The nature of herd behavior in resource allocation system

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Introduction

The formation of herd can be found in the collective behaviors of many species. It pertains to the behaviors of human formed systems, such as stock markets, the world of fashion, violent mobs, etc. To study the herd effect on economic systems, we carry out a set of behavioral economic experiments and build an agent-based model by introducing "imitators" into an extended minority game model called the market-directed resource allocation game. We analyze the preferences of players under different conditions in experiments and calculate the information entropy of agents in the model which predicts the existence of phase transition. It shows that herd behavior is not always the market-killer, and in some cases it can reduce the fluctuations and drive the market back to the balanced equilibrium state. Actually, there is precisely an appropriate size of herd which is best for the system, and the size is also related to the critical point of the market behavior phase transition.

Experiment

If $M_1/N_1>M_2/N_2$, Room 1 wins.

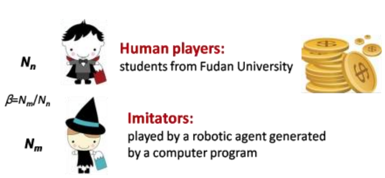


Fig. 1. The desktop of GCP used in the experiment. (a) the control panel for the organizer, (b) the panel for the game player (students).

Experiment Results

The preferences of the human players

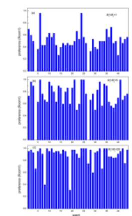


Fig. 2. Players' preferences to Room 1 in the economic experiment without imitators. The resource distributions are M_1/M_2=1, 3, 20 in (a), (b) and (c) respectively.

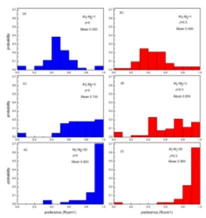


Fig. 3. The comparison of distributions of players' preferences under different situations. (a) M_1/M_2=1, β=0; (b) M_1/M_2=1, β=0.5; (c) M_1/M_2=3, β=0; (d) M_1/M_2=3, β=0.5; (e) M_1/M_2=20, β=0; (f) M_1/M_2=20, β=0.5.

●Human players have different preferences and own the ability to adapt themselves to the environment.

●When M1/M2 is relatively small, the herd formed by imitators disturbs the market and weakens the evaluating ability of the normal players. When M1/M2 becomes larger, the preference distribution does not change much.

The performance of the whole system

efficiency $e=|\langle N_1\rangle/\langle N_2\rangle - M_1/M_2|/(M_1/M_2)$

stability $\sigma^2/N \equiv \frac{1}{2N}\sum_{i=1}^{2}\langle (N_i-\tilde{N}_i)^2\rangle$

predictability W_1, the winning rate of Room1

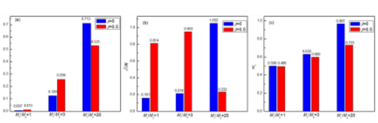
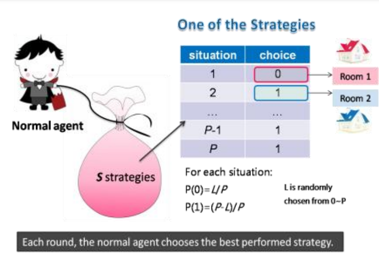


Fig. 4. The system behavior in the human experiment. N_n=50, N_m=25 (imitators), and each game lasts for 30 rounds.

Model



Simulation Results

Information entropy $S_I(X) = -\sum_{i=1}^{n} p(x_i)\ln p(x_i)$

Information content $I_i = (\ln 2 - S_{Ii})/\ln 2$

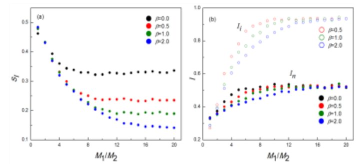


Fig.5. (a)The change of the average information entropy of all the agents. (b)The change of the average information content of the normal agents (I_i) and the imitators (I_{ii}) for N_n = 50, P= 16, S= 4, k=5, and β=0, 0.5, 1.0, and 2.0.

The market behavior for an open system

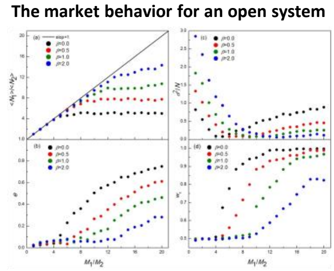


Fig. 6. (a) $<N_1>/<N_2>$, (b) e, (c) σ^2/N, and (d) w_1 as a function of M_1/M_2, for an open market system. Parameters: N_n = 50, P= 16, S= 4, k=5, and β=0, 0.5, 1.0, and 2.0. For each parameter set, simulations are run for 200 times, each over 400 time steps (first half for equilibration, the remaining half for statistics).

$$\langle R_1\rangle_{\max} = \frac{1}{NP}\left(\sum_{i=1}^{N_n} L_i + \sum_{j=1}^{N_m} L_j\right) = \frac{1}{NP}\left[N_n \sum_{\tilde{L}=1}^{P} \tilde{L}p(\tilde{L}) + N_m \sum_{\tilde{L}=1}^{P} \tilde{L}p'(\tilde{L})\right]$$

$$= 1 - \frac{1}{(\beta+1)P}\sum_{\tilde{L}=1}^{P}\left[\left(\frac{\tilde{L}}{P+1}\right)^S + \beta\left(\frac{\tilde{L}}{P+1}\right)^{kS}\right]$$

$$p(\tilde{L}) = \left(\frac{\tilde{L}+1}{P+1}\right)^S - \left(\frac{\tilde{L}}{P+1}\right)^S \qquad p'(\tilde{L}) = \left(\frac{\tilde{L}+1}{P+1}\right)^{kS} - \left(\frac{\tilde{L}}{P+1}\right)^{kS}$$

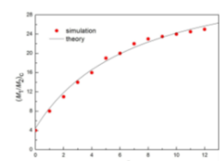


Fig. 7. Critical points of the M_1/M_2 phase transitions, $(M_1/M_2)_c$, varying with different β. Parameters: S=4, P=16 and k=5.

Conclusions

●Traditionally, people always thought that the formation of herd would ruin the market. According to our study, the common sense is true only if there is no big bias among resource distribution. However, when the environment is too complex for the normal agents to adapt to, the formation of herd would help the market to reach the balanced state.

●The proportion of imitators or the size of the herd should match the complexity of environment in order to reach the idealized market state. Some hints or guidance can be provided for the policy makers or market administrators whose mission is to keep the market in the balanced state through macro-economic control and readjustments.

Reference: Wang, W., Chen, Y. & Huang, J. P. Heterogeneous preferences, decision-making capacity and phase transitions in a complex adaptive system. *PNAS* 106, 2009.