Data gathering to build and validate small-scale social models for simulation. Two ways: strict control and stake-holders involvement

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Modelling and the search for realism

Social simulation using multi-agent paradigm (sometimes called “agent-based simulation” or “simulation with agents”) has developed quickly in the last fifteen years. The tool offers numerous new possibilities to represent rationality and structures of interaction, to take into account for heterogeneity in rationality and perception (Kirman, 1997; Bousquet et al., 1993) or social relations (Moss and Edmonds, 2005; Rouchier, 2004), and test a variety of learning models for agents with procedural rationality (Simon, 1969).
The discipline of social simulation with agents started from two distinct communities at least. One was the economics community, with regular seminars held at Santa Fe institute called “Economics as an evolving complex system” (Anderson et al., 1988). Another branch was started in Europe with the book “Artificial societies” (Gilbert and Conte, 1994).
The first developments were quite close to artificial life (Langton, 1991). Researchers were trying to build credible global behaviour from local actions, and were qualitatively inspired by social facts. For example, some would deal with emergence of hierarchies based on hypothesis by archaeologists (Doran et al., 1995), and would study which parameters have an influence on the existence and stability of the emerging phenomena. They were producing global behaviours that resemble the type of general structures that can be observed in society, and it was an important first step to be able to “grow artificial society” (Epstein and Axtell, 1992). Hence, most simulations of complex were used as "black boxes" (Simon, 1969): the influence of the changes of parameters would be studied in relation with some global observation parameters, without following necessarily step-by-step processes to understand the internal mechanisms. There was no strong request for validation at that time, and all representations put in a model as well as evaluation processes relied on the expertise of the researcher. The issue of understanding for real the influence of the numerous parameters of these complex systems however became more and more central (Gilbert and Abbott, 2005; Edmonds et al., 2003) and implied the apparition of new methods for building and validating models.

Nowadays, it has become a norm to assess results with actually comparable data and to build the hypothesis themselves by offering some empirical facts to justify for the model construction. Diverse sets of data can be used - from surveys to observations in real settings, and a large number of applications have searched for the right use of empirical data in the building of models (Moss and Edmonds, 2005). In this paper, we focus on two trends that explore the representation of small-scale interaction settings with multi-agent simulations, caring about both protocols to gather data and assess the results of their assumptions on rationality, and involve human subjects in the process.

Some researchers want to perform quantitative validation for their simulations, and try to use their models to establish positive scientific results. The method of statistical comparison with outside world data is very often used (Moss and Edmonds, 2005). In the context of experimental economics,

it is possible to acquire a lot of very precise behavioural data on micro behaviour, in context of well-defined choice. A systematic comparison of artificial and real agents' behaviour is, for some, a good way to assess the validity of the cognitive models they build for agents. A Popperian approach can be identified in these protocols, where scientists position themselves as outside observers of a social system on which they can draw objective refutable theories.
Others, at the opposite end of the validation approach, question the need to switch from qualitative validation to quantitative validation and look for scientific methods where the validation would not be abstracted from the social use they assign to social sciences. The second approach that is presented here is called companion modelling (some recent papers also refer to stake-holder approach) and is rather embedded in an instrumentalist epistemology (Zammito, 2004), referring to the Duhem-Quine thesis. Followers are conscious of the fact that their hypothesis about rationality and structure of systems are social construct (Berger and Luckman, 1969) and instead of confining the use of the model to an analytic situation, they use it as a device for communication, among those very actors who have been mimicked in the system.

Both approaches have different goals and invented settings that are suited to their general understanding of knowledge of society. We present here those two settings, which define a rather high methodological standard for validation of simulation models. They have two aspects in common: 1/ they can be applied mainly to small-scale studies; 2/ they can be related to "empirical research" since they include at the same time the gathering of data of "real behaviours", the building of the model with observed data, and the test of their assumption through a come-back on the gathered data. The differences and limits of both approaches will be presented, and some opening remarks will be made.

Simulations and economic experiments

Abstractly studying decentralisation

There is a contemporary general issue in economics: to construct a theory of behaviour for economic actions (Kirman, 1997). Researchers belonging to the trend called ACE (Agent-Based Computational Economics) have used multi-agent simulations (or "agent-based simulations") either to test models that they had inferred from the observation of economic activities or, using genetic algorithm, to discover some optimal algorithms. The idea is to describe the rationality of agents in a really decentralised setting, with imperfect information, and look at the evolution of the global data so that to judge the relevance of the model (Tesfatsion, 2006). Up until recently, those focusing on the behaviour of individuals and history of transactions rather than optimality were quite rare, and their hypotheses were based on long-term experience in micro-economics (Kirman and Vriend, 2001).

