Coordination of agents through Learning and Evolutionary Processes : a Game Theory Approach

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This article deals with the problem of agents' coordination, and with its treatment through game theory. Contrary to most works published on the subject, the emphasis is made on the process rather than on the final coordination's outcome.

The problem of coordination concerns a group of individuals - or organizations - which pursue their own interests and try to establish a new and more efficient convention, i.e. a new behavioral regularity. The study of the coordination process allows us to have a better view of the different phenomena implicated in the determination of the final outcome and to understand their influence on it. Our starting point is the observation that individuals, because of their group membership, will influence each other.

We shall try to show, how, in an uncertain universe, these interactions can contribute to learning on both sides, thus modifying the knowledge and then, the strategies of individuals in the emergence of an agreement.

At the moment, game theory constitutes, one of the tools which is the most used in the treatment of coordination problems. Game theory deals with cases in which individuals make choices in interaction, and must be able to determine the equilibrium on which the coordination will be made. However, in many cases, it is not possible to choose one equilibrium rather than an other. It implies either to use equilibrium refinements which impose additional stability criteria to reduce the field of possible outcomes or to obtain irresolution.

To study a process, we need to be within a dynamic framework, that is to postulate that individuals' choices are not simultaneous but sequential (players observe the past play before decision making). We also need to postulate incomplete information because individuals have no reason to know in every detail how the other members of the group choose their strategies. Therefore, individuals (i.e. players) have prior beliefs about the types of other players. According to the information they dispose from each play, players will have the possibility to update their expectations and beliefs. Usually, the updating process follows the Bayes rule (the Bayes rule determines the posterior probability that a player follows a particular type). This rational process of belief updating is the natural way, in game theory, to introduce a learning process. One of the main point we want to make in this article is to know if learning phenomena are limited to this unique bayesian process.

To answer the question, we start by questioning Schelling's works (1986). Indeed, T. Schelling maintains that in the research process (in a tacit way) of a common solution such as the meeting point problem, « imagination often dominates reasoning and pure logic... ».[Schelling, T., 1986, p.83]. T. Schelling also emphasizes the behavior of the population as a whole, as well as the influence of population coordination on individual decision making. « The force of many social behavioral rules (...) stems from the fact that they constitute the solution of a coordination game. Everyone thinks it would be respected by others, the contrary would imply that deviant players would be pointed at by society. Fashion in clothes or also in cars arises from a process in which nobody wants to remain outside of the emerging majority and cannot go against the course of events » [Schelling, T., 1986, p.122]. For T. Schelling, learning is not exclusively produced by rational calculation, other processes seem to put pressure on the decisions of the agents. We want to know what these pressures are, where they take place, but also which models of evolution they follow. Then, we try to see if evolutionary games constitute the appropriate tool of formalization.

Through this paper, we expect to go beyond the usual presentation of coordination in game theory (section 1) and to integrate learning processes (section 2) as well as the evolutionary processes

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able to operate on coordination (section 3). To conclude, we examine the question of a possible complementarity, or of a contradiction between the different approaches of learning (section 4).

Section 1 - Coordination of agents in games

To study coordination problems, at first, we can consider the simplest framework : a game in complete information, where players are able to anticipate the strategies of their opponents. Usually, coordination can be seen through three types of basic games : the game of pure coordination, the Battle of sexes and the prisoners' dilemma. In the one shot games, rationality is the only element which guides the choices of players. Rationality ensures convergence towards an equilibrium (a). After such an analysis, the resolution of some of the leaving problems can take place thanks to the repetition of the initial game, when it is possible. The repetition of the game introduces some new informative elements for the players (b).

a) Different kinds of coordination

Pure coordination games consider players without conflicts of interest. The equilibrium behavior is then necessarily a Pareto-optimal situation. The example often used to illustrate this kind of game is the case of two individuals trying to meet each other in a particular town, on a given time, without any precise place of meeting. As an example, in the following table, neither of the two equilibria is better than the other, both of them correspond to the choice of a same place by the two players. There isn't any obvious answer to this coordination problem :

		player 2	
		place A	place B
player 1	place A	(1,1)	(0,0)
	place B	(0,0)	(1,1)

Table 1 - Example of a pure coordination game from J.W. Friedman (1993).

