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The Evolution of Economic Theories Through Time; Towards an Evolutionary Economy Based on Agents

Overview

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ABSTRACT

Economic systems are continuously exposed to evolutions aiming to understand or even anticipate market dynamics and behaviors of different economic agents. Indeed ; consider as the starting point the first economic thoughts before the emergence of orthodox theory, which assumes firstly that the market is static and does not take into account the interactions between agents that compose it, secondly this theory assumes that economic agents have unlimited cognitive ability to have access to information. However, this is not always true in the real economy, which prompted several researchers to define new theory adapting itself to reality; namely evolutionary economics which discusses new economic aspects and corrects assumptions of orthodox theory. In this context, the present paper tries firstly to expose critics of orthodox theory, then, it details the characteristics of the evolutionary economics and its relationship with complex adaptive system, finally we present the interest of the use of an agent-based simulation of economic systems.

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Keywords: Orthodox theory, economic revolution, evolutionary economics, complex adaptive system, agent-based simulation.

1. INTRODUCTION

The multiplicity of the works aimed to study the economic systems in recent decades confirms the growing importance of these systems. The early work was led by great economists like John Maynard Keynes and Karl Marx who paved the way for the emergence of orthodox theory. This theory considers that economic

agents are endowed with perfect rationality, and the markets they inhabit are balanced [33]. It implies, indeed, that economic agents have all the skills and information needed for optimal decision making. Furthermore, these agents have different preferences and the same capacities and are independent of each other.

However, the assumption considering, that the market moves from one equilibrium to another, is not always verified in real markets. In addition, this theory is based on mathematical modelling; although using mathematical models made it limitative and simplistic. In fact, several studies have been developed in this regard, causing economic revolution that challenged the main assumptions of orthodox economics and giving birth to an evolutionary economics.

Following the revolution of economic thought, modelling economic systems approximates the reality, by considering them as a system composed of interacting agents, characterized by a self-organizing feature and the emergence of global behaviours [33].

The main objective of our work is to discuss the evolution of economic systems facing the constraints of the real economy and present a modelling approach of economic systems. The paper is structured as follows: Section 2 presents the first economic thoughts before the emergence of orthodox theory; as well as an introduction to the principles of orthodox theory. Section 3 discusses the reasons that caused the revolution. Section 4 details the new assumptions of the evolutionary economics as well as the new concepts that have appeared, while section 5 presents the modelling approaches of economic systems, especially the utility of the agent-based simulation to understand, explain and anticipate the economic systems.

2. HISTORY OF ORTHODOX THEORY'S EMERGENCE:

2.1. First Founders of Economic Thinking

According to Greek thinkers, economics refers to the art of properly administering his house. Microeconomics is historically the first form the economy has taken. During the XVIII century and especially with the physiocrat current, we discovered a first macroeconomic view, that is to say, a hierarchical representation of the economy by the flows between agents [21].

Karl Marx, a century later, will propose a schematic representation of the industrial economy of his time. At the same time, the founders of the neoclassical school used margin a list theory to aggregate the behavior of economic agents, ie consumers and producers. This aggregated microeconomics often approach from certain macroeconomic theories, it is the basis of the theory of general equilibrium of Walras, and supplemented by Kenneth Arrow and Gerard Debreu. However, this view of the economy cannot be confused with macroeconomics, since it is based solely on individual behavior and does not analyze the economy as a whole [21].

The systematic distinction between microeconomics and macroeconomics, as far as it really can be, only really emerged in the 1930s around the work of John Maynard Keynes. It was above all the repercussion of his general theory of employment, interest and currency (1936), which led to a clear separation of the two domains. Microeconomics then focused on the problems of resource allocation through relative prices, while macroeconomics studied global production and price levels [21].

Due to the failure of Keynesians to anticipate and curb stagflation due to oil shocks, macroeconomics at the end of the twentieth century raises several basic principles.

In addition, Keynes was unable to formalize the relation between micro and macro, because his theories required the possibility for agents to be different, his modern critics do have a formal microfoundation, but they get this by modelling a multitude of similar agents, i.e., by using a representative agent. As noted by Boland (1982), Keynes was more concerned with the lacking macrofoundation of microeconomics than the microfoundation of macroeconomics [8].

2.2. Orthodox theory

And from the 40 years of the twentieth century, a new theory settles, namely "the orthodox theory"; which aims to analyze economic systems in equilibrium where economic agents do not interact with their external environment.

