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Towards a new experimental socio-economics Complex behaviour in bargaining

Adolfo López-Paredes*, Cesáreo Hernández-Iglesias, Javier Pajares Gutiérrez

Departmento Organización y Gestión de Empresas, Grupo InSiSoc, ETS Ingenieros Industriales de Valladolid, University of Valladolid, 47011 Valladolid, Spain

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Abstract

Game theory has provided a rigorous conceptual support to analyse strategic decisions and bargaining behaviour. But it shares with competitive equilibrium three basic assumptions. The players are fully rational; they comprehend the faced situation; and they know all the relevant institutional parameters. Thus disregarding the social dimension of bargaining. In this paper we advocate for a consilient focus of economics, psychology and sociology. We argue that it is necessary and possible to experiment within a Multi-Agent Systems (MAS) with bounded rational agents endorsed with explicit social behaviour. The observed behaviour is obtained from a laboratory experiment with human agents and can be captured in a cognitive multi-agent modelling with artificial agents. The approach can accommodate both declarative and procedural rationality; i.e., rationality as a process and as a product of learning.

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1. Introduction

The paper reports work in progress on the application of Multi-Agent Systems (MAS) to the design and engineering of economic institutions, which began with the first author Ph.D., López-Paredes (2000). Economics is the science which deals with *social organisations* in relation to the well-getting wealth using and its distribution. Yet when economics' methods

* Corresponding author. Tel.: +34-983-423-336.
E-mail address: adlo@dali.eis.uva.es (A. López-Paredes).

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are exported to other sister social sciences, from law to politics or to the bedroom relationship, it was reconverted in the study of the allocation of scarce resources among competing uses. In this way rational behaviour was narrowed to optimisation, under suitable analytical constraints, thus clearing the field of any other dimension of human behaviour. No attention is given to motivations, emotions or social learning. The basic inquire of any science, *the true nature of things*, is substituted for predictive performance. Neo-classical economics assumes that people are highly rational and can reason their way out through the complexity of the economy. No wonder economics does not catch up with the economy under this "*as if*" approach, Hernández and López-Paredes (2000).

The economy is *complex* because we observe just real aggregated data, that comes from simple agents, myriad interactions. So that from a macro observation post, the mathematical approach may be very difficult or computationally intractable. But if we adopt a micro definition of even heterogeneous but human agents, the resulting MAS model may be generated in a reasonable and realistic way. In Hernández and López-Paredes (1999, op. cit.) we examined this issue. We showed that a posted offer auction with many buyers (300) and some sellers (15) can be generated from heterogeneous agents with cognitive capacities. They have limited memory and limited deliberation-action time; partial knowledge, emotions and reputation. We looked for regularities that emerged from the interaction of the agents, and to what extent market efficiency is improved by engineering organisation technology: a board (Internet) where sellers, buyers and producers (airline companies) put their bids, asks and reputation. *But there were not strategic social interactions between the agents*.

In this paper we deal with the other source of complexity and bounded rationality in economics. Bounded rationality is understood as rationality exhibited by actual economic behaviour. This means that we have to consider the behavioural limitations and emotional positions of heterogeneous agents that have to learn from each others decisions and actions and that think strategically. We present a procedure for modelling complex behaviour in bargaining. First an experiment is conducted in the Laboratory of the ETS. Industrial Engineering, with both fifth year undergraduates and young teachers. They played a repeated game with asymmetric information, for 30 rounds. The revealed patterns and corresponding gains are then classified and used to endorse artificial behavioural agents, using a *cognitive* model language, SDML. The results of the artificial MAS simulations confirm that we are able to reproduce reasonably well the observed human behaviour, and they open a promising alternative to simulate and engineer the strategic competition.

2. Game theory in socio-economics

Some comments are due to fix up the terms of this research. The application of game theory has been an important development in microeconomics. It is conventional wisdom to use it to understand how markets evolve and operate, and how managers should think about the strategic decisions they continually face. For instance, the prisoner's dilemma when repeated over time clears some of the logical inconsistencies of Cournot, Bertrand or Stackelberg oligopolies. It allows us to show how firms can make strategic moves that give them an advantage over their competitors or the edge in a bargaining situation. How firms can design pay off matrices that allow to develop credible threats, promises, or deter entry by potential competitors. Nevertheless game theory is concerned with the following question: *If I believe that my competitors are rational and act to maximise their own profits, how should I take their behaviour into account when making my own profit-maximising decisions*? This question is in itself difficult to answer, even under conditions of complete symmetry and perfect information.

When trying to advance an equilibrium solution one has to assume some kind of intuitive plausible information and learning strategy, plus the most likely emotional response of the contenders. The outcome of a repeated play of a game is path dependant and should be found through a process modelled using some form of learning theory. But since not such a learning theory is available, one has to enforce some mechanical replicator mechanism Peyton Young (1998), or to model observed behaviour, from controlled experiments (reinforcement learning Erev and Roth, 1998; recommended play Brandts and Bentley MacLeod, 1995, etc.). Experimental economics has shown that simple but robust learning and co-ordination models can predict observed experimental outcomes. And the outcomes of these experiments are frequently at odds with rational game theory predictions.

