THE THEORY OF THE FIRM AND THE EVOLUTIONARY GAMES

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***Abstract**: The neoclassical theory of the firm deals with the pattern of perfect competition, within which the perfect information available to economic agents provides instant allocation of production factors and access to economic goods. The Austrian School (C. Menger, L. von Mises, Hayek, etc.) supported the idea of minimal state intervention on the markets, bringing important conceptual developments on the theory of the firm. Hirschleifer (1982) put forward the model of social and institutional functioning, arguing that the game theory is able to predict the outcome of the collective behavior and the human characteristics necessary for building the respective institutions.The evolutionary theory provides the firm and the entrepreneur the recognition of the functions of innovation, of generating and exploiting information and of organizing and coordinating production. The evolutionary perspective of the firm assumes the existence of a body of knowledge that is acquired through and builds up the organizational memory, subsequently found in routines, all choices being made based on these routines (Nelson and Winter, 2002). The evolution of the firm is considered to be similar to natural selection, but unlike the classic market selection, the evolutionists suggest the existence of a plurality of selection media. The present research is structured as follows: a brief introduction into the theories of the firm, the second part of the paper analyzes the theories of the firm from an institutional, neo-institutional and evolutionary perspective. In the third part of the paper the evolutionary games are described and analyzed from the evolutionary perspective of the firm. The last part of the paper represents a study of the "hawk-dove" game dynamic replicator. The final conclusions of the paper show that the evolutionary theory brings valuable contributions to the foundation of explanations regarding economic phenomena, indicating new directions for advanced economic research.*

***Keywords**: theory of the firm, game theory, evolutionary theory, evolutionary games, dynamic replicator.*

***JEL classification**: D21, D43, L13, C73, C71*

1. Generally Introduction

In this chapter we shall identify the main views on the firm expressed by the Neoclassical Economics and the Austrian Economics and we shall present the main theories of the firm. If in the case of a perfectly competitive market the firms are of approximately equal sizes and cannot influence price formation, in the case of imperfect markets the competitive behavior of firms show that they are in active competition with each other and have some power to influence the market. The analysis of market structures is useful in identifying different types of markets, providing information on the performance of firms. The paradigm on structure,

conduct and performance (Chamberlin 1933, Bain 1956) dominated economic thought until the '80s. According to this paradigm, the structure of the market in which firms operate is ultimately the determining factor of performance and is measured through indicators such as profitability.The Neoclassical theory deals with the pattern of perfect competition, within which the perfect information available to economic agents provides instant allocation of production factors and access to economic goods. According to the neoclassical theory, the firm exists to combine production factors to achieve and maximize profit (Coase 2002).

Harvard School (J.S. Bain, E. Mason, etc.) became well-known due to the conceptual research done on the structure and functioning of markets, barriers to entry, competitive strategies, economies of scale, transaction costs and antitrust cases. Contrasting the paradigm on structure, conduct and performance, the Chicago school continued to use an approach based on the neoclassical model of long-term equilibrium in competitive markets. Thus, the resources are allocated optimally and the market is the one that has the power to balance supply and demand. The representatives of this school (A. Director, G. Stigler, W. Baumol, etc.) studied the theory regarding the life cycle of the firm, the firm's power on the market as a determinant of its integration. A significant contribution belongs to W. Baumol (1982) who promoted the theory of contestable markets, assuming that markets become competitive in the long term, and government interventions are not always considered necessary.

The Austrian School (C. Menger, L. von Mises, Hayek, etc.) supported the idea of minimal state intervention on the markets, bringing important conceptual developments on the theory of the firm. We observe such research on the competitive structure of markets, those relating to the dynamic nature of markets, as well as the research on the characteristics of firms, sectors and markets. Starting from the research done by Carl Menger and Eugen von Böhm-Bawerk, Mises Ludwig von Mises (1881-1973) helped develop theories of the firm showing that giving up private ownership of production factors makes price formation and entrepreneurial calculation in monetary terms almost impossible. More recently, researchers that may be considered as followers of neo-Austrian school, such as Kirzner (1913), Reekie (1984) and Littlechild (1986) used the term “evolutionary economics”. The theory of evolutionary economics has developed in parallel with the institutional economics. Basically, it is about the endogenous view according to which the beliefs, norms and customs of the society could lead to the formation of institutions that facilitate corporate behavior. Hirschleifer (1982) put forward the model of social and institutional functioning, arguing that the game theory is able to predict the outcome of the collective behavior and the human characteristics necessary for building the respective institutions.