Other economists focus on a more precise description of rationality: for now more than 40 years, experimentalists have been testing the possibility to implement archetypical economic settings in laboratories (Smith, 2002). They make human subjects play in a game, where choices faced are similar to those described by economic theory. Those subjects' preferences are voluntarily controlled by monetary incentives (and their rational action is computable by the one who organises the experiment); the amount of information they get is limited and carefully defined. The issue is to judge if subjects do behave in a perfectly rational way, or if they show some behavioural features that are not predicted by theory.

The experiment has one advantage which is to be perfectly *controlled* and *reproducible*. All information circulation and actions are strictly limited and recorded with the help of computers. The situation is hence different from real life, where many situations are different from ideally expected equilibrium, but it is impossible to decide if the lack of information or the lack of rationality is responsible. The experimenter does not have access to the calculus led by the subject, but can make subtle changes in distributed information, to understand better the way it is used.

The results have been gathered for some time and a huge amount of relevant descriptions on how humans treat information in economic contexts has been gathered (Camerer, 2003), concerning for example: cognitive limitations, need for reciprocity and altruist behaviours, consumer attitude, public good games, non-cooperative games. Most of the time, results are compared to theoretical expectations, and when real behaviour differs from optimal model, interpretation has to be given.

To explain the deviations from theoretical behaviours, positive models are proposed, as dynamical learning in context based on equations (Fudenberg and Levine, 1999). These models are now tested thanks to simulations. Designing these simulations is pretty easy because the settings for experiments were already ready to be transposed to produce a distributed model. All proposed equations and hypothesis have to be turned into algorithms, and when the simulation has run, quantitative data can serve as benchmarks, and using the same indicators, help selecting models (Brenner and Vriend, 2005). The main part of produced research is dealing with learning in markets (Duffy, 2001; Rouchier and Robin, 2005; Brewer et al., 2002), but some were concerned with other topics, like cooperation (Janssen and Ahn, 2003). For an excellent review on the topic, one can refer to John Duffy's chapter in the forthcoming handbook for computational economics (Duffy, 2006).

Examples and critics

An application of the abstract model referred to as EWA (**E**xperience Weighted Attraction learning model) by Ho and Camerer, can be found in Chong et al (2005). The paper is a study of the calibration of the model with some data collected through experiments. The model is considered as very good and pure, since it only depends on one variable to adjust. Authors show that it is rather good for estimating learning by individuals, and that they can characterise different type of players (sophisticated – who realize that others are learning - or not) by looking at their results. However, one can note that in the paper, they only consider rather simple games with two agents. Plus, the fit of simulated and experiments data is not so good. Some people tried to use their model in simulations using a higher number of agents, and found it rather impossible to choose the adequate parameters to fit their own data. This corresponds pretty well to the analysis by Thomas Brenner, who tries to make a complete review of the relevant use of learning models depending on the type of model that is built and shows that for the moment, each have very limited application (Brenner, 2006).

Going further, Janssen and Ahn (Janssen and Ahn, 2003) showed that, in the context of a public good provision game, it is not possible to adapt existing individual learning models to both individual and global data. Using a large set of experimental results from diverse researchers with varying pay-offs in the same game, they ran simulations using two types of models: best-response model with signalling and EWA. Both models could match human results much better (statistically) than a perfect rationality calculus. EWA was proven to be good to match individual trajectories, but was very poor to find global results; best-response was good for the global results but could not describe individual trajectories well.

A recent paper (Lelec, 2005) presents reimplementation of a set of simulations based on experiments on ultimatum game, with a reinforcement learning model proposed by Roth and Erev (1995). The paper shows that reinforcement learning is extremely sensitive to parameters settings. A very annoying result is that different parameters settings can lead to simulation results that are difficult to discriminate. Hence which model is right is difficult to choose just comparing with human subject experiments. The indicators that are usual for experimenters do not always allow discriminating, even for rather simple systems. It can be found also in the case of the reproduction of a market with artificial agents, where the speed of convergence is similar for a lot of different simulations and does not allow to decide which model is best (Rouchier and Robin, 2005).

