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Regulation effects on market with Bak-Sneppen model in high dimensions

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We present the effect of regulations on self-organized market by using biological model of Bak-Sneppen in higher dimensions. This study extends the idea of Cuniberti et.al. The higher-dimensional description of the market suffices less effect of regulation than that of lower one.

Keywords: Self-organized market; Bak-Sneppen model; Regulation; Cuniberti et al .

1. Introduction

Economic markets are known to exhibit a self-organized criticality(SOC) [1]. The SOC is characterized by a spontaneous approach to a steady state without any external tuning of parameters. However, there seems to exist many external factors which affect on the constituent companies in real economical markets such as a certain kind of control of prices, a direct regulation to the companies and so forth. Recently Cuniberti et. al.[2] introduced a regulations on the self-organized market with Bak-Sneppen model of one dimension. The Bak-Sneppen model[3,4] is known as a simple model which exhibits SOC. Although the model is originally devised to describe a evolutionary aspects of biological species which have varied niches, it seems possible to borrow the concept in order to describe the asymptotic market behavior by regarding species as companies in the market. We follow Cuniberti et al [2] and are concerned with the effects of a regulation from authorities such as governments or agencies on economic markets. In this paper, we extend the market to d-dimensional lattices and see the regulation effects for each dimension. The purpose of the present simulation is not to justify the validity of the Bak-Sneppen model as a self-organized market. Instead we aim at elucidating the nature of regulations and seeing dependency on the dimensionality.

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2. Model

We assume that companies are located on sites in d-dimensional lattices. Each company on the lattice is characterized by one single parameter which is called fitness value f_i. The fitnesses are assumed to express a certain kind of strength of the company[2]. For example, it may be the size of the company, the amount of capital, the profit and so on. We consider that a company whose fitness value is high can survive easily in a competitive and highly interactive market. The closeness of sites on the lattice represents that the companies are simular. The dynamics we employ is as follows. First we assign random numbers between 0 and 1 to each company as an initial condition. The market is updated by finding the least-fit company (the company having the lowest fitness value in the lattice) and assigning new random numbers f' to it and to the $2d$ nearest neighbor companies independently. At each time step(e.g.fiscal year), a company with the lowest fitness value may be forced to improve its performance or may go bankrupt and be replaced by a new company. The reason for incorporating the nearest neighbors is that the updated least-fit one may make a new environment around it and the nearest neighbor companies feels the change. Accordingly, a company with a high fitness does not update on its own but might eventually be affected by an updating of the neighbor company, causing either an improvement or a deterioration of its fitness. As a result of updating their fitness values, however, some may happen to get a very high fitnesses (too rapid a growth causes problems[2]). Our implementation of a regulation to this dynamics is a following way. At each time step, we identify $1+2d$ sites as updating sites. After the first updating for all $1+2d$ sites, if some of the $1+2d$ site have $f' > \eta$ ($\eta \in [0,1]$), all these sites are updated once again (new random numbers are assigned). However, even if then the new fitness values for some of the $1+2d$ sites exceed η again, we do not update them and the dynamics will proceed to the next time step. The regulation η may be considered to be a boundary imposing high tax rates on the companies above η. This procedure completes one time step. We iterate this until the market reaches its critical state.

3. Results

We performed the simulation up to 7 dimensions. We selected the lattice size L for each dimension d as follows: (d, L) =(1,20000), (2,200), (3,40), (4,13), (5,9), (6,6), (7,4). To achieve steady state, we iterated each step 10^8 times for one dimension and 10^7 times for the other dimensions. The consistent results are obtained with the previous paper[2] for all dimensions in the histogram of the fitness (probability density distribution). As an example, we show the histogram of the fitness for the three- dimensional case in Fig.1. The application of the regulation lowers the location of the discontinuity f_c and the number of companies having high fitnesses larger than η is reduced. We see, on the other hand, that the companies having lower fitness can stay in market thanks to the regulation[2].

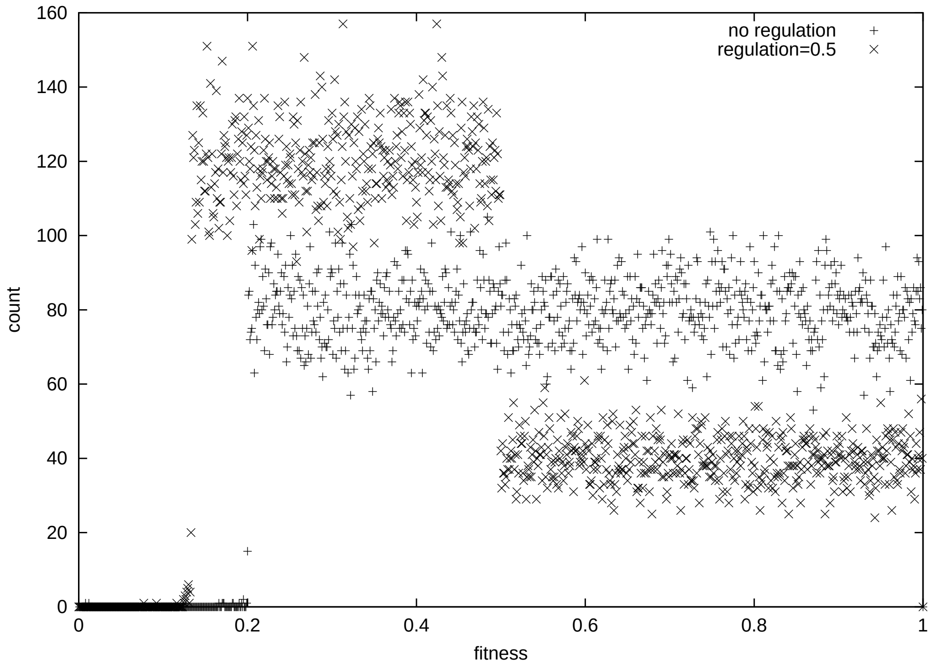

Fig. 1. Histogram of the fitness in 3 dimension with $L = 40$. Crosses and pluses shows the no regulation on the market and a regulation ,$\eta = 0.5$, respectively.