Other types of coordination problems are related to the battle of sexes game. This game is illustrated by the case of a (married) couple, in which the husband and the wife have different preferences concerning their weekly day off. They are supposed to make their choices simultaneously, without any communication. If their choices don't fit, they don't go out. The different possibilities are illustrated in table 2 :

		wife	
		match	concert
husband	match	(2,1)	(0,0)
	concert	(0,0)	(1,2)

Table 2 - Example of the game battle of sexes from J.W. Friedman (1993).

This game has two Pareto optimal equilibria (in pure strategy) when both players choose the same alternative. But neither equilibrium is dominated by the other. Even in mix strategy, coordination is not ensured.

Finally, there is a third way to appreciate coordination problems : the game of the prisoners' dilemma. Two individuals arrested without evidence have two possibilities : to confess the crime and to have a risk of punishment, or not to confess. In the latter case the behavior of the other player can be harmful to the one who did not confess, or on the contrary be favorable if he confesses. Table 3 illustrates this situation :

		player 2	
		confess	not confess
player 1	confess	(2,2)	(9,0)
	not confess	(0,9)	(5,5)

Table 3 - Example of the prisoners' dilemma from J.W. Friedman (1993).

This game admits a unique equilibrium (2,2) when both players confess. However, it is inefficient. They could have obtained (5,5) if neither of them had confessed. The problem is to know how to incite players to act jointly and take benefit from higher payoffs.

In this last case, as in the previous coordination problems, a way to assume coordination between players is to consider a repeated game.

b) Repetition of the game and starting of coordination

If they are repeated either an infinite or an uncertain number of times, repeated games are able to incite players to coordinate themselves on Pareto-optimal issues at each play.

For example, in the prisoners' dilemma (table 3), players can agree on playing the cooperative issue, except on the last play, if the game is finite. The credibility of this proposition relies on the capacity of players to punish the ones who deviate from the cooperative issue. Indeed, repeating the game offers the possibility for players to achieve their threats against the deviant ones. But this can only be possible if threats are credible, i.e. if they do not imply for the one who makes them a payoff loss. Consequently, the perfect equilibrium, which is the equilibrium outcome of a repeated game may admit the cooperative solution. In the case of an infinite repeated game, the cooperative strategy can even be an equilibrium solution if the discount factor is low (the importance of the present is weak compared to that of the future) [see R. Axelrod, 1984]. This condition strenghtens the importance of gains that arises from the cooperative choice.

In the same way, in the first problem (the meeting point - table 1), individuals who come to meet each other regularly without the possibility to communicate, will be able to coordinate their actions on a stabilized point, after a trial-and-error process (then repeated games belong to dynamic games). In this type of game, players can focus their attention more easily on one of the equilibrium of the game, because it has a strong meaning in the common background of players, or because it constitutes a common convention or a recognized way to play : we talk about focal point. This notion of focal point is then an additional equilibrium selection criterion in a situation of multiple equilibria and initiates coordination. But, the determination of a unique focal point isn't always possible. Moreover, when a focal point pre-exists, its results are rarely optimal, because it has few opportunities to be suited to the particular situation considered. J. Farrell & M. Rabin (1996), who made this remark, proposed to use « cheap talk » (which we shall examine later and which assumes incomplete information but possibilities of communication).

Nevertheless, the repetition of a game does not always result in coordination. It often yields multiple equilibria[2]. These limits have to be taken into account. But we will remain within this framework which enables us to study learning processes which can initiate coordination between individuals.

Section 2 - Learning in repeated games, resolution of coordination problems and limits

Since we assume incomplete information in repeated games, individuals have sought to reconstitute their information in order to be able to make good decisions. They are not even capable, as in classical game theory, to anticipate the entire path of the game. Therefore, they participate in a dynamic game. The dynamic aspect introduces memory effects in the game, i.e. past choices influence present decisions. Communication, pre-coordination, updating beliefs, etc. then constitute as many possible means to reach better coordination results.

