Stock Market Simulation: An Analysis of Order and Trader Types

Jake Baker
Northwestern University MSDS 460
March 16th 2025

Executive Summary:

An agent-based simulation modeled a simplified stock market analyzed Market Makers, Institutional Investors, and Retail traders. Results showed Market Makers achieved significant profits due to their price setting ability, dictating many terms of the market. Retail Traders profited from limit orders but suffered losses with market orders. Both Institutional and Retail Traders generally experienced losses. The simulation highlights the advantages of Market Makers and the importance of order type selection for Retail Traders.

Introduction:

The stock market is a complex ecosystem driven by a multitude of factors and presents itself as a fascinating–although confounding–subject for analysis and simulation. This paper explores a highly simplified agent-based simulation designed to isolate and examine key interactions between trader types and order types. In this essay, three trader types are studied, Market Makers, Institutional Investors, and Retail Traders as they place both market and limit orders. By constructing a model that emphasizes order quantities and spread dynamics, the simulation aims to shed light on the potential advantages inherent to each trader type and to assess the overall profitability of market and limit orders. It is important to note that this model does not take into account market appreciation or depreciation as the price is standardized between 99 and 101 (except potentially for a Market Maker). Utilizing biased randomized parameters to generate diverse trading scenarios, this simulation seeks to provide a theoretical framework for understanding the behavior of the margaret and the tools at the disposal of certain actors in the market. Within the confines of a controlled, simulated environment, this study

offers a clearer understanding of the interactions between trader types and order execution strategies, thereby illuminating aspects of market dynamics.

Simulation Design:

This study utilizes an agent-based model to simulate a simplified stock market. As shown in Figure 1, the simulation centers around the MarketSimulator class that manages trader interactions and order processing. Traders are modeled as individual agents, as shown in Figure 2, where a new instance of the object is created to represent a single market entity. Each trader has attributes such as balance, holdings, and trader_type and their actions drive the simulation. Within MarketSimulator, there is also an OrderBook that manages the influx of orders and finds matching trades.

The key aspect of the simulation is the distinct actions and parameters of each trader type. Market Makers have the ability to bully the market and are able to set the price and make trades of vast quantities, taking the spread as the profit. Retail Traders are entirely price takers at the mercy of Market Makers and make up the majority of investors in the model. Institutional Investors are somewhere in between; executing large trade volumes at a price calculated with a degree of randomness instead of entirely taking from the Market Maker.

At each step in time, there is a 10% chance that a given trader will generate an order. When an order is generated, there is an even chance between it being a buy or sell and market or limit order. Order quantity and price are calculated according to the type of trader that is placing them. Along with the ability to make profit off of the spread, Market Makers can also place large scale trades. In this model, their quantity is chosen randomly from a uniform distribution ranging from 25 to 500.

Similarly, Institutional Investors and Retail Traders set their holdings between 10 and 100 and 1 and 25, respectively. A sell order that would cause a trader to go into negative holdings is permitted, as that can be treated as a short. The real difference between the three trader types is how they calculate the price of the order. As mentioned before, Retail Traders are price takers, meaning that when they generate a price for a limit order they must take the price that is given to them by the market maker. This is retrieved by accessing the priority queue in the order book. The price for a limit order placed by an institutional investor is chosen randomly between 99 and 101 to indicate that they are not price takers nor makers. Market Makers set the price at the best available price ± a spread that they'll typically be able to take as profit. Regardless of trader type, if the order is market, then the price is set to 0. This will not be the price at which the trade executes, but instead is used for insertion into the priority queue, placing it at the front of the line to be executed immediately.

For the overall simulation, 100,000 simulations were run, each with 10,000 time steps. The number of traders was randomized by between 4 and 100 for each simulation. When each trader is created, there is a 2% chance that they will be a market maker, 28% chance an institutional investor, and a 70% chance they will be a retail trader. The data from each simulation is aggregated into a single data structure and stored for analysis following the simulation execution. For efficiency of execution, a multithreaded approach was used, meaning that multiple threads executed at once. This prevents the analysis of logging statements so none were created, but a standard iterative approach could be employed instead to generate potentially meaningful insights into logging statements.

Analysis and Results:

The simulation generated profit distributions and averages for each trader type and examined market versus limit orders for retail traders. Market Makers exhibited the highest average provide, accompanied by significant volatility as indicated by their wide profit distribution (Figures 6 and 7). As liquidity providers they have the potential for substantial gains but also are exposed with considerable risk. Conversely, both Institutional and Retail Investors tended to experience losses. For Retail Traders, this loss was typically due to market orders executing at a loss as limit orders were actually profitable for them (Figures 8 and 9).