An empirical-based general theory of learning under bounded rationality remains a formidable task for the future, but a claim is gaining acceptance. "*Approximating the strategies used by players . . . will be the area of future research in which low-rationality adaptive game theory will need to interact most closely with cognitive theory*", Erev and Roth (1998, op. cit.) and Selten (1998) for related work. We would like to consider the work that we report in this short paper as a contribution in this direction. We replace learning procedures as used in adaptive game theory, based on mechanical and optimising players, for cognitive learning agents with social behaviour whose decisions are agenda based.

Although the approach can be labelled as ACE or MAS i.e., computational organisation, there is a subtle difference with some works in the field. The agents have cognitive capacity and emotions. Thus object oriented programming languages will not be sufficient, since our agents are not objects. They request actions to be performed. In the object-oriented case, the decision lies with the object that invokes a method. In the agent case, the decision lies with the agent that receives the request. *Objects do it for free; agents do it for money*, could be a sharp slogan to indicate the difference.

The assumption of perfect rationality is an imperfect description of real human behaviour. Experimental studies of decision-making (see Camerer's, 1995 and Conslik's, 1996 surveys) find inconsistencies with the *SEU* version of rational choice. Models that embody SEU theory are incapable of fully explaining economic activities like incomplete contracts, advertising, transfer pricing, etc. This situation led some researches, from Simon (1982) to demand models in which players are bounded rational. Should we consider from now on NASH rational equilibrium as futile armchair economics? Certainly not, as Myerson (1999) cleverly argues.

First as indicated above, an empirically based general theory of bounded rationality (if such generality makes sense) remains a task for the future. A second reason is that the functional goal of social science is not just to predict human behaviour in the abstract, but in relation to a particular social institution and in a contingent context. And to separate, the inefficiency of the institutional setting from the inefficiency of agents behaviour will be even more difficult. Thus applied social theorist and market engineers, should find useful to analyse social institutions under the assumption that every member of that society will act, within their domain of control, to maximise welfare as they evaluate it, given the likely behaviour of others.

> "*Notice that this argument does not prove that Nash equilibrium should be the only methodological basis for analysis of social institutions. But it does explain why studying Nash equilibria should be a fruitful part of the critical analysis of almost any kind of social institution*." (Myerson, op. cit.)

Thus in spite of the efforts of research like this work, Nash rational equilibrium will be with us for a long time.

3. Artificial agents to deal with bounded rationality and complexity

The economy is indeed a *miserable experiment*. That is why we have to simulate and grow up stable aggregated behaviour. We have short data records, that sometimes are of low reliability. It is difficult to test hypotheses concerning the process from individual behaviour to aggregated regularities, in the usual way. In some areas, it may be that simulating economic processes with well founded cognitive models by trial and error procedure, is really the best we can do.

The representative agent is not a realistic assumption to start with. We have to deal with bounded rational agents, with finite processing capacity and without explicit utility functions. They adapt and settle for satisfaction under rules of thumb. They have emotions. And they are rather heterogeneous. Even if the resulting model with a representative full rational agent has high predictive capacity, it is still important to replicate the observed patterns from models with heterogeneous and bounded rational agents.

The method we use, MAS, can help to overcome the lack of capacity of economics to explain the economy as a process. General equilibrium theory and its more rigorous game theory approach to strategic firm behaviour, have been concerned mainly with static equilibria, ignoring process dynamics. MAS and computational organisation, we claim, is a natural and very soon popular methodology for studying dynamics in social systems.

The following comments on complexity and rationality will be conditioned by our *generative approach*. The aim is to provide initial micro specifications for the artificial agents, environment, and production rules that are sufficient to generate the macrostructures of interest. We shall not enter into other philosophical discussions, on rationality or complexity.

Complexity is a term used in many ways according to different schools; see Barkley (1999) for a recent survey. Most users come from the field of nonlinear dynamic models as applied to economics. Complexity is then, the fourth C in this line of research: cybernetics, catastrophe, chaos and complexity. But the field of complexity is controversial and unsettled. And there is no accepted definition of the term. There have been two prevailing views. A dynamical system is complex if it endogenously does not tend asymptotically to a fixed point, a limit cycle, or an explosion. Alternatively a situation exhibits complexity when there is an extreme difficulty of calculating solutions to optimisation problems. We use this view of complexity, that in turn comes from two sources.

From the aggregate outcome of simple agents' myriad interactions taking notice of each other agents' actions: institutional complexity. In these interactions, agents relate to each other and with the environment through agent–environment production rules, and agent–agent rules. We release an initial population of agents into the simulated environment and watch for macroscopic spontaneous order. This was the problem we addressed in Hernández and López-Paredes (1999, 2000, op. cit.).

From agents trying to model other agents modelling of them, modelling those agents, *ad infinitum*. This is the main source of complexity in game theory. Expectations about other agents strategic behaviour. This is the view we take in this paper.

