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A social network model of investment behaviour in the stock market

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ABSTRACT

To consider the psychological factors that impact market valuation, a model is formulated for investment behaviour of traders whose decisions are influenced by their trusted peers' behaviour. The model is implemented and several different "trust networks" are tested. Simulation results demonstrate that real life trust networks can significantly delay the stabilisation of a market.

1. Introduction

Under the efficient market hypothesis [1], prices of publicly traded assets (stocks, bonds, futures etc.) should reflect all the available relevant information. As a consequence, price should maintain a certain level of stability and only change when new information becomes available. Empirically, this hypothesis is contrary to the widely held ideas of "bull" and "bear" markets corresponding to the protracted periods of gradual increase or decrease of the asset prices in comparison to the benchmark trends (GDP, inflation, etc.). In particular, a significant challenge to the hypothesis comes from the existence of the extreme versions of "bull" and "bear" markets referred to as "market bubbles" and "market panics", defined as times with "trade in high volumes at prices that are considerably at variance with intrinsic values" [2–5]. This supports behavioural economics' claim that psychological biases prevent investors from acting fully rationally and thus undermine the basic premise of the efficient market hypothesis [6].

For example, in Ref. [7], the author divides the traders in the market into rational and emotional traders. Emotional traders always keep a bubble going whereas rational traders have the potential to burst the bubble. Conlon [8] considers the market as a two-player game in which each of the players follows the "law of greater idiots". Even if a player knows that the current stock is overpriced they may still buy, hoping that the other player will buy the stock at a higher price. In Ref. [9], Wei et al. propose that instability in the stock market is partly due to social influences impacting investors' decisions to buy, sell, or hold stock. By developing a Cellular Automata model of investment behaviour in the stock market they show that increased imitation among investors leads to a less stable market.

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In this paper we build on the basis laid by Ref. [9] and develop a social network model of the stock market. In particular, we follow [9]'s modelling technique and build a three-state (buy/sell/hold) model that takes into account a trader's peers. Traders' states are arrived at by considering: perceived price, change in price perception, the peers' influence, and 'personality'. The underlying premise of our model is that for a bubble to persist in a market composed of rational traders, those traders must have rational reasons to buy when prices are higher than stock value. These reasons – if they in fact exist – are almost certainly to be found in the behaviour of the other traders, as Ref. [9] pointed out. The behavioural influence, on the other hand, has to be tempered by the actual reality of the asset valuations. This can be viewed as a mix of information which is global (price), and information which is local to a node (trader) in the trust network. Interplay between stock value assessment and the behaviour of trusted traders is at the core of our model.

Our model also furthers the research of Wei et al., by extending the eight neighbour Cellular Automata structure used in Ref. [9, Eq. (2)] with an arbitrary (but static) network structure. This removes the unlikely assumption that each investor is influenced by exactly eight neighbours. Instead, each trader in the market has their own *trust network* (people they trust or distrust). The behaviour of trusted peers directly affects their behaviour, instead of indirectly and anonymously through price. It is important to note that the notion of "trust" in this context extends beyond simply believing that a trusted trader has better information about the actual value of the traded asset; it can also include the belief that the trusted trader's actions will broadly influence the market. The latter enables our model to incorporate the "social" effects of "superinvestors" such as large funds or highly influential individuals.

Naturally, our model also incorporates stock price into investor decisions, and investor decisions drive stock price. For example, if all investors seek to buy stock, then stock price will increase. Conversely, a high stock price will encourage investors to sell, driving price down. This provides a necessary feedback mechanism not found in Ref. [9]'s work. Finally, unlike Ref. [9], we assume that the amount of stock available is finite. Thus, for each trader who buys stock, there must exist a trader who sells stock. These notions provide an increased level of stability in the stock price, and investor behaviour. Nonetheless, our model demonstrates that social trust networks can cause highly stochastic behaviour in stock value and investor behaviour.

2. Social network model

The basic element of the model is the price of the good being traded. For the purposes of the model, price is normalised to zero around the long-term nominal value of the good. Long-term nominal value includes things such as risk estimates, rates of return, volatility, etc… A normalised price of zero means the price of the stock is equal to the value of the stock defined in this way. A positive normalised price means that the price of the good is higher than what the perfectly rational investor acting in isolation with a long-term investment goal should be willing to pay. This way of normalising price eliminates concerns about traders analyzing price history. Traders do so to determine whether a good is overpriced or underpriced. By our normalisation this "analysis" is assumed to be precise and available to all traders.

Like Ref. [9], the basic model consists of a collection of investors examined over a series of time steps, and we assume that at each time step investors exist in three possible states: buy, sell, and hold. Each trader is also given a list of other traders that they "trust". At each time step the model determines the normalised stock price. Each trader's decision to buy, sell, or hold is based on the current normalised price of the stock, the change in normalised price of the stock between the last time step and the current time step, and the actions of their trusted traders during the previous time step. The stock's normalised price is generated by determining what stock price nearest to the price at the previous time step would cause the number of traders who buy to be equal to the number of traders who sell.

In addition we study the effect of possible uncertainty about the true normalised price by replacing normalised price with a perceived normalised price. The perceived price is defined as the correct normalised price plus a small stochastic error based on a normal distribution around 0. Perceived prices are unique for each investor at each time step. A broad spectrum of trader knowledge scenarios and their effect on the market volatility can be studied using this model.

2.1. Notation and model parameters

We begin by setting our two indices:

- let $i \in I = \{1, 2, \ldots N\}$ represent the index of individuals within the model, and I be the set of all individuals; and
- let $t \in T = \{1, 2, \ldots\}$ represent time state, and T be the set of all possible time states.

In this paper, we will use a number of parameters that are specific to each trader, and some variables specific to each trader during a certain time step. Parameters are subscripted to indicate specific individuals and shown as a function of time when appropriate, e.g., A_i and $\varepsilon_i(t)$. When the subscript is omitted, the parameter or variable refers to the matrix (usually a column vector) in which the ith row 'belongs' to the ith individual.

For each pair of traders (i, j) we have

- $\alpha_{i,j}$ set to 0 or 1; a zero represents that trader i is not influenced by trader j, a 1 represents that trader i is influenced by trader j.