In a laissez-faire market without no regulations ($\eta = 0$), we plotted the f_c against the dimension in the log-log scale in Fig.2. The straight line on the plot shows a power law property, $f_c \sim d^{-1.1}$.

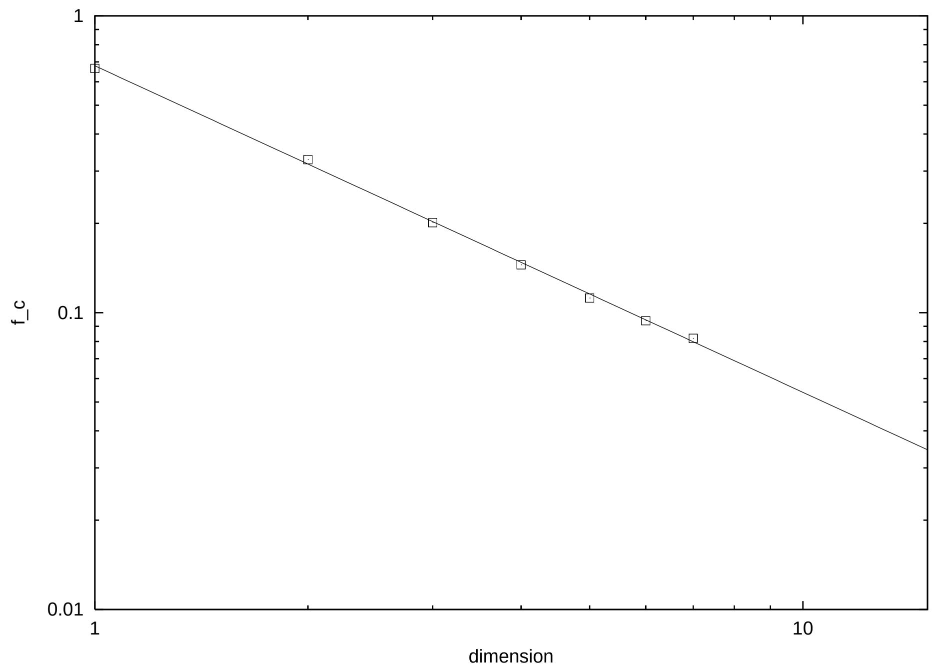

Fig. 2. The critical fitness against the dimension. Since the straight line on log-log plot means a power low, we find the relation $f_c \sim d^{-1.1}$.

Fig.3 shows the effect of regulations on critical fitness value. We can see the market with higher dimension shows less effect of the regulation than that of lower dimension. Moreover there is a most efficient value of η lowering the critical fitness value η_{eff}. The η_{eff} shifts towards small values as the market dimension increases.

4. Summary

We have simulated the Bak-Sneppen model in higher dimensions to see the effect of control on the self-organized market. Previously, Ray and Jan[5] simulated the Bak-Sneppen model up to 4 dimensions in a different context. However the relation between the critical fitness and dimensions was not given there. We found a simple power-law relation between them $f_c \sim d^{-1.1}$. Furthermore, in the description of the market in higher dimensions, the market allows companies to have a wider range of their fitnesses and we may say that the application of regulations have not so much

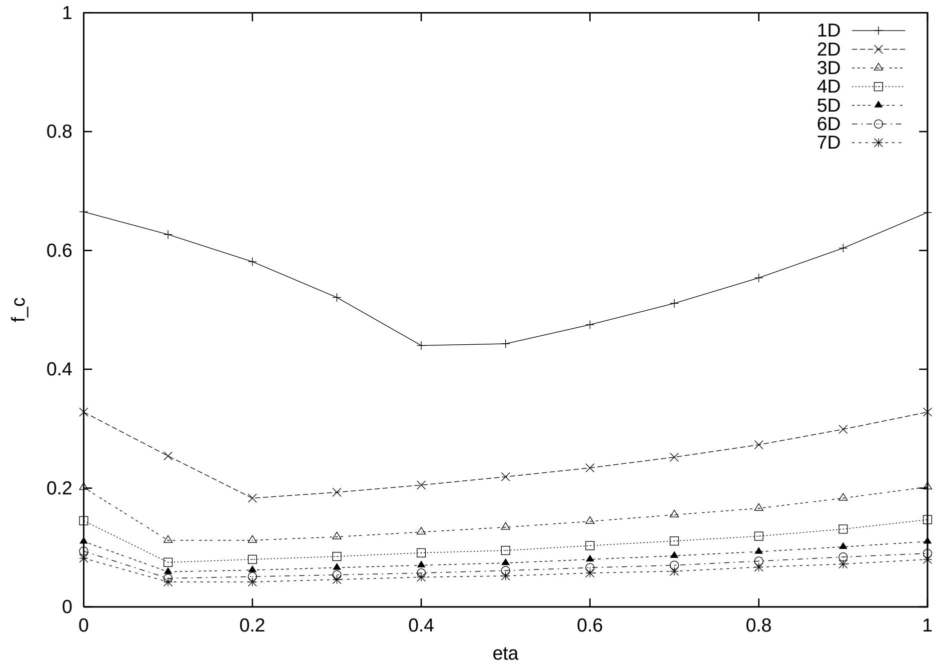

Fig. 3. The critical fitness value against the regulation for d-dimensional market. The regulation lowers the f_c in all dimensions.

effects on the market.

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