Need, Greed and Noise: Competing Strategies in a Trading Model

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Abstract

We study an economic model where agents trade a variety of products by using one of three competing rules: “need”, “greed” and “noise”. We find that the optimal strategy for any agent depends on both product composition in the overall market and composition of strategies in the market. In particular, a strategy that does best on pairwise competition may easily do much worse when all are present, leading, in some cases, to a “paper, stone, scissors” circular hierarchy.

Key words: Agent-based models; Economic models; Strategic games;

1 Introduction

Human activity often takes the form of exchanges. These exchanges typically consist of goods that can be quantified by value, but also opinions or other types of information may be traded. The former define a market economy. There have been several proposals to model such markets, see, for example the review by Farmer [1]. Most of the proposed models aim at reproducing the fat tails and volatility clustering in a stock or currency market [2,3,4,5,6]. Earlier we have proposed a market model (“Fat Cat” model) where agents trade products according to individual price estimates. These estimates were dynamically adjusted as a function of the trading encounters of each agent [7].

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The model mentioned above is one of many similar models that could be considered for such a market, each model being distinguished by a strategy that defines which product a buyer should select from a seller and how he should price it later. In the present paper we study the interplay of a few strategies. The relative performance of these strategies is quantified by the wealth of agents employing them.

We organized the paper by first reviewing the “Fat Cat” model in section II. The extension of this model to the case of other strategies is described in section III. Then, in section IV we discuss how the model could be extended to cases where agents are able to change their strategies according to their performance and give our concluding remarks.

2 Rules of the game

We picture our model as a cartoon of the trading situations found in a real market. As shown in fig. 1, this minimalistic model consists of a system where agents trade a set of \( N_{pr} \) different products. Each agent \( i \) is assigned one of three possible strategies selected to be either based on profit (i.e. “greed”, which is the strategy adopted in the original “Fat Cat” model), on the need for a particular product, or on a random selection without regard to the level of profit or need.

Other strategies could be explored; for example, agents could act as “garbage collectors”, buying whatever product has the lowest possible price. In this paper we limit ourselves to the three, probably most basic, strategies outlined in fig. 1.

Each of the \( N_{ag} \) agents starts with \( N_{un} \) units of goods. The goods are randomly selected, for each agent, among the \( N_{pr} \) different products. Thereby we form the stock \( S \) of each agent that together with some initial amount of money, \( N_{mon} \) define the initial state of the economy. We describe below the dynamics that arises from the interactions among these agents.

During the time evolution of the system, each agent \( i \) has, at each time step, an amount of money \( M(i), i = 1, ..., N_{ag} \), and a stock of the different products \( j, S(i,j) \), where \( j = 1, ..., N_{pr} \). The prices of the different items in the stock of agent \( i \) are denoted \( P(i,j) \) which initially are taken to be integers uniformly drawn in the interval \([1, 5] \). In all cases we have verified that the evolution of the system does not depend on this particular choice. Agents then meet and exchange products and adjust prices. Price adjustment is such that large differences in pricing between agents are lowered, but also such that price
1) A buyer meets a seller who shows the price list for his products.

Buyer

\[8 \ 4 \ 1 \ 4\]

Seller

\[5 \ 4 \ 2 \ 3\]

2) The buyer selects a product and buy if possible. The selection can be done according to either:
p) profit: (buyer would select \(\square\) for price 5)
n) need: (buyer would select \(\triangle\) for price 3)
r) random: (buyer selects \(\square\) or \(\triangle\))

3) If trade not possible, seller lowers price and buyer raises it.

Fig. 1. Pictorial representation of the model. A buyer and a seller in a market with \(N_{pr} = 4\) products meet. The buyer has one of products 1 and 3, two of product 2 and none of product 4. The seller, has one of products 1 and 4, two of product 3 and none of product 2. The buyer values the four products at 8, 4, 1 and 4 units of money and the seller values them at 5, 4, 2 and 3, respectively. The buyer compares his price list for the four products with the seller’s price list, and according to strategy proposes a deal.

differences are induced by some noise when they are small, as in real markets.

As in our simulations for the original “Fat Cat” model, we assume that at each time step the following procedure takes place:

- **1** Buyer \((b)\) and seller \((s)\) are selected at random among the \(N_{ag}\) agents. If the seller has no products to offer, then another seller is chosen.
- **2** The buyer selects a product \(j\) in the seller’s stock according to his strategy \(\sigma(i)\).
  - i) If strategy \(\sigma(i)\) is “Profit” then he selects the product \(j\) which maximizes \(P(b, j) - P(s, j)\), (i.e. his profit).
  - ii) If strategy \(\sigma(i)\) is “Need” then he selects the product \(j\) which he has the least in his stock (minimizes \(S(i, j)\)).
  - iii) If strategy \(\sigma(i)\) is “Random” then he selects a random product \(j\) in the seller’s stock for which \(P(b, j) - P(s, j) > 0\).