The research called “An Evolutionary Theory of Economic Change” (Nelson and Winter 1982) represents the starting point and a reference for the trend addressing the theories of the firm from an evolutionary perspective (Arena and Lazaric 2003). Nelson and Winter (2002) have criticized the neoclassical theory considering that the profit maximization assumption is not valid in all cases, indicating that excessive attention is not to be allotted to market equilibrium, but rather to dynamic processes arising from economic exchanges exposed to risk and uncertainty. In economics, the concept of evolutionism has resulted in an institutional type of evolutionism. One of the most important authors who advocated for evolutionary type approach was Friedrich A. Hayek, who observed that efficiency is approached from a dynamic point

of view, contrary to the neoclassical theory where the approach was from a static point of view profit maximization.
The evolutionary theory defines the firm as a set of essential skills, gathered based on its learning ability. The evolutionary approach adopts the concept of limited rationality, the individuals and the organizations have much to learn in a complex environment characterized by uncertainty in the context of the knowledge economy. From this perspective, the firm is regarded as being a coherent system of activities associated with the production of synergistic effects (Gould 2002).

2. The institutional and neo-institutional perspective on the theories of the firm
The Walrasian model (1873) was imposed, economics focused exclusively on production and consumption. Postulating institutions and rational behavior made it possible to develop mathematical models by which the interaction on the free market could be conceptualized. Thorstein Veblen (1899) argued the need for a reorientation of the economic theory from the exclusive concern regarding individual choices towards the study of institution's impact and evolution. John R. Commons (1931) advanced the idea that the economy is defined by institutions and conflicts of interest. The institutional paradigm developed as a reaction to the tendency of economics' specialization on supply and demand issues, ignoring the problem of institutions that enable the functioning of markets (Veblen 2005).
Knight (1921) paved the way for highlighting the role of institutions in reducing uncertainty, and Coase (1937) showed that an institutional framework conducive to economic development is one that reduces uncertainty and transaction costs. The framework developed by R. Coase is the one that reduces transaction costs so that participants in the economic game to take advantage of market opportunities.
The institutional perspective on the theory of the firm is closely related to the issue of transaction costs, of uncertainty, and of innovation (Sherer (1967), Stoneman (1983), Doris (1989) and Reingenum (1989)). Institutions influence behaviors through information on individual action, social overseeing and fostering cooperation (North 2007). The basic idea of institutionalism is that institutions create economic game rules, generates economic incentives, and these incentives influence the behavior of economic agents. The institutional system generates incentives with specific and predictable effects on the behavior of decision-makers, contributing to the efficient allocation of resources and stimulating the flow of innovations.
The hypothesis put forward by O. Williamson were considered and applied: in the history of economics (North 1981), in the game theory and organizational economics (Alchian and Demsetz 1972, Nelson and Winter 1982, Grossman and Hart 1985). Until the '90s, the dominant school of economic thought continued to produce models that excluded the institutions from among the relevant factors. North (1990) considered as a source of transaction costs, the overall costs of maintenance and operation of a property rights system in the conditions of increasing specialization and labor division expansion. These economic theories make up the group of institutional theories on rational choice and set the transition from institutionalism towards neo-institutionalism.
A significant element, approached by the institutional economics is represented by the identification of socially optimal exchange structures to ensure maximize wealth. This requires a functioning market system in which economic agents will select those rules that will allow them profit maximization. Rational individuals compete not only

