

Introducing Ethical Characteristics in Microeconomic Markov Models

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Abstract

The theoretical foundations and meaning of an ACE simulation project intending to connect Microeconomics with CST, are presented. The paper does not contain or explain the simulation itself, but it discusses the possibility of modeling economic situations with morally heterogeneous agents, a considerable departure from usual microeconomic models. Taking moral heterogeneity as a matter of principle reflects better the Catholic concept of moral life than merely supposing it must be the result of the interaction of self-interested agents within certain institutions. ACE is seen as a methodology suitable for introducing moral heterogeneity due to ethical principles, in regular microeconomic models. Some of the epistemological advantages and problems of this use of ACE are discussed.

Keywords

Catholic Social Teaching (CST), Microeconomics, Agent-based Computer Economics (ACE), moral heterogeneity.

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And the Lord said, "If I find at Sodom fifty righteous in the city, I will spare the whole place for their sake." Abraham answered and said, "Behold, I have undertaken to speak to the Lord, I who am but dust and ashes. Suppose five of the fifty righteous are lacking. Will you destroy the whole city for lack of five?" And he said, "I will not destroy it if I find forty-five there." Again he spoke to him and said, "Suppose forty are found there." He answered, "For the sake of forty I will not do it." Then he said, "Oh let not the Lord be angry, and I will speak. Suppose thirty are found there." He answered, "I will not do it, if I find thirty there." He said, "Behold, I have undertaken to speak to the Lord. Suppose twenty are found there." He answered, "For the sake of twenty I will not destroy it." Then he said, "Oh let not the Lord be angry, and I will speak again but this once. Suppose ten are found there." He answered, "For the sake of ten I will not destroy it." And the Lord went his way, when he had finished speaking to Abraham, and Abraham returned to his place.

– Genesis, 18,26-33

1 What is (Neoclassical) Microeconomics

We will use a logical point of view to define (Neoclassical) Microeconomics as a scientific field. The advantage of doing so, is that we will point at the bare minimum necessary to build a Microeconomics in the Neoclassical tradition, not introducing substantive aspects easier to criticize (but otherwise prescindible within a purer Microeconomics).

1.1 A rational model of social interactions

Microeconomics is a science that produces social models populated by agents that interact intending to get rationally the maximum value of a target function. Several points

to take into account:

- The agents are decision units that act coherently to maximize a single target function. They need not be individuals, not even personal agents. A Microeconomics of machines can be done (and it is done, for example, when describing computer interactions within networks). And, of course, families and companies, as different from individuals, are often considered the agents of microeconomic models.
- The possible objects of the agents' interactions are goods, services and/or values both scarce and transable. That includes time, effort, capabilities...
- Each agent pursues the maximization of its target function through interactions in a rational way. The meaning of *rational* in Neoclassical Microeconomics will be discussed later in the article.
- The rational maximization intent of the agent in Neoclassical microeconomic models is expressed with some mathematical language: Calculus, Algebra, Topology.
- The point of departure of Microeconomics is made of some suppositions about:
 - How agents interact.
 - How agents decide in those interactions, if they have a choice.
- The objective of Microeconomics is to produce models of social interactions, in order to explain and predict the values of some magnitudes pertaining the economy under study: amounts, prices, and the like.
- Those models, as it happens with all scientific models, are restricted by a *caeteris paribus* clause. Whatever is out of the model is supposed to remain the same. In other case, the results of the model could always be attributed to (changes in) the circumstances out of the model itself, and this would lose its interest as a model. It would explain and predict nothing.

1.2 The correspondance between model and social reality

A microeconomic model can be taken in two different ways:

- As an actual model (of a portion) of social reality, which intends to predict its future evolution from its current state and past evolution.
- As an exercise in the mathematics of maximization under the general conditions already presented (each agent intends to maximize rationally its own target function through relations with other agents) and the particular conditions described in the model itself.

Though often despised as *blackboard economics* the second purpose is respectable when used to understand the basic logics underlying real economic systems, even if the model actually intends to describe none in particular.