The selected product \(j\) is called \(j_{bb}\) (best buy).
• **3a** If the buyer does not have enough money, (i.e. if $M(b) < P(b, j_{bb})$), we return to the first step and choose a new pair of agents.

• **3b** If the buyer has enough money we proceed. If $P(s, j_{bb}) < P(b, j_{bb})$, the transaction is performed at the seller’s price. This means that we adjust: $S(b, j_{bb}) \rightarrow S(b, j_{bb}) + 1$, $S(s, j_{bb}) \rightarrow S(s, j_{bb}) - 1$, $M(b) \rightarrow M(b) - P(s, j_{bb})$, $M(s) \rightarrow M(s) + P(s, j_{bb})$.

• **3c** If $P(s, j_{bb}) \geq P(b, j_{bb})$, the transaction is not performed. In this case, the seller lowers his price by one unit, $P(s, j_{bb}) \rightarrow \max(P(s, j_{bb}) - 1, 0)$, and the buyer raises his price by one unit, $P(b, j_{bb}) \rightarrow P(b, j_{bb}) + 1$.

The prices are always non-negative integers. Also note that since, as defined in step 3 above, the price offered by the buyer cannot be higher than the amount of money it has, we are not allowing for the agents to get into debt. In case there are several products that fulfill the selection criterion in 2, a random one of these is chosen. One should emphasize that due to the price adjustments performed in unsuccessful encounters, the prices never reach equilibrium, and different agents typically assign different prices to the same product.

To quantify the system, we define the total wealth of an agent $i$ as the amount of money plus the value of all goods in the agent’s possession:

$$W(i) = M(i) + G(i)$$  \hspace{1cm} (1)

The value of product $j$ is defined as the average of what all agents consider its value to be:

$$P_{\text{ave}}(j) = \frac{1}{N_{\text{ag}}} \sum_{i=1}^{N_{\text{ag}}} P(i, j),$$  \hspace{1cm} (2)

and the value of all of agent $i$’s goods, $G(i)$ is defined as

$$G(i) = \sum_{j} S(i, j)P_{\text{ave}}(j).$$  \hspace{1cm} (3)

The “Fat Cat” model’s “profit” rule was studied extensively in our earlier paper. There it was found to lead to persistency and fat tails in the agents’ wealth fluctuations with time, hence its name. We now study the other strategies and their interactions.

### 3 Fixed Strategies

The three strategies given above lead to different wealth of the respective agents. We will now study this in some detail. Our first step is to illustrate how the wealth of the agents gets distributed in a system where all agents employ the same strategy. For that purpose we consider a system composed of
50 agents, 50 different products. Each agent is given 40 units of products and 20 units of money. The result, shown in fig. 2, is that there are appreciable differences in the wealth distribution according to the strategy. For a profit-minded system (the original “Fat Cat” model), there is a long tail of wealthy agents, which becomes less pronounced when the strategy is based on the stock needs. In this case there are no rich agents, but instead a large concentration of middle-wealth agents. If the strategy adopted is to buy a random product, the long tail disappears and the middle-wealth peak is shifted to lower values than in the previous case.

The situation can change when the economic conditions, as defined by the number of units of products and money in the economy, are changing. We will show that there is no best rule for all situations. This is shown in fig. 3, where we have changed the number of units of products, while keeping all other model values the same, in markets composed of equal numbers of agents employing two different strategies. In this case, where \( N_{un} < N_{pr} \), each agent has a few of many possible products, thus representing an antique dealer market where there are many special items and no one can have everything. We see, in the upper panel, that for this market the “need” strategy, is better than “profit” above 10 units. However, below 10 units, the result is unstable, one strategy leading to better results than the other depending on the initial conditions. In the middle panel we see that the “random” agents have a higher
average wealth than the “profit” motivated ones when the number of units is above 45, the situation is reversed for a number of units below 35, and there is unpredictability in between these two values. Finally, the lower panel shows that “need” works better than a “random” strategy for all number of units in the range shown. For other parameter values, namely when the number of units of products and money is large, the “random” strategy outperforms “need”.