These economic agents have an individual and independent behavior. They aim to maximize their usefulness. They are considered automatons seeking balanced trade in a world where time and uncertainty do not exist. Economic models based on this theory have mainly focused on the static analysis of the system.

The orthodox theory is based specially on the following assumptions:

- Market in equilibrium: the orthodox theory assumes that the environment is static. It does not account for the interaction of economic agents that compose it. Rather, they seek to optimize their usefulness;
- Perfect rationality: the orthodox theory assumes that all possible states of the market are known by the economic agent. Bejean and all [2] specify that perfect rationality assumes that the economic agent has unlimited cognitive ability and he has all the capabilities necessary to process the information.

In other words, it assumes that the agent knows all his actions, he is qualified to accurately assess the consequences associated with each of its actions, and he is finally able to identify among these actions the optimal action [22].

Perfect rationality then assumes that these agents are equipped with the unreal ability to solve problems. Kechidi [22] notes that this rationality implies that the agent can maximize its utility assuming perfect information.

This conception of rationality based on a separation between decisions, economic, social and historical context as Cahuc explains [7] that in economy, the rationality principle means that individuals act in the best use of available resources, given the constraints they face.

In its decision, the economic agent is limited to maximize its revenues. He offers a homogeneous product and excludes any diversification strategy. Moreover, it ignores the uncertainty in so far as it considers that the behaviors of other economic agents are predictable.

The orthodox approach is simplistic and restrictive in terms of the number and the heterogeneity of agents. This approach simplifies also relations between agents assuming they are independent of each other. That means that these assumptions may lead to incorrect results generalizations [33]. Finally, we can say that models that assume a general equilibrium in the market cannot provide an ideal representation of the economy.

All these points lead to a divergent and conflicting situation between orthodox economic theory and economic reality, between the tendency of a market equilibrium and equilibrium itself as noted by Schumpeter [37]. All of these have led to a revolution in economic thought whose main objective is to explain economic developments.

2.3. Computable General Equilibrium Models

In parallel, trying to model a market economy, Leon Walras exposes his first attempt in 1874. His general equilibrium theory of the competitive market economy was further extended by Kenneth Arrow and Gérard Debreu to proofs of existence and stability of the equilibrium. These studies are of a general, abstract and rigorous nature and do not include numerical analysis. In contrast, Computable general equilibrium (CGE) models are designed to establish a numerical framework for empirical analysis and evaluation of economic policies. This is why they are called `computable general equilibrium models` [28].

The pioneering CGE model was the Norwegian multisectorial growth model developed by Johansen (1960). Since then, many CGE models have been developed to analyse, for example, development issues by Dervis et. al., (1982) and taxation and international trade issues by Shoven and Whalley (1992). A model of the Australian economy, known as ORANI with its variants, was built by Dixon et. al., (1992).

CGE modelling has become popular because of increasing needs for analysis of policies related to resource-allocation issues. At the same time, it must be noted that CGE modelling has been made possible by the algorithm introduced by Scarf (1973), in combination with rapid improvements in computer technology [28]. Indeed, several software make possible to model the CGE models such as the software Games.

3. REVOLUTION IN ECONOMIC THOUGHT

Simon [38] points out that classical economics does not provide an absolute way to describe the process that managers use to make decisions in complex situations. One of the alternatives he proposes is the study of the economy through the complexity theory.

The work of Simon [39] had a decisive contribution to the renewal of economic thought. These contributions have allowed to consider the social aspect and to migrate from a purely economic to social-economic view by introducing the concept of "bounded rationality". Simon [40] has revolutionized the representations of reasoning in social-economics based on his research in cognitive psychology.

In fact, Simon replaces perfect rationality by bounded rationality and the concept of optimization by the notion of satisfaction or satisfying. He suggests modelling economic systems as open systems, whose behavior is completely unpredictable.

3.1. Bounded Rationality

The notion of bounded rationality has been the subject of recent research [38]. It has spawned numerous discussions regarding its interpretation. We can consider that rationality is limited when the behavior is the result of an appropriate process of decision making [2].

Béjean et. al., [2] consider that in reality the successive decisions of individuals affect the range of possible states of the market. It is therefore not possible to assume that the list of market states is

predetermined. Bounded rationality, unlike the perfect rationality takes into account imperfect information. According to Simon [38], the rational process is one that gradually integrates information acquired in the process of choice, allowing reaching a solution considered among the best but that is not necessarily the optimal solution in terms of perfect rationality.