Conclusions:

This simulation, designed to model a simplified stock market, provided valuable insights into trader profitability and the impact of order types. The results highlighted a clear advantage for Market Makers, who demonstrated the highest average profit and significant volatility. Both Institutional and Retail traders typically had losses, suggesting that in this largely randomly generated environment, Market Makers are in the best position to profit as there is no way for Institutional and Retail Investors to benefit from true appreciation of the asset. The simulation underscores the importance of strategic order selection for Retail Investors and provides a foundation, both in terms of codebase and of thought, for more complex simulations to examine market dynamics in the future.

Appendix:

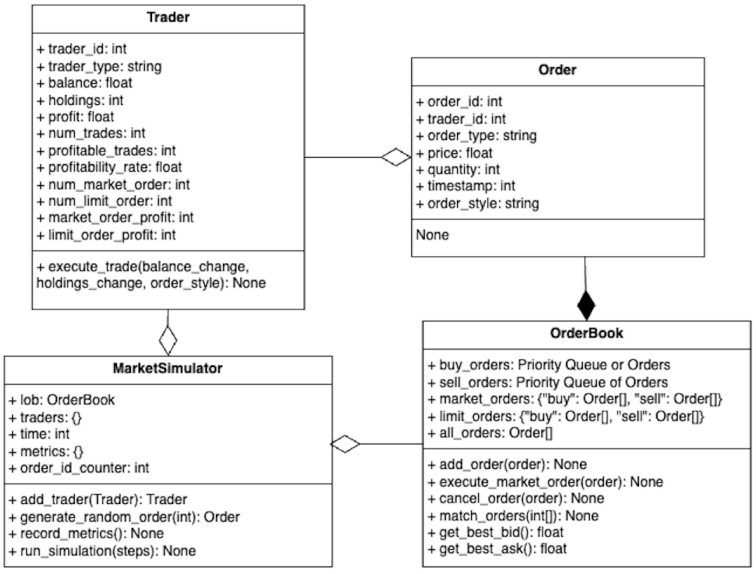

Figure 1: Object relation chart of model. A MarketSimulator has Trader objects and an OrderBook that is made up of priority queues of Orders, and each Order has a corresponding Trader that placed it.

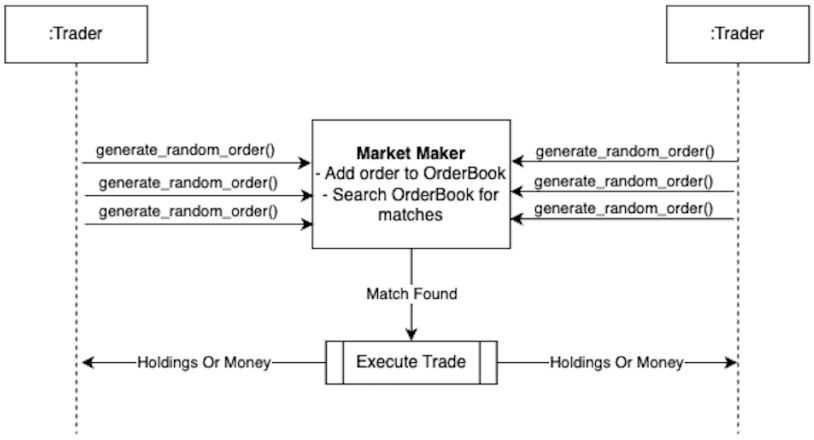

Figure 2: Agent-Based order flow. Traders repeatedly generate random orders that get added to the order book, matched by the Market Maker, and executed.