to maximize benefits under a specific set of rules, but they also try to change these rules and obtain higher earnings (Demsetz 1972).
Neo-institutionalism provides recognition for the contributions of the neoclassical school of economic thought, using both quantitative and experimental methods to solve relevant issues (Diermeier and Krehbiel, 2003). A number of authors (Meyer and Rowan 1991; Williamson, 1991; Kalai and Lehrern 1993, Foss 1994, Langlois 1996, Joskow 2002, Aoki 2005) studied the efficacy issue of alternative mechanisms of governance as well as the role of institutions in generating economic performance by lower transaction costs.
The existence of institutions, whatever form they adopt, is subject to selection processes depending on the environment and mental constructions of individuals. From a set of institutions, the individuals can choose a type of institution that lasts over time. This phenomenon has three explanations: the first is related to the evolutionary theory in biology, where the processes of selection, learning and imitation find their explanation; the second path concerns ideology, the changes occurred in social values which represent a major factor in institutional change; the third explanation concerns the set of rules that individuals have become accustomed to even if they are harmful and can lead to inappropriate behaviors.
Assuming that rationality is limited, it is considered that individuals, even if they have access to new information, operate under pre-existing mental constructions. In this vein there can be perceived a return to the Austrian school (Simon and Hayek), which integrates the two concepts in the analysis: limited rationality and procedural rationality. If the first concept was integrated in a shorter time, for the second it took a while longer. Kalai and Lehrern (1993) get closer to the Austrian approach by introducing the notion of subjective rationality of players. The only condition they admit is that the players' beliefs are updated through learning.
Aoki (2005) introduced in the analysis of institutions the idea that individuals have subjective representations of strategic profiles. The notion of mental models, which Denzau and North (1991) have used to justify the importance of institutions, is consistent with the Austrian view of rationality. The individuals are subject to a set of rules not because they understood them, but to respond effectively to environmental changes. The rules that allow groups that have adopted them to thrive and grow are imitated allowing the guidance of individuals' behavior (Garrouste 2007). These are ways of acting which individuals do not need to understand explicitly, they represent procedural rationality.
Below we present the evolutionary perspective that suggests a long-term analysis of the company's behavior on adapting to the competitive environment of the market, this adjustment being made based on random processes as well as on the identification of new routines.

3. The evolutionary perspective of the firm and evolutionary games
In biology, the concept of evolutionism is closely linked to that of natural selection. The mechanism of evolution is explained by the fact that members of a population differ among themselves by different traits. Among these, only some features represent an advantage, and the individuals that hold them are better adapted to the environment than others. These individuals will survive longer and have more off spring, the traits are passed on through genetic inheritance, helping their survival within that respective population.

D. Bacaicoa and A. Brazales (2004) compared the properties of the human action theory formulated by Ludwig von Mises and Friedrich Hayeck's spontaneous order with the appearance of emerging properties, of self-organization and path dependency in the complexity theory. The evolutionary theory of the firm refers to complex systems, including economic ones, in which there operate independent network composed of multiple agents acting according to internal rules.

The evolutionary theory deals with the innovation activity as irreversible enlargement process regarding the complexity of economic activities. According to evolutionists, knowledge, the skills, the learning have central place in encouraging the innovation process, constituting its core.

Uncertainty is caused by the increasing complexity resulting from continuous changing of the economic and social reality and from an increasing number of variables that have to be considered. Institutions are seen as factors reducing uncertainty, the evolutionary theory recognizing competition, imitation, cooperation and domination as elements of survival in the market. The dynamic character of firms is endogenously generated by innovation in products, processes and organizational forms.

Organizational routines materialize knowledge generated by learning, being generated by repeated interaction between agents and environment. Routines are defined as patterns of interaction which represent efficient solutions for specific problems. Learning is conceived as a collective process that allows each individual to overcome the limited rationality by three factors: the relationship of imitation and emulation among individuals; their joint contribution to the understanding of complex problems and the existence of a common code of communication and of some coordinated procedures to search for solutions (Smith and Szathmáry 1997).

The company's development process is guided by the identification of new routines that are subject to selection at market level. In this configuration, the existence of production resulting from the behavior of firms and market conditions is one that opposes the traditional concept of market structures configuration (Dosi, Teece and Winter 2008).

The evolutionary theory defines the firm as a set of essential skills, gained from its learning ability. The evolutionary approach adopts the concept of limited rationality, individuals and organizations have much to learn in a complex environment characterized by uncertainty in the context of the knowledge economy. From this perspective, the firm is regarded as a coherent system of activities associated with the production of synergistic effects (Gould 2002).

