Epistemological considerations on agent-based models in evolutionary consumer choice theory

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This paper analyzes the epistemological implications of complexity studies on consumer theory. Agent-based models in complexity studies are a good fit to try to describe individual consumption via evolving patterns, and are being painstakingly researched (Potts, 2001, Fonseca and Zeidan, 2002). The implications of this research are that new theories and models are being created, and a paradigm shift is occurring that will probably lead to a new orthodoxy in consumer theory. However, a question arises as of how this shift is taking place, through a Kuhnian incommensurability approach or a Popperian evolution. This paper is a speculative piece on the methodology of studies of complex adaptive systems in economics, in special as regarding to consumer theory, and tries to assess costs and benefits of both approaches as regarding the new complex theories of consumer behavior. The main proposition is that authors should look into a non-Kuhnian approach to the problem, trying to incorporate the complexity approach into a framework understandable by orthodox economists.

Introduction

This paper stems from the perception that the changes impacting on economics theory due to complexity studies are being widely viewed as a Kuhnian paradigm shift instead of a Popperian evolution of theories. This leads to important methodological implications, especially if we take into account two crucial factors, first, Kuhn's concept of incommensurability between alternative paradigms and, second, the fact that complexity theory has been alienating many orthodox economists. The goal of this paper is to analyze the influence of new models of individual's behavior, particularly agent-based models, in consumer theory. To do so, evolutionary models used in economics will be classified into two divisions: the first involves we are calling "pure" evolutionary models, with all the costs and benefits of this new methodology; and the other will be termed "hybrid" models, those that are built on orthodox foundations but try to incorporate evolutionary features. To exemplify each division, two models will be taken as exemplary, Potts' (2001) summary work on evolutionary economics, which has a section on consumer choice theory, and Riechmann's (2000) paper on consumer choice under bounded rationality and a complex environment.

Consumer theory and complexity.

Consumer theory is the part of economics that deals with the decisions of individuals as regarding what bundle of goods will be preferred and consumed. Orthodox consumer theory assumes an individual maximizing a utility function constrained by his/her income and the relative prices of the goods he/she is choosing. The utility function is the main feature of microeconomic models of individuals, as all the difficulties rely on the fact that value, as constructed by the individual, is subjective, and a formal model of the individual's decisions ought to be an objective model. To achieve such an objective view, a utility function is built using marginal utility as its building block. In its turn, marginal utility represents the fact that the utility of the second unity of a normal good has a lesser value than the first, the third lesser value than the second, and so on, thus an ordinal set of value can be ascribed, and marginal utility is a decreasing function of value. From marginal and total utility the concept of preferences is born, i.e., the model can describe what space of choices are available and how the individual relates to such a space of choices. Consumer theory, then, is a very powerful tool but is built upon a precarious foundation, the individual's preferences.

Complex agent-based dynamics in its turn, however, models the world's behavior through the use of "agents". In this context, an agent is a computer program that acts according to a set of rules, e.g., in a self-interested manner as it deals with numerous other agents inside a specific economic environment. This arrangement can be set-up to mimic almost any interactive system, including consumer theory.

A typical agent model (Fonseca and Zeidan, 2002) – be it a genetic algorithm, classifier system or genetic programming model, can be described as a sequence represented in the figure below:

Individual Agent → Population → Organizations
Set of Simple Rules → Modes of Behavior → Strategies

In these models, the actions of the agents in their environment can be assigned a value (performance, utility, payoff, fitness or the like) so that the agent behaves in such a way as to improve this value over time (Holland & Miller, 1991: 365).

The selection mechanism affects the market structure throughout a group of variables that provoke changes in the behavior of agents/firms. In a complex environment, these units use a decision making mechanism called a routine-search device. One of the hypotheses of the present model is that the search for innovation and new rules takes place at the same time that the decision-making process is going on. As the rules grow more sophisticated, they reveal recurrent patterns of interaction. Becoming more aggregated, they should expose new forms of behavior and evolved forms, called strategies. From this, it follows that rules and procedures characterizing behavior, modes of behavior and strategies, are used to represent groups of agents. Initially a set of rules becomes a strategy if: a) they specify a sequence of decisions; b) they reveal some form of anticipation in the sense of what to do in a situation that might arise (Axelrod, 1994); c) they are developing into organizations.

Nelson and Winter (1982) have employed the concept of routines or rules to illustrate not only the adherence of norms and conventions to society, but also to display the emergence of new patterns of behavior. In this way economic activity is developed according to rules (or routines) established in the previous practice and in methods of search. The search for new rules is triggered by existing routines, and innovation - the outcome of this process, emerges from the comparison between the new and the old rules.