That kind of theoretical Microeconomics is often used for teaching students or for exploring the potential workings of new fields of interaction.

The obvious problem, for which Neoclassical Microeconomics has been much criticized, arises when models originally elaborated for the second purpose are used for the first, without very careful *translation*. Particularly, certain *ceteris paribus* clauses that can be used freely in theoretical models may not be suitable at all for specific real situations. As explained later, a clear example of that is the supposition of absence of externalities.

2 Preference theory

The point of departure of Neoclassical Microeconomics is a target function of each agent that applies to all possible states of the world S_i . That function $t(S_i)$ is ordinal, meaning that it needs not give a concrete value to each state but only rank them in a certain order of preference. Then: $t(S_1) > t(S_2)$ means that the state S_1 is preferred by the agent to the state S_2 and $t(S_1) = t(S_2)$ that the agent is indifferent between them.

The states of the world relevant S_i are those that the agent may produce with its decision. In consequence, the dominion of t is formed only by the states of the world achievable by the agent using the resources it actually has. The agent may hold preferences about many others states of the world, but they are not the subject of its economic decision. They are beyond its possibilities and the agent cannot decide about them.

Each agent may have a different target function, provided that all of them share these characteristics regarding all possible states in the system:

- Completion: Given any S_1 and S_2 , either $t(S_1) > t(S_2)$ or $t(S_1) < t(S_2)$ or $t(S_1) = t(S_2)$.
- Reflexivity: Given any S_1 , $S_1 \geq S_1$.
- Transitivity: Given any three S_1, S_2, S_3 , if $S_1 > S_2$ and $S_2 > S_3$, then $S_1 > S_3$.

Transitivity is the only necessary condition of rationality for the agents' preferences. It is a property related not to the content of those preferences but to their consistency. It is clearly connected to the logical non-contradiction principle.

In our definition, all reachable states of the world are the dominion of preference functions. However, what differentiates those states from each other introduces an important hidden assumption. Microeconomics requires the difference to be expressed in terms of baskets of economic goods, services and values. The object of the transactions between agents are elements contained in those baskets (scarce and transable). The agent may improve its basket (in the sense of getting a basket more preferred to it) through free transactions, or improve/worsen it through transactions forced upon it by the public powers. Goods of other kinds, such as relational goods or contemplative ones, must be approximated through their economic elements but cannot be fully taken into account by themselves.

For example, contemplation can be approximated through the time available for it (the target function may then value free time highly), or fairness as a relational quality may be approximated through the relation of the economic gains of the parties in a transaction.

A second idea of rationality is implicit in the use of the preference function: the agent's decision follows its preferences. Given that we have defined the preference function over the dominion of all states of the world achievable with the agents' resources, the agent will choose the alternative with a higher preference for it. That is, the agent is a maximizer of its preference given the constraint imposed by the resources available to it. This is a property related not to the content of those preferences but to the consistency between decision and preference function. Sometimes it is called *instrumental rationality*.

3 General suppositions regarding preferences

The following suppositions are necessary in order to make the analysis meaningful:

- Preferences stability. Each agent's target function does not change during the period under analysis.
- No externalities.¹ The same as there is a price for each good, service or value in the target functions of the agents, no good, service or value in those target functions is received but at that price. In other words, no variable in the target functions is dealt with out of the market.

If any of these two suppositions didn't happen, any phenomenon observed in the system could be explained through a variation in some agents' preferences and/or through the existence of factors relevant to their decisions and external to the system.

4 Additional suppositions

The above properties (2) and suppositions (3) are necessary for any Neoclassical microeconomic model.

However, in order to produce models tractable with the mathematical tools mentioned in 8.1.1, some additional suppositions are often introduced. They can be relaxed, however, keeping the essential logic of Microeconomics, but at the cost of making more difficult the mathematical analysis of the model.

For our purpose, we will differentiate the suppositions with an immediately ethical meaning from all the rest (mostly but not only related to informational conditions).

