A cognitive approach to individual learning: some experimental results[1]

Marco Novarese and *Salvatore Rizzello*
Centre for Cognitive Economics
Università del Piemonte Orientale (Italy)
marco@novarese.org, salvatore.rizzello@unito.it

FIRST DRAFT

July 2001

Abstract: This study describe an experiment on individual learning in the domain of cognitive economics. The authors' main goal is to observe and to describe how subjects elaborate rules and regularities in problem solving.
Involved subjects are asked to choose between different scores related to an evaluation of some hypothetical exams. The game is repeated a wide number of times, sufficient to permit the emergence of accurately observable results. A particular software has been developed to support the experiment.
Results seem to show that subjects elaborate coherent rules in a path-dependent way; they manifest a tendency to consolidate these rules also when they are aware that they are wrong; and, at the same time, they exhibit an opposite predisposition not to confirm some rights rules.

JEL Classification: C91, D83, A12

Keywords: Experimental economics, cognitive economics, path-dependence, satisficing, framing, rules.

1. *Introduction*

Since economic analysis does not deal with omniscient and perfectly rational agents as actors of social phenomena, the comprehension of the role of individual learning in decision making is now considered more and more important in explaining how people choose. Nevertheless, economists tend to use analytical concepts such as learning, which are traditionally pertinent to other disciplines, such as psychology, in a very superficial way. Though this is true in particular for traditional economists[2], it should be noted that the

---

[1] The experiment here presented has been realized at the Centre for Cognitive Economics of the Università del Piemonte Orientale in Alssandria, Italy. The authors are grateful to the staff of the Centre and in particular to Chiara Antonello, Simona Mazzarello, Elena Passalacqua and Cesare Tibaldeschi. We have presented a previous versions of this paper at the Workshop on Cognitive Economics (November 2000) held in Alessandria and Torino, at the workshop on Simulation in Economics with Artificial and Real Agents (June 2001) held in Torino and in an invited seminar at the Creuset, University of St. Etienne (July 2001). We thank all the participants in the discussion during the workshops and seminar and in particular for their comments Michel Bellet, Massimo Egidi, Pierre Garrouste and Pietro Terna. The authors are very grateful to the Società per l'insediamento universitario per Alessandria – Asti which has partially supported this research.

2 As Börgers wrote (1996, p. 1384) the reason might be that "economists naturally do not welcome research which calls into question the foundations of their work". To

multifarious panorama of contemporary economics presents a heterogeneity of positions.

A recent and widespread tendency among economists is proposing, in fact, an interdisciplinary approach to the study of human behavior emerging at the crossroads of the heterodox tradition in economics and cognitive sciences, and it has given birth to a new branch of economics, i.e. cognitive economics, as it has recently been named[3]. This paper aims at belonging to this branch.

Though there is no doubt that the analytical novelties proposed by this new approach are relevant and concern all aspects of economic analysis and method, we will focus here our attention only on the theme of this paper: the role of human learning in problem solving. Literature distinguishes two different kinds of learning: learning from direct experience (learning by doing, learning by using) and vicarious learning (learning by the observation of others[4]). This paper deals with the former.

We decided therefore to turn to that particular field of research of cognitive economics, experimental economics, whose interest in learning is increasing. In particular we are referring to that specific sector of experimental economics, devoted to the experiments on individual and organizational learning (Novarese – Rizzello 1999).

Our starting point concerns what happens when individuals face a problematic situation under bounded information, i.e. one of the most widespread conditions in economics, in which people act when it is not possible to use routines that have already been experimented in similar circumstances.

We can note that, when these conditions recur, a lot of psycho-neurobiological processes, deeply illustrated elsewhere (Rizzello 1999), are spontaneously activated to help individuals to decide. First of all, a process of representation and framing of the problematic situation is activated, which depends on both the subjective mental structures and on the individual's previous experience. Psychology gives evidence that this process of framing is incomplete. This is due to an economic cognitive activity of the mind and to its use of shortcuts to reduce complexity. As maintained in previous works, it is reasonable to think that these mechanisms of human reasoning and learning are differentiated[5] from one individual to another, just like the perception of external data, on which they strongly depend[6].

