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Asset price and trade volume relation in artificial market impacted by value investors

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ABSTRACT

The relationship between return and trade volume has been of great interests in a financial market. The appearance of asymmetry in the price–volume relation in the bull and bear market is still unsettled. We present a model of the value investor traders (VIs) in the double auction system, in which agents make trading decision based on the pseudo fundamental price modelled by sawtooth oscillations. We investigate the system by two different time series for the asset fundamental price: one corresponds to the fundamental price in a growing phase; and the other corresponds to that in a declining phase. The simulation results show that the trade volume is proportional to the difference between the market price and the fundamental price, and that there is asymmetry between the buying and selling phases. Furthermore, the selling phase has more significant impact of price on the trade volume than the buying phase.

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1. Introduction

Economics and physics have combined to yield great insights about market dynamics, agents behaviours, and wealth distribution in a financial market, leading to an active field of econophysics [1,2]. Ideas and concepts from physics, such as statistical mechanics, phase transition, etc. have been helpful to treat problems in Economics [1,2]. Various models in econophysics have been successfully applied in real situations; see Ref. [3], and references therein.

In economics of a financial market, the relation of the stock's price change (return) and the trade volume is a very attractive subject. There are many studies about the price–volume relation. For instances, Chen and Liao [4] investigated the price–volume relation by simulating the artificial price and agent-based system, and found that "the understanding of appearance or disappearance of the price–volume relation can never be complete if the feedback relation between individual behaviours and aggregate outcome is neglected". Later, Chen [5] empirically studied the S&P500 index from 1973 to 2008 and found that the returns and trade volumes are negatively correlated in the bear market, whereas they are positively correlated in the bull market. In addition, the asymmetric return–volume relation is statistically significant. In 2015, Xinghua Liu et al. [6] presented a simple artificial price model, in which they investigated the effects of information-driven trades on the price–volume relation. They concluded that the price–volume relation is apparent when traders used information in trading, but this relation is less apparent if no information is used in trading. Moreover, they estimated the trade volumes to be linearly proportional to the absolute return price of the asset.

In our work, we are interested in the price–volume relation; in particular, we construct a simple model that gives rise to this relation and its asymmetry. Here, we model the trading dynamics in the market as the double auction model inspired

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by Ref. [7], which is realistically used in many models [8–11]. The relationship between the stock price change and trade volume has been of great interests in the financial market for long time. Several works have investigated this relation by empirical studies or modelling simulation. Yet, the causes of the volume–price relationship remain unsettled. We present the artificial price model with the double auction trading system, where our model is assumed to have only value investors who try to buy or sell the assets based on the fundamental price. We imagine there are two scenarios for the time series of the pseudo-fundamental prices. The first scenario is that the asset price is in a growing phase, where the price slowly increases, but there may exist some rare events that cause the fundamental price to drop quickly and drastically. The second scenario accounts for the opposite phase, where the asset price is currently in the decline phase, but some rare events make the sudden increase of the asset price.

Arguably, in the stock market, most investors can be commonly categorized into two groups: the value investors (VI), and the technical investors (TI). The former uses the market information from the company's fundamentals to determine whether to buy or sell stocks. The latter uses the stocks price graphs with indicators or trends to make their decisions to buy or sell. In our model, a virtual market is assumed to have only VIs, so we create a model for the VI trading under the influence of the pseudo-fundamental price. It is also assumed that the agents behave in manners to chase the price when the price is deviated from the fundamental price, i.e. the agents would likely buy if the price is lower than the fundamental price, and would likely sell in the opposite scenario.

Under these hypotheses, we will demonstrate with a simple model that there exists a price–volume relation, and there is a asymmetry between the buying and selling phases. This paper is organized into three parts. First we introduce the agent's decision model, and the double auction system. In the next sections, we describe the details of our simulation, and finally, we present the simulation results and discussions.

2. Agents decision model

Imagine a financial market where one (virtual) asset is monitored. The system is homogeneous such that all agents have the same decision logic. The agent's behaviours mimic those from the real VIs who try to buy the asset if the fundamental price is higher than the actual trading price, and sell the asset vice versa. The price and volume are produced by the order book trading system [7]. When an agent wants to buy or sell an asset, there are two choices; namely by placing either a limit order or a market order. If the agent chooses to place the limit order, the order will wait in queue in the order book until it matches the market order or until the order is expired. The best price (highest price for buying or lowest price for selling) will be traded first. If the market order is sent, the transaction takes place immediately if the order book has the limit order to be matched. If the market-order has more volume than the limit-order, the order will be matched partially. If there is no waiting limit order in the book, the market order is cancelled.

Suppose that the fundamental price is S_F and the current asset price in the market is S, we define

$$z_{buy} = \frac{1}{2} - \frac{1}{2}\left(\frac{S - S_F}{S_F}\right), \tag{1}$$

and

$$z_{sell} = 1 - z_{buy}. \tag{2}$$

It is possible that the values of z_{buy} and z_{sell} are negative or greater than one. Thus, they do not determine the probabilities of buying or selling, respectively. We can obtain such probabilities by defining

$$p_{buy} = \begin{cases} 0 & \text{if } z_{buy} < 0 \\ 1 & \text{if } z_{buy} > 1, \\ z_{buy} & \text{else.} \end{cases} \tag{3}$$

Similarly,

$$p_{sell} = \begin{cases} 0 & \text{if } z_{sell} < 0 \\ 1 & \text{if } z_{sell} > 1, \\ z_{sell} & \text{else .} \end{cases} \tag{4}$$

If the $S = S_F$, then $p_{buy} = p_{sell} = 0.5$, as it should be. Conversely, if $p_{buy} = p_{sell}$, the current price may on average stay at S_F. If $S > S_F$, then p_{buy} is lower than 0.5, so that there is higher chance for agents to sell the asset. Finally, p_{buy} would be equal to zero if $S \geq 2S_F$, meaning that no VI would buy the asset if the current price doubles that of the fundamental price. Such scaling is not unique or special. Similar behaviours are seen if $S \geq kS_F$ for any $k > 1$.

After the agent has decided to buy or sell, he or she also has to decide what type of orders to be exercised: either the limit order or the market order. The probabilities to execute the limit order for buying or selling are determined by the parameters

$$z_{buy,limit} = 1 + \frac{1}{2}\left(\frac{S - S_F}{S_F}\right) \tag{5}$$

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