

# Statistical Mechanics Approaches to Socioeconomic Behavior

Steven N. Durlauf

Department of Economics, University of Wisconsin at Madison  
Santa Fe Institute

August 15, 1996

I thank William Brock for innumerable conversations on the issues raised in this paper as well as Lawrence Blume, Kim-Sau Chung, Brian Krauth, Susan Nelson, Richard Palmer, and conference participants at the National Bureau of Economic Research and Santa Fe Institute for comments on an earlier draft. Financial support from the National Science Foundation, the John D. and Catherine T. MacArthur Foundation, and the Santa Fe Institute is greatly appreciated.



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### Abstract

This paper provides a unified framework for interpreting a wide range of interactions models which have appeared in the economics literature. A formalization taken from the statistical mechanics literature is shown to encompass a number of socioeconomic phenomena ranging from out of wedlock births to aggregate output to crime. The framework bears a close relationship to econometric models of discrete choice and therefore holds the potential for rendering interactions models estimable. A number of new applications of statistical mechanics to socioeconomic problems are suggested.

Steven N. Durlauf  
Department of Economics  
1180 Observatory Drive  
University of Wisconsin  
Madison, WI 53706-1393

email: [durlauf@macc.wisc.edu](mailto:durlauf@macc.wisc.edu)

## 1. Introduction

This paper is designed to provide a unified discussion of the use of statistical mechanics methods<sup>1</sup> in the study of socioeconomic behavior. The use of these methods in the social sciences is still in its infancy. Nevertheless, a growing body of work has shown how statistical mechanics and related probability techniques may be used to study the evolution and steady state behavior of heterogeneous populations. Examples of the range of applications of statistical mechanics methods include social pathologies such as out of wedlock births and crime (Brock and Durlauf (1996), Glaeser, Sacerdote, Scheinkman (1996)), asset price behavior (Brock (1993,1995)), expectation formation (Brock and Hommes (1995)), business cycles (Bak *et al* (1993) and Durlauf (1991,1994)), technology adoption (An and Kiefer (1995)), and endogenous preferences (Bell (1995)). In addition, Blume (1993,1996) has shown how these methods can provide insight into the structure of abstract game-theoretic environments.<sup>2</sup>

These disparate phenomena are linked by the possibility that each is determined at least partially by direct interactions between economic actors. Put differently, each of these phenomena is a case where the decisions of each individual are influenced by the choices of others with whom he interacts. This interdependence leads to the possibility that polarized behavior can occur at an aggregate level solely due to the collective interdependence in decisionmaking. This explanation of polarized group behavior may be contrasted with explanations which rely on the presence of highly correlated characteristics among members of a group.

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<sup>1</sup>The statistical mechanics models I employ are also referred to as interacting particle system or random fields models.

<sup>2</sup>Alternative approaches to the modelling of complex interaction environments include Arthur (1987,1989), Ioannides (1990), Kirman (1983), and Krugman (1996).

Interactions between economic actors are commonplace in economic models. However, these interactions are typically mediated through markets. What distinguishes the bulk of the interactions in the recent inequality literature is the focus on interdependencies which are direct.<sup>3</sup> Examples of such direct interactions are role model, social norm and peer group effects.

At first glance, statistical mechanics methods, which underlie the theory of condensed matter, would appear to have little to do with socioeconomic phenomena related to inequality. However, strong metaphorical similarities exist between the two fields of research. The canonical question in statistical mechanics concerns the determinants of magnetization in matter. As a magnetized piece of matter is one in which a substantial majority of the atoms share a common spin (which can either be up or down), magnetization would appear to be an extremely unlikely phenomenon, as it would require the coincidence of many atoms sharing a common property. However, if the probability that one atom has a particular spin is a function of the spins of surrounding atoms, the possibility of collective interdependence renders magnetism understandable. As techniques for the study of economic phenomena, statistical mechanics approaches have proven valuable for studying the aggregate behavior of populations facing interdependent binary choices. In particular, statistical mechanics methods hold the promise of providing a general framework for understanding how collective interdependence can lead to the emergence of interesting and rich aggregate behavior.<sup>4</sup>

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<sup>3</sup>While markets may not exist to directly mediate these interactions, this does not imply that economic actors do not alter their behavior in order to account for them. For example, as discussed in Bénabou (1993,1996a) and Durlauf (1995,1996a), the presence of within-neighborhood interactions can play a primary role in determining the composition of neighborhoods.

<sup>4</sup>See Crutchfield (1993) for a discussion of the meaning of emergent phenomena.

Of course, any metaphorical similarity between physical and social models of interdependent behavior is of little interest unless the specific substantive models underlying each can be shown to have similar structures. An important goal of this paper is to show how statistical mechanics structures naturally arise in a number of socioeconomic environments. Also, it is important to recognize that the potential for interesting aggregate behavior to emerge from individual decisions has been explored in previous economic contexts. Two prominent examples include Becker's (1962) work on aggregate demand with zero-intelligence agents and Schelling's (1971) analysis of racial segregation.<sup>5</sup> Statistical mechanics approaches should thus be regarded as complementary to disparate strands of previous work.

The rest of this paper is organized as follows. Section 2 outlines some general issues in modelling binary choices with interactions. Section 3 analyzes binary choice models with global interaction structures. Section 4 analyzes binary choice models with local interactions. Section 5 provides a discussion of limitations and outstanding questions which arise in statistical mechanics models of social behavior. Section 6 contains summary and conclusions.

## 2. General considerations

The statistical mechanics-inspired models of socioeconomic phenomena which have typically been studied focus on environments where a group of individuals each faces a binary choice. Many individual decisions which are relevant to understanding inequality are binary in nature. Standard examples include decisions to have a child out of wedlock, drop out of school, commit a crime. Not only are these decisions of interest in

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<sup>5</sup>Schelling's model possesses a structure which is quite similar to some of the statistical mechanics models which are discussed below.