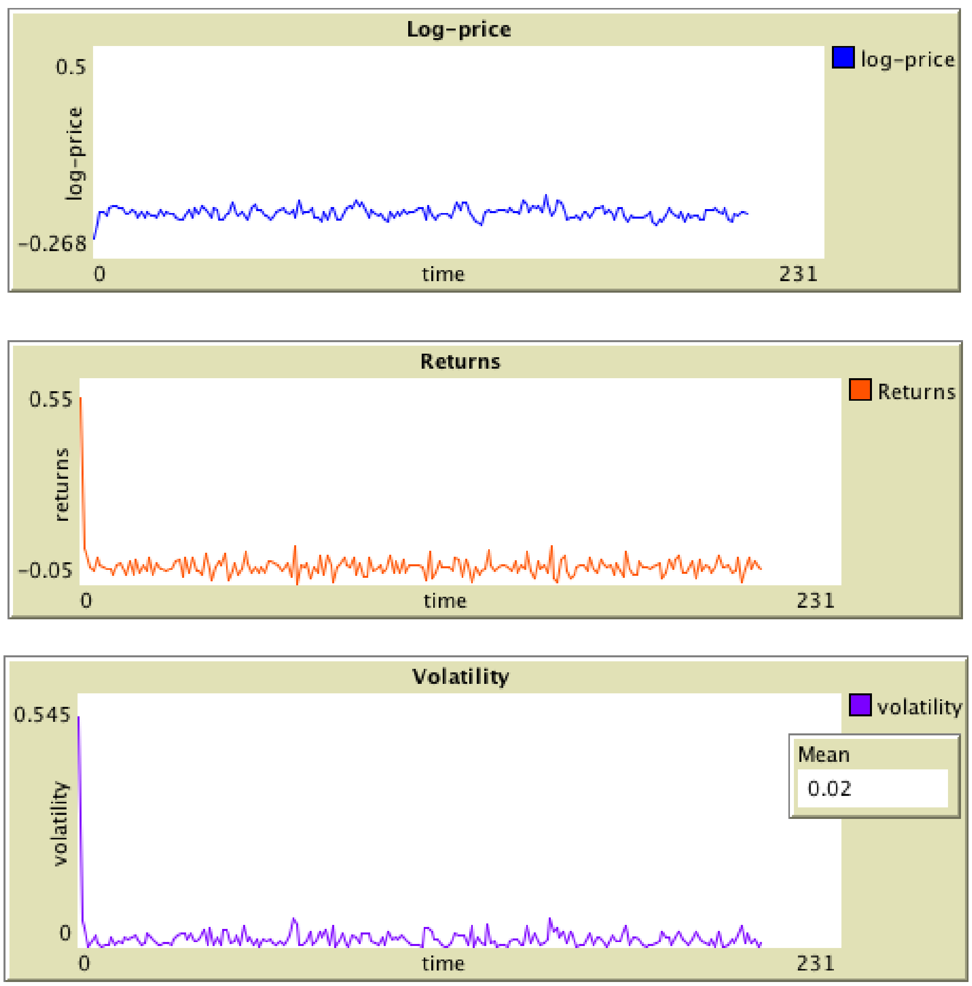


Figure 3

Outputs analysis: In the Figure 3, we clearly notice that the dynamic of price became stable and by the same way bubbles followed by crashes disappear. Herding behaviour is now limited and consequently volatility didnot change with time (stable at 2%).

The difference between these two last simulations is that the limitation of short selling to the held number of shares by each trader, leads to create an equilibrium between demand and supply in the market and consequently affects positively its stability by reducing volatility phenomena.

6. CONCLUSION

According to the Efficient Market Hypothesis (EMH) the prices reflect the whole of the information regarding the value of any asset traded in a financial market. The price of the asset is, thus, never above, nor below its intrinsic value. The EMH, closely related to neoclassical economics, was, and still is, the main hypothesis of the mainstream academic finance, however, its strength has been largely weakened, since its beginnings in the 1960s.

Asset prices seem to be more volatile than was predicted by the theory, crashes and speculative bubbles happen with a larger frequency than was expected, and many more.

Schleifer (2000) identifies three theoretical arguments in which the case for EMH rests on, these are (Schleifer, 2000, p.2):

"(…) investors are assumed to be rational and hence to value securities rationally (…) to the extent that some investors are not rational, their trades are random and therefore cancel each other out without affecting prices (…) to the extent that investors are irrational in similar ways, they are met in the market by rational arbitrageurs who eliminate their influence on prices."

As shown by Carlos Pedro Gongalves (2003) in his Artificial Financial Market Model, instead of assuming the usual dichotomy rational/irrational, or rational investor/noise trader, we considered in our model that all individuals are boundedly rational and heterogeneous. If individuals were the agents of the EMH the decision they would form would reflect only their individual sentiment. However, in our model, of heterogeneous and boundedly rational agents, to this decision contribute not only the individual sentiment, but also the transmitted decision of the individual's closest colleagues, thus, that leads to the final decision.

As Carlos Pedro Gongalves (2003) did, we have shown in this paper that the volatility phenomena in actual markets may emerge as a consequence of deviations to EMH, and that it can be a consequence of the dynamics of herding.

However, the main finding of this paper is that the explanation for the volatility phenomenon, according to our model, is not only the dynamics of herding, but also the unlimited short selling existing in markets nowadays. We have proven that short selling prohibition; which is an Islamic principle, allows more market stability and shown how it reduces the excess volatility in the logarithmic returns and the frequency of bubbles and crashes.

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