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Physica A 347 (2005) 639–652

PHYSICA A

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# Invisible hand effect in an evolutionary minority game model

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Received 27 February 2004
Available online 11 September 2004

**Abstract**

In this paper, we study the properties of a minority game with evolution realized by using genetic crossover to modify fixed-length decision-making strategies of agents. Although the agents in this evolutionary game act selfishly by trying to maximize their own performances only, it turns out that the whole society will eventually be rewarded optimally. This "invisible hand" effect is what Adam Smith over two centuries ago expected to take place in the context of free market mechanism. However, this behaviour of the society of agents is realized only under idealized conditions, where all agents are utilizing the same efficient evolutionary mechanism. If on the other hand part of the agents are adaptive, but not evolutionary, the system does not reach optimum performance, which is also the case if part of the evolutionary agents form a uniformly acting "cartel".


*PACS:* 02.50.Le; 05.65.+b; 87.23.Ge

*Keywords:* Invisible hand effect; Genetic algorithm; Minority game

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doi:10.1016/j.physa.2004.08.029

## 1. Introduction

In his book of 1776 Adam Smith outlined a mechanism which he supposed to describe the behaviour of economic societies [1]. He postulated that individuals who try to maximize their own gain without active regard to the society's welfare will eventually reward the society most effectively. As the mechanism how this should actually happen Smith described it as an "invisible hand" of a benevolent deity administering human happiness by leading individuals to act in a certain way. In the modern context invisible hand processes have been studied as part of game theory, a branch of mathematics dealing with payoffs and strategies, where the interrelationships between the best productivity of individual actors and the society has been refined by John Nash through equilibrium concept [2–4]. He indicates that individuals could only maximize their own benefit by taking other individuals into account. However, Smith's assumption about the optimal performance of the society through selfish individuals turns out to be valid in certain circumstances. For example, this is the situation for the minority game introduced by Challet and Zhang [5], see also Refs. [6–12].

Minority games are repeated coordination games [2,3] where agents use a number of different strategies in order to join one of the two available groups, A or B, and those who belong to the minority group are rewarded. In the original MG [5] the agents are exposed to $P$ different histories and the strategy of an agent determines the choice of the group for each history. Thus, the length or dimension of a strategy equals $P$, and the set of all possible $2^P$ strategies composes a strategy space from which the agents' strategies are randomly drawn in the beginning of the game. Strategies are cumulatively scored based on correct minority group choices, and at each step of the game the choices of the agents are determined by their highest-scoring strategies. In the following, we shall refer to this basic minority game with the above-described adaptation mechanism as BMG, and use the abbreviation MG to refer to the minority game concept in a more general fashion.

Minority games can be viewed as simulating the performances of competing individuals and the welfare of the society they compose. This kind of mechanism could coarsely speaking be involved in a stock market where investors share information and make buy-or-sell decisions in order to gain profit. If the number of sellers of a particular stock is larger than the number of buyers, supply exceeds demand and one expects a decrease in the stock price [13]. Then the buyers, being in minority, would win due to the low price levels. In the opposite case sellers would win, because excess demand would increase the price of the stock. In the long run, the price of the stock eventually settles down to its equilibrium value, i.e., supply and demand are, on average, close to each other and the public information has been efficiently utilized. In relation to this the utility or performance of the society can be viewed as the number of content individuals. In other words if everybody agrees on the price, both the sellers and buyers are content. In the framework of MG, this means that the numbers of buyers and sellers are as close to each other as possible and the game is in one of its pure-strategy Nash equilibria [2,3,14–16]. On the other