¹"Externalities refers to situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided". <http://stats.oecd.org/glossary/detail.asp?ID=3215>

4.1 Suppositions related to non moral aspects of the system

- Zero transaction costs. It can be relaxed to introduce an indirect tax, for example.
- Zero information costs. Relaxing this assumption and introducing uncertainty about the consequences of any decision, gives place to the 'limited rationality' of Herbert A. Simon. Agents will then have to decide to which point to invest more money in getting more and better information. At a certain point they will declare themselves satisfied with the expected results of the decision they have information to make, and won't pursue the search.
- Complete information: Every agent knows the target function of the others and the structure of the model but may not see all of the actions made by other agents in the past.
- Perfect information: Every agent knows past moves of other agents, but may lack some information about their target functions, or on the structure of the game.
- Symmetric information. Both parties in every transaction have the same information about all relevant aspects.

4.2 Suppositions related to moral aspects of the system

- Private property is respected by all private (non State) agents.
- All contracts are fulfilled in the terms they establish.
- The law is publicly known, equal for all, and entirely fulfilled both by private and by State agents.
- Agents homogeneity. Agents may have different target functions, thus different preferences. But the structure of those preferences follows the above rules for all agents.
- The target function is non-lexicographical: any loss in any of its terms can be compensated with a gain big enough in other term(s).
- Egotism: the dominion of the target function is only made of baskets of goods, services and values under the property or use of the agent.

The three first suppositions define the basic ethics necessary for a system to function based on voluntary agreements, in the context of a legal system of rights. As far as its future is defined by the participation in contracts public or private, the agent can predict its fate in it.

If any or three of these suppositions may be broken, we can still do an 'Economics of crime', following Gary S. Becker ².

The other three suppositions specify what is often called the *homo oeconomicus* as the model of agent in the microeconomic system. They are our main issue of concern here.

²"Some common properties are shared by basically all legislation, and these properties form the subject matter of this essay. In the first place, obedience to law is not taken for granted." Becker(1974:2)

4.3 The possible meanings of the *homo oeconomicus* suppositions

It is important to notice that Neoclassical Microeconomics does not strictly require our last three suppositions. However, they are used much more often than not in economic models. One could wonder why. Three kinds of reasons can be given (or chosen among):

- Anthropological reasons: by nature, most agents follow the *homo oeconomicus* pattern of preferences in most of their economic transactions.
- Evolutionary reasons: agents that follow the *homo oeconomicus* pattern of preferences end up displacing in the economic dynamics of concurrence agents with other possible patterns.
- Mathematical reasons: assuming the *homo oeconomicus* pattern of preferences makes microeconomic models more tractable from an analytical point of view. In particular,
 - it reduces the analytical problem of the agent to maximizing a target function over a basket of its own goods, services and values, and
 - it reduces the analytical problem of the market to voluntary transactions among similar agents intending each one to maximize such target function through exchanges with other agents.

This depicts the easiest possible scenario for Mathematical analysis.

5 Relaxing the *homo oeconomicus* suppositions

We shall focus in the last three moral suppositions of 4.2. For the time being at least, we shall accept the rest of the properties and suppositions enunciated in 2, 3 and 4.

5.1 Can moral life be represented with those last three suppositions?

It cannot. Human moral life includes as essential elements:

- The existence of agents who make decisions using target functions that include goods, services and values owned or used by other agents (additionally to their own). That's the way of modeling moral phenomena different from the respect for private property, contracts and the law, considered in the first three suppositions of 4.2. Phenomena like fairness beyond the law, altruism or envy cannot be modeled unless we accept that terms related to the possessions of others can make part of the target function of any agent.
- The existence of agents that make decisions following lexicographical target functions. If a loss generated in the terms that refer to goods, services and/or values under possession of others can be compensated in the agent's target function with gains in goods, services and/or values under its own possession, moral concepts such as fairness or charity beyond the law cannot be modeled. In general, any

concept that must be understood deontologically (fairness is a good example), requires lexicographical precedence over one's possessions. In other case, the agent would violate those moral obligations if offered a price high enough.

Of course, we could think of a non-lexicographical target function where that price were so high that the mentioned violation wouldn't happen in any realistic scenario. However, such target function wouldn't model moral life well. It would have a structure unsuitable from a moral point of view.