Generally speaking, learning can be defined as the human capacity to modify behavior in a more or less permanent way, whenever new experience is acquired. Cognitive psychology furthermore specifies that this ability depends on the subjective cognition of the environment (it is linked to perception and the process of mental imagination) and on how this cognition affects behavior (Droz, 1977).

These specific characteristics of human cognition and the link between previous experience and perception make room for the further hypothesis that

---

support the idea of a superficial use of psychological concepts we may refer to Piaget's opinion that unfortunately for psychology all think to be psychologists (1979, p. 28).

3 For the foundations and the historical evolution of the cognitive approach to economics see Egidi-Rizzello (2002), and for the characteristics of cognitive economics see Rizzello (1999).

4 The theory of social cognitive learning, based on vicarious learning, has been elaborated by the Canadian psychologist Albert Bandura, but it still little widespread among economists. A few exceptions are: Witt (2000) and Rizzello-Turvani (2002).

5 Rizzello (2000a, and 2000b).

6 Hayek 1952 deeply illustrated these mechanisms, later confirmed by psychology and neurobiology (see Rizzello 1999).

learning happens in path-dependent terms (Rizzello, 1997 and 2000a: Egidi-Narduzzo, 1997).
With these two simple hypotheses about human learning, (differentiation and path-dependence) we designed an experiment to observe individuals in laboratory and to describe their behavior in a decision making context. Obviously, our aim is also to try to explain how they produce rules and regularities in behavior, and why they consolidate them also when they appear not to be correct.
Usually, experimental economics tends to test strong theories by building simple contexts. This is not our goal. Our attention is devoted to the comprehension of the nature and functioning of learning. Then, it is principally dedicated to the process, not only to the outcomes of a learning process, as happens in a great part of experimental literature on learning[7].
The paper is structured as follows. Section II illustrates the characteristics of the experiment. Section III presents the detailed results. Section IV offers some concluding remarks.

2. The experiment

Subjects were given the following instructions:

- A subject has to take a series of exams. Each of these exams should be evaluated as: very good, good, middle, bad, very bad. If the subject scores very good or good, he'll pass the exam. If he scores bad or very bad he will not pass the exam. If he score middle he will have to repeat the exam.
Each exam is evaluated with a new system of score; it receives:
- a colour (black, blue, white or yellow)
- a shape (heart, circle, square or rectangle)
- a dimension (big or small)
Then, for example, an exam could be evaluated as blue - heart - small
- The connection between shapes-colours-dimensions and the final result of the exam is not known

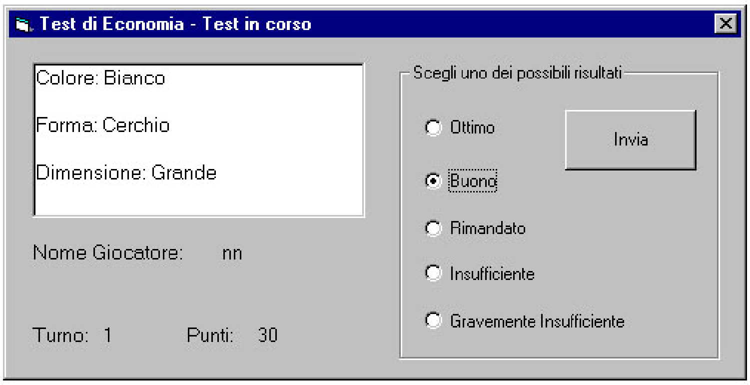
Then the game worked in this way:
- the subject was presented the first combination of shape-colour-dimension,
- he had to choose one of the possible scores,
- he was informed whether his answer is right or not and which is the right solution;
- he was presented another combination
- and so on for 231 rounds.

A specific software was realised to perform the experiment. Figure 1 shows the main screen presented to the players.

According to their answers, subjects were given points, later converted into credits for the exam (therefore students had a strong motivation to do their best). We will discuss these point later.

7 In "diagnostical task experiments" (see for example Kelley and Friedman, 1999; Kitzis et al, 1998; and the related theoretical work of Marcet and Sargent, 1989) which present a few similarities with the experiment here described, the authors' attention is focused on the subjects' ability to correctly estimate the parameters of a known model.

Figure 1. The screen presented to the players



Between the combinations of information and the right answer there is a logical relation, stable for all rounds, described in Table 1[8].