Individual preferences evolve in terms of new information and experience. They are acquired through learning and become an object of study relevant. Hommes [20] shows that the agent with limited rationality must formulate its expectations based on observable information and adapt its prediction rules when he makes additional observations.

Béjean et. al., [2] points out that bounded rationality confers power of adaptation to the reality of the system to be analyzed: a complex and evolving system. This rationality has the advantage:

- To consider an evolutionary decisional environment,
- To have greater cognitive wealth,
- To allow greater freedom in the decision criteria of the individual.

Bounded rationality has led to changes in how to pose and solve economic problems. By focusing on the deliberative aspect of decision making and the understanding of individual behavior, it seeks to identify first the method of decision making, not his motives, in other words it identify the objective to be pursued.

3.2. Notion of Satisfying or Satisfaction

In most cases, the individual confronted with a choice, built a simplified model of reality by referring to his own experience. His behavior is more common than reasoned. When the individual is not referring to his experience, and because of lack of time, information or capacity, he is seeking a solution to bring him some satisfaction. Its limited rationality does not allow him to find the optimal solution. For example, when buying a product, consumers do not always through all the shops in town but just acquired the product with the best quality/price ratio in the same store. It is therefore a reasonable choice, but on the basis of incomplete information.

Bejean et. al., [2] noted that human reasoning from a limited rationality can be characterized by a selective search within a large space of possibilities. The search stops when a satisfactory solution is found. This decision creates a mechanism to identify possible options as well as a decision rule called satisfaction.

3.3. Dynamic Markets

The goal is to move from optimizing market in equilibrium in search of equilibrium as much as possible for these markets. This leads to foster self-regulation of these systems by feedback loops instead of central planning.

Markets are characterized by a set of firms in interaction. Indeed; firms are not isolated entities but interact with other firms. This interaction can be:

- Directly as in the case where the firms have common commercial actions;
- Indirectly by considering the effect of other firms on the market or by observing the strategies of firms that succeeded.

The market presents the following characteristics [33]:

- *Strong competitiveness:* The increasing importance of information and know-how generated strong competition among firms, as well as increased uncertainty and complexity;
- A significant number of firms;
- *Uncertainty:* The market is uncertain since it is impossible to define in advance all market conditions. This is because it is difficult to prevent the evolution of all factors affecting the future. The prediction of these factors is dependent on information relating to the natural environment (Climate effect on a crop), the social or political environment (wars effect, for example) or the behavior of others firms that may be influenced in turn by the market;
- *Stability/turbulence:* Several factors are behind the market dynamics. We can especially mention:
    - Evolving technologies overnight,
    - Introducing new competitors,
    - Reorganizing the structures of firms,
    - Structuring the market, in other words, the number of competitors and their weight, the firm's position relative to its competitors and the emergence of organizational forms which defines itself the importance of the direct competitive pressure,
    - Disappearance of some firms, the heterogeneity of firms regarding their structure and behavior.

However, Simon [41] concluded that the current understanding of the dynamics of real economic systems is grossly imperfect. We particularly lack of empirical information on how the actors, with limited cognitive abilities, develop expectations of the future and how they use these expectations to challenge their own behavior.

4. NEW ECONOMIC THEORY: EVOLUTIONARY ECONOMICS

4.1. Definition of Evolutionary Economics

Evolutionary economics is defined as an attempt to consider an economic system, from the point of view of the world or from the perspective of its parts, as a continuous process in space and time [3].

The evolutionary economics includes ideas of several economists such as Arthur [1] and Nelson and Winter [27]. It assumes as Singh [42] that:

- The economic agents are endowed with rationality and limited cognitive abilities,
- The goal of these agents is looking for satisfaction and not for optimization,
- The use of organizational learning is required.

The basic unit of this theory is the firm. The term firm is used to characterize a company when the economic aspect is predominant in the company. The firm is essentially the economic side of the company, that is to say its production tools, its returns or profitability [33].

4.2. History of Evolutionary Economics

The evolutionary approach has emerged through the work of Schumpeter [37] who considered the equivalence between biological evolution and economic development. However, the work that has had the most success and is considered representative of this theory is that of Nelson and Winter [27]. This theory attributes to the agent the ability to deliberate in addition to technical skills. They are based on the concept of organizational routines; which are the manifestation of the agent memory and its response capacities and actions. The agent chooses a strategy from a set of existing strategies based on their relative performance. These relative performances are measured by the profitability and on the utilization of this strategy by the other firms.