- The moral heterogeneity of personal agents. Any realistic model of moral agents require that agents with different moral profiles coexist (for example, agents with an *homo oeconomicus* pattern of preferences along with agents with a non egotistic, non lexicographical moral pattern).

Actually, modeling moral life also requires a controlled relaxation of the supposition of stability of the target functions. That's the way of considering ethical changes in the agent, for the better or the worse. Personal agents may change their target functions, both in their content (affecting with different coefficients, exponents, etc. the different possible terms) and their structure (making them lexicographical if they were not, or the opposite).

Changes in the agent's target function are also possible for other reasons. For example, as an effect of the exposure to the marketing industry or as a result of learning from more successful agents. But those cases are less relevant for our purpose here, because they are compatible with the *homo oeconomicus* suppositions.

5.2 What is the meaning of those relaxations?

In 4.3 we discussed three possible reasons to accept the moral suppositions that we grouped under the *homo oeconomicus* label. They have very different entity.

The anthropological reason must be rejected out of hand. As we discussed in 5.1, those suppositions violate basic phenomena of moral life, turning people in kind of automata. They cannot be used as a description of human moral life in any realistic sense; using them would make impossible to model moral life, except as a legal one. But the ethical characteristics of an agent and the legal characteristics of a social system are deeply different.

Actually a much cleverer defense is made by Milton Friedman (1964:11) in "The Methodology of Positive Economics":

Positive economics is in principle independent of any particular ethical position or normative judgments. As Keynes says, it deals with "what is," not with "what ought to be." Its task is to provide a system of generalizations that can be used to make correct predictions about the consequences of any change in circumstances. Its performance is to be judged by the precision, scope, and conformity with experience of the predictions it yields. [3]

Obviously, this position has no anthropological pretensions. Economic models are only to be evaluated by the exactitude of its forecasts, as compared to reality.

To find some anthropological pretensions one must move backwards, to a time more influenced by the thinkers of the classical school in Economics, in any case before Lionel Robbins, whose *Essay* was first published in 1932. For example, in 1890 Alfred Marshall starts his *Principles* with some anthropological statements:

Political economy or economics is a study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of wellbeing.

Thus it is on the one side a study of wealth; and on the other, and more important side, a part of the study of man. For man's character has been moulded by his every-day work, and the material resources which he thereby procures, more than by any other influence unless it be that of his religious ideals; and the two great forming agencies of the world's history have been the religious and the economic. [...] Religious motives are more intense than economic, but their direct action seldom extends over so large a part of life. For the business by which a person earns his livelihood generally fills his thoughts during by far the greater part of those hours in which his mind is at its best; during them his character is being formed by the way in which he uses his faculties in his work, by the thoughts and the feelings which it suggests, and by his relations to his associates in work, his employers or his employees. [6]

Pretensions of the like disappear from Microeconomics after Robbins, under the influence of Neopositivism, but they remain strong in the popular culture.

The mathematical reason is more pragmatical than the anthropological one. It has to be taken care of because a model that we cannot solve matematically, it's of little use as a model. In 6.1 we discuss a possible way out of it through agent-based computer simulations.

Finally, we're going to test the evolutionary reason with those simulations. We are interested in knowing what would be the effects of having a certain proportion of agents following a decision pattern different from the one expressed by the three last suppositions in 4.2, when they act in a world populated by agents that, for the rest, follow those suppositions.

There are two kinds of effects we may be interested in:

- Aggregated effects on the system as a whole: production, stability, equality...
- Effects on each agent according to its particular profile (ethical profile, but also other aspects).

Thus, the purpose of our work is to produce microeconomic models where some agents (but not necessarily all) follow lexicographic preference funtions that include terms related to the possessions of others. That way we intend to represent moral life within models that follow for the rest the Neoclassical guidelines. We discuss now how that can be done, and what limitations we must expect to find.

