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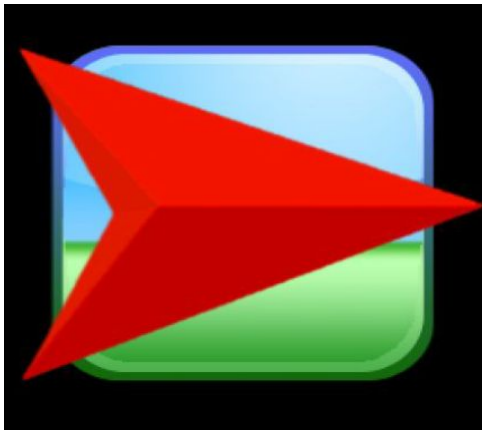

He Said, She Said: Agent Based Model of Financial Markets Based on Consumer Confidence

Mark Xue
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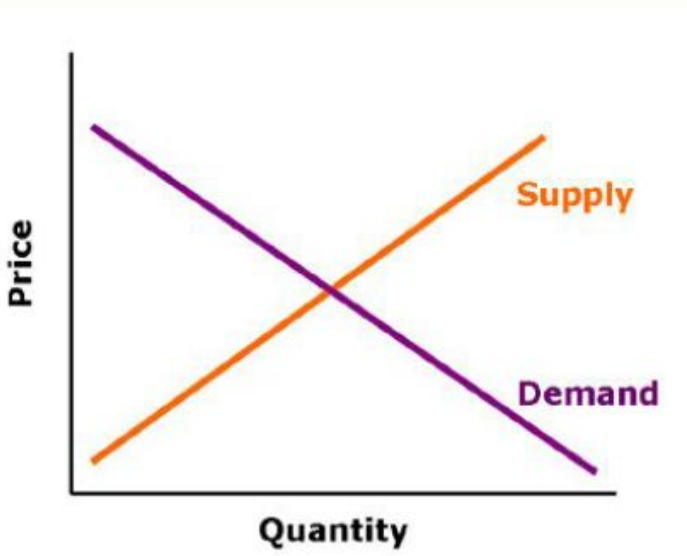
Northwestern University

1. Abstract

The financial markets is an essential element in the U.S. Economy whose effects extend in many aspects of our lives. From the corn we eat to the interest rate we earn on our savings, the financial markets influence the prices we pay or receive for goods and services. In this NetLogo project, I aim to model how agents interact in the financial markets based on confidence. I hope to explore how external shocks affect agent behavior in the market and any emergent behavior which arises.

2. Introduction



The main mechanism behind the financial markets is idea of supply and demand. If there are more people willing to buy than sell a product (more demand than supply), then the price of the product will rise. If more there are more people willing to sell a product than buy (more supply than demand), then the price of the product will fall. When there is an equal number of people willing to buy and sell a product, then the price stabilizes at an equilibrium.

So what drives the supply and demand of a product? Consumer products like livestock, vegetables, electronics have a supply function based on producers (farmers, factories, etc), factoring in elements of cost and profit. The demand functions are determined by the need of the consumers, with some influence from outside parties (advertising). Under normal operations, the supply and demand in the market would be in equilibrium with thousands of parties interacting, buying and selling the product. Prices would move to a new equilibrium as the number of suppliers and consumers changes. However, supply/demand shocks may also occur (such as news of outbreak of Mad Cow Disease or a drought) which may temporarily drastically shift the supply/demand functions, and in turn, affecting the equilibrium price in the market.

But how is the price determined for a product that has no direct intrinsic value for the consumer? How are the prices of products which cannot be consumed, such as stocks and bonds, determined in the financial market? How are the supply/demand of these finance products determined? To understand this, we must first discuss the origins of the financial markets and its products.

Financial instruments were first created to facilitate business growth and interactions. For example, a farmer planting next year's crops may be worried about the price a year in the future. What if the price of the corn he plants falls and he cannot afford next year's seed crop? Likewise, industrialist may want to expand his cereal factory, but may be worried that the price of corn may rise too high next year and he may not have enough money to expand his factory and afford the cost of cereal production. The ensure future price stability, forward and future contracts were created. These contracts sets the price and quantity of a good to be bought or sold between two parties at a specified future date. Stocks and bonds were created to raise money for business expansions and growth. Interest rates and foreign exchange products were created to mitigate the risk of long term or foreign investments.