Models developed using this framework are used to simulate agents' responses in a complex environment. While doing so enables some quite interesting insights into decision-making processes, it also can alienate orthodox economists who are used to the usual static models of consumer behavior. However, couldn't it be possible for a utility function of the orthodox type (albeit modified) account for consumer choice under a complexity theory model as well? Both yes and no answers have been found in the literature to this question. Thus, Riechmann (2000) develops a model which he calls "an extended version of the consumer choice problem. Different from the standard model, prices are not fixed but arise from Walrasian interactions of total demand and a stylized supply function for each of the goods. Three different types of evolutionary algorithms are set up to answer the question whether agents can learn to solve the problem of extended consumer choice" (Riechmann, 2000: 2). He models consumer choice through a bounded rationality utility function, which is maximized for consumers dealing with a complex environment. Potts (2001), however, develops what he calls a heterodox agent: the *hetero economicus*: To summarize, our agent hetero economicus is a complex system composed of three subsystems: a set of resources and technology, a set of control algorithms and schemata; and a set of tags for interaction (Potts, 2001: 130).

Potts (2001) calls the orthodox individual homo economicus. He emphasizes its difference to the new, evolutionary, hetero economicus, in his Table 1, reproduced below (Potts, 2001: 113).

	Homo economicus	**Hetero economicus**
Space	R^n	Z^n
Variables	Commodity bundle (V)	Preferences, Technology (E)
Parameters	Preferences, Technology	Rules of Search
Limits	Scarcity in V	Scarcity/Complexity in E
Objectives	Optimize over V in R^n	Satisfice over E in Z^n

Table 1 *Two models of economic agent*

Kuhnian versus Popperian history of science

Table 1 summarizes almost every difference encountered in evolutionary models. This is a *Kuhnian* approach and is the most used one in new evolutionary models. In regard to the economic agents, in evolutionary models they should not be classified solely by their individual attributes, but mainly by the fact that they are subjected to selective forces. Additionally, the selection environment is defined independently of the agents; it is the environment that evaluates the various entities and transforms their selective characteristics into selective advantage. It is the process of competition that unifies a group of individuals into a relevant population making their characteristics "selectively" relevant[1] (Fonseca and Zeidan, 2002).

Although this approach is formally correct and follows the evolutionary economics literature (Nelson and Winter (1982), Holland (1998,1999), Metcalf (1998), *et al.*), its implicit Kuhnian perspective alienates most economists precisely because it assumes a revolutionary, not an evolutionary orientation. That is, Kuhn's theory of the evolution of science contemplates a paradigm shift whenever a better theory is discovered. In his view, a theory is a social construction that competes with other theories, with one emerging as dominant theory. However, a theory is not only better than another if explains better the phenomena being studied. It also has to be accepted by the scientific community. On the other hand, Popper and others have developed a history of science where better new

theories evolve from former dominant theories. Yet, Kuhn's view precludes theories from evolving in this fashion, because of its claim of an incommensurability among theories, i.e., the new theory not commensurate with the older ones. This implies a radical separation between theories. A new theory, forged inside the scientific community, if accepted because of its better prediction power, cannot be an evolution of a former theory because it entails new language, new concepts, and reformulation of older concepts, all that could not be translated into the former theory, and hence, new and older theories are incommensurable.

The biggest problem with Kuhn's view is that, up to the point of the paradigm shift, proponents of the older and newer theories cannot be speaking the same scientific language, and, in fact, alienate each other from their respective views of the world. This problem permeates complexity studies in economics, where most economists cannot begin to cope with the new theory because of its inherent incommensurability.

In consumer theory, most complexity-based models which have been developed have the characteristics of Potts' model of the hetero economicus, and, thus implicitly follow Kuhn's incommensurability paradigm shift. Riechmann´s (2000) model has the characteristics of an orthodox model but achieves its result by extending the model to allow both an evolutionary algorithm to account for learning process by the individual and a modified constraint function. This way, the individual operates on a complex world, but in a way epistemologically equivalent to that of orthodox economics. Thus, although Riechmann (2000) achieves a model that does not alienate most economists, is it the better approach?

A theory is better than another if it explains world phenomena in a more comprehensive way, and Riechmann (2000) would be a better approach if all the simulations were performed in pure evolutionary models, like the many done at Santa Fé institute but resulted in worse predictions than even Riechmann's model. To date, consequently both kinds of model have performed less-than satisfactorily. Riechmann's work concludes with "Can bounded rational agents learn the optimal consumer choice? — They can, if the problem is not too complicated. And they do even better if they have some memory of the past. This is all of the message this paper can give…" (Riechmann, 2000: 23). Yet, simulations on pure evolutionary models have not fared much better to this day. Although many insights have been gained on how agents operate, evolutionary economics is not near a complete descriptive model like that found in orthodox consumer theory.

