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Order aggressiveness, pre-trade transparency, and long memory in an order-driven market

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ABSTRACT

Recent empirical research has documented that the state of the limit order book influences stock investors' strategies. Investors place more aggressive orders when the same side of the order book is thicker, and less aggressive orders when it is thinner. We conjecture and demonstrate that this behavior is related to long memories of trading volume, volatility, and order signs in stock markets. We investigate our conjecture in two types of artificial stock markets: a transparent market, in which agents observe all limit orders on both sides of the book and order volumes at those prices before they trade; and a less transparent market, in which agents observe only the best five bid and ask quotes with the depth available at these limit prices. The first market structure resembles certain actual stock exchanges in the level of pre-trade transparency, such as the Australian Stock Exchange, NYSE OpenBook, and the London Stock Exchange, whereas the second market structure is consistent with stock exchanges such as Euronext Paris, the Toronto Stock Exchange, the Tokyo Stock Exchange, and Hong Kong Exchanges and Clearing. We demonstrate that our long memory results are robust with different levels of pre-trade transparency, implying that the strategy constructed by the state of the order book is key for explaining long memories in many actual stock exchanges.

1. Introduction

Long-memory processes of trading volume, volatility, and order signs are important features in the high-frequency time series of stock markets, and yet the market is informationally efficient in that returns are uncorrelated over time.[1] Recent empirical research has demonstrated these results, but theoretical attempts to explain these observations have foundered on the challenge of simultaneously explaining all phenomena. This paper achieves this goal in an agent-based model.

We conduct simulations on a continuous double auction market, where agents place their orders to an electronic order book. The price is determined once the submitted order is matched and executed with the limit orders in the book. Consistent with the behavior of stock investors in reality, the trading strategy of our agents is influenced by the state of the order book. Our agents tend to submit more aggressive orders as the depth on the same side of the order book becomes thicker, and less aggressive orders as it becomes thinner.[2] This suggests that our agents' trading decisions involve a trade-off between

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[1] Lobato and Velasco (2000) find the long memory of volume. Ding et al. (1993) demonstrate this for volatility. Bouchaud et al. (2004) and Lillo and Farmer (2004) show an informationally efficient market in the presence of strong dependence in order signs.

[2] This has been found in many empirical studies in the finance literature. See, for example, Biais et al. (1995), Duong et al. (2009), Griffiths et al. (2000), Hall and Hautsch (2006), Handa et al. (2003), and Ranaldo (2004). In the literature, the most aggressive order is the market order, while limit orders within the spread are more aggressive than limit orders outside of the spread but are less aggressive than market orders.

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advantageous price and non-execution risk. When an agent places a limit order rather than a market order, the agent can obtain a favorable execution price, but at a higher risk of non-execution, as the order may be left unfilled, and the agent failing to receive any profits. Such risk of non-execution increases as the depth on the same side of his order becomes thicker. If an agent observes the order book and recognizes that the book is thick, then the agent places more aggressive orders. An agent who places a market order can soon execute it, ensuring certain positive profits, but he will then lose the opportunity to execute his order at a more favorable price. If the book is thin, the agent reverses his strategy, placing less aggressive orders because his order is likely to be executed. We model the order placement strategy in terms of a trade-off between advantageous price and non-execution risk, and conjecture that such a strategy is related to long memories of volume, volatility, and order signs. We demonstrate that this strategic behavior is critical for simultaneously generating all long memories.

We examine our conjecture within two types of artificial stock markets: a *transparent market*, in which agents observe all limit orders on both sides of the book and order volumes at those prices prior to trading; and a *less transparent market*, in which agents observe only the best five bid and ask quotes with the depth available at these limit prices before trading. In terms of the level of pre-trade transparency, the first market structure resembles certain stock exchanges in reality, such as the Australian Stock Exchange, NYSE OpenBook, the London Stock Exchange, and the NASDAQ, while the second market structure is consistent with stock exchanges such as Euronext Paris, the Toronto Stock Exchange, the Tokyo Stock Exchange, and Hong Kong Exchanges and Clearing.[3] We demonstrate that both markets can simultaneously generate the above-mentioned long memories, implying that an order placement strategy involving a trade-off between advantageous price and immediacy of execution is a possible source of the long memories in many actual stock exchanges.