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The evolutionary games were first used and applied in evolutionary biology (Taylor and Jonker 1978, Maynard-Smith 1982). Since the 60s and 70s there was an increase in interest regarding the application of the game theory in biology, particularly stochastic games, the games of 'n' people with non-zero sum and those in extensive form. Lewontin (1961) has shown that stochastic games can be used in the study of the evolutionary problems of species. Turner and Rapoport (1971) have

discussed the concept of preference in economics and biology. Marchi and Hansell (1973) considered the evolutionary type processes and biological studies on non-cooperative game. Dawkins (1976) and Selten (1978) presented a mathematical analysis of associated strategies for stable and non-cooperative equilibriums.
Strategic interaction, identified in biology, regarding obtaining the gain is further developed and applied in the field of economy. Therefore, there were identified solutions to evolutionary economic games such as Nash type equilibrium ones (NE) and multiple selection (Binmore1991, Fudenberg and Kreps, 1993, Samuelson and Zhang 1992). Evolutionary games were developed as a distinct class of economic games based on the pioneering research of Robert Axelrod (1997). The class of evolutionary game was designed to reflect gain survival and maximization. Evolutionary game models are suitable to explain the existing interaction in a large population of individuals. Many of the applications of biology on routine, myopia and genetic transmission of behaviors can be successfully applied today in business (Gould 2002). Based on the dynamic behavior of systems in the long run and on aspects related to learning and development, we are witnessing an expansion of the range of economic applications of evolutionary game which include: models of cooperative and non-cooperative games, repeated games, sequential games, stochastic differential games, and progressive games. Among these are distinguished as important the stochastic evolutionary games providing a simple framework for describing strategic interactions between a large number of players providing static stable equilibrium (ESS) and dynamic replicator (Tembine 2007).
In the literature in the field the evolutionary games are becoming more present although their economic applications are still quite isolated (Friedman 1991, Maynard-Smith and Szathmary 1999, Hofbauer and Sigmund 2003 Tembine H. et al., 2007). Further we analyze the evolutionary game model by studying the delayed dynamic evolutionary games. The evolutionary game model studies the behavior of populations made up of a large number of individuals who repeatedly engage in strategic interactions, the result of every individual depending not only on his/her own choice, but also on the choice of others (Samuelson and Zhang 1992; Sandholm 2010). Regarding the durability of cooperative behavior between individuals the evolutionary game model uses the prisoner's dilemma game in studying the development of the cooperation behavior between individuals (Zhang.'s., 2011, Zhang et al. 2011, Zhen and Perc 2010).
In a real competitive environment affected by risk and uncertainty, there are considerable differences in performance between firms that interact in the market. The dynamic model associated with evolutionary games can be studied using the tools of dynamical systems theory, the stochastic processes theory and the game theory. An evolutionary game expresses a formal model of strategic interaction, characterized by the fact that there will often be chosen strategies that generate high gain at the expense of the ones generating lower gain, and the players will not influence the future actions of other players (Friedman 1998).

4. A study of the “hawk-dove” game’s dynamic replicator

The dynamic Replicator describes the frequencies by which various adopted strategies may vary over time (Alboszta and Miekisz 2004, Friedman 1998) and the players’ gains depend on the frequency with which strategies are adopted within a population (Yi, T., Wang, Z., 1997).

Starting from the evolutionary game characteristic, i.e. the time evolution of strategies, in the literature in the field we identify the problem of the discrete approach of the dynamic replicator, the study of the conditions necessary for the for stability and the introduction of the delay in two different models: the social model and the biological model (Alboszta and Miekisz 2004).
Tembine et al. (2007) conducted a presentation of the dynamic replicator by which they described the evolution of strategy frequencies within the population and they studied the stability of the equilibrium point depending on delays. This study will continue in this pattern, taking into account the stochastic case in addition.
In the dynamic evolutionary games checked will be usually only the conditions for which the equilibrium is stable. In the proposed model we shall study the effect of delay on the stability of the dynamic replicator. The delay occurs due to the fact that the outcome of a decision is not instantaneous, so there is a period of time between the decision and its effect.
We consider that each pure strategy corresponds to a delay. We consider an infinite population of players, and each player chooses a pure strategy out of the S set of strategies where S = {1, 2, ..., n}. It is assumed that only pure strategies are considered, i.e. each player chooses one strategy only.
The matrix of gains will be noted with A. Because players will interact in pairs, the matrix A is expressed by the relation:

$$A = (ka_{ij}), i, j = 1..n,$$

Let $x \in R^n$ be the n dimensional vector, called the state of the population, for which the component x_i is the frequency by which the strategy "i" is adopted.

