Researching Financial Market Dynamics through Algorithmic Trading Agents

Short Paper

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Abstract: The evolving landscape of financial markets demands the integration of advanced technologies and quantamental paradigms like market simulations and artificial intelligence. This study explores the use of agent-based interactive discrete event trading simulations to analyze financial market scenarios and detect anomalies. The research involves various market fees and synthetic competition between exchanges, utilizing an inter-market spread arbitrage machine for price stability. This approach enables the observation of anomalies related to spreads, execution speed, traded volumes, liquidity, order execution probability, and agent decision-making influence. This study could serve as a valuable tool for financial institutions and regulatory authorities in strategic decision-making concerning financial market challenges.

Keywords: autonomous agents, simulations, financial markets, DEMAS

1 Introduction

Our research explores the use of Agent-based Interactive Discrete Event Simulations (ABIDES) for the analysis of complex financial market scenarios and the identification of potential anomalies. The goal is to experimentally simulate financial market issues instead of observing them, for example, in controversial pilot programs on real reference markets. Our work encompasses various market fees and a synthetic competition between two exchanges, employing an inter-market spread arbitrage machine to enable price stability between the exchanges. In other experiments various market scenarios were simulated, and key metrics such as the impact on execution quality, generated turnaround, and market share of exchanges were analyzed under different marketplace fee scenarios. This approach allows the observation of anomalies related to spreads, execution speed, traded volumes, liquidity, probability of order execution, and the impact on agents' decision-making.

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2 ABIDES and Related Work

The application of scientific computing models from information and game theory with discrete event multi-agent simulations (DEMAS) in the study of financial markets has garnered significant attention among economic researchers [Ha12]. This is particularly relevant in light of the 2010 flash crash, in which Navinder Singh Sarao, acting from his bedroom, was able to trigger a significant disruption in the U.S. economy through the use of high-frequency trading (HFT) of the e-mini S&P 500 [VL20]. This incident highlighted the need for a deeper understanding of the underlying dynamics of such anomalies in order to ensure effective regulation within HFT.

The discrete event multi-agent simulation (DEMAS) experiments, developed and customized for our research, are implemented using the open-source framework ABIDES, introduced by Byrd et al. [BHB19] in collaboration with researchers from J.P. Morgan AI Research [Am21]. The framework is utilized to evaluate the defined reference market problems. ABIDES is a multipurpose discrete event multi-agent simulation environment designed based on the NASDAQ equity trading protocols ITCH and OUCH [Am21b]. ABIDES offers access to complex financial market problems, enables nanosecond precision, and repeatable double-auction trading simulations [BHB20].

There is vast literature on financial market simulations in general: A good overview is given e.g. in [AF22]. Discrete event multi-agent simulations (DEMAS) combine the advantages of parallel discrete event simulations (PDES), for fast and efficient execution, and agent-based models (ABM), for flexibility and logical processes. In [BHB19] all major research related to DEMAS and ABIDES is presented, including former research projects and frameworks.

Hedge funds and investment banks discovered the opportunities of experimental simulations like DEMAS as support for backtesting on investment strategies [Pr18, Am21]. As such, researchers utilized such test-bed environments in experiments to gain a more comprehensive understanding of the events that led to the flash crash [Ba19].

In order to establish the capability to infer deterministic causal relationships in such financial market scenarios, we extended the existing model and introduced a competing exchange to the original simulation model. This approach follows a similar methodology as a study from the Japan exchange group (JPX) [HMY22]. To achieve price stability and high liquidity between these exchanges, we implemented a so-called arbitrage machine between markets with the possibility of arbitrage transactions. O'Hara et al. describe such a strategy as inter-market spread arbitrage by HFT market makers [Oh13].

The development and injection of reinforcement learning (RL) agents into the presented ABIDES models was introduced in another study, addressing similar research goals [DVB22]. In the meantime, J.P. Morgan AI Research introduced Phantom, another Multi-agent reinforcement learning (MARL) framework, giving also its comparison to other RL frameworks in [Ar22].

3 Approach

For our research we use the Agent-based interactive discrete event simulations (ABIDES) framework described above and add some new developments to investigate the impact of various market fee structures on trading agents with two competing exchanges.

All experiments are implemented in Python. Logged data from the ABIDES framework is used to feed our newly developed post-experiment analysis dashboard. Due to its broad functionality and possibilities, the dashboard is implemented as a web-based application.

Our goal was to extend the base model experiments for market turnover and execution quality by a secondary competing exchange with separate market fee models, and provide specific agents the ability to make a price and fee-effective order placement decision. We wanted to realistically constitute a synthetic competition between two exchanges and obtain evaluable results for market share, turnover and execution quality. To achieve price stability and high liquidity between exchanges, a so-called arbitrage machine between markets with the possibility of arbitrage transactions was implemented. The primary objective of this inter-market spread arbitrage machine is to achieve price stability, akin to that of high-frequency traders, by utilizing an arbitrage strategy.

4 Results and Outlook

The primary objective of our experiments was to simulate a security's trading activity with a fundamental value of $1,000 on a U.S. stock exchange during a usual trading day, which spans from 9:30 AM to 4:00 PM. In our experiments, we have implemented three different types of trading agents. The simulation aimed to replicate the dynamic interactions of market participants and the price movements in the security. The experiment was run five times, each utilizing a different distinct pseudorandom number generator (PRNG) seed.

The preliminary results are promising and demonstrate the potential utility of this framework. We could observe interesting behaviors between agents in different market scenarios and also conclude significant differences in the turnover and the speed of execution between the exchanges with different fee strategies. Our newly introduced arbitrage machine showed a realistic behavior in all simulations.

It should be emphasized that our experiments are still very simplified and that real-world financial markets are complex, but the objective should be to strive for comprehensive and highly realistic simulations. Further efforts are required to enhance these methods and optimize them into a fully operational system. There are plenty of options to extend the experiments presented in this research. E.g. the implementation of more extensive experimentation is planned for the future, including more market participants and a wider variety of trading strategies, in addition to more detailed parameterization. Also, the Machine Learning-based ABIDES-Gym with RL agents could be used to make decision even more realistic. These extensions could allow a more detailed analysis of HFT agents between two exchanges and the observation of manipulation strategies such as price layering, spoofing, and quote stuffing [Oh13].

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