Most significantly, this paper contains the following five contributions. First, our model reproduces all long memories simultaneously.[4] Several papers investigate possible sources of long memories, but each paper reproduces only one of them. For example, Alfarano et al. (2008) and a series of spin-type models, such as those created by Bornholdt (2001), Chowdhury and Stauffer (1999), and Kaizoji et al. (2002), explain the long memory of volatility in their herding economies.[5] Several papers, such as that of Chiarella et al. (2009), assert and demonstrate that the cause of long memory of volatility is the chartists' trend-following behavior. Lillo et al. (2005) consider an order-splitting strategy widely used by investors in actual stock markets, whereby stock investors split their large orders into smaller pieces and execute them piece by piece so as to minimize the price impact.[6] Their model successfully generates the long memory of order signs.

Our second contribution is that we formulate our agents' trading strategies based on the order-book condition as well as the past price history. In most existing agent-based models, the trading strategies are based only on past price information.[7] However, stock investors in reality can also refer to order-book information, which can provide information about likely market dynamics. Agents in the previous papers do not observe the order-book condition, and hence, they do not consider the trade-off between advantageous price and immediacy of execution.

Third, we examine the impact of the varying degrees of transparency on the dynamic aspects of volatility, trading volume, and order signs. Some empirical studies in the finance literature also investigate the impact of changes in the pre-trade transparency regime but only on the static aspects of the economy. For example, Madhavan et al. (2005) examine the impact on liquidity and volatility when the Toronto Stock Exchange disseminated information of the limit order book to the public.[8] They find that the increase in transparency decreases liquidity but increases execution costs and volatility. Boehmer et al. (2005) demonstrate that an increase in pre-trade transparency with the NYSE OpenBook service influences the liquidity and the price impact of trades.[9] For example, they demonstrate that investors submit smaller limit orders and cancel limit orders in the book more quickly and more frequently, whereas NYSE specialists trade less and add less depth to the quote. They also present an increase in displayed liquidity in the book and a decline in the price impact of trades.

Fourth, in addition to long memories, we provide a condition that reproduces the conditional frequencies of order types on spread width and order-book depth, which are observed in some empirical research. Several empirical papers find that investors tend to place more (less) aggressive orders as the spread size becomes narrower (wider)[10] or the depth on the same side of the book is thicker (thinner). On the one hand, our simulation results explain that the conditional frequency on the spread is generated regardless of agents' strategic behavior, and is instead actually related to the order-book market structure itself. On the other hand, we replicate the conditional frequency on the depth when agents' order placement strategy involves the trade-off between advantageous price and immediacy of execution.

[3] Other than those markets, the Jakarta Stock Exchange and the Singapore Exchange are examples of markets displaying a full limit order book to the public. The level of pre-trade transparency in Asia-Pacific exchanges is explained in Comerton-Forde and Rydge (2006).

[4] Other than this paper, the herding mechanisms due to agents' mutual imitation in LeBaron and Yamamoto (2007, 2008) and the order-splitting model of Yamamoto and LeBaron (2010) also replicate all long memories at once.

[5] Kirman (1993) and Lux (1995) are two of the classical papers on agent-based herding models.

[6] Vaglica et al. (2008) provide empirical evidence on order-splitting in the Spanish stock exchange.

[7] Among several agent-based models of this type, see, for example, Brock and Hommes (1998), Chiarella et al. (2009), Frankel and Froot (1990), Kirman (1991), and LeBaron et al. (1999).

[8] On April 12, 1990, the Toronto Stock Exchange instituted a computerized trading system that increased the level of pre-trade transparency. This system introduces public dissemination of the depth and quotes of the best five limit orders. See Madhavan et al. (2005) for more details.

[9] NYSE's OpenBook was introduced in January 2002 and provides order-book information to traders off the exchange floor. In particular, it allows them to observe depth in the book in real time at each price level for all securities. See Boehmer et al. (2005) for more details.

[10] Biais et al. (1995), Duong et al. (2009), Griffiths et al. (2000), Hall and Hautsch (2006), and Ranaldo (2004) make this observation.