6 Agent-based computer simulations

Agent-based Computer Economics (ACE) is the application to Microeconomics of the general methodology of agent-based computer social models (sometimes called ABS or ABM). It allows to model indefinitely complex situations without having to solve the difference and/or differential equations that describe the model. With the problems discussed in 6.4, the mathematical reasons for choosing a morally 'too simple' agent for our microeconomic models are addressed, and the evolutionary aspects of including ethically more complex agents can be studied.

6.1 General idea

The ACE models are made of a sufficiently big number of agents (of different classes, if the model so requires), each one endowed with:

- Some resources, according to a distribution that reflects the original state of the model.
- A preference function, which may be used to embody its ethical characteristics.
- Some productive capabilities, if production and not mere exchange is going to happen in the model.
- Some informational capabilities, that allow the agent to estimate which available decision will produce a more preferred state of the world for it. They may include the ability to form a reputation of each other agent, in order to guide the decision about with whom to interact. The moral heterogeneity captured in the different preference functions may so extend to differentiated ways to see the other agents.

Additionally, an ACE model must include some rules common to all agents, of the type:

- Interaction rules, that define the voluntary engagement of agents. They may include:
 - Production rules.
 - Distribution rules.
- Legal rules, imposed by the State (often an agent external to the model, though it can be included as a different kind of agent with coercive capacity). They may include some redistribution, in which case it is necessary to define:
 - Collection rules.
 - Redistribution rules.
- Innovation rules, that increase the agents' productive capabilities following their investment of resources.
- Memory rules, that establish how many facts each agent is going to remember, and how, in order to use its informational capabilities.

6.2 Loops and external dynamics

We shall call a *loop* any dynamics of the system where a certain decision about the use of resources increases or decreases the amount of resources available to the agent in future tics. In Economics, detecting and modeling as many loops as relevant in the system, is essential for the usefulness of a model.

Different from that, we shall call *external dynamics* any decisions with the same effects, but taken by the State. The ACE models we are proposing may collect several loops.

- The production-innovation-debt loop. The amount of resources must be divided in three parts, dedicated to production, innovation and loans/debt. *Coeteris paribus*, a bigger production will generate not only bigger gains for the agent in the present, but also a better reputation in the eyes of other agents (which will make it more eligible for transactions in the future), and so a bigger future income. Resources devoted to innovation, if this is successful, may also increment the future productive capability of the agent, with similar effects. And finally, money loaned in this tic will be collected back with interests in the future.
- The ethical loop. *Coeteris paribus*, acting in an ethical way may decrease the amount of resources appropriated by the agent (thus the amount available to it for the production-innovation-debt loop), but at the some time increases the amount appropriated by its counterparty. That will improve the reputation of the first agent in the eyes of the second. It may also happen that this counterparty is sensible to the moral quality of that first agent, which in turn improves more its reputation.

Several external dynamics are also relevant:

- The inequality in the initial distribution of resources.
- The redistributive decisions of the State.
- Variation in the legal rules according to the ethical profile of the agent.

6.3 Objective and relation to the CST

A model devoted to study the impact of the agents' ethical profile will try to establish to which point and under which conditions the ethical loop is significant in the system modeled, both for the results of the whole system and for the fate of each agent in it, as mentioned in 5.2.

This is relevant from the point of view of the CST. It would make little sense to address moral recommendations to the human liberty and, at the same time, to use economic models where the agents are supposed to be morally predetermined by some assumptions incorporated in the models themselves. It would amount to impose moral ends to quasi-mechanical models. Moral considerations would then be completely external to the models, just the same as they may be external to rocket science: only a matter of for what purpose rockets are used for. Such an external relationship between

moral ends and economic means is precisely what Lionel Robbins proposed in his *Essay* (1932:132-133):

Economics deals with ascertainable facts; ethics with valuations and obligations. The two fields of enquiry are not on the same plane of discourse. Between the generalisations of positive and normative studies there is a logical gulf fixed which no ingenuity can disguise and no juxtaposition in space or time bridge over. (...) Propositions involving the verb "ought" are different in kind from propositions involving the verb "is". And it is difficult to see what possible good can be served by not keeping them separate, or failing to recognise their essential difference. [7]

However, it is obvious that the operation of any economic system (described with 'is', in the terms of Robbins) depends on the (heterogeneous) moral qualities of the agents therein involved (which can also be described by 'is'). The ethical aspects make part of the descriptive baggage of economic models, in a descriptive, not a normative fashion. The external character of moral considerations is merely an artifact produced by some suppositions incorporated in most economic models, quite often implicitly via the examples used. The first objective of these simulations is to show internal descriptive connections between the agents' moral qualities and the model operation.