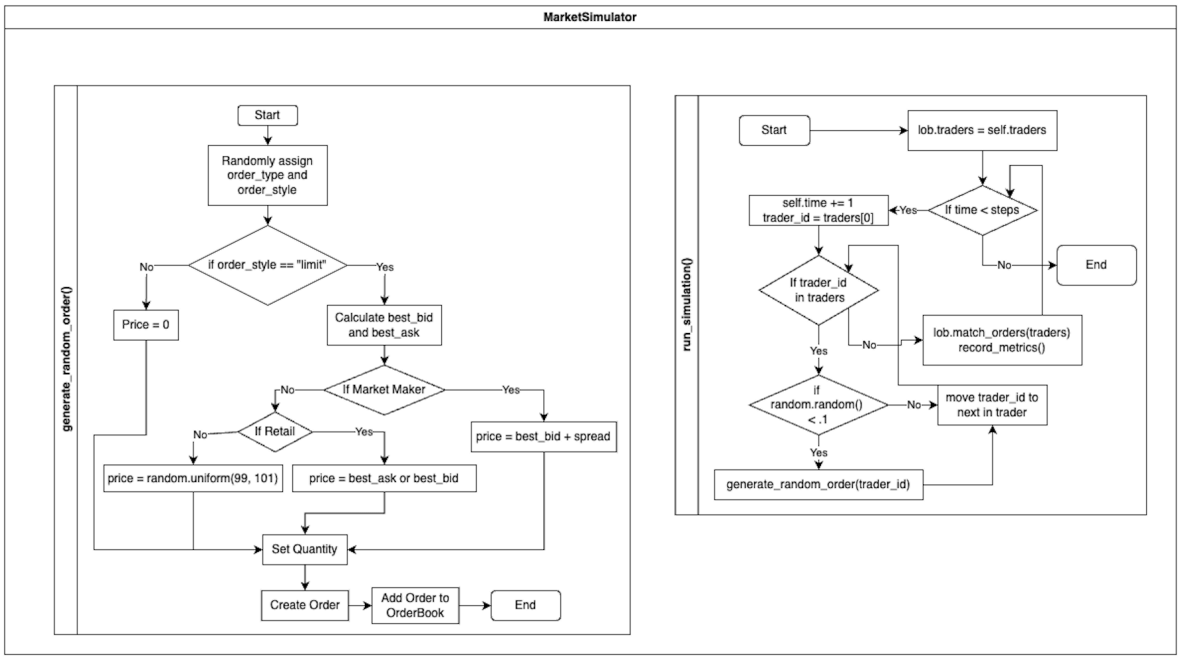

Figure 3: UML Flowchart showing two key functions within the MarketSimulator class, generate_random_order() and run_simulator().

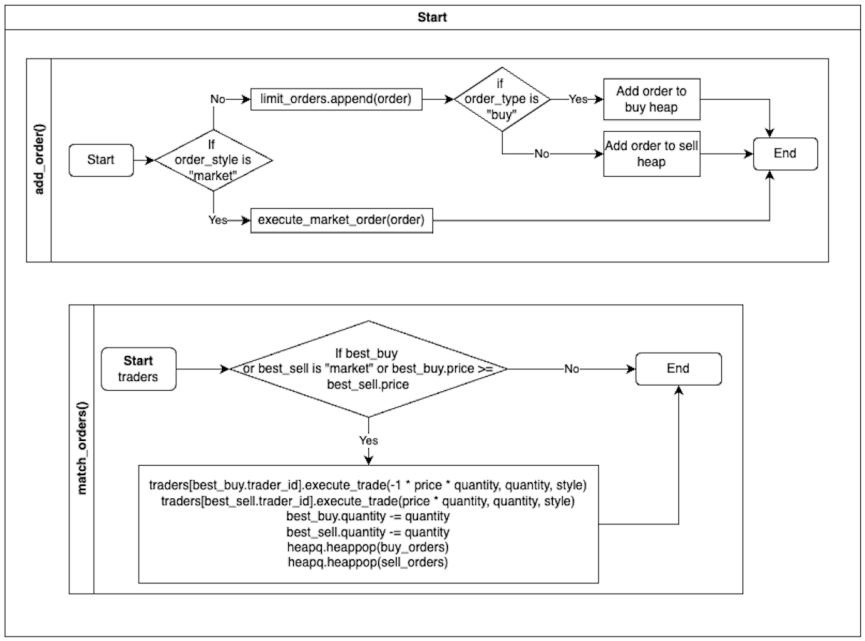

Figure 4: UML Flowchart showing key functions within the OrderBook class, add_order() and match_orders().

