Computational Economics **19:** 1–4, 2002.

Introduction

When Hans Amman asked me to edit a special issue of Computation Economics dealing with the theme of *'Evolutionary Processes in Economics',* I was certainly enthusiastic, although it was at the same time somewhat unclear to me how this issue would look like. After all, there are so many, often partly overlapping, fields in economics making reference to the term *'evolutionary'* nowadays. First of all, there is the branch of Industrial Organization in the Schumpeter or Nelson and Winter tradition that is also known as evolutionary economics. Second, we have evolutionary game theory. Third, especially also within experimental economics, bounded rationality, learning and adaptive behavior get a great deal of attention. Often the way to model such behavior is using some algorithm with some evolutionary flavor. Closely related to this is the computational literature on evolutionary computation and evolutionary algorithms, such as Genetic Algorithms. And fourth, the study of complex adaptive systems has been related to economics, examining (co)evolutionary processes and self-organized, spontaneous orders, and their emergent properties.

So what is this *'evolutionary'* all about? Some modern people tend to associate the term *'evolutionary'* almost exclusively with Darwinian selection dynamics. That is somewhat unfortunate since the term has a much wider meaning. The Latin *evolvere* has two broad meanings. First, it denotes the evolving or unrolling of things themselves. An essential characteristic of evolutionary phenomena is that they relate to some dynamic process, as is illustrated by the topics analyzed in the papers in this special issue. But the contributions to this issue are also evolutionary in a second sense. The Latin *evolvere* also has the more figurative meaning of disentangling, exposing, and narrating such complex dynamic phenomena. In short, *explaining* them. In other words, the models themselves are evolutionary. Notice that the numerical analysis of these models implies the generation of a dynamic processes as well. But in some sense this is secondary. The specification of the model itself (and not the numerical analysis of it) is the disentangling, i.e., explanation, of the evolutionary phenomenon. The fact that the numerical analysis of such a model entails the generation of a dynamic process is merely a repercussion of the need to carry out consistency checks with the evolutionary phenomena to be explained.

The Call for Papers for this issue on *'evolutionary processes in economics'* was relatively open as far as the meaning of *'evolutionary'* is concerned. The papers in this issue reflect this. Occasionally we find Darwinian type of selection dynamics in them. But they all concur with the broad meaning of *'evolutionary'* sketched above. They are interested in dynamic, unrolling phenomena, and these complex things are explained by evolutionary models.

Yildizoglu (2002) examines an Industrial Organization model in the spirit of Nelson and Winter. More specifically, he studies the relevance of learning with respect to R&D decisions in highly uncertain environments by contrasting an adaptive R&D strategy with an R&D strategy based on fixed rules of behavior. Learning is modeled at the individual level with help of a Genetic Algorithm (GA). What matters is that some evolutionary process has been used to represent the presence of learning and of experience-oriented search. The genetic operators as such do not seem essential, and hill climbing would most likely work as well. To focus on the importance of the learning process, the IO model itself is kept simple, and the main determinant of the industry dynamics is the R&D process. However, there is also an evolutionary process taking place at the industry level. Firms need to allocate investments between physical capital and R&D, but investments can be financed out of own past profits only, with these profits in turn determined in the market where different firms compete. One of the questions Yildizoglu considers is how different market configurations with different numbers of firms per type (either learning or fixed rule behavior) lead to different market dynamics.

Brenner (2002) studies learning dynamics of boundedly rational agents as well, but this time in the context of market pricing behavior. The buyers need to learn which sellers to deal with and which prices to accept, whereas the sellers decide upon a pricing strategy. They can either use take-it-or-leave-it prices, or they could be prepared to offer a whole series of prices sequentially (i.e., bargaining). In both cases they would need to decide the specific prices to be offered as well. The agents engage in bilateral interactions and they learn on the basis of their experience. The algorithms Brenner uses to model the individual learning involve a combination of aspiration levels, learning direction theory, and satisficing behavior. Since both buyers and sellers need to learn about and adapt to each other at the same time, what we have here is a coevolutionary process. The numerical analysis of the model focuses on identifying the circumstances leading to the occurrence of bargaining, and to price dispersion.

Joshi, Parker and Bedau (2002) are interested in the trade and price dynamics of a stock market in which the forecasting rules of the individual agents evolve endogenously. The model they use is the well-known Santa Fe stock market, in which there is one risk-free and one risky stock, and agents explicitly form forecasts as a linear function of the current price and dividend. Individual agents learn through their experience, where learning takes place on the basis of accuracy (discarding inaccurate rules and generating new rules similar to existing successful one, with help of a GA). Obviously the learning behavior of the agents leads to an evolving market. But since the return to investment decisions depends also on what others traders have learned to do, what we get is a coevolving ecology of forecasting rules, and the corresponding market dynamics. Earlier analysis had shown that a quick revision rate of forecasting rules would lead to a rational expectations equilibrium, whereas more rapid revisions would lead to more volatile market patterns. Hence, the central factor that Joshi et al. analyze, following a game-theoretic approach combined with numerical analysis, is the rate at which traders want to revise forecasting rules.

Chiarella and He (2002) also consider an asset pricing model. Building on earlier observations that the dynamics of financial markets might be caused by an endogenous mechanism, this paper examines the role of heterogeneous beliefs in this. Hence, the main concern of the paper is how the dynamic behavior of the model, and in particular the price dynamics of the market are affected by the relative risk attitudes of the different types of investors. This question is dealt with using bifurcation theory and numerical analysis. The agents are ex ante heterogeneous, as they have different preferences with respect to risk. Moreover, they learn individually, on the basis of their own experience, leading to heterogeneous beliefs. Chiarella and He consider different types of agents (fundamentalists, trend chasers and contrarians) who employ different prediction strategies to update their beliefs on mean and variance. Examining also the impact of different lags in the formation of beliefs, they, then, analyze how the interaction between these types of traders influences the price dynamics.

Carpenter (2002) presents some evolutionary models of bargaining for the specific case of the well-known Nash demand game, which has multiple Nash equilibria, most of them asymmetric. His main concern is to understand the evolution of conventions, in particular the prevalence of the equal split as a bargaining convention. To achieve this understanding, he employs two methodologies. On the one hand, he investigates the bargaining dynamics of an infinite population with help of the standard replicator dynamics (analyzing the differential equations numerically). On the other hand, Carpenter considers an agent-based model of interaction in a finite population, in which agents in each period adopt a strategy with probability equal to the strategy's relative success in the population. To check the consistency of these approaches with the phenomena he set out to explain, Carpenter considers three variations of both models. One in which agents randomly experiment, another one in which interactions are not random but assortative, and finally one in which strategies are somewhat more sophisticated (responsive).

References

Brenner, T. (2002). A behavioural learning approach to the dynamics of prices. *Computational Economics* **19**, 67–94 (this issue).

Carpenter, J.P. (2002). Evolutionary models of bargaining: comparing agent-based computational and analytical approaches to understanding convention evolution. *Computational Economics* **19**, 25–49 (this issue).

Chiarella, C. and He, X.Z. (2002). Heterogeneous beliefs, risk and learning in a simple asset pricing model. *Computational Economics* **19**, 95–132 (this issue).
Joshi, S., Parker, J. and Bedau, M.A. (2002). Financial markets can be at sub-optimal equilibria. *Computational Economics* **19**, 5–23 (this issue).
Yildizoglu, M. (2002). Competing R&D Strategies in an evolutionary industry model. *Computational Economics* **19**, 51–65 (this issue).

NICOLAAS J. VRIEND
Queen Mary,
University of London, U.K.,
October 2000