a) Interactions, learning and coordination

We have to distinguish different levels of interactions between individuals. The first one is the process by which individuals seek to identify the players' type. This process will be called **learning**, just as the models describing these kinds of mechanisms. By learning, they mean the process by which players update their beliefs and their knowledge systems about other players, as they acquire new information on the players' type (from a more general viewpoint, learning shows the evolution of behaviors, beliefs, etc. after the cumulation and assimilation of experience implying the pursuit of some actions and the drop or the modification of others). We present what such learning models are, their

[2] cf. Folk Theorem. « Its formulation can be as follows : each individually rational issue (providing to each player a gain strictly above its security level) of the basic game can be, by infinite repetition, an equilibrium issue of the supergame » [B. Guerrien, 1995].

characteristics and the different ways to describe them. Thus, we shall try to have a better understanding of how this learning can contribute to the resolution of coordination problems.

1. Learning models in repeated games and simple learning

For D. Fudenberg and D.K. Levine (1996) a learning model can be define as « any model that specifies the learning rules used by individual players, and examines their interaction when the game (or games) is played repeatedly ». The appropriate framework to study learning is repeated games or more generally dynamic games, because they include time in their analysis. Bayesian games satisfy this definition of learning models with the Bayes rule as learning rule.

A simple way to study learning is to consider a two-person game played repeatedly, « ... in such an environment, players ought to consider not only how their opponent will play in the future, but also about the possibility that their current play may influence the future play of their opponents » [D. Fudenberg and D.K. Levine, 1996]. A player can thus « teach » his opponent to play a best response by playing a particular action over and over. D. Fudenberg et D.K. Levine consider the following example : « a sophisticated and patient player facing a naive opponent can develop a reputation for playing any fixed action, and thus in the long run obtain the payoff of a Stackelberg leader[3] ».

		player 2: L	player 2: R
player 1	U	(1,0)	(3,2)
	D	(2,1)	(4,0)

Table 4 - Basic learning game from Fudenberg & Levine (1996)

If player 1 plays as if he was in a one shot game, he chooses D. If player 2 observes that 1 has played D, he chooses L, so the system converges in (D, L). But if player 1 is patient and knows that 2 is naïve (which means that he chooses at each period the payoff maximizing action by expecting player 1 action), then player 1 can obtain better outcomes playing U bi inciting player 2 to play R [D. Levine & D.K. Fudenberg, 1996, p.6].

2. Characteristics of learning models

Characteristics of most of the learning models in game theory can be synthesized in table 5 :

	Learning models
Level of individuals' aggregation	individual (sometimes) population
Level of players' rationality, cognitive capabilities and learning sophistication	Rational individual, reasoning capabilities (optimization), expectation capabilities, beliefs formulation from priors. Possibilities of sophistication depending on the model's capacity to read the past
Selection criteria of the solution	Perfect (bayesian) equilibrium : at each informational set the player chooses an optimal behavior (given the players' beliefs - determined by the Bayes rule)
Use of available information	Reference to the experience cumulating by the players themselves during their meetings.

Table 5 - Synthesis of some characteristic elements of learning models

Learning is based on the game history's knowledge of the players (which constitutes the source of information for updating) and, on the players' rationality (rationality ensures strategies to be best responses). In an incomplete information environment**,** players only know the extensive form of the game and their own payoff functions. They are unaware of their opponents' possible issues. In such a situation, from one step to an other, players only learn the distribution of strategies used by their opponents. If

[3] in other words, the leader (here the patient player) obtains a better gain than the follower (here the naive player).

players obtain information concerning their opponents' payoffs, they use it to establish prior beliefs on the way they are waiting to play[4].

We can also distinguish different levels of aggregation of individuals, and then different levels of learning sophistication :

a) in the first case, players just try to anticipate how their opponents will play (individual model). If they play repeatedly together, they have to take into account that their present game will influence the future game of their opponents (cf. game table 5). In such repeated game models, the incitement to fail is weak.
b) In the second case, the focus is on a large population, where people interact anonymously. The size of the population is large enough compared to the discount factor (indicating the relative importance of the future from a present perspective). « There are a variety of models, depending on how players meet, and what information is revealed at the end of each round of play »[5] [D. Levine & D.K. Fudenberg, 1996, p.6].