A second issue central to the CST is the link between better (micro)behavior of the agents in a social system and better social (macro)results of the system as a whole. Private virtues are expected to produce social good results, different from the modern conviction that there is no correlation between the desirability of the behaviors at the micro and at the macro levels. We have discussed the point elsewhere³. Studying the connection between the two levels is a second purpose of the study of economic models with ethically heterogeneous agents.

Finally, we must notice that the ACE methodology is especially well suited for these two purposes. The approach we propose would:

1. start from any microeconomic *homo oeconomicus* model;
2. convert it into an ACE model;
3. make its agents ethically heterogeneous in variable proportions.

The relevant comparison would be between the (micro and macro) results of the *homo oeconomicus* ACE model and the results of the same model for different proportions of agents with other moral profiles. We should then be able to study in which sense, if any, the introduction of ethical profiles different from the *homo oeconomicus* one produces different results.

Comparison to reality is secondary in this approach, not the main issue. Discarded any anthropological significance of the *homo oeconomicus* pattern of decision, the actual moral profile of the population can change due to moral dynamics. It is not primarily a

³see González Fabre (2005:47 ff.)

matter of concern which model reflects social reality better.

There is an all important loop in moral life: agents may change their target functions with their ethical beliefs. If an *homo oeconomicus* model happens to describe social reality better than other with different proportions of ethical profiles, that only means that agents behave more like *homo oeconomicus*, not by nature but due to their ethical options. It still makes sense to call them to change those ethical options.

ACE models with morally heterogeneous agents have thus an *if...then* structure. They intend to show what would happen if more agents acted according to a pattern different from the *homo oeconomicus* one. They should be useful to the normative statements of CST providing a sense of the economic consequences of moral changes. That sense of consequences is necessary to any ethical proposal not based merely on principles.

Actually, the underlying structure of Catholic Ethics has been Platonic from the very beginning. During the Middle Ages, its Platonism was nuanced with an Aristotelian consideration of consequences, incorporated within the virtue of prudence. The resulting Ethics looks for appropriate balances between principles and consequences in the real world, not merely for the realization of moral principles irrespective of the consequences.

In that sense, both Kantism and (any) Consequentialism must be considered out of Catholic Ethics, because they emphasize one of the poles of moral life (principles or consequences) disregarding the other. Following the old tradition of Catholic Social Ethics, CST must prescribe ethical commitments that, at the same time, reflect sound moral principles and have good social consequences. Estimating the sense of the consequences of following certain ethical principles in the agent's decisions, is the main objective of our proposed use of ACE models.

6.4 Some epistemological issues

6.4.1 Purposes of Microeconomic models

As every social science, Microeconomics intends to capture somehow the essential dynamics below some aspect and/or part of social reality. In this regard, microeconomic models may have two different intentions:

- Empirical: Actually model a part of social reality using relevant parameters provided by Econometrics, in order to connect the operation of the system with the operation of the agents in it.
- Theoretical: Provide stylized models of economic interactions, useful to understand the sense in which a certain system will move given its constraints. This purpose needs not be realistic in reflecting an actual part of the social system.

ACE can be used with any of these purposes, but we are more interested in the second one. On the one hand, CST does not give recommendations for particular social situations. It's far more general: its application to specific social situations is left to the

Catholic decision makers in each case. On the other hand, Neoclassical Microeconomics is widely used with a theoretical purpose for education and social communication, almost always supposing a *homo oeconomicus* way of decision making. That way, many people come to understand that the *homo oeconomicus* pattern actually reflects the ethical essence of economic decisions (as if there were an 'ethical essence' by nature, not ethical options behind each decision). This is a cultural challenge that requires more than statements based on principles to be addressed.