Table 1. Logical relation between combinations and results

Score	**colour**	**shape**	**Dimension**
very good	bright (white and yellow)	not angular shapes (circle and heart)	Big
good	bright (white and yellow)	not angular shapes (circle and heart)	Small
middle	dark (black and blue)	not angular shapes (circle and heart)	small or big
	bright (white and yellow)	angular shapes (square and rectangle)	
bad	dark (black and blue)	angular shapes (square and rectangle)	Small
very bad	dark (black and blue)	angular shapes (square and rectangle)	Big

The data gathered with this experiment enable to link choices and available information and to observe possible changes in the behavior of the players during the game. Such possibile changes are obviously the effect of learning processes.

At the beginning of the game, players don't know the relation between information and result. So they have to find and learn it.
As the game is based on a relatively small number of different sequences of information (there are 4*4*2=32 different combinations of *shapes-colours-dimensions* and the same combination appears many times during the game), subjects might try to remember them. In this case, the results of the experiment, would probably be less interesting (i.e. more artificious and conditioned by the experimental setting). Therefore subjects were not explicitly told that there were fixed and repeated sequences (while they were informed of the logical relation between information and results), and, as their mathematical skills are low, they could hardly be able to understand it before the game (this idea is supported by the answers given in the post-experiment survey). Besides, remembering 32 sequences is not so easy. Then subjects are expected to try to understand the game instead of learning single answers by heart.

8 The categories of color and shape are not explicitly used in the description of the game given to players.

3. Results

The experiment were realised in Alessandria in October 2000. Sixty-four subjects (students in Law, with no Economics back-ground) participated[9].
The length of the experiments was between thirty minutes and one hour. Subjects were arranged in different rooms, with no possibility to communicate during the experiment.

The main results are presented in the following sections.

Tendency to develop rules

As said, a single combination of shape-colour-dimension appears many times during the game (never in two rounds running).
By taking into account all the answers a subject gives to a given combination during the game, we can count the number of wrong answers he gives and the number of times wrong choices are confirmed.

Table 2. Answers given by Player 1 to some combinations

Round	**colour**	**shape**	**Dimension**	**correct result**	**subject's result**
9	yellow	Rectangle	Big	Middle	Middle
16	**yellow**	**Square**	**Small**	**Middle**	**Good**
33	**yellow**	**Square**	**Small**	**Middle**	**Good**
43	yellow	Rectangle	Big	Middle	Very good
50	**yellow**	**Square**	**Small**	**Middle**	**Good**
60	yellow	Rectangle	Big	Middle	Very good
67	**yellow**	**Square**	**Small**	**Middle**	**Good**

For example, the sequence yellow-square-small (bold type in table 2) appears four times in the part of game reported in table 2. One of the participants in the experiment (name him/her player 1) confirms the same wrong answer after the three errors in the table. Then, we can say that he confirms 3 errors after 3 wrong choices (100% of confirmation). It's possible to count a similar rate for all the combinations (and for the whole game) of the same player and to build a mean value.
The distribution of these values between all players is shown in table 3.

Table 3: Distribution of the mean ratio of wrong answers confirmed by players

0%-25%	13
25%-50%	38
50%-75%	13
75%-100%	0
	64 players

Thus the tendency to confirm wrong choices is quite generalised among subjects. In many cases they understand the right choice after confirming the

9 Similar results were obtained in a pilot experiment realized in March 2000 in Alessandria with a smaller group of subjects remunerated with money.

wrong one. Sometimes they never understand it, and confirm the wrong answer till the end of the game.
We might explain this event through the subjects' bad memory, thus wrong choices would be the result of a random process. This hypothesis has been verified and rejected with a statistical test (99% of significance) for most of the subjects (47 out of 64)[10].

Table 2 also shows the sequence yellow-rectangle-big. At its first appearance, player 1 gives a right answer (round 9) but at the following one he gives a wrong one. Then we can say that (at round 43) he doesn't confirm a right solution.
Many other players show a similar behavior. There are players who give a right answer to the same sequence for a number of rounds (at least two in the data shown in table 4)[11] and then change it till the end of the game.