Each of these financial instruments are bought and sold in its own market by agents such as brokers, corporations, market makers, speculators, etc. Each of these agents will consider information regarding the market such as government policies, state of the economy, business performance, macro events, and etc. This will affect the agent's sentiment regarding the markets, perception on how other agents in the market will behave, and how he/she will trade these instruments accordingly.

3. Overall Description

By applying Multi-Agent Based Modeling in the financial markets, I am able to stimulate the behavior of agents participating in equity index markets under different conditions. The agents are randomly distributed as bullish (want to buy) or bearish (want to sell) of the market. How each agent behaves in each tick will change the confidence level of the agents for the markets, affecting their decision to buy or sell the instrument, and ultimately affecting the market price of the index. Different trading logic and market conditions are implemented, to simulate the reactions of the agents to different events which occur.

4. What Can Be Learned

The market is a system and those who operate in it are it's agents. There is a cycle effect where the market affects the agents and the agents also affect the market. What governs agent behavior is its confidence in the markets based on what occurred previously and how the agent expects the market to perform moving forward. This model aims to explore how the market price affects the confidence level of its participants and vice versa. It aims to experiment and analyze different ways the agents react to external events, such as a demand or supply shock to the market. Finally, it aims see what emergent behaviors occur in the market when the agents perform according to a set of trading logic.

5. Rationale/Motivation

The financial markets move because of the decisions and actions of hundreds and thousands of participating agents; each action of the agent in turn affects others in the markets. While there exists a lot of market data, it is hard to make sense of it. A lot of ways people try to make sense of the data is backward looking, trying to find a relationship out of randomness. I feel that by abstracting away from the historical data, and modeling how agents behave will be a better way to learn how certain events or behaviors emerged within the financial markets. This makes computational agent-based setting as a good choice because it is easier to experiment and simulate different conditions and see how the effects are. NetLogo offers a way to model market participant behavior, from hundreds to thousands of agents, in a cost effective way. It also offers an easily accessible method to test the effectiveness of trading logic and strategies. If there is further potential in this project, HubNet may be used to implement market simulation experiments on real subjects.

6. Design and Implementation

There are 100 agents in the model which represents traders within the financial markets. The fundamental logic with trading in financial markets is to buy low and to sell high. Therefore, agents would be tempted to buy what they believe is cheap (or what would appreciate in value in the future) and sell what is expensive (or what they believe will depreciate in value in the future). The simulate an agent's sentiment on how the market will

perform, each agent will possess a confidence level ranging from -100 to 100. The more positive the confidence level is, the more optimistic (bullish) the agent is about the market and will buy the stock. The more negative the confidence level is, the more pessimistic (bearish) the agent is about the market and will sell the stock.

The market price of the stock index is determined by the sum of the confidence level of each individual agent. An individual agent's confidence level will be affected by events which have occurred during the previous period. If the market price of the index have increased, then the confidence level of the agent will increase and the agent will become more bullish. If the market price of the index have decreased, then the confidence level will decrease and the agent will become more bearish.

In the real world, historical data is used by financial professional to help make an educated guess on what may occur in the future. Historical data will also influence trading decisions of the agents by influencing their confidence levels. As the market price approaches all time highs, the agents may be opportunistic and believe that it is a good time to "sell high." This may decrease the confidence level of the agents, influencing the agents to sell and decreasing the market price. As the market price approaches all time lows, the agents may again be opportunistic and believe that it is a good time to "buy low." This may increase the confidence level of agents, influencing the agents to buy and increase the market price.

The user of the model may experiment with the moving-average strategy popular with finance professionals. In this strategy, if the market index price is above the 50-tick moving average, there is a chance that the agents within the markets may believe the stock is expensive and sell, thereby decreasing their confidence levels. If the market index price is below the

moving average, then the agents may believe the stock is cheap and buy, thereby increasing their confidence levels. Additionally, the user may also introduce an external macro shock in the confidence level through selecting add shock. This will cause a one time disturbance in the confidence level of the agents.

