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On the emergent properties of artificial stock markets: the efficient market hypothesis and the rational expectations hypothesis☆

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Abstract

By studying two well known hypotheses in economics, this paper illustrates how emergent properties can be shown in an agent-based artificial stock market. The two hypotheses considered are the efficient market hypothesis and the rational expectations hypothesis. We inquire whether the macrobehavior depicted by these two hypotheses is consistent with our understanding of the microbehavior. In this agent-based model, genetic programming is applied to evolving a population of traders learning over time. We first apply a series of econometric tests to show that the EMH and the REH can be satisfied with some portions of the artificial time series. Then, by analyzing traders' behavior, we show that these aggregate results cannot be interpreted as a simple scaling-up of individual behavior. A conjecture based on sunspot-like signals is proposed to explain why macrobehavior can be very different from microbehavior. We assert that the huge search space attributable to genetic programming can induce sunspot-like signals, and we use simulated evolved complexity of forecasting rules and Granger causality tests to examine this assertion.

JEL classification: G12: asset pricing; G14: information and market efficiency; D83: search, learning, and information

Keywords: Artificial stock markets; Emergent properties; Efficient market hypothesis; Rational expectations hypothesis; Genetic programming

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1. Background and motivation

While it is claimed quite frequently that the stock market is a complex adaptive system, conventional financial models, constrained by computing power, are not capable of demonstrating this feature. However, recent progress in computing technology has made possible a more ambitious vehicle to construct and simulate the stock market. The fledgling research field, known as the artificial stock market, is distinguished from the conventional model-building in many essential ways.[1] Generally speaking, models in this field are composed of many heterogeneous interacting adaptive traders. The conventional devices such as the rational expectations hypothesis and the representative agent are discarded (Arthur, 1992). In principle, the artificial stock market is a promising way to study the stock market as a complex adaptive system. By that, we mean two things. First, the artificial stock market is rich in dynamics. Second, it is rich in emergent properties.[2]

The rich dynamics of the artificial stock market have been documented in the literature. One of the early attempts of this research was to show that many econometric properties (stylized facts) of financial time series can be replicated by artificial stock markets. The properties replicated include volatility clustering (autoregressive conditional heteroskedasticity (ARCH)), excess kurtosis (fat-tail distribution), bubbles and crashes, chaos, unit roots, and many others.[3] Thus, there is little doubt that the artificial stock market can generate rich dynamics. However, being able to generate rich dynamics is only a minor part of complex adaptive systems. To be a complex adaptive system, rich dynamics must be generated endogenously (or from bottom up), rather than be given exogenously (top down). It is this difference that leads to the main characteristic of complex adaptive systems, namely, emergence.

Emergence is about "how large interacting ensembles exhibit collective behavior that is very different from anything one may have expected from simply scaling up the behavior of the individual units" (Krugman, 1996, p. 3), or "... in a structured system, new properties emerge at higher levels of integration which could not have been predicted from a knowledge of the lower level components" (Mayr, 1997, p. 19). Examples of emergence abound in other fields (Holland, 1998), and economists are anything but unfamiliar with the significance of this term. Apart from the Santa Fe Institute Economists, Krugman (1996) and Epstein and Axtell (1996) are among the first few economists who exemplified emergence with a series of economic phenomena. Nevertheless, the emergent properties of the artificial stock market has not received a full attention. This paper considers a different research direction. Instead of replicating the econometric properties of financial time series, though it is still worth doing, we are concerned with identifying some areas of the artificial stock market where the phenomena observed can be plausibly argued as emergent behavior. The areas considered in this paper are two celebrated hypotheses in economics and finance, namely, the efficient market hypothesis (EMH) and the rational expectations hypothesis (REH).

[1] See LeBaron (2000).

[2] Publishing the article "More is Different" in 1972s Science magazine, Philip Anderson, the 1977 Nobel laureate physicist, may be regarded as the father of the science of emergence.

[3] See, e.g. Lux (1995, 1997, 1998), Lux and Marchesi (1999), and LeBaron et al. (1999).