In this last case, namely for $N_{un} \gg N_{pr}$, each agent typically has many copies of all products, which represent a mass production market with many copies of few items; A supermarket world. In this case, a pairwise comparison of the three strategies shows an interesting situation, depicted in fig. 4: “need” outperforms “profit”, which outperforms “random”, which outperforms “need”. So, in this case no strategy is better than both of the other strategies when studied pairwise.

In fig. 5 we explore the triple market further, implementing a market where there is only one agent with “need” strategy among 25 agents with “profit” and 25 agents with “noise” as strategies, so that there are all together 51 agents. Without the single “need” strategy, “random” would outperform “profit” with a large margin. A single “need” agent in the system will slowly collect a large fraction of all products in the market. This is because it has a large competition advantage over the “profit”, which overcompensates its disadvantage to the
Fig. 4. Pairwise competition between strategies for a rich market, in which each agent has initially $N_{un} = M = 400$. The remaining parameters are the same as in Fig. 3. Here we find the circular hierarchy “need” > “profit”, “profit” > “random”, and “random” > “need”.

“random” ones. If the number of “profit” agents were reduced and that of the “random” agents increased, the “need” agent would do worse. This illustrates the fact that the number of agents employing the different strategies is also determinant in the relative success of the agents adopting them.

4 Outlook and conclusions

As we have seen, one may have different strategies for different agents. An interesting direction to extend this model is to let the agents to select the strategies they adopt in order to improve their performance. A further extension development would be to allow the strategies themselves to evolve. In the following we show a preliminary example of how the agents could choose strategies.

A simple mechanism consists in updating, at fixed time intervals, the strategy of the poorest agent in the system. This agent just changes his present strategy to any of the other two, at random. The resulting time evolution for a system composed of 45 agents initially equally distributed according to their strategies is shown in fig. 6. We see that, after an initial transient, the number of agents
Fig. 5. a) Competition between 25 agents employing the “profit” strategy with a similar number of “random” agents, in the same rich market as in Fig. 4. b) Competition where a single “need” agent is introduced into the system of the panel above. Note that this agent gathers so much wealth that he rapidly grows out of the scale of the illustration.

following the “need” and “random” strategies becomes approximately equal and constant for a considerable period of time, while the “profit” strategy is followed by a small fraction of the agents. An increase in the “profit” agents leads to a change in the conditions which lead the “random” strategy to almost disappear from the system, to a dominance of “need”, and the persistency of “profit” at a very low level. From the fig. 4 we see that were it not for the existence of “profit”-thinking agents, “random” would dominate over “need”.

The results shown in fig. 6 also demonstrate that the hierarchy “paper — stone — scissors” illustrated in fig. 4, for the same system, does not seem to lead, in the time interval considered, to alternations in the number of agents employing each strategy. There could be several reasons for this. One is that these changes take longer and longer time to alter enough the market conditions to significantly modify the performance of the different strategies. Another is that while in fig. 4 one measures the average wealth of the agents using each of the three strategies, the criterium for changing strategies is based on the performance of poor agents, i.e. on the agents’ wealth distribution in the region close to the origin. As suggested by fig. 2, a strategy yielding a higher average wealth than another, may also have a larger number of poor agents than the other. These issues need to be further explored for an appropriate strategy selection procedure and will be discussed in the future.
Fig. 6. *Number of agents employing each of the three strategies as a function of time. The model parameters are the same as in Figs. 4 and 5.*

Compared to earlier models of market dynamics the model presented here has some new and related key features: there is local optimization of utility (estimated market value) and all trades are done locally without the equilibrizing effects of a global information pool. This gives arbitrage possibility which drives a dynamic and evolving market. Earlier market models, such as the minority game, have a global information pool, and lack dynamical signals that could be associated with stock market fluctuations. The evolving Boolean network for minority games of Paczuski, Bassler and Corral [6], on the other hand, works with local information exchange, but the reward function is still global. Also the frame of minority games makes it difficult to treat a multi-product market, which we believe is important for understanding real stock markets.

The model we propose is for a market composed of agents, goods and money (or People, Prices and Products). We have demonstrated that such a market easily shows persistent fluctuations of wealth with time, and seen that the persistency is closely related to an interplay of having many products that influence each others trade probability. A similar result was obtained in the simpler model in [8], where it was demonstrated that persistency could arise even without money. The setup proposed here with agents and products with individual local prices allows for individual strategies of the agents. This opens for evolution of strategy as a part of the financial market, and we have seen that evolving strategies indeed give a dynamics where wealth is often rapidly redistributed.
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