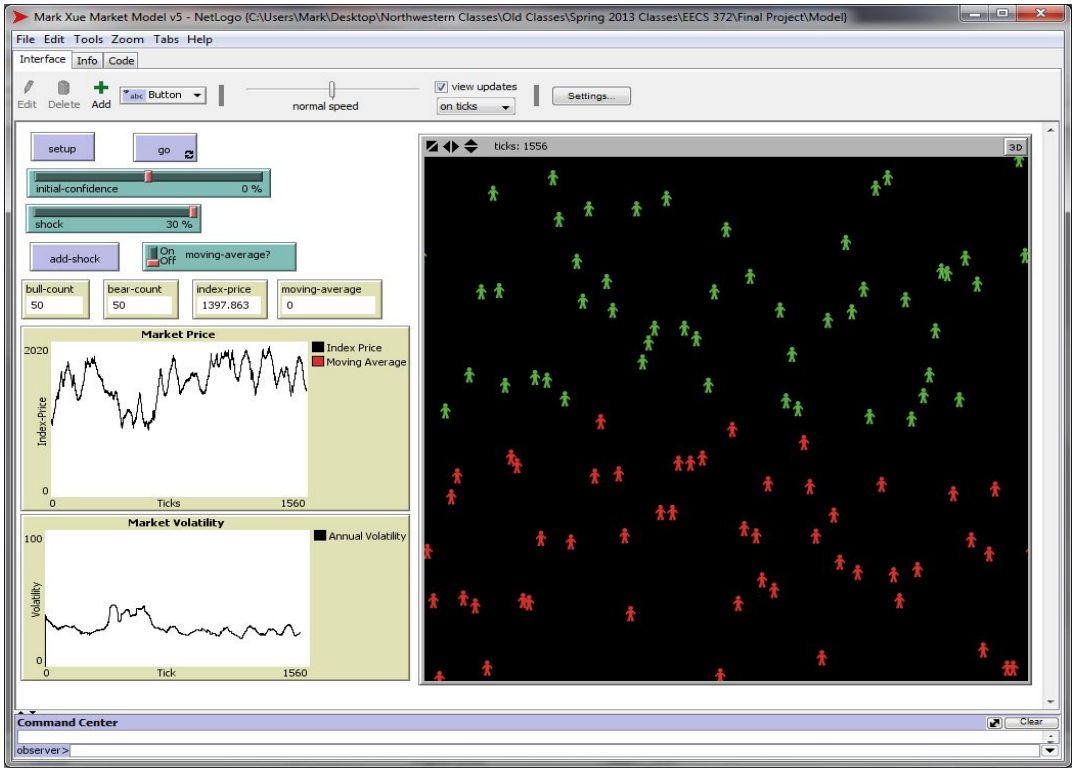
Summary of Agent Rationale

- If the market price increases compared to the previous tick, my confidence level will increase.
- If the market price decreases compared to the previous tick, my confidence level will decrease.
- If the market price reaches all time highs, then there is a chance that I will sell and my confidence level will decrease.
- If the market price reaches all time lows, then there is a chance that I will buy and my confidence level will increase.
- If there is an external shock introduced, my confidence level will be adjusted accordingly.
- If the moving average strategy is turned on:
    - If the market price is below the moving average, I will become more bullish, buy the stock, and my confidence level will increase.
    - If the market price is above the moving average, I will become more bearish, sell the stock, and my confidence level will decrease.