John Duffy (2001), in a complete research, reveals all these issues and looks for experiments to go further in understanding human rationality in context. His example was an attempt to lead human subjects, and then artificial agents, to speculate. In his first experiments, he recorded behaviours, asked his subjects about their logic and produced hypothesis on learning. From these assumptions he built an algorithm and led simulations. He insists on saying that, to compare, he used the same number of agents and the same time-length as in real experiments (which is rarely done). Since he could not match data for individual agents' trajectories and global results, he mixed agents and subjects. Then all results, including human behaviours, changed a lot. In no case could he get his artificial agents to act like humans globally, only individual behaviours would qualitatively match humans' ones.

The need for new protocols

The comparison of experiments' results and simulation data seems quite easy to realise at first sight, due to the perfect reproducibility of experiments and the possibility to produce simulation settings where the representation of information circulation is very close to the one of experiments.

The idea of building a general algorithm that mimics human learning is apparently not a reasonable short term aim in the contemporary context and might never be. When it comes to understanding better the structures that emerge through iterative learning, it seems clear that several issues are at stake. There is a need to rely on a strict methodology to build indicators and link results to each initial parameters of the simulation. To know the context of learning should enable to decide which learning model is better in different cases (Brenner, 2006). One can note that for the moment, representation of intelligence for humans is indeed very little inspired by some of the great theories of mind that have inspired the apparition of Artificial Intelligence as a field. Maybe the fact that all reasoning is represented through linear equation based models is a problem. The composition of mind as an emergence of different interacting sub-computers is a hypothesis that maybe should not be ignored when representing learning, even in economics (Minsky, 1985; Bateson, 1972).

When writing about the importance of experiments, Vernon Smith (2002) stresses the fact that no experiment can actually destroy or prove a theory, just ask new questions, and identify application boundaries for theories. This is a rather usual assertion nowadays, and corresponds roughly to what is referred to as the Duhem-Quine thesis: experiments embed so many hypothesis that one result can not be taken into account to refute or assess a specific aspect. Simulations can be seen as having a similar status, and are just a way to test the coherence of hypothesis (or cognitive consistence) and show their limits, from which new assumptions should be expressed. The question of "truth" of a complex model seems so impossible to evaluate that many researchers now consider that it should not be used on its own, as an abstract object that can more or less prove anything, but only considered in its context of use (Barreteau et al., 2004). This is similar to the efficiency paradigm of the instrumentalist approach, also said to be emphasised by Quine (Zammito,). A rather different protocol for research with simulations and human subjects has evolved in that sense, usually referred to as "companion modelling", enables to accumulate knowledge on human behaviour through the confrontation of simulated and real behaviours.

Companion modelling

Resource management and complexity

Simulations have been widely developed for the representation of social-ecological systems for management application, with social entities interacting with the resource and with each other through the resource. Resource management issues are usually grounded in reality and imply to superpose several points of view on a system. One can list for example three different issues that are relevant in these studies (Janssen and Ostrom, 2006): how to solve social dilemma and achieve co-ordination with sometimes competing interests (close to economics); the analysis of how humans deal with uncertainty (rather psychological issue); the influence of social networks on human activity (sociology). Each of these elements is still a question under study per se, where knowledge about how to represent humans' actions is very limited. Hence, to be analysed and represented, resource management issues need the insight from different sciences when it is dealt with in context. And it is rather clear that depending on the main point of view taken on the system, sociology, geography, economics, different conclusions will be drawn. It is even possible to prove this influence of point of views by building a multi-agent modelling where actors act differently according to the approach that is chosen (Bousquet, 1994).

Another issue when dealing with resource management is that the problems are not abstractly arising. They are usually situated within a political context, where the researcher himself has to be conscious that, as a knowledge builder, he is an actor in a global social process (Berger and Luckman, 1966). In this sense there is no possibility to really believe in the position of scientist as an outside expert who would define the problem on its own and bring optimal solutions to the population. Legitimacy of any representation or solution has to be recognised by the group under study (Barreteau et al., 2003).