However, the revolution in economic thought introduced by the work of Simon [25] has generated:

- Emergence of new economic theories such as behavioral theory of firm (March and Simon [25]), evolutionary economics (Schumpeter [34] Nelson and Winter [27]), resource theory (Penrose [32]), the evolutionary theory of the firm based on resources (Durand [14, 15]). The aim of these theories is to explain the behavior of economic agents and economic systems in general,
- Consideration of economic systems as complex adaptive systems (the work of Arthur [1] Holland [19] Tesfatsion [43]) and the use of the systems approach to model such complex systems. This modelling approach focuses on interaction, organization, emergence and complexity and includes new modelling approaches based on the tools of artificial intelligence [33].

4.3. Complexity in Economy

The new vision of economic systems introduced by Simon [7] has given rise to two different research topics:

- Rational reasoning processes involved in economic behavior,
- Complexity of the modelling process of economic systems.

Both topics orient economic researchers to a consideration of economic systems as complex systems, and in the course of time several new notions and concepts begin to appear in order to be able to understand and describe economic phenomena:

- *Homeostasis:* However, the notion of equilibrium, if it is reduced to the intersection of two curves on a graph, seems a little too mechanical to apply to the complexity of the dynamics of real economic systems, whose adaptive capacities recall rather the ability of living organisms to maintain their physical integrity in a dynamic process. Cannon (1932) calls homeostasis the stability of the organism of living beings, maintained by particularly complex coordinated physiological processes, a concept which does not imply the idea of immobility and stagnation peculiar to states of physico-chemical equilibrium in Which a set of known forces balance [31].

  Cannon, a physiologist, believes that all sorts of complex organizations - including economic ones - are likely to harbor homeostatic self-adjusting mechanisms similar to those of biological organisms.

- *Complexity:* Market economies seem to have properties that allow coordination of actions of multiple agents and competitors who compose without the analysis permits identification of

specific organ able to ensure the observed coordination; As if the whole was "superior" to the sum of the parts. This description refers to the notion of a complex system [31]:

According to Simon [38], a complex system is one made up of a large number of parts that interact in a no simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole.

- *Emergence:* Called "emergent properties", the properties of a system that is not directly deducible from the observation of the elements composing it. (Tesfatsion 2006, Farmer and Geanakoplos 2009).

  In other words, we can say that we employ the term emergence to simply characterize the arising of stable and orderly aggregate structures from simple adaptive individual rules of conduct. Loosely stated, we shall argue to be in the presence of an emergent phenomenon whenever the whole ensemble achieves functionalities or properties which its constituent parts lack [11].

- *Bottom-up approach:* We cannot approach the notion of the bottom up without mentioning that of emergence. In economics, a plethora of empirical evidence and experimental tests have persuasively demonstrated that aggregation generates identifiable regularities which cannot be immediately conduced to the characteristics of individuals, indeed, simple individual rules, when aggregated, produce statistical regularities or wellshaped aggregate functions that cannot be derived from the behavior of individual entities taken in isolation [11]. This transition from the individual level to the group level that generates an unexpected emergent phenomenon defines the approach bottom-up.

- *Notion of Adaptation:* Adaptation is the way an agent adjusts to market fluctuations to maintain or improve performance. Adaptation is the process of decision of the agent defined by its ability to detect the market signals, select the most important information and decide based on that information. Consider the case of the agent firm, the followers of the quoted mechanism above, such as Levinthal [23], Pajares [30] Bruederer and Singh [6], Lomi and Larsen [24], Dosi [12] assume that firms are flexible and have a learning capacity enabling them to deal with continual changes in their market. This notion of adaptation improves rationality allowing the development of knowledge of the firms.

  The uncertain and unpredictable nature of the market makes the adaptation difficult. But adaptation in turn contributes to uncertainty as it affects the market. This is confirmed by Wishbone [5], who considers the firm as an active entity that by its own actions and its own interest is able to change the state of the market, so we can consider the agent firm as an adaptive agent.

- *From bounded rationality to the procedural rationality:* However, the notion of bounded rationality developed by Simon as opposed to what he calls the substantive rationality proper to neoclassical microeconomics seems to imply a limitation of the cognitive abilities of agents.