Summary of System Behavior

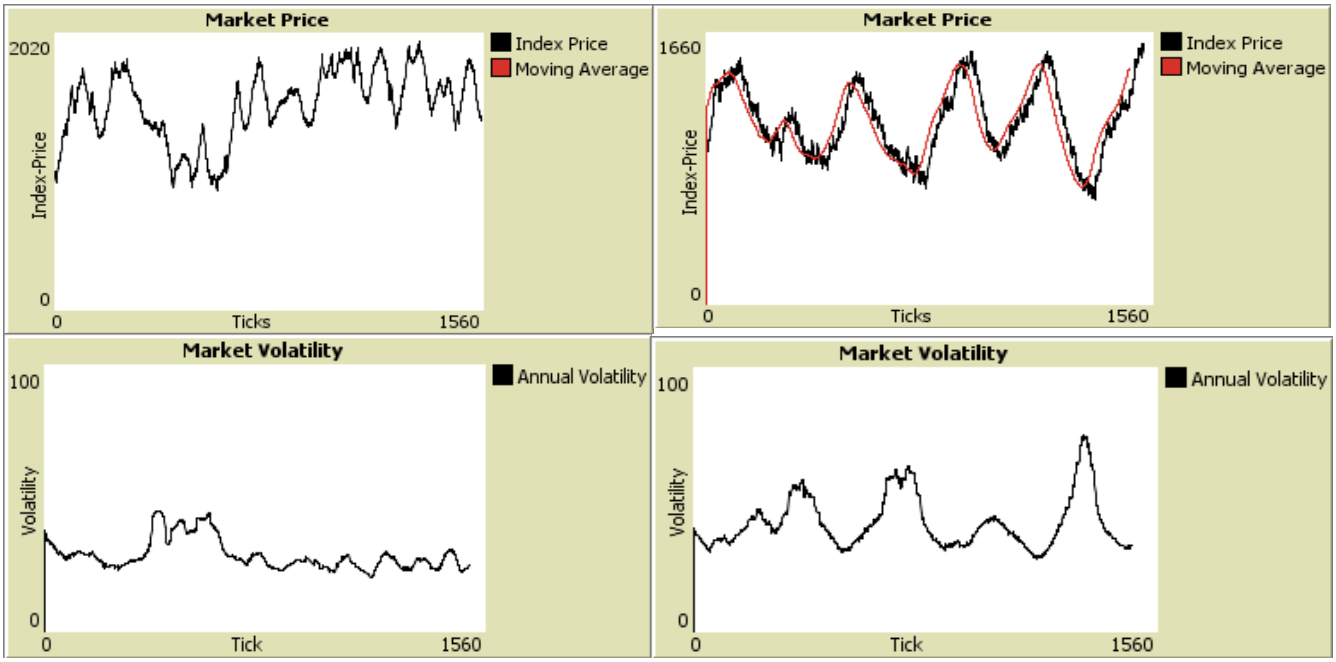
- The market index price is the sum of all the agents' confidence level.

7. The Model



The image above is the output screen for the model. Upon start-up, the user may specify the initial confidence of the agents. The agents' confidence level will be randomly distributed around this initial level. Agents who are bullish have confidence levels greater than zero and will be colored green. Agents who are neutral have a confidence level of zero and will be colored white. Agents who are bearish have confidence levels less than zero and will be colored

red. Finally, the magnitude of the agents' confidence level is displayed through how high it is on the screen: the higher the confidence level, the higher the agent will be on the screen and vice versa.

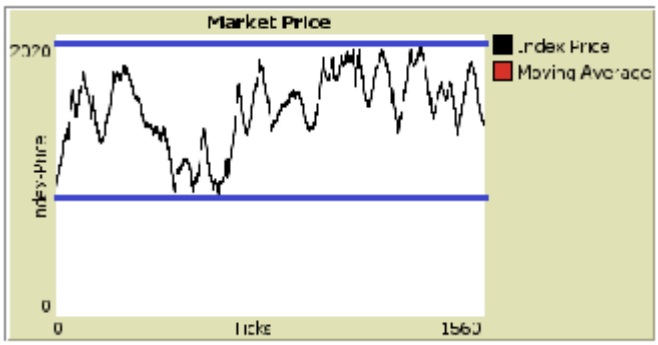


Output without Moving Average Strategy Output with Moving Average Strategy

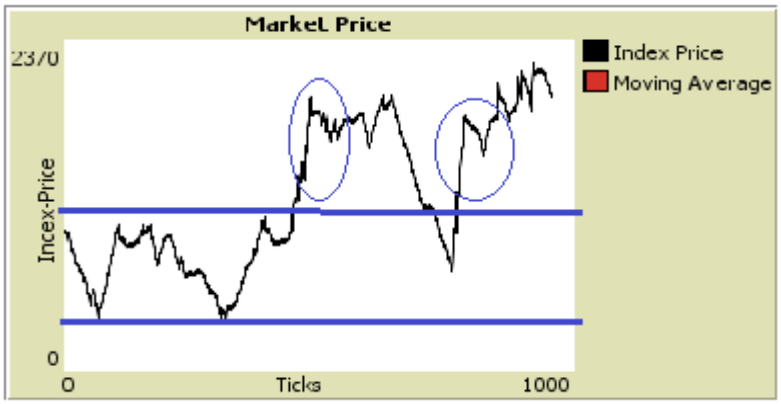
The historical market price and volatility is displayed graphically. This will help the user visualize what may happen when he/she introduces an external shock to the market or what happens if the moving average strategy is turned on.