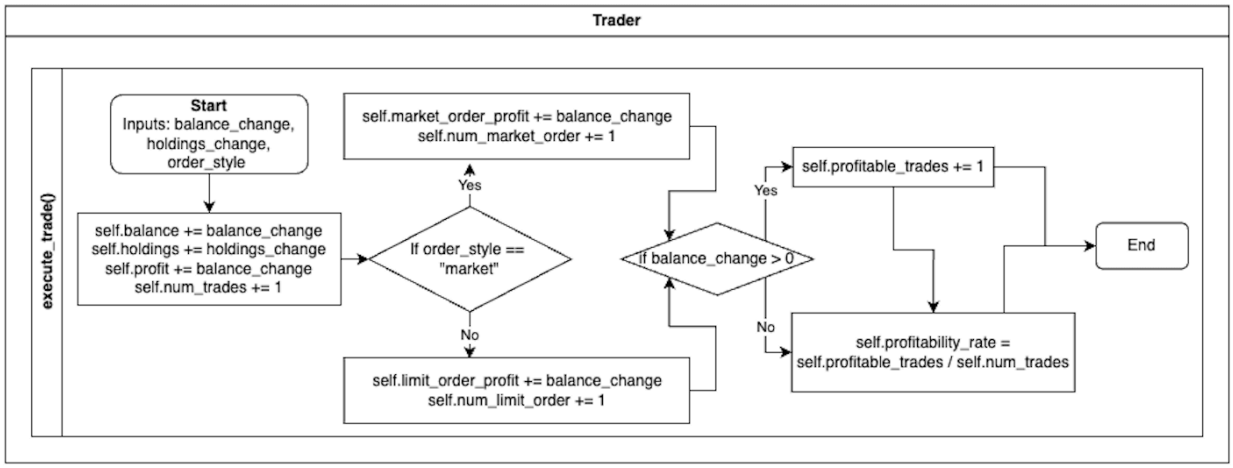

Figure 5: UML Flowchart showing function within the Trader class, execute_trade().

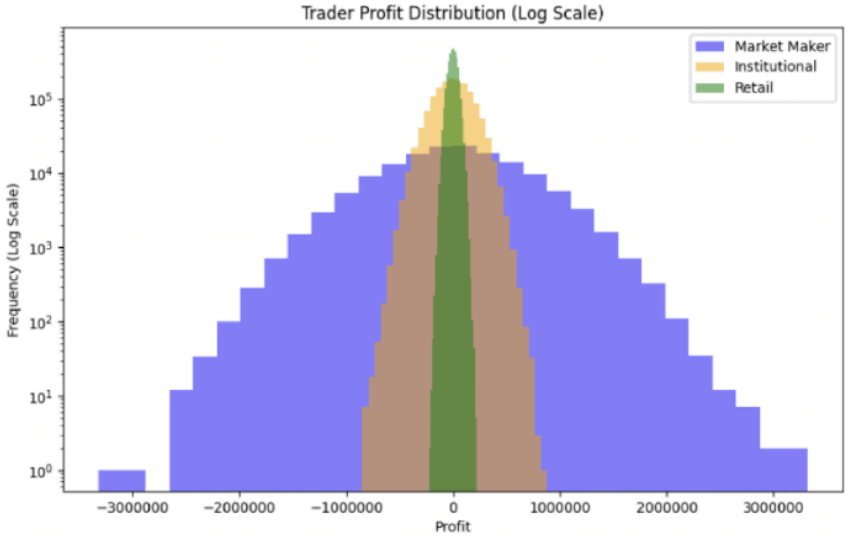

Figure 6: Distribution of profits by trader type with a logarithmic scale on the y-axis.

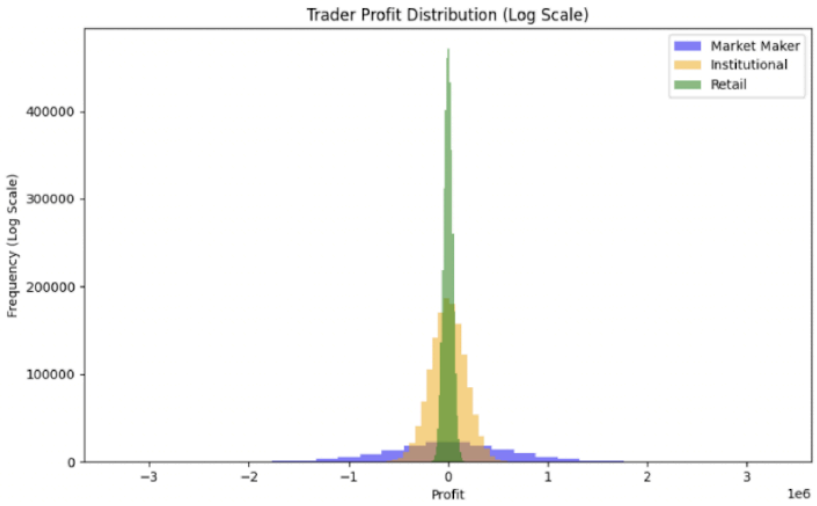

Figure 7: Distribution of profits by trader type.

