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Intraday trading patterns in an intelligent autonomous agent-based stock market[☆]

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ABSTRACT

Market microstructure studies of intraday trading patterns have established that there is a regular pattern of high volumes near both the open and close of the trading day. O'Hara (1995) points out the many difficulties in specifying all the necessary elements of a strategic model for determining and attaining an equilibrium describing intraday patterns. We develop an autonomous agent-based market microstructure simulation with both informed agents and uninformed liquidity-motivated agents. Both types of agents can learn when to trade, but are zero-intelligence on all other behavior. We do not impose an equilibrium concept but instead look for emergent behavior. Our results demonstrate that trading patterns can arise in such a model as a result of interactions between informed and uninformed agents even though the agents are non-strategic and not fully rational. As long as there is rudimentary social or individual learning, uninformed liquidity-motivated agents can coordinate to avoid trading with informed agents and suffering adverse selection losses. The extent and pattern of coordination between uninformed agents depends on the learning specification, the percentage of informed agents and the degree of cooperation/competition among the informed agents.

1. Introduction

Market microstructure studies of intraday trading patterns have established that there is a regular pattern of high volumes near both the open and close of the trading day. This U-shaped pattern has been documented for stocks trading on the New York Stock Exchange by Jain and Joh (1988), Lockwood and Linn (1990) and others. Admati and Pfleiderer (1988) furnish a possible explanation for this pattern. They build a model where concentrated trading patterns can arise as a result of strategic interactions between traders with asymmetric information. Our paper uses a different approach to look at similar questions. We build an intelligent autonomous agent-based model and use computer simulations to analyze intraday trading patterns.

O'Hara (1995, pp. 150–151), discusses the robustness of strategic trading models in general, and the Admati and Pfleiderer model in particular, and states:

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> While the outcome argued by Admati and Pfleiderer seems economically plausible, it need not be the equilibrium that actually occurs. . . The problem is that to characterize the actual equilibrium one would need to know not only the equilibrium concept being applied, but also the specific game being played. . . This problem highlights a major difficulty in applying strategic models to market microstructure issues. To formally model the underlying game in a market requires specifying the rules of the game, the players, their strategy sets, and their payoffs. . . Exactly how the players strategies and beliefs are tied together is crucial for determining the resulting equilibrium. . . Moreover, the ability to ever attain the proposed equilibrium in any actual market setting may also be a serious concern. Nonetheless, strategic models of trader behavior can provide substantial insight and intuition into the trading process.. . .

O'Hara's comments correspond exactly to the type of problem for which intelligent autonomous agent-based models were developed. Agent-based computational economics studies complex systems involving agents who act according to exogenously specified, relatively simple behavioral rules. The autonomous agents can adapt or learn through interactions with others and from their past experiences. The approach is to devise a simulation where autonomous agents interact and to look for emergent behavior. Further, experiments can be conducted to explain the properties of the simulated economy.

We develop a system to analyze how asymmetric information might induce intraday trading patterns. Instead of the strategic modeling approach typically used by market microstructure theorists, we construct an autonomous agent-based model. Our model corresponds to typical market microstructure models in that there are two types of agents, informed agents and uninformed, liquidity-motivated agents. However, our agents learn when to trade during the day according two types of learning: a social learning using genetic algorithms and an individual learning using a modified Roth-Erev reinforcement learning algorithm. Further, our model differs from many typical market microstructure models because we do not impose an equilibrium concept. Instead, all trading occurs in the framework of a double auction.

Agent-based approaches to economic modeling usually relax the assumption of perfect rationality and can allow specification of a detailed trading institution. Behavioral finance theorists usually replace rationality with a behavioral assumption (e.g., overconfidence) so that agents are rational in all respects except for the behavior of interest. As in other agent-based asset markets, our approach is to replace rationality with simple behavioral rules. Our agents are non-strategic and are near zero-intelligence. Since we are interested in intraday patterns, our agents behave randomly in all respects except for the decision of when during the day to trade. Our agents learn when to trade either through social learning or through individual learning.

Even though our approach differs from Admati and Pfleiderer's strategic trading model, our main result is quite similar. Liquidity-motivated agents learn that they can minimize losses by trying to trade at the same time during the day *if* there is some degree of social or individual learning. The result is important because it suggests that concentrated trading patterns can occur in environments other than those featured in many theoretical market microstructure models. Even markets with near zero-intelligence agents possessing very rudimentary learning abilities can feature concentrated trading patterns.

Specification of a trading institution provides additional results as well as insights into the coordination process. In many theoretical models prices are determined by application of an equilibrium concept. Our model does not. We model trading as a process resulting from agents arriving and placing orders in a limit order book.[3] When concentration and coordination occurs in our simulations, it almost always occurs in the first period of the trading day. As time progresses, profitable limit orders (from the agent accepting the order's perspective) are likely to have already been taken off the book through orders accepted by informed agents. Liquidity-motivated agents soon discover that trading later in the day is more likely to be unprofitable. Our simulated economy is a dynamic model which can be used to study the process as well as the conditions under which both concentration and coordination occur.

The organization of our paper is as follows. Section 2 summarizes previous research. Section 3 describes our autonomous agent-based model, and presents the experimental design for characterizing the economy. Our results are presented in Section 4, and Section 5 concludes.

2. Previous research

We are unaware of any previous studies using agent-based computer models to study intraday trading patterns. However there are empirical and theoretical studies of intraday trading patterns, as well as a number of applications of agent-based models to interday trading patterns and other finance topics.

2.1. Intraday trading patterns

Market microstructure studies have established a U-shaped trading volume pattern on several stock exchanges. Jain and Joh (1988) and Lockwood and Linn (1990) report this pattern for NYSE stocks. Similar patterns have also been reported for the Toronto Stock Exchange (McInish and Wood, 1990), the London Stock Exchange (Werner and Kleidon, 1996), the Hong Kong Stock Exchange (Ho and Cheung, 1991) and the Taiwan Stock Exchange (Lee et al., 2001).

[3] Other agent-based models (designed to study interday prices) have featured trade through agents interacting with a limit order book. See Chiarella et al. (2009b) for an example, as well as a discussion of these models.