Physica A 417 (2015) 168–175

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Wealth distribution of simple exchange models coupled with extremal dynamics

N. Bagatella-Flores [a], M. Rodríguez-Achach [a,*], H.F. Coronel-Brizio [b], A.R. Hernández-Montoya [b,c]

[a] Universidad Veracruzana. Facultad de Física e Inteligencia Artificial, Departamento de Física, Lomas del Estadio s/n Zona Universitaria, Xalapa, Veracruz 91000, Mexico

[b] Universidad Veracruzana. Facultad de Física e Inteligencia Artificial, Departamento de Inteligencia Artificial, Sebastián Camacho 5, Xalapa, Veracruz 91000, Mexico

[c] Programa de Doctorado Sobre Desarrollo Científico y Tecnológico para la Sociedad (DCTS), Centro de Investigación y de Estudios Avanzados del IPN, Av. Instituto Politécnico Nacional 2508, Col. San Pedro Zacatenco, Delegación Gustavo A. Madero, Código Postal 07360 Apartado Postal: 14-740, 07000 México, D.F., Mexico

HIGHLIGHTS

- We study the wealth distribution simulating two well known asset exchange models.
- We select Yard sale model (YS) and the theft and fraud model (TF).
- Effect of Punctuated Equilibrium (PE) was introduced in YS and TF Models.
- PE makes results from YS and TF Models more realistic avoiding "Economy collapses".
- Wealth distribution for YS Model decays as an asymptotic power law.

ARTICLE INFO

Article history:
Received 6 February 2014
Received in revised form 21 June 2014
Available online 8 August 2014

Keywords:
Econophysics
Agents exchange models
Punctuated equilibrium
Wealth distribution
Gini index

ABSTRACT

Punctuated Equilibrium (PE) states that after long periods of evolutionary quiescence, species evolution can take place in short time intervals, where sudden differentiation makes new species emerge and some species extinct. In this paper, we introduce and study the effect of punctuated equilibrium on two different asset exchange models: the yard sale model (YS, winner gets a random fraction of a poorer player's wealth) and the theft and fraud model (TF, winner gets a random fraction of the loser's wealth). The resulting wealth distribution is characterized using the Gini index. In order to do this, we consider PE as a perturbation with probability ρ of being applied. We compare the resulting values of the Gini index at different increasing values of ρ in both models. We found that in the case of the TF model, the Gini index reduces as the perturbation ρ increases, not showing dependence with the agents number. While for YS we observe a phase transition which happens around $\rho_c = 0.79$. For perturbations $\rho < \rho_c$ the Gini index reaches the value of one as time increases (an extreme wealth condensation state), whereas for perturbations greater than or equal to ρ_c the Gini index becomes different to one, avoiding the system reaches this extreme state. We show that both simple exchange models coupled with PE dynamics

* Corresponding author.
E-mail addresses: nbagatella@uv.mx (N. Bagatella-Flores), manurodriguez@uv.mx (M. Rodríguez-Achach), hcoronel@uv.mx (H.F. Coronel-Brizio), alhernandez@uv.mx (A.R. Hernández-Montoya).

http://dx.doi.org/10.1016/j.physa.2014.07.081

give more realistic results. In particular for YS, we observe a power low decay of wealth distribution.

1. Introduction

In the seminal paper of Bak and Sneppen, a Self-Organized Critical (SOC) model [1] is introduced to describe the ecological co-evolution of interacting species. The success of the model in reproducing the punctuated equilibrium behavior proposed by Gould [2], and already observed in the fossil records [3], has attracted many authors to study the model, and variations of it, through several approaches ranging from simulation [4,5] to the renormalization group [6,7]. Bak and Sneppen's model has found interesting applications in economic studies [8,9], bacterial evolution [10] and even optimization problems [11,12].

The Theory of Punctuated Equilibrium emerged as an opposition to Phyletic gradualism, which is a theory of speciation that states evolution occurs uniformly and by the steady and gradual transformation of whole lineages, so that no clear line of demarcation exists between an ancestral species and a descendant one. Punctuated equilibrium, on the contrary, states that evolutionary change takes place in short periods of time tied to speciation and extinction events, separated by large time periods of evolutionary quiescence, called stasis. Evidence for these ideas has been found in the fossil record of bryozoans [13]. This record shows that the first individuals appeared about 140 million years ago, remain unchanged for its first 40 million years (stasis). After that, an explosion of diversification is observed, followed by another period of stasis. Other well known events, observed in the fossil record and explained by Punctuated Equilibrium are the extinction of dinosaurs, about 50 million years ago, or the huge number and sudden emergence of new species during the Cambrian period, in the Paleozoic Era, about 500 million years ago, called the Cambrian Explosion.

On the other hand, the study of wealth and income distributions in society, is a very important and fundamental area of research for practical and theoretical reasons to social scientists, economists, econophysicists, sociologist, philosophers, etc. and also concerns to politicians, government administrators, international bankers, and surely to national security agencies from many countries and of course to every common citizen. Although questions on the origin and causes of inequality are very old; attempts to answer them have been not very successful, even if many ideas have been proposed to understand and solve the problem. Between these ideas, we can mention the following: difference in religious ethics, lack of a qualified workforce, dependence on external technology, low level of internal savings, non-equilibrium between exports and imports, low cognitive and schooling skills of population, level of corruption and quality of democracy, capital's rate of return exceeding rate of output and income, and many more [14–23].

Even more, large scale social and ideological experiments, intended and implemented by force, to solve the inequality problem by centralization of economy, have failed spectacularly with a terrible prior and posterior cost in human suffering and lives, human rights violations, famines, waste of economic resources, political and economical instability, "hot" and "cold" wars, immigration waves, etc.

The important fact is that currently the extreme economic inequality problem seems is not any more only restricted to the beforehand called "Third world countries", but is also becoming a big concern and serious problem in developed economies, where the social and wealth gap between the low-medium income segments of population and the richer one, has been recently increasing fast and systematically [1] (for an extensive and polemic discussion on this topic see Ref. [23]).

The first empirical studies to understand wealth distribution were made by Pareto [24], who proposed that the wealth and income distributions obey a universal power law. Subsequent studies have shown that this is not the case for the whole range of population wealth values. Mandelbrot [25] proposed that the Pareto conjecture only holds at the higher values of wealth and income. The initial part (low wealth or income) of the distribution has been identified with the Gibbs distribution [26,27], while the middle part, according to Gibrat [28], takes the form of a log-normal distribution.

Recently, due to great advances in Complexity Sciences and computing power new ways to model and understand social and economic systems have emerged. Between the most important and well known applications of this computational methods we can mention the use of multi-agent based models to investigate the problem of wealth distribution [27,29–33]

In this work, by using a multi-agent computer methodology, we explore the effect of introducing the extremal dynamics of the already mentioned Bak–Sneppen model, on the wealth distribution produced by two very simple economic exchange models and study their corresponding Gini indices.

In particular, we focus our attention in two well known toy-models of economic interactions that have been used extensively due to their simplicity, such as the so-called "Yard-Sale" (YS) and "Theft and Fraud" (TF) models [34]. Although these two models have the advantage of their simple rules for analysis and simulation, they are over simplified, toy model versions of a real economy and they do not produce realistic wealth distributions. For this reason, several authors have made some refinements to introduce and model more realistic situations, such as the introduction of savings [35], changing the

[1] Although some economists and policy designers do not make any distinction between inequality and poverty, they are different issues. A society or country can be quite equal with a high number of very poor people or vice versa.