  In fact, the notion of procedural rationality, more precise and better suited to the behavior of rational agents placed in a context of radical uncertainty (Simon 1996, pp. 26-27).

This procedural rationality consists in developing and implementing heuristics, that is to say, approximate methods of finding solutions to complex problems**.**

According to Simon [39], heuristic methods provide an especially powerful problem-solving and decision-making tool for humans who are unassisted by any computer other than their own minds, hence must make radical simplifications to find even approximate solutions. In the face of real-world complexity, the business firm turns to procedure that find good enough answers to questions whose best answers are unknowable.

- *Complex adaptive systems:* We consider a system as a complex system if it checks the following properties:
  - The agents that compose the system interact between each other.
  - The system presents emergent properties due to interactions between agents and not specific to the agents themselves.

In addition to the definition above; we define a complex adaptive system as a complex system that includes reactive units, i.e., units capable of exhibiting systematically different attributes in reaction to changed environmental conditions [26].

Complex economic structures are usually attached with adaptive agents. Indeed, according to Delli-Gatti [10], the complex economy is centred upon agents endowed with limited information and bounded rationality so that they adopt rules of thumb (instead of optimization procedures) and are naturally led to interact with other agents to access information, learn and imitate. In this sense, complexity goes hand in hand with evolutionary theories and direct interaction among agents [4].

4.4. Evolution of Economic Systems Over the Time

In order to summarize the evolution of economic theories over time; we have grouped the most interesting work in a Chronological table to be useful for researchers who want to discover the history of the economy.

Table 1
Important works describing the evolution of economic systems over the time

Researchers or Authors	*Theories or books Titles*	*Periods*
The physiocrat current	Notion of macroeconomy: giving a hierarchical representation of the economy by the flows between agents.	18 century
Karl Marx	Schematic representation of the industrial economy of his time.	19 century
-Leon Walras	General Equilibrium Theory	1874
John Maynard Keynes	Distinction between microeconomics and macroeconomics.	1930
Schumpeter J.	"The Theory of Economic Development"	1934
Kenneth Arrow, Lionel McKenzie and Gérard Debreu	Proofs of existence and stability of the equilibrium.	1950
Nelson R.R. and Winter S.J	"An evolutionary theory of economic change"	1982
Schelling T.	"Dynamic models of segregation,"	1971
Arthur W. B	"Complexity and the economy"	1999

Researchers or Authors	*Theories or books Titles*	*Periods*
Holland J. H	"Complex adaptive systems"	1992
J.M. Epstein and R.L. Axtell	"Growing Artificial Societies: Social Science from the Bottom Up",	1996
Tesfatsion L.	"Agent-based modelling of evolutionary economic Systems"	2001
M.W. Macy and R. Willer	"From factors to actors: Computational sociology and agent based modeling,",	2002
N. Gilbert	"Agent-Based Models"	2007
Domenico G. , Edoardo G., Saul D., Pasqual C. et. Mauro G.	"Macroeconomics from the Bottum-up"	2011
H. Dawid, S. Gemkow, P. Harting, S.V. Hoog, M. Neugart	"The Eurace@Unibi Model, An Agent-Based Macroeconomic Model for Economic Policy Analysis"	2012
Kevin Chapuis	Happywork: modelisation multi-agents de la satisfaction au travail.	2016

In this table we have cited the theories that have marked the evolution of economic systems since the twentieth century until today.

5. MODELLING APPROACHES OF ECONOMIC SYSTEMS

Durand and Simon [38] consider that the simulation is the best way to understand the complex economic systems. It allows trying any type of experience without the need to initiate an experiment with the risks it represents, especially when it involves companies or economies. Simulation is not only a modelling tool for the study of economic systems or other but also an object of study itself, to improve understanding of some of the properties of these systems. It uses computer techniques of artificial intelligence (Cellular automata, genetic algorithms, etc.).

5.1. Reductionist Modelling

It consists in attempting to reduce the complexity of the real - and in particular the decentralized nature of the interactions between agents - in order to have a simplified system to which one can apply the mathematical tools available. This solution is used by all general equilibrium models.

Nevertheless, Solow (2010) warns against the abusive nature of the simplifications on which the most advanced general equilibrium models are based, the stochastic general equilibrium models (DSGE models) used in particular by the central banks as models of decision and forecasting. In particular, he points out that these models are based on a single representative agent, both "worker-owner-consumer" and so on, which necessarily leads to representing the economy as a system in which there are no conflicts of interest, no incompatibility of expectations, no disappointments. The whole economy is treated as a single individual who tries conscientiously and rationally to serve the interests of the representative agent, depending on the circumstances [31].