It would be all the more difficult to pretend to be an expert, than it is very difficult to actually predict with accuracy the future of a relation between man and nature. We saw in the preceding section that the evaluation of simple behaviour models is almost impossible with econometrics, even when one compare with experimental data (Janssen and Ostrom, 2006). With data gathered in vivo, and considering the permanent technical and institutional innovation that take place, the importance of each factor gets so confused that it seems almost dangerous to pretend to evaluate quantitatively the future. Contemporary decision-making in resource management is certainly due to rely on adaptive policy-making rather than top-down imposed plans (Holling, 1978) and there is a need for methodology sustaining this research. The “companion modelling” approach, using simulation as a qualitative disputable representation of reality, has been developed in such a post-normal direction (Funtowicz et al., 1999), where the scientist is just one of other actors in the research for solutions.

Methodology and applications

Companion modelling is one among other approaches involving stake-holders in building and evaluating models and less heavy approaches can be applied (Taylor, 2004). It’s characteristic is the great care which is given to make sure the issue which is predefined by researchers can be appropriated as a hypothesis by users, and often discarded in the definition of new research objects. It has been for the moment dedicated to policy-making for organising sustainable resource management. Sustainability implies that individuals that are going to use the new institution or infrastructure will be able (and willing) to do so. To describe environment and society as accurately as possible, diverse points of view have to be taken into account in the model when considering the complex and often conflict-based situations - from scientific experts to local stake-holders (Barreteau and Bousquet, 2000).

Coming as an expert on the field and getting individuals to express their points of view is not an easy task, and the usual methodology used by those referring to companion modelling is: build a first analysis to roughly identify the relevant stake-holders for management or conflict resolution; involve them in discussions and present them a first draft model. To present a model, the use of a role-playing game is the main tool. It represents an easy way to discuss about rules and interactions with a group, but also to make sure that all participants of the meeting understand the core of the model, to be able to use it for a session. After the game it is usual to gather suggestions about new scenarios, and run subsequent simulations, giving rise to new discussions about the model, and requests for change. This represents the beginning of the protocol, and usually researchers have acquired, at this stage, a lot of crucial information on the real representation of local actors, and of interactions and decision-making dynamics that exist on the field (Etienne et al., 2003).

To make sure that stake-holders are not manipulated by researchers and do not reveal just what was present as an understatement in the model and game, time is a good ally. The revision of the model is presented few months later, in new sessions where stake-holders themselves propose new people to involve in the discussion, and focus the discussion more clearly on the aspects they feel more relevant in the conflict. The repetition of sessions (usually 3 at least) of play, scenario building and comments, helps a stuck or unclear situation to evolve. A better understanding of reasons of institutional blockage arises, and solutions emerge through discussion.

It has been shown that the model does increase the ability of individuals to communicate and find viable solutions. First, when discussing the model, most of social hierarchies can stay out, and people can discuss a bit more openly (with limits) (Daré and Barreteau, 2003). Second, in any type of negotiation, there is a need of an intermediate object, to position discussions (especially when the issue is not clearly delineated as in these initial situations), and the model is very efficient to serve this role (Bousquet et al., 2002). Eventually, the fact that the model has been co-constructed implies a higher level of legitimacy than if it had been imposed - during the long intervals, stake-holders understand the modelling process and are able to formulate their own hypothesis and understanding of situation, and to use the meetings as confrontation period. The process in itself gives roots to the enforcement of the decided policy since relevant individuals get involved. This is the main validation point of the model that is built: it is perfectly legitimate for users, and useful as a tool for action on the considered group.

For the moment this process has been shown successful for numerous applications. In Senegal it helped securing irrigation systems in several villages (Barreteau and Bousquet, 2000), and solve conflict threatening herders (d'Aquino et al., 2003). In Holland, organisation of traffic could be better managed (Duijn et al., 2003). In Vietnam, it sustained decisions taken for land-use changes (Castella et al., 2005). In Thailand, it helped creating local decision-processes for land-use and revealed issues of access to credit for farmers (Barnaud et al., submitted). Discussions on sylvopastoral management in France have been also greatly sustained by the use of the method (Etienne, 2003).

In this last example, as well as the irrigation one in Senegal, the games that had been created through negotiations have been transformed so that to match educational purposes and help explore group behaviours in various contexts. Observing diverse audiences while they are playing can indeed inform a lot about the processes that lead to the apparition of new institutions (d'Aquino et al., 2003).