Most of the individual learning models are **bayesian models**. Bayesian players only seek to learn their opponents' type. Because those models are individual, players use their own experience and not the observation of the population's experience to learn. Prior beliefs constitute a basis from which the learning is made (in the last section, we will try to see what imply priors). They « specify the probabilities with which Nature chooses the type of the players at the beginning of the game » [E. Rasmusen, 1994, p.145]. Then, beliefs are updated with the Bayes rule (see below). The updating process permits to check the validity of players' expectations.

Rule of Bayes

$$p(s_i/m_j) = p(s_i)*p(m_j/s_i)\Big/\sum p(s_k)*p(m_j/s_k)$$

$p(s_i/m_j)$: probability that the player *i*'s strategy is « s_i » when the message « m_j » is observed.

$p(s_i)$: probability that the strategy of player *i* is « s_i ».

$p(s_i)*p(m_j/s_i)$: probability that the message « m_j » comes from type « B »

$p(m_j)=\sum p(s_k)*p(m_j/s_k)$: probability that the message « m_j » be sent

[from B. Guerrien, 1995]

The revision of beliefs permits to pursue an equilibrium behavior - the solution is called perfect bayesian equilibrium. D. Fudenberg and D.K. Levine (1996) affirm that agents do not need to be completely rational, i.e. to base their inference on a correct model of the world. They can also be naïve, and so unaware of the possibility for the other players to learn and to answer to past strategic choices.

The **fictitious play** is also a foundational learning model. It's a myopic adjustment process, relying on best response functions. As in bayesian models, players only observe the result of their own two by two meetings. As in bayesian models, players are naïve and do not try to influence the play of their opponents. But in fictitious play, players' behavior is not sophisticated (players could be replaced by automata). They operate as if they were facing a stationary and unknown distribution of opponents' strategies and choose a best response depending on the historic frequency of the game (relating the opponents' actions in the entire past). Their beliefs rely on that unknown distribution. The strategy of players is then a deterministic best response function of their past observations.

Fictitious play had been used, at first, as a preplay calculation game of equilibrium, providing a way for players to coordinate their expectations on a particular Nash equilibrium. Fictitious play is now considered as a learning model [K.Sigmund & P.H.Young, 1995]. « It consists of nothing more that seeing what happens in the long run when the game is played by robots programmed to use the trial-and-error adjustment process. [...] Thus each robot computes the frequency with which an opponent has used

[4] It is also possible for players not to have information on their opponents, or even not to know they are playing a game. In other cases, they may just observe their own payoffs' history and strategies, and discover new strategies by experimentation or deduction.

[5]They can constitute an alternative to naive games explanations, precise D. Levine & D.K. Fudenberg (1996).

a pure strategy in the past, and optimizes on the assumption that the pure strategy will be used with that probability at the next stage » [K. Binmore, 1992, p.409].

We can notice that by studying unsophisticated players, fictitious play and its best response dynamic can be compared to the replication dynamic used in evolutionary games[6] (seen below).

b) Need of signalling communication, pre-coordination and coordination

Within an incomplete information environment, players can't perfectly anticipate the behavior of all the game's participants. An additional interaction structure can be used between players : **signalling communication**. To describe this element, we can use the game of « cheap talk ». As E. Rasmusen noticed it, « Cheap talk refers to costless communication before the game proper begins » [E. Rasmusen, 1994, p.76]. This costless communication is able to reduce the inefficiency of the equilibrium in a conflict contest, as in the battle of sexes. A sender (S) sends a message to a receiver (R), which informs the latter about S's type. Then, the receiver chooses an action depending on the nature of the message he received. This action implies the final payoffs of the two players whereas the message has no direct effect. However, the message can modify R's belief on S's type, and then modify R's action, which influences players payoffs. The « cheap talk » equilibrium is a perfect bayesian equilibrium. But, the message which is sent has no need to be informative. S can lie about his real preferences. In that case a « cheap talk » communication has little value, and introduces the question of the credibility of messages. « A message that is both self-signaling and self-committing seems highly credible » [J. Farrell & M. Rabin, 1996]. If those characteristics are of common knowledge, « cheap talk » is able to resolve the coordination problem. If there are conflicts, the credibility of the messages is less easy to ensure, firstly because players get better payoffs from being selfish (against self signaling) and secondly because the sender has no interest to follow what he said (against self committing). In such a situation, even if individuals would have an interest to coordinate themselves, « cheap talk » does not ensure they attain the most efficient equilibrium.