The gain function of the player following the strategy "l" and " $f_i(x)$, , $i = 1..n$ is given by the relation:

$$f_i(x) = k\sum_{j=1}^{n} a_{ij}x_j$$

If a player chooses the "l" strategy at a certain time "t", then the expected gain is expressed by the equation $f_i(x(t-\tau_i))$, where τ_i is the delay corresponding to strategy "i" and 'and x(t) is the state of the population at the time "t" .
The dynamic replicator is given by the equation (1):

$$\dot{x}_i(t) = x_i(t)(f_i(x(t-\tau_i)) - F(x(t))), \quad i = 1..n \qquad (1)$$

Where: $F(x) = \sum_{k=1}^{n} x_k(t)f_k(x(t-\tau_k))$ is the medium gain of the population.
Strategies that generate higher expected profits quickly spread at population level.
X_0 will be considered as the equilibrium. The right side of the system (1) is equal to zero in the x_0 equilibrium point. Thus, the following conditions occur:

$$x_{0i} = 0 \; sau \; \sum_{j=1}^{n} a_{ij}x_{0j} = \sum_{k=1}^{n}\sum_{l=1}^{n} a_{kl}x_{0k}x_{0l}, \quad i = 1..n$$

Further shall be considered the simplified case with only two strategies for which the matrix for gains is $A = (ka_{ij}), i, j = 1, 2$, and the gain functions associated with each strategy are:

$$\begin{aligned} f_1(x(t-\tau_1)) &= k(a_{11}x_1(t-\tau_1) + a_{12}x_2(t-\tau_1)) \\ f_2(x(t-\tau_2)) &= k(a_{21}x_1(t-\tau_2) + a_{22}x_2(t-\tau_2)) \end{aligned} \quad (2)$$

The medium winning of population F(x) is provided by the relation:

$$F(x(t)) = k(x_1(t)(a_{11}x_1(t-\tau_1) + a_{12}x_2(t-\tau_1)) + x_2(t)(a_{21}x_1(t-\tau_2) + a_{22}x_2(t-\tau_1)))$$

Considering the assumption that each player takes a single pure strategy, we determine the dynamic replicator expressed by the equation (3):

$$\dot{y}(t) = -kdy(t)(1-y(t))(\alpha y(t-\tau_1) + \beta y(t-\tau_2) - y_0) \quad (3)$$

where:
$y(t)=x_1(t))$ represents the frequency of players who adopt a strategy at the time ,,t"
$0 < y_0 < 1$ and y_0 is the only equilibrium point:

$$d = a_{21} - a_{11} + a_{12} - a_{22}, y_0 = \frac{a_{12} - a_{22}}{d}, \alpha = \frac{a_{11} - a_{12}}{d}, \beta = \frac{a_{21} - a_{22}}{d}$$

In "hawk-dove" model game, analyzed by Smith and Price (1973), the "hawk" is represented by players who adopt strategies of aggressive type, while the "pigeon" is represented by the players who adopt peaceful strategies. The model of the "hawk-dove" game serves to analyze the conflict between aggressive and peaceful strategies.
The numerical simulation was performed with two players, each player having only two strategies. Implemented on a duopoly market, the "hawk-dove" game refers to two firms which have to choose between two types of strategies: non-cooperation on the market (NCI) and market cooperation (Ci).
Ordering the four outcomes of the game can get the game winning matrix of "hawk-dove" type, shown in Figure 1.

		The player B	
		NC_B	C_B
The player A	NC_A	(-0.5;-0.5)	(1;0)
	C_A	(0;1)	(0.5;0.5)

Figure 1: The matrix of gains for the "hawk -dove" game

Figure 1 shows that in the case of the classic game of "hawk-dove" type (Smith and Price, 1973), the matrix for gains (A) integrates the following components:

$$a_{11} = -0.5, a_{12} = 1, a_{21} = 0, a_{22} = 0.5. \quad (4)$$

In this particular case the dynamic replicator will be given by the equation (5):

$$\dot{y}(t) = -kdy(t)(1 - y(t))(1.5y(t - \tau_1) - 0.5y(t - \tau_2) - 0.5) \quad (5)$$

The equilibrium point of the dynamic replicator's equation (5) is y_0=0.5.

5. In conclusion

In conclusion, the theories of the firm contribute to the foundation of explanations regarding phenomena of the real economy. By their use, as a frame of reference in representing the behavior of economic agents, these opened the way for a large field of investigation.

The problem of microeconomics is not to study the functioning of markets anymore, but to examine the ways in which firms can coordinate their decisions based on dynamic configurations in a competitive environment affected by risk and uncertainty.

The developments registered in the field of the theory of the firm lead to the conclusion that economics opens a large research area that can certainly be extended towards advanced economic research.

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