We cite in particular the stochastic models which can be described as a set of numerical parameters and a set of mathematical relationships that describe how some of these parameters, called causes, act on other called effects [13]. The stochastic simulation was used to model economic systems based on the orthodox theory. The stochastic simulation allows determining optimal strategies in a static context. It requires in part for agents an excessively reductive simplification and organization conditions of economic exchange, especially with respect to their temporal arrangement [29].

During several years, the simulation was used to apply analytical treatment of mathematical models [44]. Rivero et. al., [34] for example, offer the combination of formulation through econometrics and resolution via a digital simulation of nonlinear differential equations models. These models have some problems:

- Difficult to solve,
- Technological progress and changing strategies usually involve a change in the equations coefficients,
- Strategy of agents depends not only on the past and present states of the system but the expectations of agents concerning the future behavior of the system.

In addition to these points, Durand [15] has identified four limits that oppose the use of the approach based on mathematics to model economic systems considered from the viewpoint of the evolutionary approach:

- Behavior of agent and information change over time. It follows that the evolution of the economic reality represented by the mathematical models is very simplified and that inter-temporal phenomena are not taken into account (Durand [15]).
- Heterogeneity of behavior of the agents. Using mathematical models based on the homogeneity of behavior. It is simplistic and does not reflect the economic reality including a diversification of activities.
- Economic system is an open system characterized by the appearance of new innovative agents and disappearance of others, but mathematical models consider them to be in balance.
- Economic development can come from many sources, from flow of innovation, competition between agents, market operation, and modification of the rules of the organization. Then incorporating theses changes and innovations is difficult in mathematical models.

According to Drogoul [13], the point of view of the stochastic simulation on the simulated phenomenon is macroscopic. It does not take into account the microscopic components such as the behavior of the components and their interactions. It models the system as a whole [44]. It does not explain the why of some collective behavior resulting from the aggregation of individual actions. However, these phenomena are omnipresent in economics. Therefore, stochastic simulation is not suitable for the presentation of economic models.

5.2. Constructivist Modelling

There is another way to understand the mechanisms that link individual behavior to macroeconomic behavior. Because these mechanisms are complex, it is very difficult to reduce them to simple mechanisms without distorting them. Rather than attempting to simplify these mechanisms, it is a question of attempting to reconstruct them according to what Epstein calls a "generative" approach [31].

This search for explanations by reconstruction is the first objective of agent-based models (Tesfatsion 2003). Agent-based models are radically different from conventional models. They are inherently decentralized computer models. They do not consist of a system of equations linking macroeconomic variables.

Agent-based simulation proposes to model explicitly the behavior of the entities; called agents and considers that the global dynamics of a system, at the macroscopic level, is the direct result of the interaction of behavior at the microscopic level. Indeed, agent-based approach allows modelling each individual's behavior and interactions that result from the pooling of these individuals. The global dynamics of the system is then a conclusion of all of these individuals [31].

The agent-based simulation preserves the heterogeneity of the system to simulate. It is characterized by the opportunity to represent several levels of granularity in heterogeneous systems [39].

5.2.1. Origin of Models with Multiple Agents

Originally, multi-agent systems appear in the field of computer science, as a research object in the field of Distributed Artificial Intelligence. Their application to economic modelling has been developing gradually since the 1980s on the basis of individual initiatives and scattered but gradually gaining strength and cohesion, until they constitute themselves in "movement" [31].

According to Arthur, over the last twenty years a different way of doing economics has been slowly emerging. It goes by several labels, complexity economics, computational modelling, agent-based modelling, adaptive economics, research on artificial economies and generative social science, each of these has its own peculiarities, its own followers, and its own nuances. Whatever the label, what is happening, he believes that is more than just the accumulation of computer-based or agent-based studies. It is a movement in economics.

These early initiatives were based on a series of precursor work which are mentioned bellow.

5.2.1.1. University of Carnegie Mellon Group

The real precursors of Agent-Based Approach are the members of the research group of the university of Carnegie Mellon (Simon 1961, Simon 1955, Simon 1959, Cohen 1960, Cohen et. Cyert 1961, Simon 1962, Cyert et. March 1963).