8. Results

The all time high and low price levels provided support and resistance levels for the market index price. These levels are marked by the two horizontal blue lines on the model's output graph to the right. This meant that the market price tended to fall when it reached the all time high levels and raised when it reached the all time low levels. We observe this phenomenon occur in financial markets due to profit taking and herd mentality of the market agents. Without additional new information, the market agents may assume that prices greater than all time highs may be expensive and will anticipate other agents will sell. Therefore, the agent will lose confidence in the market and will join the "herd" in selling, leading the a fall in market prices. The reverse occurs when the market prices reach all time lows.



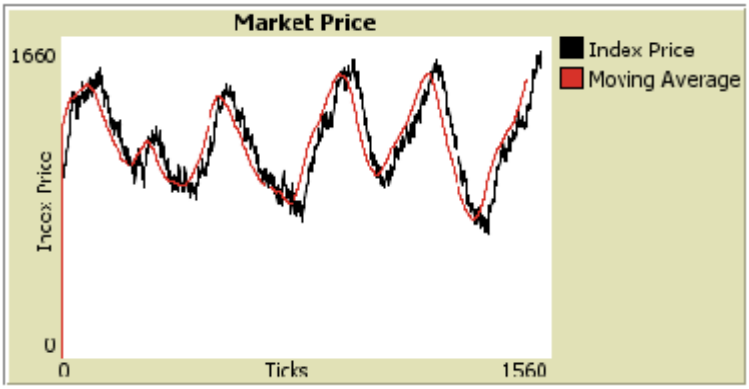
However, when an external shock is added to the market, it was easier for the market to break through these support/resistance levels to achieve new highs/lows. This is evidenced by the areas circled on the model's output graph to the left. During these periods, an positive external shock was able to help the market break resistance levels and achieve new all time highs. This makes sense because



the external shocks offer new information to the markets, changing the agents' market sentiment. The U.S. Economy experienced something similar in Fall 2012 when the Federal Reserve launched Quantitative Easing 3. This external shock increased the confidence of traders in the markets which in turn pushed market indexes to all time high.

Moreover, in Fall 2013, the government shutdown decreased market confidence leading to a drop in equity index prices. The eventual budget agreement ended the government shutdown and the Federal Reserve announcement of continuing Quantitative Easing policies greatly increased market confidence, breaking resistance levels and achieving all time highs. This is exemplified by the highlighted area of the S&P 500 Index graph above.

The output graph below is of the market price when agents follow the moving average trading strategy. In this strategy, if the market price of the index is above the 50-tick moving average, then there is a probability that some agents will believe the stock is too expensive, decreasing their confidence level, and selling the stock. If the market price of the index is below the 50-tick moving average, then there is a probability that some agents will believe the stock is too cheap, increasing their confidence level and buying the stock. We see an emergent pattern where the points where the market price cross the moving average marks turning points in market behavior. If the moving average is above the market price and crosses underneath the market price, it indicates the market price will fall in the future and vice versa. This is an important technical indicator for market agents. If we think about this in more detail, we may realize that if the entire market follows this technical indicator, then it becomes a self-fulfilling prophecy. Therefore, it may be interesting to experiment with the model to see what is the minimum percentage of agents using a particular strategy/indicator in order to affect market behavior and make the strategy/indicator a self-fulfilling prophecy.



9. Conclusion

The financial markets revolve around the actions of its participants, such as corporations who seek to mitigate risk or speculators who wish to make profits. The participants make decisions based on their confidence and sentiment on the markets, which is affected by their analysis of information such as economic health, government policies, and macro events. Through Multi-Agent Based Modeling, I tested out several trading logic. I saw how external event shocks and or specific strategies affected the markets. And ultimately, I learned that some trading strategies become self-fulfilling prophecies.

10. Moving Forward

There are many different ways to take this project moving forward. This model may be adapted to follow a variety of different trading strategies and logic, such as Fibonacci numbers or momentum trading. There is the saying within the trading community, “buy the rumors, sell the news.” A lot of traders work together and influence each other, sharing ideas. The agents may be linked together into several networks, with the agents affecting the confidence level of each other within the networks. We may observe how the overall market reacts when “rumors” or shocks are directed towards specific networks.

This model may be extended into a HubNet activity to see how real market participants react to market price movements and external events/shocks. Volunteers may participate and decide whether to buy or sell the stock at each tick. It will be interesting to see how human

emotions will affect the logic of their trading decisions. This may be compared to participants who follow strict logical rules detailed in the previous section for the original NetLogo model.

11. References

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