While the process got generalised, new issues arose since various relations to RP games and simulation (each having a distinct role in the process of elicitation and resolution) could be observed. For example, associated sociological research was led to understand individual learning processes in Thailand, and enabled to anticipate on the future impact of the decision made in the context of the game (Patamadit and Bousquet, 2005).

Limits

Companion modelling produces model that are validated in the sense that they are accepted and efficient for leading local policy changes; it is an excellent tool to reveal the precise shape of interest conflict; it also reveals new questions and hence help furthering social theoretic research. However there are still some limitations in the method in its existing form. The first and most obvious one is the lack of accumulation of a knowledge that could be generalised to more than one situation. The following remarks are examples that might be irrelevant to the practitioners, but that are striking when reading this literature.

Companion modelling has been applied to a lot of cases where it has revealed hidden reasons for conflicts. However, there has been little accumulation of knowledge on a relation between the reality of conflict and its main expressions. One can imagine that there are various forms of conflicts with the same base, and maybe certain type of draft models could be more adapted than others facing given situation. In every case, this time consuming activity treats one situation, but even if it can be compared to others in terms of resolution, authors never tell. From the list that has been drawn, a more general view on how to help the appropriation of the process by actors could be valuable. The transmission of this knowledge has been done through formation of researchers, but couldn't it be shared via usual standards of transmission?

To attain this aim, one necessity seems to be the reproduction of conflict situation in the laboratory, as was the case for two RPG and subsequent model was adapted to match various audiences and tested. A

study of produced patterns and possibility to produce simulation models could be interesting. Reproducibility of the experience is the strength of experimental economics, who established standards to describe settings and results. This is also what made it so easy to turn into simulations. Maybe it could be a good way to judge the findings of companion modelling to offer readers an archetypical game they could challenge in another context. Since research is now being led to join both protocols, maybe proposals will arise in that direction.
One last remark concerns the lack of use of psychological models in simulations (Janssen and Ostrom, 2006). The assumption is that points of view have to be captured and revealed, since they have an impact on the evolution of the system. If they were written in the simulation models following psychological representation of exploring and learning from experience, it could maybe be possible to delineate psychological effects from those linked to the conflict setting itself.

Conclusion

To build and evaluate agent-based models, one has to make hypothesis and assess them by comparing with data at two levels: the internal rationality of individual agents, the emerging patterns that can be observed (for individual behaviour and global trends in the group). In this paper two approaches were presented that use almost similar settings, controlling at the same time simulated and human behaviours in the elaboration of the model: simulations linked with economic experiments, and companion modelling.
In the first one, human subjects have to accept a predefined problem, and choose with their rationality facing a situation they have no way to question. What is observed is a highly constrained behaviour, and the tested models can hence give presumably very general models on human rationality. For the moment, although some experimentalists have tried to actually make questionnaire to subject to understand their internal processes (Nyarko and Schotter, 2002), simulating researchers are not using these techniques to elaborate their assumptions. There is a danger in staying so far from an evaluation by the concerned actors: simulation is for the moment very unreliable to demonstrate the quality of an assumption of its uniqueness and cannot just by itself be used in such a Popperian approach.
The second approach wants to spot rationality by allowing the actors themselves to build the model and accept it when all assumptions and global behaviours have been analysed by the actors. Validation comes from the fact that the model is useful for the resolution of social dilemma in the context of resource management, as an acceptable and legitimate representation. The understanding of processes is more at the centre of research than in the case of economics, and the model is not considered as an external truth. The problem in this very self-conscious instrumentalist approach is that it lacks accumulation of knowledge: by giving account of actors' interpretation of simulations only in their context of production, like companion modelling has mostly done, it was certainly possible to miss numerous patterns that could be more generalised.
One can suppose that intermediate approaches could be chosen: a companion modelling where only a (possibly large) selection of abstract games would be proposed and where actors would have to select among them which one fits the best their conflict situation, and then behave accordingly and build agents that would be useful in other contexts; an experimental approach emphasising more a Turing-like situation (Turing, 1950) where human subject would have to recognise some agents as behaving like they themselves do. Simulations involving human participants look like a key feature of future researches. It will certainly have to add more tool than just gaming and experiments - like video-games, questionnaires, comments on agents and other players - and find ways to accumulate the information on actions and interpretation of rational humans. The sole use of complex system and analysis of the parameters do not seem to be enough when facing the sets of simulated data of high complexity.