A communication between players can arise through a pre-play game before the real game. This phase gives the opportunity for each player to announce his intentions before playing. If the pre-coordination phase is long enough, players have the possibility to reduce the divergence between players' strategies.

Precommitment is another form of communication : in that case players choose to commit at the start of the game on a strategy for the rest of the game. Then, precomitment implies different results from the perfect equilibrium [E. Rasmusen, 1994, p.129].

c) Some limits of learning models

For us, a set of restrictive hypothesis constrains the scope of the learning models we have presented. They postulate for example, that the **state of the world is fixed**. This hypothesis implies that only the marginal processes of change are considered. The learning extent and possibilities of individuals seems then strongly reduced.

An other limit is due to the **probabilistic environment** of the analysis, which is able to treat risk matters, and not uncertain phenomena. Moreover, the priors, on which **beliefs** are grounded, are given. One of the consequence of this hypothesis is that if messages contradict prior beliefs, they will not be modified. Once again, we observe that the kind of change studied is only an incremental one.

It seems that these limits are needed to conceive learning as the result of a rational behavior. Thus, L. Blume et D. Easley (1993) propose to pay more attention to how learning interacts with other dynamics and then withdraw from the limiting rational learning dynamics. They try to show « ... that in a simple economy, the forces of market selection can yield convergence to rational expectations equilibria even without every agent behaving as a rational learner » [E. Blume et D. Easley, 1993]. In the next sections, we try to emphasize such learning dynamics, and more precisely to see if evolutionary models can contribute to the emergence of an agreement.

Section 3 - Evolutionary models and coordination

In fact, there exists other models relying on different dynamics (than the ones we've seen) and also on different hypothesis concerning the players' behavior and possibilities of action. It is the case of

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[6] We have to notice that « an evolutionary model is not only the formalization of the idea that players can learn to play Nash » [G.J. Mailath, 1992].

evolutionary games, where the players considered are pre-programmed entities without any possibility to choose their strategy. The selection mechanism follows replication dynamics. The equilibrium concept is the notion of evolutionary stable strategy (ESS). The learning models we've described in the previous section, were adjustment processes of beliefs, expectation and information's interpretation. For example, in bayesian models the learning's object was usually players' type. This learning could serve to reduce individual uncertainty to coordinate themselves. But, do coordination exclusively result from the reduction of uncertainty? Certainly not. We think that evolutionary models participate to a larger understanding of this concept. In the case of coordination problems, they become interested in the equilibrium emergence process. The equilibration process is guided by the following rule : the strategies that constituted good answers in the past will be played in the next period by a larger number of players. In games with multiple equilibria, the convergence process toward an equilibrium is strongly linked with initial conditions : then we can say that there is a strong path dependency. And, the notion of equilibrium corresponds to a strategy profile such that no player with a new strategy can invade and receive a higher payoff than the first player.

a) Evolutionary games, selection, heritage, mutation

F. Vega Redondo (1996) described evolutionary models as specific dynamic processes characterized by particular forces : selection, heritage and mutation. Selection is a force that determines the survival opportunities and the reproduction success of individuals following a particular behavior. Heritage is a « force that relies (upon a) behavioral model through consecutive generations ». For an effective selection, heritage has to ensure the transfer of a behavior from one generation to another in a sufficiently stable way. The mutation is a force generating new behaviors, able to improve the previous behavioral model and adapt it to the environment. It can be defined as « the repeated introduction (either deterministically or stochastically) of new strategies into the population » [D. Fudenberg et D.K. Levine, 1996].