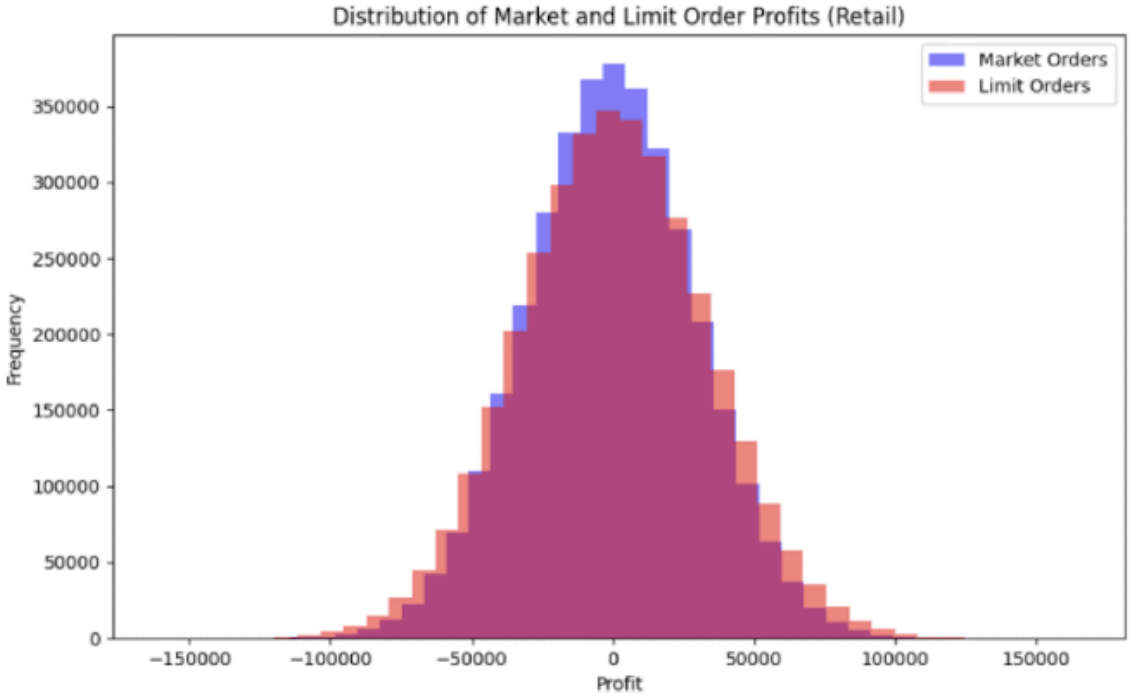

Figure 8: Distribution of profits for retail traders by order type (market or limit)

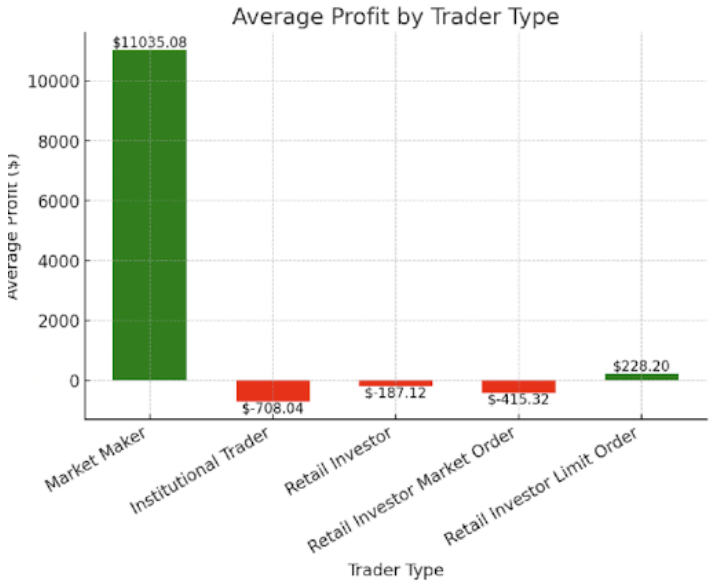

Figure 9: Bar graph illustrating the average profit by trader type and order type for Retail Investors.