Table 4 Distribution of the number of right answers given at least two times and then no longer confirmed

number of answers not confirmed	number of players
0	21
1	10
2	9
3	11
4	5
5	5
6	0
7	2
8	0
9	1
	64 players

The results we have shown regard the whole game, from the very beginning. It is also necessary to concentrate on the last part of the game, to see if players tend to develop regularities of behavior and if they understand the rationale of the game.
As a first step, it is necessary to give a definition of rule (specific for this experiment). Let us take into account the third part of the game (the last 77 rounds), where many sequences appear 3 or 4 times.
For each sequence we can count how many times a subject gives the same (right or wrong) answer:
- "rule 75" means that the subject gives the same answer 75% of the times;
- "rule 100%" means that the subject gives the same answer 100% of the times.

The idea is that if a player gives always or almost always the same answer when faced with the same sequence, he has probably developed a kind of routine[12].

---

[10] The probability of confirming by chance n wrong answers on m confirmations is equal to the probability of n successes in m independent repetitions in a binomial casual variable with probability equal to 1/5.
11 As the same right answer is given at least in two following appearance of the same sequence, it is unlikely that they are given just by chance.
12 As the game is very long and repetitive, it seems reasonable to think that a subject who has developed a rule can make a mistake and give, in some cases, a different

Table 5 reports the distribution of the percentage of "rule 75" developed by the players on all the sequences appearing at least 4 times during the whole game (later we will analyse some of the sequences that appear only few times). The table shows that there is a wide heterogeneity among players, but that most of them seem to have developed a very routinised behavior.

Table 5 Distribution of the percentage of rules developed by players

	rule 75	rule 100
0	0	0
0%-25%	1	4
25%-50%	9	10
50%-75%	12	22
75%-100%	31	18
100%	11	10

While there are 22 subjects who develop only right rules (table 6), there are also many players who develop a significant percentage (15% or 16%) of wrong rules. Then routinization does not mean that subjects have understood the right rules. In other words, not all the rules developed by the subjects are right.

Table 6 Percentage of rules (total and wrong) developed by players, mean values*

	rule 75	Rule 100
total percentage of rules developed	75%	70%
percentage of wrong rules developed	16%	15%

Values are computed only for the sequences that appear at least 4 times during the whole game

It is now useful to focus our attention on the behavior of player 1. We have seen that he confirms several times the wrong answer "good" for the sequence yellow-square-small, while he does not confirm the right answer to the sequence yellow-rectangle-big. Table 6 helps us to understand the reason for this apparently strange behavior, and to link it to the development of rules in the last period by the same subject. This table reports for the first 77 rounds (period I) and for the last 77 ones (period III) the answer given to each sequence. For example, in the first period, the subject answers in all cases (100%) "very good" to the sequence yellow-circle big. This sequence appears 3 times in the period (as we can see in the last column, where freq=3). The coloured cells indicates the right answer.

This table suggests the reason for the exemplified errors of this player. The answer "good" (confirmed though it is wrong) to the sequence yellow-square-small is coherent with the routines developed (from the very beginning) for the sequences yellow-circle/heart-small. The right answer (not confirmed) "middle" for the sequence yellow-rectangle-big is not coherent with the others and with the system of rules emerging in the final part of the game, in which "square" and "rectangle" are compared to "circle" and "heart". The system of

answer. Moreover, the rule could be in evolution and not perfectly defined at the beginning of what we define third period. That is the reason why we also use a definition like "rule 75".

rules developed (also the part which is not shown here) is then wrong but it seems to be coherent.
This is only one example, yet similar results can be found for other players (see also, for example, table 10 below).

Table 6 A more detailed analysis of the behavior of Player 1

period	Colour	Shape	dim.	Very bad	Bad	Middle	Good	Very Good	freq
I	yellow	circle	big					100%	3
			small				100%		5
		heart	big					100%	2
			small				80%	20%	5
		square	big						0
			small				**100%**		**4**
		rectangle	**big**			**50%**		**50%**	**4**
			small						0
III	yellow	circle	big					100%	3
			small				100%		4
		heart	big					100%	1
			small				100%		3
		square	big					100%	1
			small				100%		4
		rectangle	big					100%	3
			small				100%		1

Answers to the new sequences

An interesting question is related to the features of the rules developed and to the way subjects build them.
Do subjects build broader categories starting form available information? A different way of stating the problem is: do subjects extend the domain of validity of rules beyond the field in which they were developed and tested? The extension of the validity of a rule is obviously dependent on the process of abstraction.
As said, in the last rounds of the game eight new sequences, never presented before, are proposed to the players. Surely, they cannot remember the right solutions for them. A right answer to (most or all of) them, can then be taken as evidence that players have understood the rationale of the game, and also that they have created categories[13]. Table 7 shows the distribution of right answers to the new sequences.