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References

Anderson P. W., Arrow K. J. and Pines D. (eds), 1988, The Economy as an Evolving Complex System. Proceedings of the Global Economy Workshop, September 1987, Santa Fe, New Mexico, Santa Fe Studies, n 5, Addison-Wesley : Santa Fe.
Barreteau, O., Bousquet, F., 2000, SHADOC: A Multi-Agent model to tackle viability of irrigated systems. Annals of Operations Research, vol 94 (pp 139-162).
Barreteau O., 2003, The joint use of role-playing games and models regarding negotiation processes: characterization of associations, Journal of Artificial Societies and Social Simulation 6 (3).
O. Barreteau, C. Le Page and P. D'Aquino , 2003, Role-Playing Games, Models and Negotiation Processes, Journal of Artificial Societies and Social Simulation 6 (3).
Barreteau O, Bousquet F, Millier C, J. Weber, 2004, Suitability of multi-agent simulations to study irrigation system viability: applications to case studies in the Senegal River valley. Agricultural Systems, 80:255-275.
Bateson G., 1972, Steps To An Ecology of Mind. Balantine: New York.
Bousquet, F., Morand P., Quensière J., Mullon C. and A., P. 1993. Simulating the interaction between a society and a renewable resource. Journal of Biological Systems, 1:199-214.
Bousquet F., 1994, Des milieux, des poissons, des hommes : étude par simulations multi-agents, Orstom éditions, Paris.
Bousquet, F., Barreteau, O., D'Aquino, P., Etienne, M., Boissau, S., Aubert ,S., Le Page, C.,. Babin, D., Castella, J.C., 2002, Multi-Agent Systems and role games: collective learning processes for ecosystem management,. In: M. Janssen (Ed.) Complexity and ecosystem management: the theory and practice of multi-agent approaches.Edward Elgar Publishers.
Brenner, T., & Vriend, N.J., 2005, On the Behavior of Proposers in Ultimatum Games. *Journal of Economic Behavior and Organization*.
Brewer P., Huang M., Nelson B., Plott C. (2002). On the behavioural foundations of the law of supply and demand: human convergence and robot randomness, Experimental economics (5) 179-208.
Burger P., Luckman T., 1966, The Social Construction of Reality: A Treatise in the Sociology of Knowledge, Doubleday: New York.
Castella, J., Trung T. and Boissau S., 2005. Participatory Simulation of Land-Use Changes in the Northern Mountains of Vietnam: the Combined Use of an Agent-Based Model, a Role-Playing Game, and a Geographic Information System. Ecology and Society 10 (1): 27.
Camerer C., 2003, Behavioral Game Theory: Experiments on Strategic Interaction, Princeton: Princeton University Press.
Chong J-K, Camerer, C., and Ho, T-H. "A Learning-based Model of Repeated Games with Incomplete Information," Games and Economic Behavior, 2005, forthcoming.