Thus, we shall concentrate on the theoretical intention of Microeconomics, in order to discuss some epistemological limitations of ACE models. Some other limitations may be found when considering ACE models for empirical purposes, but we shall not discuss them here.

6.4.2 Our ACE model in practice

For our purpose, we find adequate a Model-to-Model approach, where the results of models populated by agents purely with an *homo oeconomicus* moral profile are compared to the results obtained in models populated by agents with mixed moral profiles, being all other aspects of both kinds of model the same. In practice, we start from an *homo oeconomicus* model, then change only the agents' moral profiles, and finally compare the same relevant results in both models. That implies:

- No correspondance between the different models and reality is studied. We do not intend to show that a model of mixed ethical profiles is more realistic than a purely *homo oeconomicus*' one. That may well be so if the mix of moral profiles we use is closer to reality at a given moment than simply considering everybody an *homo oeconomicus*; it also may be the opposite if our mix is further away from reality. But moral reality itself changes according to cultural influences (at the social level) and personal options. We are rather interested in seeking some support for the cultural influence CST intends to develop, via showing how a better ethical quality of (part of) the agents produces better social results (if that is the case). For the rest, the correspondance to reality is a task we gladly leave to the original *homo oeconomicus* model. The usefulness in front of reality of our models is derived from the usefulness of the *homo oeconomicus* model they start from.
- The usual approach to moral issues in ACE considers every agent an *homo oeconomicus*, and then try to derive the existence of different kinds of social rules that seem to express (apparent) altruism or consideration for the other. For example, there is a vast literature regarding the prisoner's dilemma and the truly enigmatic issue of how a society is possible if made only of egotistic agents. Our conception of moral life is entirely different: we follow the CST in thinking that action based on ethical principles is possible, even if the agent reaps no benefit from it in terms of goods, services and values under its possession or control.
- However, precisely one of the advantages of the ACE methodology is to allow heterogeneity in the agents. Analytical Microeconomics takes into consideration the diversity of preferences in consumers (even if the dominion is generally the

same; baskets of goods, services and values possessed by the agent). With regard to companies, the basket is reduced to money (profits), so that more is simply better than less. Differences in the production function are also possible. The 'limited rationality' Microeconomics pays much attention to the differences in information availability and its cost to the agents, introducing other source of heterogeneity. Here we intend to introduce a third source of heterogeneity: the moral variation between different agents.

6.4.3 Epistemological problems

Having clarified these issues, let us notice that an ACE model is always concrete. No equations about the state of the system are solved, but that state results (emerges, it is often said) from the interaction of the agents populating it. This is quite different from an usual microeconomic model based on Calculus or Topology, because all parameters and independent variables must receive a value. That introduces some problems.

Galán and Izquierdo (2005:1.3) affirm:

As a matter of fact, the dynamics of agent-based models are often so complex that we (model developers) often do not understand in exhaustive detail how they operate. Not knowing exactly what to expect makes it impossible to tell whether any unanticipated results derive exclusively from what the researcher believes are the crucial assumptions in the model, or whether they are just artefacts created in its design, its implementation, or in the running process. Artefacts in the design of a model can appear when assumptions which are made arbitrarily (possibly because the designer believes they are not crucial to the research question and they will not have any significant effect in the results) have an unanticipated and significant impact in the results (e.g. the effect of using different topological structures or neighbourhood functions). When this occurs, we run the risk of interpreting our simulation results beyond the scope of the simulation model (Edmonds and Hales 2003a). Implementation artefacts appear in the potentially ambiguous process of translating a model described in natural language into a computer program (Edmonds and Hales 2003b; Rouchier 2003). Finally, artefacts can also occur at the stage of running the program because the researcher might not be fully aware of how the code is executed in the computer (e.g. unawareness of floating-point errors (Polhill, Izquierdo and Gotts 2005a; Polhill, Izquierdo and Gotts 2005b)). [4]

Several major additional problems follow from this reflective account of experience:

- Regarding the theoretical value of an ACE model. It is not only, as Galán and Izquierdo remark, that the researcher may be cheated by some artefacts he is introducing inadvertently. He may also cheat the reader by manipulating the design and/or the implementation of the model, in order to produce results that support his theory. A model with an apologetic intention (where one has the answer before formulating the question) is not relevant from a scientific point of view, even if it can be used for propaganda.