It is true that these researchers did not build a model populated by multiple agents. However, their work in the field of limited rationality and procedural rationality has led to very significant advances both from a technical (artificial intelligence) and sociological (business behavior) point of view [31].

Moreover, they are the real introducers of computer programming in economics, not only from a technical point of view (for the implementation of models and simulation) but also as a "natural theoretical language" for the description of processes in complex economic systems.

5.2.1.2. Thomas C. Schelling:

Although Shelling did not use a computer for its first simulations, its spatial segregation model (Schelling 1971) holds a very important place in the literature of "agent-based computational economics" as a pedagogical model. In fact, this model makes it possible to illustrate both concretely (spatial segregation is a social fact) and theoretically (the model is of great simplicity) the notions of a complex system (here an urban space with a heterogeneous population) and of emergence (in this case, the formation of homogeneous neighborhoods of populations, in spite of an individual behavior that is not very segregated) [31].

5.2.1.3. John H. Holland:

It is in the more abstract domain of artificial intelligence that the contribution of Holland (1975) is located, with the invention of genetic algorithms. Genetic algorithms are optimization systems based on the metaphor of genetics and natural evolution [31]. They concern for two reasons builders of agent-based models:

In principle: genetic algorithm relies on a population of individuals distributed in the research space. This population, subjected to repeated operations of selection, crossing and mutation, will progressively converge towards a solution of the problem modeled as a function to optimize (Osman et. Kelly 1996, Alliot et. Durand 2005, Chinneck 2006).

In their applications: genetic algorithms are one of the main techniques used to model individual and collective learning abilities in models based on multiple agents

5.2.1.4. Characteristics of Agent-based Simulation

Ferber [17] notes that the agent-based simulation is used to study complex systems. It represents complexity of a phenomenon through the interaction of a set of simple entities called agents. Each agent can:

- Communicate with other agents in order to exchange information,
- Receive and act on all or part of the environment,
- Apply knowledge, skills and other personal resources to accomplish its individual goals [17].

In other words, an agent has the following properties:

- Autonomy: the agent controls his actions according to its internal state and its environment, without external intervention,
- Proactivity: the agent has his own business and his own goal and not just reacting to the environment,
- Adaptation: the agent is able to regulate his skills (communication, behavioral, etc.) depending of the agent with which it interacts and / or of the environment in which it operates [18].

5.2.3. Utility of Agent-based Simulation for the Economic Systems

Durand [14] shows that the interests of agent-based simulation of economic models are threefold: theoretical, methodological and technical. On the theoretical level, the agent-based simulation is an essential extension of the reflection that can be conducted within the framework of the current resource. Methodologically, unlike conventional methods, simulation does not require strong assumptions about the optimal or rational behavior of economic agents. Technically, it gives maximum freedom to the idiosyncratic definition of the agent. It allows representing the agent as an entity able to act according to market changes.

The agent-based simulation models provide solutions to the limitations of the mathematical approach, it allows to [16]:

- Represent the inter-temporal phenomena in economics,
- Represent heterogeneous behaviour,

- Ignore the assumption loop back model and represent for example changes without a constraint demand or budget,
- Represent a continuously evolving system and consequently avoids the account equilibrium,
- Consider the consequences of strategic choices on the properties of resources committed by the agent in the competitive process (integration of changes and innovations).

The agent-based simulation differs from other approaches in that it takes into account both multiple levels of analysis: the micro level and the macro level. Dawid [9] points out that the agent-based simulation binds on one hand, individual strategies, market structure and micro effects, and on the other hand, the development of some economic variables at the macro level such as economic growth.

6. CONCLUSION

The revolution in economic thought after the works of several researchers; namely the work of Simon [38]; has led to a new economic system study approach. This new approach examines economic systems from the viewpoint of complexity. It enabled a transition from the study of behavior predicted of the neoclassical model to study the behavior observed. It has therefore extended the neoclassical approach of economy by acting on its main principles; it replaced:

- The equilibrium concept by the notion of change and evolution,
- The perfect rationality of agents by bounded rationality,
- The search for an optimal solution by a search for suboptimal and robust solutions.

It approaches the modelling of economic systems from reality by considering them as complex systems [19], composed of interacting agents, showing a self-organizing feature and emergence of coherent global behaviour [33].

It has also allowed highlighting some aspects of the economic systems that have long been neglected despite their importance; we also exposed in this work the relevance of agent-based simulation regarding economic systems; as a modelling tool to effectively represent the reality and explain the emerging phenomena.

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