Re-implementing Lux's Financial Markets model

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Abstract

Speculative Markets are usually modeled as random walks, however, real-world speculative markets display behaviour which is not well explained by such models. Examples of these behaviors include leptokurtic returns distribution, volatility clustering, correlation between volatility and demand and price bubbles/ crashes. Lux's Financial Markets model[1] is a model of speculative markets consisting of traders with different trading strategies and beliefs. The model and our extension are able to recreate many of these phenomena and also display chaotic attractor behaviour.

Introduction

Lux's Financial Markets model is an agent based model of markets. The model has two types of traders, namely, Fundamentalist traders and Chartist traders. Fundamentalist traders make their trading decisions by comparing the current asset price with what they believe to be the 'fair price' for the asset. Chartist traders make their trading decisions based on their sentiment about the direction of price movement for the asset, which can be Optimistic or Pessimistic. The decisions of these traders decide the future price of the asset. These traders also interact with each other and these interactions can lead them to change their trading strategies. The model then seeks to study how these interactions lead to complex behaviour in the market. It is able to recreate phenomena such as leptokurtic returns distributions and price bubbles/crashes. The model has attractor behaviour (In the space of Fraction of Fundamentalists vs Sentiment Index of Chartist Traders) for some parameter values.

A rough overview of the process scheduling of the model is as follows. At the beginning of each time step, each trader decides an order quantity based on their respective trading strategies. For fundamentalist traders, this involves comparing the current price with their belief about the 'fair price' and buying a quantity which is proportional to this difference. On the other hand chartist traders always buy/sell a fixed quantity in each time step.
The excess demand is then calculated and the price of the asset is changed in proportion to this excess demand. Once the price is updated, each agent meets another agent. This meeting can result in the agent changing their trading strategy. The probability of this change occurring is a function of the difference in profits made/expected to be made by the two traders and of the proportions of traders using their trading strategies in the overall market.

The model assumes that there is a market maker with infinite liquidity who can absorb all excess demand and adjust the price accordingly. It also assumes that trading is frictionless and perfectly divisible assets. There are some limitations of the model as well. It is not able to model any external shocks such as the impact of news on asset price movement. It also has a highly limited number of trading strategies (i.e only 2 strategies). The model implementation has each Chartist trader buy or sell the same fixed quantity of asset in every time step. It also makes the simplification that all new entrants in the market are Chartists to begin with. The asset price is also very unstable (i.e it will crash to zero or rise very quickly) for a wide range of parameter values which makes it harder to run simulation experiments.

Motivation and rationale for the extension

The model has some limitations which might make the model overly simplistic or hard to simulate as mentioned in the previous section. We have extended the model to try and deal with these limitations.

To be able to study the impact of external shocks, we have introduced a news process which will impact the beliefs fundamentalist traders have about the 'fair value' of the asset. We have experimented with different types of news processes such as a process with equal probability of positive and negative news or a process with a sudden large negative news. The news process is responsible for generating 'news' at the end of each timestep. We assume all traders have perfect knowledge of this news and update their beliefs accordingly.

To increase the number of possible trading strategies, we have introduced two new types of traders, namely, Contrarians and Followers. Contrarians always bet on a reversal in asset price direction while Followers always bet on the continuation of the current trend in prices.

To stabilize the price changes, we have limited the maximum percentage change in prices in a time step. The quantity of assets a Chartist/Contrarian/Follower orders was also made random.

Results and discussion

For all the experiments, many different variables were tracked throughout the lifetime of the simulation. These variables include the asset price, the excess demand, the proportion of traders utilizing a given trading strategy and the news process. We tried different news processes as mentioned earlier. We found that the asset price roughly follows the 'fair price' believed by the fundamentalists. It fails to exactly follow this price due to the decisions of 'noise traders' (which include the chartists, contrarians and followers). Figures 1 and 2 show the price evolution and the evolution of the fair price. It also shows the sudden drop in the fair price caused by sudden large negative news. We can see that the price curve tries to follow the fair price curve.