Since J. Maynard Smith et G.R. Price (1973) showed that animal conflicts could be treated through games, biologists have used evolutionary game theory to study these evolutionary forces. On the side of human science, this theory sought to understand the strategies' evolution of players with very limited rationality. Then, evolutionary game theory appears to be on the opposite side of the usual framework of game theory dealing with interactions of fully rational players. The goal of evolutionary game theory is different. « The goal is not to explain how players would rationally pick actions in a given situation, but to explain how behavior evolves or persists over time under exogenous shocks ; Both approaches end up defining equilibria to be strategy profiles that are best responses in some sense, but biologists care much about the stability of the equilibrium and how strategies interact over time » [E. Rasmusen, 1994, p.111].

b) Evolutionary models characteristics

Table 6 synthesizes evolutionary models' characteristics :

	Evolutionary Models
Level of individuals' aggregation	large population
Level of players' rationality, cognitive capabilities and learning sophistication	limited rationality, myopic players, following preprogrammed strategies. unsophisticated players
Selection criteria of the solution	evolutionary stable strategy : Nash equilibrium refinement (not as strong). This stability concept implies that the ESS is able to repeal new strategies invasion.
Use of available information	reference to the past experience of the population. Players guess a stationary environment.

Table 6 - Synthesis of the characteristic elements of evolutionary models

Evolutionary models are concerned with **large populations.** Interactions between players may result from pairwise meetings (if the game is a two players game) in repeated games [Mailath, 1992]. Matching is anonymous and random (at each period, different players are considered). So here, learning is based on players experience, learning through replication dynamic (RD) comes only from the population **experience** [G.J. Mailath, 1992]. Population can be either homogenous (players are almost identical - then their behavior is not correlated with players' identity), or heterogeneous (players belong to different sub-populations, and have different roles - for example : buyer and seller...).

Individuals are myopic and simple, in other words, they do not expect the other players to revise their strategy. They act as if they were in an unchanged strategic environment. More than individuals, **strategies** are the reference points. Players do not consciously choose their strategies, they are preprogrammed, i.e. each player follows a particular role according to the population he belongs to. Players establish neither beliefs or expectations, they do not analyze their previous observations. Their strategies are also transmissible.

The performance criterion used is fitness. The fitness of a strategy i facing strategy j is the number of descendants (offspring) of i when j is played. Thus, the fittest behaviors will be reinforced. The strategies rewarded are those above the mean fitness, which are not necessarily the best. But the players who follow a bad strategy disappear.

The evolution process is a simple replication dynamic with the following principle : « the share of the population using each strategy grows at a rate proportional to that strategy's current payoff, so that strategies giving the greatest utility against the aggregate statistic from the previous period grow most rapidly, while those with the least utility decline most rapidly » [D. Fudenberg, & D.K. Levine, 1996, p.9]. The replication dynamic « describes how the strategies employed change over iterations, whether because players differ in the number of their descendants or because they learn to change their strategies over time » [E. Rasmusen, 1994, p. 113]. This evolution is slow, continual, reversible (random) [B. Walliser, 1996] whereas usually in economic games, players reach instantaneously equilibrium.

The concept of solution is the evolutionary stable strategy : « An ESS is a Nash equilibrium strategy of a symmetric bimatrix game which satisfies the additional stability requirement that it cannot be beaten by any rare, alternative strategy » [E. Van Damme, 1996, p.214]. The ESS is more than a best response : it has the highest payoff and it is a best response to itself. An ESS has the capacity to make the system return to its initial state after a little shock (E. Van Damme (1996) also shows that the ESS is asymptotically stable in the corresponding replication dynamics). What is needed then to know the equilibrium is the initial sharing of players in sub-populations, meetings and mutations aleas [B. Walliser, 1996].

Against evolutionary games, Foster et Young (1990) notice that usually, evolutionary processes face repeated stochastic shocks and not only isolated shocks as supposed in evolutionary game theory. In that case, two shocks can be too close to let the system return to its initial state. The appropriate stability notion is then the stochastic stability one. P. H. Young (1993) uses this equilibrium notion to explicit the emergence of a conventional equilibrium from the process dynamics.