25 players gave a right answer to all the new sequences and many others answered correctly to many new sequences. The mean time used to give an answer in the cases under exam is equal to about 5.8 seconds (a very short time as compared to that used to answer to the first new sequences at the beginning of the game, which was equal to 12.8 seconds).
These players are not just remembering answers by heart, but they are able to extend the domain of validity of rules correctly. Yet, some results presented in the previous section seem to suggest that sometimes rules are also applied

13 This hypothesis could be tested, in other ways, with the data of this experiment. Table 7 is also an evidence that at least a few players are not just memorizing the answers.

in a less appropriated way, and that wrong categories are build up. We can see this fact with another example.

Table 7 distribution of right answers to the new sequences in the last part of the game

number of right answer	frequency
0	0
1	4
2	7
3	7
4	5
5	5
6	7
7	4
8	25

The new sequences presented in the last part of the game are: white-heart-small, white-square-small, blue-circle-big, blue-heart-small, yellow-square-big, yellow-rectangle-small, black-circle-big, black-heart-small
For each of them, let us take into account one of the most similar sequences, the one with the same dimension and shape but with a different colour: yellow instead of "white" (and viceversa), "blue" instead of "black" (and viceversa). The similar sequences are then respectively: yellow-heart-small, yellow - square-small, black-circle-big, black -heart-small, white-square-big, white - rectangle-small, blue-circle-big, blue -heart-small[14].

Now, let us restrict our attention to these similar sequences and take into account those in which subjects have developed a wrong "rule 75" (i.e. they have answered in at least 75% of case in the same wrong way). Table 8 shows the distribution of the number of wrong answers to the new sequences that are identical to those given to the similar ones (for which subjects have developed a "rule 75").
In other words, for example, 10 players developed wrong "rules 75" for the sequence white-square-big[15]. Imagine that they answer "very good" - and not "middle" - in at least 75% of the times they meet this sequence. 3 of them declare "very good" even when faced with the sequence yellow-square-big. It is possible to make a similar test for all the sequences and count the number of identical answers.
Between the groups of the so called "new sequences" and that of the so called "similar sequences" there are common elements (blue-circle-big is the "similar sequence" of black-circle-big and viceversa, and the same for blue-heart small and black-heart-small). They are then considered only once (so the total number of new sequences is 6).

---

14 It seems reasonable to think that a player can build a similarity between these kinds of sequences as the similarities are suggested by the game itself. There are yet other possible and reasonable similarities (for example sequences with the same color and dimension, and with similar shape, or sequences with the same color and shape and different dimension …). So the test presented here is necessarily very partial and only aims at giving an idea of the process of extension of rules.
15 It is not possible to give here a detailed account of the complete distribution of this values.

Table 8. Number of wrong answers identical to those of the similar sequence

number of wrong answers identical to those of the similar sequence	number of players
0	38
1	15
2	7
3	2
4	1
5	1
6	0

There is one player who apparently "transfers" 5 wrong rules to the new sequences; another one (name him player 2) seems to transfer 4 of them, and so on. It is important to stress that this test is only a way to show - from a different point of view and for more players - a fact that has already been perceived elsewhere.

Table 9 A more detailed analysis of the behavior of Player 2

period				Very bad	bad	middle	Good	very good	freq
III	White	circle	Big					100%	4
			small				100%		3
		heart	Big					100%	4
			small				100%		**1**
		square	Big					100%	3
			small				100%		**1**
		rectangle	Big			100%			1
			small			100%			3
	Blue	circle	Big	100%					**1**
			small		100%				2
		heart	Big	33%		67%			3
			small		100%				**1**
		square	Big	75%		25%			4
			small		100%				1
		rectangle	Big	100%					1
			small		100%				4
	yellow	circle	Big					100%	3
			small				100%		4
		heart	Big					100%	1
			small				100%		3
		square	Big					100%	**1**
			small				100%		4
		rectangle	Big			100%			3
			small			100%			**1**
	black	circle	Big	100%					**1**
			small		100%				2
		heart	Big	100%					2
			small		100%				**1**
		square	Big	100%					3
			small		50%	50%			4
		rectangle	Big	100%					3
			small		100%				4

