# Testing Leverage-based Trading Strategies under an Adaptive-Expectations Agent-based Model

## (Extended Abstract)

Elton Sbruzzi
University of Essex
efsbru@essex.ac.uk

Steve Phelps
University of Essex
sphelps@essex.ac.uk


## ABSTRACT

In this paper we introduce a novel trading strategy for trading in continuous-double auctions for risky assets. The principle underlying our strategy is an optimising of the level of leverage using numerical methods. Previous studies have shown that similar strategies can perform well when tested against theoretical models of asset price processes such as geometric Brownian motion, or back-tested against historical empirical price data. However, the former approach fails to account for phenomena such as non-Gaussian return distributions which are observed in real markets, and the latter cannot take into account how other participants in the market would likely respond to a newly introduced trading strategy. In order to account for both of these issues, we test our strategy using an existing agent-based model of financial markets which has previously been shown to replicate many of the statistical features observed in empirical financial time-series data. We analyse our strategy by simulating its behaviour under this model, and find that the key variable which influences its performance is the size of the market.



## Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent Systems*; J.4 [**Social and Behavioral Science**]: Economics

## Keywords

Agent-based models, optimal level of Leverage, numerical methods


## 1. AGENT BEHAVIOUR AND LEVERAGE

One of the principle advantages of agent-based models over more traditional economic models is that they are able to take into account the behaviour of individual agents [2]. Thus, it is important to determine what dictates such behaviour. The main objective of the individual investor is to maximise the end of period wealth [4]:

$$K_T = K_0(1 + ER_T)$$

where $K_T$ is the end of period wealth, $K_0$ is the initial capital and $ER_T$ is the end-of-period equity return.

Maximising the end of period wealth $K_T$ is the same as maximizing the end-of-period equity return $ER_T$ which is the product of different single-period equity returns:

$$ER_T = \prod_{t=1}^{T} (1 + er_t) - 1 \quad (1)$$

where $ER_T$ is the cumulative equity return after $T$ periods, and $er_t$ is the single-period equity return.

The single-period equity return is dependent on two different parameters: the stock return and the level of leverage:

$$er_t = r_t * l_t \quad (2)$$

where $r_t$ is the stock return, and $l_t$ is the level of leverage.

The formula of the stock return is:

$$r_t = \frac{P_t}{P_{t-1}} - 1 \quad (3)$$

where $P_t$ is the close price and $P_{t-n}$ is the open price.

By substituting Eq.(2) and Eq.(3) in Eq.(1) we obtain:

$$E_t(P_t, P_{t-1}, l_t) = \prod_{t=1}^{T} [1 + (\frac{P_t}{P_{t-1}} - 1) * l_t] - 1 \quad (4)$$

Hence, the end of period equity return depends on three different parameters: the open price, the close position price and the level of leverage.

## 2. MODEL

Iori and Chiarella [1] propose an agent-based model of a financial market which replicates the operation of an order-book in a continous-double auction. Agents decide the direction and the price of their orders, while the quantity is fixed at one unit per order. We extend the original model by allowing agents to vary their level of leverage by alternating the quantity of their orders. We introduce a group of three agents who use various trading strategies which place orders with varying quantities. Agents are split in three different approaches on leverage. The first agent uses the optimal level of leverage using numerical methods [3] to calculate the quantity in the order:

**Appears in:** *Proceedings of the 12th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2013)*, Ito, Jonker, Gini, and Shehory (eds.), May, 6–10, 2013, Saint Paul, Minnesota, USA.

$$\max_l \prod [1 + er_t(l)]^{\frac{1}{T}} - 1[\prod_{t=1}^{n}(1 + lr_t)]^{\frac{1}{n}} - 1$$

where $l$ is the level of leverage, and $er_t$ is the equity return.

Thus, since $p_t * q_t = K_t * l_t$ [3], where $K_t$ is the current equity, $p_t$ is the price at time $t$, and $q_t$ is the current quantity of the position at time $t$, the quantity to be held by the optimally-leveraged agent is:

$$q_t^{opt} = \frac{K_t l^*}{p_t}$$

where $q_t^{opt}$ is the quantity ordered by the optimally-leveraged agent and $l^*$ is the optimal level of leverage.