To achieve this rapid description of evolutionary games, we can notice the remark of E. Blume et D. Easley (1992) saying that it is necessary to distinguish the evolutionary games in reference to biology and human and social evolutionary processes belonging to dynamic economics. In that case, the evolutionary aspects are related to the natural selection in markets which favor the optimal decision makers' survival. It is also important to identify divergence between economists and biologists in the use of evolutionary games [K. Sigmund & H.P. Young, 1995].

c) Evolutionary models and social conventions

For F. Vega Redondo (1996), evolutionary models provide an appropriate framework to deal with individuals with limited capacities of calculation, attention and association, who refer to simple rules which operated successfully in the past. On the basis of those past performances, they adjust their disposition to choose one of the past rules, as if they were proceeding to an internal (mental) selection. Social and economic environment represents an additional level of selection, closer to the biological selection process. Environment's complexity, our informational deficit and our imperfect understanding leave a potential for improvement in usable actions and rules. The discovery of novelty can then result either from non intentional actions or appears consciously « by combining a limited understanding of the problem with random sets of new choices » [F. Vega Redondo, 1996]. Occasionally, a good action can be found. It's then selected, and becomes a part of the present and past choice set. A mutation can also affect the evolutionary path of future actions. In absence of mutation, population stays in the same path.

But if a mutation exists, and pass the new behavior to his offspring, then the mutant strategy can become successful [E. Rasmusen, 1994, p.114].

Evolutionary models provide a description of conventional evolution (necessarily slow). Convention is considered as the coordination game's equilibrium, emerging from random interactions of limited rationality players. R. Boyer & A. Orléan (1994) studied the problem of emergence of a convention using the concept of ESS. In their study, R. Boyer & A. Orléan supposed a large population, with random matching. Individuals had to choose between two strategies I and J. The evolution of strategies is linked to their relative performance, calculated by players' expected utility. To become evolutionary stable, a strategy needs its expected utility to be strictly above the expected utility of the other strategy. If this condition is satisfied, a mutant strategy (associated with a small population) cannot destroy the dominant behavior. However, if several ESS exist, the system can be locked in a Pareto-inefficient situation. The system is then unable to evolve toward an other convention unless the players' percentage of individuals adopting the mutant strategy goes beyond a particular threshold. To resolve the problem of equilibria multiplicity, several authors, including R. Boyer & A. Orléan propose to return to the random matching hypothesis, and to work on a localized interactions structure. S.K. Berninghaus et U. Schwalbe (1996) for example, demonstrated that the coexistence of several conventions in society is linked to the anonymous degree in a society, i.e. to the number of common neighbors for two adjacent players.

After these different remarks, we note that the way we can use evolutionary models to participate to the resolution of coordination problems is totally different from the way and the field studied by learning models. It seems to be difficult to use replication dynamics to describe individual behavior, because the temporal space of both these processes is not compatible. One of the conclusion of an experimental work from J.B. Van Huyck & alii. (1996), is that evolutionary models do not provide a satisfying representation of individual learning processes, but seem to be suited to the populations' process' studies.

However, different works, as the one by R. Boyer and A. Orléan, are based on evolutionary models to describe a stabilized behavior's emergence, refering to the resolution of coordination by focal points. Thus, these propositions can probably lead to distinguish the elements contributing to a kind of **pre-coordination** of agents and those which intervene during the coordination process, contributing to reduce uncertainty around agents. The first would be studied through evolutionary models, and the second ones through learning models.

Section 4 - Between evolutionary models and learning models : which alternative ?

Learning models and evolutionary models have their own interest. But, neither can by itself explain the phenomena described by the other. Then a question still remains : are those processes (the evolutionary and learning ones) able to coexist, and if so, what is the nature of their relations ? It seems difficult to consider societies exclusively constituted either of « hyper rational » individuals, or of simple individuals. The possibility to learn does not exclude the existence of evolution processes, nor the capacity of these processes to act on agents' choices. In this conclusive section, we then think about learning and the evolutionary processes interrelations. Through several recent works, we seek for identifying the nature of the interrelations (b). But firstly, we can see how the processes can be reconciled (a).

a) Learning and evolution : extremities of a same model ?

Some authors are trying to identify the different variables (complexity, population's size, rationality, cognitive capacities...) from which it is possible to distinguish the action fields of learning and/or evolutionary processes, and then to bring out their differences.

Thus, B. Walliser (1996) constructed a typology of the different types of learning, from the most sophisticated type (« eductive process ») to the less sophisticated one (evolutionary processes). He established a link between individual learning models and evolutionary learning models, describing populations' behavior. B. Walliser uses the criterion of agents' cognitive capacities to separate four types of learning : (i) - « eductive process » - each agent has enough information to simulate other players' behavior and immediately go to equilibrium ; (ii) - « epistemic learning » - individuals establish beliefs on future strategies of other players thanks to their past actions (bayesian learning) ; (iii) - « behavioral learning », each individual changes its strategy according to the payoffs obtained from its past actions ; and (iv) - « evolutionary process » - each player has a fixed strategy and reproduces it according to the utility obtained through stochastic interactions.