The extended model also produces leptokurtic returns distributions (as can be seen from Figure 3) but the shape of the returns distribution now depends on the news process. The exact kurtosis also depends on the news process and it is possible to get highly leptokurtic returns.
The extended model had a much more stable price behaviour over a wider range of parameter values. This allowed us to conduct experiments with different starting proportions of trading strategies which allowed us to observe attractor behaviour like the one seen in Figure 5.
Another observation was that high volatility was usually accompanied by high excess demand (which is also observed in real financial markets) as shown in Figure 4.

Figure 1: Asset price vs Time (for an example simulation)

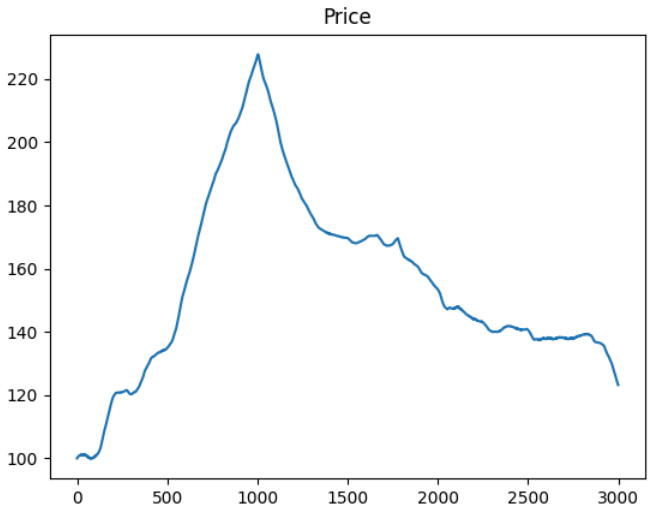


Figure 2: Fair Price believed by fundamentalists vs Time (for the same simulation)