- The curse of dimensionality. The parametric space (where the model has to be defined, even if those parameters do not change within the model itself) may include many values. Any conclusion stands only for the vector of the established values of the parameters. If the conclusions are going to be of any general value, the whole relevant parameter space must be explored. But this space is p -dimensional, being p the number of independent parameters. Doing that exploration would imply a prohibitively high number of simulations to be run, with each possible combination of the different p parameters.
- The introduction of computational artefacts due to the design of the model includes issues related to the order of different operations and of different agents executing each operation. Social life is a continuous process where agents develop their operations simultaneously, but computer simulations have to be discrete, at least to the number of available processors, and proceed in a certain order determined within the program.

6.4.4 Some answers

We propose to (partially) handle these problems with some measures:

- The pretension of our models must be modest, in the sense that no general assertion is to be made from their results. Any exploration of the parametric space would be useful to get an idea of the robustness of the model's conclusions. But even that cannot be ensured using a discrete exploration: a sudden change in the results could happen between two points explored, and pass undetected. In other words, the complexity theory behind ACE models does not presuppose any kind of linearity that would allow to infer intermediate values from the two extremes'. In consequence, these models only allow for illustrative conclusions regarding the sense in which dependent variables move (or don't) along or against the movements of the independent variables.
- In that sense, our model's results cannot pretend a theoretical value bigger than the Microeconomic models populated by agents with an *homo oeconomicus* profile, which make their point of departure. Precisely in order to make our models as theoretically valuable as possible, we should be interested in showing the theoretical adjustment of the *homo oeconomicus*' model behind. It would be useful to test this last model against the existing analytical Microeconomics.
- Finally, the recommendations of Galán and Izquierdo are also useful for our purpose. The models have to be:
 - programmed carefully, as to prevent computational artefacts.
 - run for several different random seeds, taking central values (the mean or the median) as representative of the results obtained.
 - replicated independently, in different programming languages by different persons.

7 Conclusion

References

- [1] Becker, G. S. "Crime and Punishment: An economic approach", in Becker, G. S., W. M. Landes, et al. (1974). *Essays in the economics of crime and punishment*. New York, National Bureau of Economic Research.
- [2] Becker, G. S. (1992). "The Economic Way of Looking at Life": Nobel prize lecture. www.nobelprize.org/nobel_prizes/economic_sciences/laureates/1992/becker_lecture.pdf
- [3] Friedman, M. (1964). *Essays in positive economics*. Chicago; London, University of Chicago Press.
- [4] Galán, José Manuel, and Izquierdo, Luis R. (2005). 'Appearances Can Be Deceiving: Lessons Learned Re-Implementing Axelrod's 'Evolutionary Approach to Norms''. *Journal of Artificial Societies and Social Simulation* 8(3)2 jasss.soc.surrey.ac.uk/8/3/2.html.
- [5] González Fabre, R. (2005). *Ética y economía: una ética para economistas y entendidos en economía*. Bilbao, Desclée de Brouwer.
- [6] Marshall, A. (1920). *Principles of Economics*. Library of Economics and Liberty. <http://www.econlib.org/library/Marshall/marP.html>
- [7] Robbins, L. C. (1932). *An essay on the nature and significance of economic science*. London, Macmillan and Co.
- [8] Squazzoni, F. (2009). *Epistemological aspects of computer simulation in the social sciences : second international workshop, EPOS 2006, Brescia, Italy, October 5-6, 2006*. New York, Springer.
- [9] Tesfatsion, L. and K. L. Judd (2006). *Handbook of computational economics*. Amsterdam; Oxford, Elsevier.
- [10] Varian, H. R. (2010). *Intermediate microeconomics: a modern approach*. New York, W.W. Norton and Co.