D. Levine et D.K. Fudenberg (1996) use the complexity as the relevant variable. They explain that because individual models of learning are becoming more and more complex, particularly for large populations of players, some works make hypothesis directly on aggregate population's behavior (evolutionary models). We suppose that a non specified process exists at an individual level leading the entire population to adopt strategies which improve payoffs. This evolutionary process corresponds to the aggregation of plausible learning rules for agents.

b) Some binding possibilities between learning and evolutionary models

1. An example of binding between a collective dynamic (convention) and an individual learning process (expectation formation) : role of beliefs.

In evolutionary models, players' strategies are pre-programmed. Players who belong to a same population follow the same strategy. Isn't it possible to revise this strong hypothesis, which constrains the individuals' autonomy, and consider only that the element shared by people of a same population is a set of common references ? These common references or conventions could influence the way individuals interpret their information, but leave them free to use their own reply function given their cumulated experience through their multiple meetings in the repeated game. This proposition rejoins P-A. Chiappori's thesis (1994), who says that « In general circumstances, not only behaviors, but even the very foundations of the agents' economic knowledge, the representation they have concerning the economic context in which they grow, can be of conventional nature ». « (...) An initial convention can then fix all the future beliefs of agents - and then all the resulting economic facts ». His conclusion is that there is no incompatibility between conventional behaviors and individual rationality. The problem is then the coexistence of different conventions : on which convention agents will manage to coordinate themselves ? and is it always a common convention ?

2. Learning from experience or a way to go beyond bayesian learning

P.M. Brown (1995) sought to show that normative learning models, as bayesian learning do not relate all the reality of individual learning processes, and more particularly the existence of learning from experience. « Instead of choosing the forecasting rule that minimizes their forecasting errors, the learning process can be characterized as searching for a decision rule that promises returns above a subjective reference point »[P.M. Brown, 1995]. It doesn't mean that individual choices won't be optimal. The validity of the model will only depend on the reference point chosen by agents and so, of the payoff structure of actions.

3. Example of interaction between learning dynamics and others market selection dynamics : towards better results than bayesian learning.

E. Blume et D. Easley (1993) studied the question of how individual learning interacts with other dynamic forces. They showed that in a simplified economy, market selection forces could induce a convergence toward rational expectations equilibria, without postulating a necessary rationality of players. They revised the hypotheses (necessary in bayesian learning) that individuals have positive prior beliefs on a correct model and behave according to the Bayes rule to update beliefs. These hypotheses, as we saw them, are not realistic. They proposed new adjustment dynamics to link temporary equilibria and to determine the long run behavior of equilibrium prices. In their simplified model, the additional connection comes from the adjustment dynamic of wealth share. In time, individuals prosper and so dominate the market. Equilibrium points reflect beliefs. Then there are two possibilities :

- either learning is reinforced by wealth adjustment dynamics : the individuals with the best beliefs will be rewarded by the market and become dominant in the population (if players are bayesian, in the long run beliefs will be right, they will dominate the market and the asset will be correctly assesses) ;
- or « differences in decision rules more then compensate for differences in learning rules, and so rational learners may be driven from the market ».

If bayesian learning dynamics and wealth adjustment dynamics complement each other, E. Blume et D. Easley (1992) showed that « the higher savings rates of the incorrectly informed traders overwhelms the better information of the correctly informed traders ».

Different works of this type seek for a better view on the binding between individual processes oriented on decision making and the particular context they belong to, which can be characterized by dynamics with mechanisms of selection, heritage and mutation. For instance, we follow P-A. Chiappori who considers that the binding is established at that the level of beliefs and the representation agents have about their environment. This would be the level on which agents will integrate conventional elements in their individual process of learning.

Thanks to E. Blume et D. Easley (1993), those mix adjustment processes can lead to better results than pure individual learning processes in spite of the informational gap. This open path need to be pursued.

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