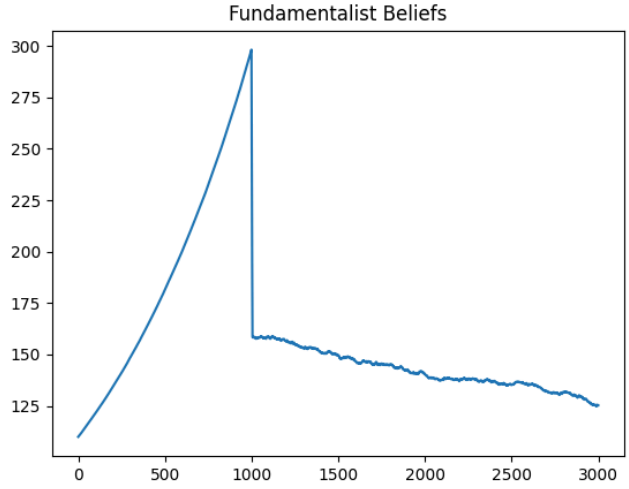


Figure 3: Histogram of the leptokurtic returns distribution

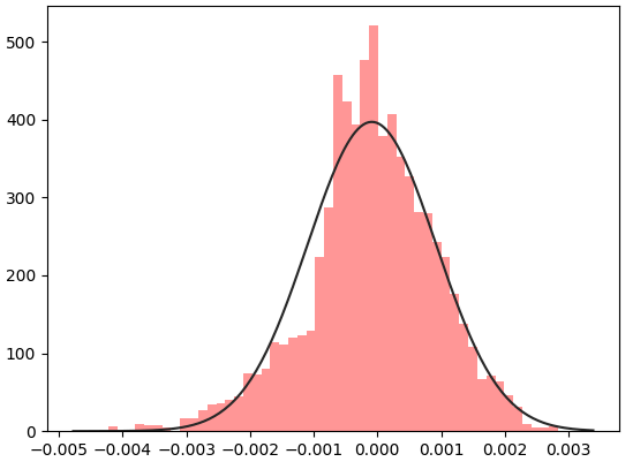


Figure 4: Price vs Time and Excess Demand vs Time graphs for a simulation

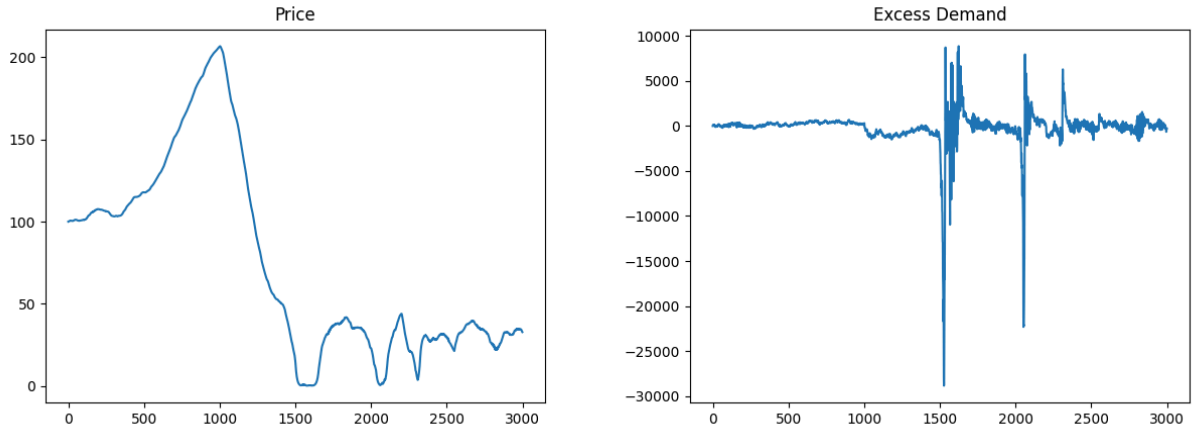
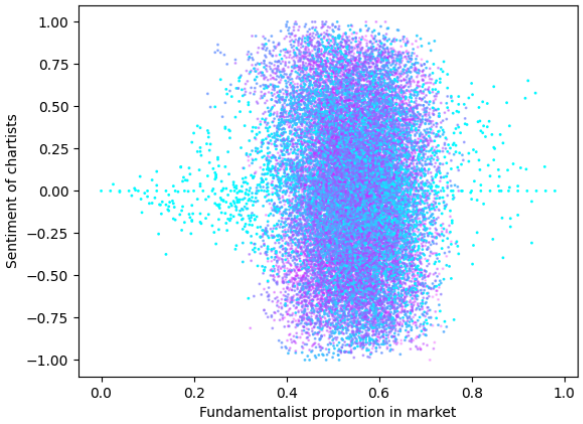


Figure 5: Attractor behaviour observed (Each simulation starts at a light blue point and the points get darker with each timestep) as all starting conditions lead to an equilibrium around one point



Source: Simulations conducted by the authors

Summary and conclusion

Lux's Financial Markets model is an agent-based model of speculative markets consisting of traders with different trading strategies and beliefs. The model has two types of traders, namely, Fundamentalist traders and Chartist traders, and is able to recreate many real-world phenomena such as leptokurtic returns distribution, correlation between volatility and demand and price bubbles/crashes. However, the model has some limitations, such as the inability to model external shocks and a limited number of trading strategies.

To address these limitations, an extension to the model was proposed, which includes a news process to simulate external shocks, new types of traders such as Contrarians and Followers to increase the number of trading strategies, and limits on the maximum percentage change in prices in a time step to stabilize the price changes.

The extended model produces leptokurtic returns distributions and is more stable over a wider range of parameter values, allowing for the observation of attractor behavior. The asset price roughly follows the 'fair price' believed by fundamentalists, but the decisions of noise traders (Chartists, Contrarians, and Followers) cause deviations from the fair price. High volatility is usually accompanied by high excess demand, as observed in real financial markets.

References

1. Lux, T. (1998). "The Socioeconomic Dynamics of Speculative Markets: Interacting Agents, Chaos and the Fat Tails of Return Distributions." Journal of Economic Behavior and Organization 33: 143-165