The core dilemma and a proposal

The question, therefore, that faces us is how to proceed. Is the *Kuhnian* or the *Popperian* approach better for understanding the apparently revolutionary insights that evolutionary economics provides us? Take consumer theory, for instance. On the one hand, orthodox consumer theory has the individual maximizing a utility function. Riechmann (2000) describes a world where it is hard to maximize such a function, but is a world with the *homo economicus.* On the other hand, with *hetero economicus*, as defined by Potts (2001) and implicitly accepted by pure evolutionary models, there is no utility function, and the choice process is developed in an altogether different framework. Evaluating what choice theory is best should be an empirical problem, but to the date it cannot be answered because the results are not clear.

What we propose consequently is a line of research that takes orthodox models into consideration but then tries to build a complexity framework upon them, much in the line of Riechmann (2000). The reason is a pragmatic one. If research is done in this fashion, the transition to a new orthodoxy that would seriously entertain evolutionary economics will be much easier and much more could be accomplished since 90% of the economists would not be alienated from research in this new field. The only problem with it, though, is also a practical one: is it at all a possible scenario? That is, there a way to transform a orthodox utility function into something workable in a complex environment? If we take a static consumer choice model using a orthodox utility function, we then have an optimal point that leaves no place for any interaction with a complex environment. To really have a utility function that would be usable in a complexity framework, one would need to transform it into a dynamic function.

Usually, dynamics are achieved in economics by using econometric models based on unit-root tests and error-correcting methods (ECM), e.g., co-integration. However, ECM models are econometrically dynamic but do not incorporate any feature characteristic of evolutionary models such as a balance between randomness and conservancy, the presence of some efficiency which could prove that evolving systems keep improving or doing better[2], as well as efficiency on the information exchange process. In fact, ECM are models that have a long-term equilibrium and the so-called dynamics are fluctuations in short-term periods, with long-term corrections towards an equilibrium.

But take a genetic algorithm like the one on Goldberg (1989). It follows that the individual agent is represented as a finite-length string:

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$A = x_1 x_2 x_3 x_4 x_5,...,x_n$, where x_i is either 0 or 1, and there is any number of q strings $A_1,...,A_q$ with individual length n.

To define schemata is necessary to introduce another letter to the binary alphabet. A symbol such as '*' (that means 'don't care', i.e., individual strings are part of the same schemata if all a_i that are not represented by a '*' are the same). This way, a schema represented by 1001* comprise both strings 10010 and 10011. Also, it should be noted that some schema are more specific than others, the schema 011*1** is a more definite statement about important similarity than the schema 0******. This way, a schema is a family of strings with particular characteristics, and any notional device that can be used to separate the string population into families can be used. For any schema H there is a fitness function $f(x)$ associated with it. This fitness function, as discussed above, can be any objective function relating the strings with some result that, in turn, will associate this result with a probability p of the string being selected for the next generation[3].

There is nothing preventing the model from incorporating orthodox language to deal with consumer theory. The string can represent a vector of goods to be selected, or bundles to be compared. The selection process can deal with these bundles, selecting those that give high utility. The fitness function then could have some properties of orthodox consumer theory and operate through selection process in a complex world.

In conclusion, nothing prevents complexity studies from trying to incorporate the orthodox language while developing new models and insights into economics processes. Also, the benefits towards expanding evolutionary economics into the orthodox world seem to outweigh the costs of formality and trying to cope with the old language. To approach evolutionary economics in a Kuhnian way can mean throwing out a lot of precious insights from orthodoxy, especially considering the fact that the results from evolutionary models do not justify a paradigm shift. In the humble opinion of the author, evolutionary economics, especially when dealing with individual choices, can benefit from orthodox insights. Trying to rebuild the wheel can cost a lot of research time and grief when dealing to most economists and it is simply not necessary at this juncture in economic theory building.

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NOTES

[1] This also applies very well to the economic agent. Taken separately, the units of business, or firms, present notable differences; as members of a population they perform in a very similar way.

[2] It should be noted that this does not mean that it ever reaches an equilibrium where efficacy is at a maximum.

[3] For instance, Goldberg (1989) uses a fitness function in the form of f(x) = x^2. The probability p is defined as f(x)/$\sum$f.