4. Some selected facts on bounded rationality and social behaviour

To endorse our artificial agents with instruments for unbounded rational, but consistent behaviour, one has to recall some facts.

4.1. Socio-economics: the basic dimensions

Following Selten (1998), the mental bounded rationality process comes from the interaction of motivation (the driving force), adaptation (routine adjustment without reasoning), and cognition (reasoning and deliberation). Thus our cognitive approach has to accommodate a process for reasoning and a process for adaptation. And this implies that unbounded rationality goes far beyond "the imitation paradigm" as in Vega-Redondo (1999).

4.2. Bounded rational agents are computationally strong

Full rational decision-making methods (the usual methods drawn from logic, mathematics, and probability theory) are computationally weak: incapable of solving the natural adaptive problems.

> "*Despite widespread claims to the contrary, the human mind is not worse than rational (e.g., because of processing constraints) but may often be better than rational. On evolutionary recurrent computational tasks, such as object recognition, grammar acquisition, or speech comprehension, the human mind greatly outperforms the best artificial problem-solving systems that decades of research have produced . . . . How can this be? General-purpose systems are constrained to apply the same problem-solving methods to every problem and can make no special assumptions about the problem to be solved. Specialised problem-solvers are not handicapped by these limitations . . . . Natural selection could equip humans' cognitive specialisations. For the problem domains they are designed to operate on, specialised problem-solving methods perform in a manner that is better than rational*." Cosmides and Tooby (1994)

The departure from rationality does not at all imply that we retreat, *malgré nous*, to second best outcomes. Thus individual adaptive and satisfying learning does not necessary lead to inferior emergent results.

4.3. Spontaneous order and the social component

The wide variety of situations where the social interaction outcome was surprisingly different from individuals motivations and expectations, first shown in economics by Schelling

(1978) and then in the wide literature of experimental economics, underlies the fact that institutional rules themselves matter and change as a result of myriad of individual actions. This causes the spontaneous order as outcomes from bounded rational agents which can be more efficient than expected from rational agents. Thus learning and knowledge acquisition has a social component. Our instruments for bounded rational agents, explicitly should make methodological individualism and social knowledge compatible views.

4.4. Simons' Ltd.

Bounded rational modelling should then include: motivations (and perhaps emotions), adaptation to accommodate social learning (can we name them knowledge externalities?) and cognition. But is there a place where we could find such desirable stock of tools to model our bounded rational agents? The answer is yes, surely. The concepts warehouse is Simons' Ltd., the premises to be located in his collected work, Simon (op. cit.). The cognitive facilities to assemble his ideas of procedural and substantive rationality are available in recent developments by Anderson (1993). The convergence of these two contributions allows for a consilient unification of the social science with a reasonable balance of relevance, realism and rigour.

In a nutshell Simon distinguishes between *substantive rationality*—we prefer to call it declarative knowledge, taking from Anderson (op. cit.)—and *procedural rationality*. Substantive rationality refers to behaviour that is appropriate to the achievement of given goals within the limits imposed by given conditions and constraints. On the other hand, behaviour is procedural rational when it is the outcome of appropriate deliberation. It is the outcome of some strategy of reasoning within the repository of valid rules, and it is selected among those credited as the best so far.

The following classroom example, Pyndick and Rubinfeld (1995) will help to clarify the two concepts. Three contestants A, B and C, each have a balloon and a pistol. From fixed positions, they fire at each others balloon. When a balloon is hit, its owner is out of the game. When only a balloon remains, his owner is the winner and receives a $1000 prize. At the outset, the players decide by lot the order in which they will fire, and each player can choose any remaining balloon as his target. Everyone knows that A is the best shot and always hits the target; that B hits the target with probability .9 and C with probability .8. Which contestant has the highest probability of winning the $1000? When asked to advance an answer within 5 min, some will come up with a reasonable and correct one: Contestant C.

The intuitive argument—cognitive efficient—is that, as in real life, under perfect rationality, the observed fact is that mediocrities are the winners: this is procedural rationality. Of course, in this case, declarative learning will lead to the same answer that substantive one. Ancillary assumptions about the emotional attitudes of the contestants: aggressive selfishness are needed. There is a well specified protocol for the game, a sequentially random order.

A longer version of this paper can be obtained from the JSE editors or from the authors in the url address www.insisoc.net. We detail there how these ideas have been implemented in a two players repeated game with asymmetric information. The players are bounded rational and they are endorsed with explicit social behaviour. Their bargaining behaviour is empirically obtained from a laboratory experiment with human players. Then the artificial agents are modelled using SDML as developed by Moss et al. (1998). The reader can see there how we demonstrate the usefulness of the modelling procedure advocated in this short version of our work.

5. Conclusions

Our conclusions, based upon the arguments of this paper, and the experimental evidence reported in the extended version, are totally in agreement with Erev's statement. That to approximate the strategies used by players, will be the area of future research in which low-rationality adaptive game theory will need to interact most closely with cognitive theory and social behaviour. Our paper shows a possible way to achieve this goal, in a consilient focus of economics, psychology and sociology.

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