D'Aquino P., Le Page C., Bousquet F. and Bah A., 2003, Using self-designed Role-Playing Games and a Multi-Agent System to empower a local decision-making process for land use management: the SelfCormas experiment in Senegal, Journal of Artificial Societies and Social Simulation 6 (3).
Daré W. and Barreteau O.,2003, A role-playing game in irrigated system negotiation: between play and reality, Journal of Artificial Societies and Social Simulation, 6 (3).
Doran J and Palmer M (1995) The EOS project: integrating two models of Paleolithic social change. In *Artificial Societies: the computer simulation of social life.* (Eds) N. Gilbert and R Conte, 103-125. UCL Press: London.
Duffy, J., 2001, Learning to Speculate: Experiments with Artificial and Real Agents. Journal of Economic Dynamics and Control (25). (pp 295-319).
Duffy J., 2006, Agent-based models and human subject experiments. In: Judd and Tesfatsion (eds.) Handbook of computational economics, Vol 2, North-Holland, to be published, Spring 2006.
Duijn M, Immers L.H, Waaldijk F.A and Stoelhorst H.J., 2003, Gaming Approach Route 26: a Combination of Computer Simulation, Design Tools and Social Interaction, Journal of Artificial Societies and Social Simulation 6(3).
Etienne, M. 2003. SYLVOPAST: a multiple target role-playing game to assess negotiation processes in sylvopastoral management planning. Journal of Artificial Societies and Social Simulation 6(2).
Etienne, M., Le Page, C. and Cohen, M. 2003. A Step-by-step approach to building land management scenarios based on multiple viewpoints on multi-agent system simulations. Journal of Artificial Societies and Social Simulation 6(2).
Fudenberg D. and Levine D. K., The Theory of Learning in Games. Cambridge, Massachusetts: MIT Press, 1999.
Funtowicz, S.O., J. Martinez-Alier, G. Mundo and J.R. Ravetz. 1999. "Information tools for environmental policy under conditions of complexity." European Environment Agency.
Gilbert N. and Abbott A., Introduction, American Journal of Sociology, Vol. 110, n 4: 859 - 863
Holling C.S., 1978, Adaptive environmental assessment and management, John Wiley, London.
Langton, C.G. (ed.), 1991, Artificial Life 1. Redwood City, CA: Addison-Wesley.
Janssen M. and Ahn T. K. (2003), Adaptation vs. Anticipation in Public-Good Games, In: Rouchier J., Edmonds B., Hales, D. (Eds.). Model to model workshop electronic proceedings.
Janssen M. and Ostrom E., 2006, Governing Social-ecological systems. In: K. L. Judd and L. Tesfatsion (Eds), Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics, Handbooks in Economics Series, North-Holland, to appear Spring 2006.
Kirman, A. (1997). The Economy as an Interactive System. In: W. B. Arthur, S. Durlauf, D. Lane (Eds.) The Economy as an Evolving Complex System. Studies in the Sciences of Complexity, XXVII, n 2. Santa Fe: Addison-Wesley.
Kirman, A., Vriend, N. (2001). Evolving Market Structure: An ACE Model of Price Dispersion and Loyalty. Journal of Economic Dynamics and Control. 459 – 502 .
Lelec Fabrice, Inertia and learning in the Ultimatum Game Explaining experimental behaviors as a weakly-learning agents system convergence, Proceedings of AESCS, Tokyo, July 2005.
Minsky M., 1985, The society of mind, Simon & Schuster.
Moss S. and Edmonds B., 2005, Sociology and Simulation: Statistical and Qualitative Cross-Validation, American Journal of Sociology, Vol. 110, n 4: 1095–1131
Nyarko Y. and Schotter A., 2002, An experimental study of belief learning using elicited belief". Econometrica, 70, 971-1005.
Patamadit I. and Bousquet F., 2005, The thai traditional learning process in folk culture: implications for the companion modelling approach, In: BousqueT, Trébuil & Hardy (eds) Companion modelling and multi-agent systems for integrated natural resource management in asia, IRRI press.
Roth A.E., Erev I. (1995) Learning in Extensive-Form Games: Experimental Data and Simple Dynamic

Models in Intermediate Term. Games and Economic Behavior. Special Issue: Nobel Symposium 8, 164-212.
Rouchier J., 2004, Re-implementation of a multi-agent model aimed at sustaining experimental economic research: The case of simulations with emerging speculation, JASSS, 6,4.
Rouchier J. and Robin S., 2005, Double-auction for real and artificial agents Information perception and price dynamics, Simulation and gaming, special issue, forthcoming.
Simon H. 1969, The Sciences of the Artificial, MIT Press.
Smith V., 2002, Method in Experiment: Rhetoric and Reality, *Experimental economics* 5, pp 91-110.
Taylor R., 2003, "Agent-Based Modelling Incorporating Qualitative and Quantitative Methods: A Case Study Investigating the Impact of E-commerce upon the Value Chain", Doctoral Thesis, Manchester University.
Tesfatsion L., 2006, Agent-based computational economics: a constructive approach to economic theory. In: K. L. Judd and L. Tesfatsion (eds), Handbook of Computational Economics, Vol 2: Agent-Based Computational Economics, Handbooks in Economics Series, North-Holland, to appear Spring 2006.
Turing A. M., 1950, `Computing Machinery and Intelligence'. *Mind*, 59:433-460.
Vriend, N.J., 2004, ACE Models of Market Organization. Revue d'Economie Industrielle, No. 107, 63-74.Vriend, N.J. (2005). Computing in Economics and Finance. Guest Editorial, Journal of Economic Dynamics and Control, 29, Nos. 1/2, 1-2.
Zammito John H., 2004, A Nice Derangement of Epistemes: Post-Positivism in the Study of Science from Quine to Latour, The University of Chicago Press.