The second agent targets a level of leverage of 1, i.e. the agent is unleveraged. Thus, the quantity to be hold by the unleveraged agent is:

$$q_t^{unl} = \frac{K_t}{p_t}$$

where $q_t^{unl}$ is the quantity ordered by the unleveraged agent.

Finally, the third agent orders a quantity in order to maintain the agent's level of leverage at 10. Thus, the quantity to be hold by the excessively-leveraged agent is:

$$q_t^{exc} = \frac{10K_t}{p_{t-1}}$$

where $q_t^{exc}$ is the quantity ordered by the excessively-leveraged agent.

# 3. EXPERIMENT

We run three different experimental treatments, each with a different number of agents, in order to verify the ability of the optimally-leveraged agent to outperform the unleveraged agent and the excessively-leveraged agent in different sizes of market. The number of agents in the first treatment is 10, in the second treatment is 100, and in the third treatment is 1000.

In the first treatment, with 10 agents, three of the agents have the ability to order quantities grater than one per round which corresponds to 30% of the participants. From this treatment, we obtain the following results. Firstly, the value of the kurtosis and the skewness shows that the series of end of period return of the excessively-leveraged agent presents fat tails and asymmetry. Secondly, the null hypotheses of equality of the ends of period returns between the optimal leveraged agent and the unleveraged agent and between the optimal leveraged agent and the excessively-leveraged agent are rejected; and, due to the positive values of the confidence interval, the end of period return of the optimal leveraged agents is superior to the end of period return of the unleveraged agent and to the end of period return of the excessively-leveraged agent with the statistical probability of 95%, respectively.

In the second treatment, with 100 agents, three of the agents have the ability to order quantities grater than one per round which corresponds to 3% of the participants. From this treatment, we obtain the following results. Firstly, the value of the kurtosis and the skewness shows that the series of end of period return of the excessively-leveraged agent presents fat tails and asymmetry. Secondly, the null hypothesis of equality of the end of period return between the optimal leveraged agent and the excessively-leveraged agent is accepted. However, the null hypothesis of equality of the end of period return between the optimal leveraged agent and unleveraged agent is rejected and, due to the positive confidence interval, the end of period return of the optimal leveraged agent is superior to the end of period return of the unleveraged agent with the statistical probability of 95%.

Finally, in the third treatment, with 1000 agents, three of the agents have the ability to order quantities grater than one per round which corresponds to 0.3% of the participants. The value of the kurtosis and the skewness shows that the series of end-of-period returns of the optimal leveraged agent, the unleveraged agent and the excessively-leveraged agent exhibit fat tails and asymmetry. Under this treatment, we do *not* reject the null hypotheses that the mean end-of-period return is the same for each type of agent.

# 4. CONCLUSION

In this paper, we introduced a trading strategy which uses numerical methods to optimise the level of leverage when trading in a continuous-double auction for a single risky asset. We tested the hypothesis that the use of a trading strategy based on optimising the level of leverage has the ability to improve the investment performance of individual traders. In order to do so, we used an agent-based model in order to simulate the agent's strategy.

To the best of our knowledge, our work is the first to systematically analyse the performance of leverage-based trading strategies under realistic assumptions about market microstructure. By testing the performance of our strategy using an agent-based model, we have been able to evaluate its performance taking into account important details of the market mechanism, and how other traders in the market are likely to react. Although our approach shows some promise, our results demonstrate that deciding the quantity by numerically optimising the level of leverage is no guarantee of improvement in investment performance irrespective of market conditions; in particular we have demonstrated that there is a negative correlation between the performance of the strategy and the size of the market.

In future research there are two area of interest. Firstly, it would be interesting to investigate the connection between trading strategies and leverage intelligence. Secondly, in this paper we assumed no credit limits and consequently, no margin calls, and it would be interesting to examine the effect of these in future experiments.

# 5. REFERENCES


[1] Iori, G. and C. Chiarella. 2002. *A Simulation Analysis of the Microstructure of Double Auction Markets.* Quantitative Finance 2: 346-353.

[2] LeBaron, B. 2006. *Agent-based Computational Finance.* Handbook of Computational Economics 2: 1187-1233. Elsevier.

[3] Sbruzzi, E. and Phelps, S. 2011. *Optimal Level of Leverage using Numerical Methods.* CCFEA, University of Essex.

[4] Williams, J.. 1936. *Speculation and the Carryover.* The Quarterly Journal of Economics 50 (3): 436-455.