Table 8 shows that some players give the same answer to many different but similar sequences. There are relatively few players "transferring" many wrong rules, but we are analysing only one of the possible similar rules. Certainly the fact that some players give the same answer is not a definite proof of the transfer of rules (or of the building of higher-level categories). These could be just random results but probably, for some players it is not so. A random similarity among 5 or 4 answers has a very low probability. A detailed analysis of players' behavior support the idea that these are not random results.
Table 10 shows the last part of player 2's game. As we can see, he has developed a "rule 75" that says: white-square-small=very good. He replies "very good" also to the sequence yellow-square-small. He might do so by chance, but this answer is coherent with his overall system of rules. In fact he compares "square" to "circle" and "heart" for all colours.

Similar analyses could be done for all sequences (not only for the new ones) and using other "similar rules" (in fact subjects could build other kinds of categories). Other example of transferring of rules would probably emerge.

The effect of the systems of compensation

Points were assigned to subjects according to two different systems (table 10) The first one tends to give a high reward to right answers, while very wrong answers are strongly penalised. Not-too-wrong answers receive an almost null reward. The second system of remuneration has a low variance of points between right and wrong answers.

Table 10. Systems of Compensation

distance from the right solution*	points gained - case 1	points gained – case 2
0 - right answer	+10	+6
1	+2	+3
2	0	+1
3	-2	0
4	-10	-1

**for example if the right answer is very good and the answer is very bad, the distance is 4; if the right answer is very good and the answer is good, the distance is 1*

The two systems seem to have a strong effects on players' learning processes. Results are partly unexpected: the players in group 1 tend to develop a lower number of rules and a higher ratio of wrong rules (table 11).

Table 11. Mean values of many indicators by system of compensation

	group 1	group 2
right answer by subject	137	158
Percentage of "rules 75"	0,74	0,81
Percentage of "rules 100"	0,65	0,76
Percentage of wrong rules on rules 100	0,18	0,10
Percentage of wrong rules on rules 75	0,19	0,12

Because of the limits of a single article, it is not possible to discuss here the results in detail. However, it seems necessary to stress that these results highlight again that individual learning is not a process converging necessarily towards a predefined path (leading necessarily to the "best rule"). Environment and context (in this case the system of compensation) seem in fact to have a strong effect, and they can influence the direction of the process.

4. Concluding remarks

Though the emergence of routines and regularities in human decision making and the role played by learning are widely acknowledged in literature, some relevant problems are still open in economics. Among these, we decided to focus our attention on the crucial question "how do rules consolidate after they emerge?". We are aware that finding a satisfying answer to this question is a very hard task, which should at the same time include both an individual and a social level of analysis (concerning individual and vicarious learning). There is no doubt also about the fact that, besides decision making, this open question is particular relevant to a very large spectrum of economic tradition, including Austrian economics, evolutionary economics, economics of innovation and new institutional economics.

After previous investigations on the theoretical and methodological grounds (see in particular Rizzello, 1999, and Novarese-Rizzello, 1999), we are now convinced that only the experimental domain will help us point towards a solution, by observing and describing human learning. As accurate observations can be made only step by step, the above illustrated experiment referred only to a first step. Authors' intention is to build new experiments soon, also on vicarious learning and co-ordination, and then to cluster all these results.

What has emerged up to now encourages us to continue this research on this specific branch of cognitive and experimental economics. This paper seems to suggest in fact to the above question "how do rules consolidate after they emerged?" at least a few answers.

If, on the one hand, results seem to confirm what is already largely known in literature (i.e.:individuals spontaneously tend to generate new rules in decision making, when they cannot use preexisting routines), on the other hand, more interesting, it has also emerged that individuals manifest a tendency to consolidate such regularities also when they are aware that these rules are wrong. At the same time, they exhibit an opposite predisposition not to confirm some rights rules. This appears to us as an important outcome and though we can correctly affirm that this last aspect cannot be still generalized, from a detailed analysis (a kind of case study) of the results of at least a few of the players emerge that "the strategy's rules have to be memorized and represented with some degree of abstraction, to allow one drastically to reduce their number. Raising the level of abstraction with which a strategy's rule is represented, means to extend the domain of validity of the rule beyond the field in which the rule has been experimented, and it may therefore induce one to include inadvertently domains in which the rule is inefficient" (Egidi 2000).

As seen, besides, rules developed by the players in exam seem to be coherent. They are not perfectly correct, but they are satisficing, also in the sense that they are easy to remember and apply.

Finally, one could contend that the fact that the results are not readable in a general and comprehensive way is an insurmountable limit towards the development of a robust model, and it would correctly suggest to abandon this research. This is not the case. When the goal is to "observe and describe" and not to confute or validate a model, it is right to take into account also behaviors which in this phase could seem performances of niche and in a future not too far could instead represent good foundations for a new theory[16].

References

- Börgers T. (1996), On the Relevance of Evolution and Learning to Economic Theory, *Economic Journal* 106, 1274 – 1385.
- Egidi M. (2000), *Biases in Organizational Behavior*, paper presented at the "Workshop on Cognitive Economics", Alessandria Torino, November 2000
- Egidi M., Narduzzo A., (1997), The emergence of path-dependent behaviours in cooperative contexts, *International Journal of Industrial Organization*, 5, 677-709.
- Egidi M., Rizzello S. (eds.) (2002), *Cognitive Economics*, E. Elgar forthcoming
- Friedman D. 1998, "Evolutionary economics goes mainstream: A review of the theory of learning in games", *Journal of Evolutionary Economics*, 8: 423-432.
- Fundenberg D., Levine D.L. 1988, *The Theory of Learning in Games*, MIT Press.
- Hayek, F. A. (1952) *The Sensory Order. An Inquiry into the Foundations of Theoretical Psychology.* London: Routledge & Kegan Paul
- Kelly H. and Friedman D. (1999), *Learning to forecast Price*, University of California Santa Cruz, Economics Department working papers
- Kitzis S.N, Kelley H. Berg E., Massaro D.W., Friedman D. (1998), Broadening the Tests of Learning Models, *Journal of Mathematical Psychology*, 42, 327-355
- Marcet A. and Sargent T (1989), Convergence of least squares learning mechanisms in self referential linear stochastic models, *Journal of Economic Theory*, 48, 337-68
- Novarese M and Rizzello S. (1999), Origin and Recent Development of Experimental Economics, *Storia del Pensiero Economico*, n. 37
- Rizzello S. 1997, The Microfoundations of Path-dependency, in L. Magnusson - J. Ottosson (eds.) *Evolutionary Economics and Path-dependence* , E. Elgar, Cheltenham, pp. 98-118.
- Rizzello S. 1999, *The Economics of the Mind*, Edward Elgar, Aldershot.
- Rizzello S. 2000a, Economic Change, Subjective Perception, and Institutional Evolution", *Metroeconomica*, 51 (2), pp. 127 – 150.
- Rizzello S. 2000b, Hayek e la conoscenza come processo path-dependent" in Rizzello – Clerico (eds.), *Organizzazione, informazione e conoscenza. Saggi su Hayek vol. I*, Torino, UTET
- Rizzello S., Turvani M., 2002, Subjective Diversity and Social Learning: A cognitive perspective for understanding institutional behavior, *Constitutional Political Economy,* forthcoming
- Simon H. 1992, Colloquium with H. A. Simon, in Egidi M., Marris R. (eds.), *Economics, Bounded Rationality and the Cognitive Revolution*. Aldershot, U.K.: Elgar.
- Witt, U. (2000), *Social Cognitive Learning and Group Selection – A Game-theoretic Version of Hayek's Societal Evolution*, Paper presented at the INEM – ASSA Session "Austrian Economics and Game Theory, Boston, January 8, 2000.

---

[16] The following Herbert Simon's (1992, p. 20) methodological remarks on the analysis of the firm seems to hold also in this case: "If you are trying to understand what firms are and how they operate, you will learn a lot from this kind of very detailed study of the processes of decision … Of course, we should not stop with five firms. Biologists have described millions of species of plants and animals in the world, and they think they've hardly started the job. Now, I'm not suggesting that we should go out and describe decision making in a million firm; but we might at least get on with the task and see if we can describe the first thousand. That doesn't immediately solve the aggregation problem, but surely, and in spite of the question of sampling, it is better to form an aggregate from detailed empirical knowledge of a thousand firms, or five, than from direct knowledge of none. But the latter is what we have been doing in economics for too many years".