

Dipartimento di Ingegneria della Produzione, Termoenergetica e
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*Top-down and bottom-up interactions
between individual
and
collective behaviors*

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Lorenzo Cioni

e-mail: lcioni@di.unipi.it, l.cioni@sns.it

Ph.D. Supervisor:

Prof. Agostino Bruzzone

To Daniela
salmastro dei miei mari ...
vino odoroso dei miei giorni ...

to Jona and Juno
honey and salt ...
sun and moon ...

to Yuri
nostalgia ...



Yuri ©

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Some history

This thesis¹ had a very troubled gestation.

When I² presented, on September 2008, my application for the PhD course of which this thesis is the conclusive act I enclosed the description of a research project whose title was “The use of multi-agent systems for the analysis of strategic behaviors of real agents engaged in the solution of environmental problems”.

The basic idea was to analyze the various modes of interaction³ (such as competition, coordination and cooperation) among decision makers⁴ and stakeholders (both to be seen as the real agents⁵) for the solution of problems that affect their welfare and the environment (both social and natural) in which they live. Within this framework I wished to find tools that the real agents can use to devise agreed on solutions to such problems and to understand how they can share among themselves the benefits and the costs associated to such solutions in order to define the best solution. To attain this aim it is necessary that the real agents define criteria to verify the fairness or equity ([24], [25], [125], [124]) of the solutions and apply them in order to rank the devised solutions.

From an abstract perspective we can define some basic mechanisms that are involved in such solutions. The mechanisms that I was able to identify (see also the section “Preface or the genesis”) include the following:

- auction models,
- barter models,
- bargaining models.

During the year 2009, my first year of PhD course, I started to analyze such models and formalized some types of auctions and some types of iterative barter models.

For what concerns the **auctions** we developed two family of models or the

¹In what follows we use also the term **dissertation** so to show off a richer lexicon.

²In the dissertation I use the pronoun “I” (and its variants) whenever I want to stress something really personal otherwise I use the impersonal form “we” with its variants.

³In these introductory sections we use some terms without providing their formal definitions and essentially relying upon their common language or intuitive meanings. Formal definitions of such terms will be provided whenever and wherever they will be required.

⁴In the text we use also the term **decider** as a synonym of the term decision maker essentially for reasons of personal taste.

⁵With the term real agent we define any entity in the real world, whatever this may mean, that is able to take more or less autonomous decisions.

positive auctions family and the **negative auctions** family.

We have a **positive auction** whenever we have a certain number of bidders who voluntarily attend the auction so to submit their bids in order to get the auctioned items. According to the number of the items and the rules of the auction a certain number of bidders are declared as winners. If the auctioned items are goods the winning bidders get the single items and have to pay the proper sums for this. If the auctioned items are bads (or negative goods) the winning bidders get the single items but are compensated by the auctioneer for this.

In a **negative auction** ([33]) the bidders attend the auction because they are selected by the auctioneer. In this case we have only a bad as the auctioned item and the bidders submit their bids in order to not get it. The lowest offering bidder (the losing bidder), however, gets that item but is compensated by the other bidders (the winning bidders) for his sacrifice. The compensation is equal to the bid made by that bidder and is shared among the others in proportion to their individual bids.

In both positive and negative auctions we may have that an auction's termination depends either only on the actions of the bidders or also on some random mechanism. In the latter case we speak of candle auctions or random termination auctions, see [45] and [46].

For what concerns the **barter models** we devised essentially **iterative** models where two (bilateral barter) or more than two (multilateral barter) players interact through a succession of proposals, counterproposals and concessions in order to exchange the items from two privately owned and evaluated baskets of items. In all these cases we have no exchange of any numerary good (such as the money) among the players but only of some of the bartered items so that, at the start of each procedure, we have a certain number of baskets whose compositions change during the barter so that:

- at the end every basket may have been modified;
- as a whole the baskets are unchanged.

In this way we have that, according to the evaluation of each player, all the players may be better off at the end of a barter.

Last but not least **bargaining models** ([47], [39]) have been devised to allow a certain number of decision makers to select one project from a set of competing projects on the basis of the benefits and costs that the deciders themselves associate to each project.

These activities were carried out under the very loose and listless supervision of my first self-proposed and self-appointed tutor/supervisor and went

on until the end of 2010 when that tutor suddenly announced to me his retirement, practically without any real advance notice, and suggested me to find a new tutor with whom to carry on my thesis.

In this way I was compelled to find a new tutor and I considered myself very lucky to find a new one at the end of 2010, the current supervisor of this PhD thesis. After the change of tutor I went on with my foregoing “classic” topics until when I went into a stalemate that forced me to change my perspective and my topics, more on this in the section “Preface or the genesis”.

Such changes, anyway, can be seen as an abstraction step since I have moved my interests from particular types of interactions (auction, barter and bargaining) to more general types of interactions among players where the former models can be seen as special cases of the latter.

Basic remarks

The present thesis has no sociological or philosophical ambitions nor it aims at presenting a general model of the interactions between the individuals and the society of which they are members (see the section “Preface or the genesis”).

Its aims are somehow more limited since they can be resumed, for the most part, in the search for mechanisms that are able to attune the individual responses to some collective accomplishment ([105], page 32).

In the thesis we adopt three approaches (descriptive, normative and prescriptive, see [94]) and we move at three levels (microlevel, mesolevel and macrolevel, see [105] and [106]).

The approaches span from the less binding (descriptive) to the most binding (prescriptive).

According to a **descriptive approach** the models we present try to describe how the involved individuals behave in real situations so to predict their behaviors in such situations ([94]). In these cases we pose “what is?” questions ([94]) in order to derive answers on the ways the individuals behave in real settings.

According to a **normative approach** we wonder how the individuals ought to behave in given decision situations ([94]). In this case we have to define what we mean by both “rationality” and “rational decisions” ([94]) and how can we account for the “bounded rationality” of the individuals ([98], [21]). According to this approach we pose “what ought to be?” questions ([94]) that can be answered, in many though not all the cases, once we have established the preferences and the values of the involved individuals.

Last but not least, according to a **prescriptive approach** we bind the indi-

viduals to act in prescribed ways through the use of sanctions or penalties in case of detected violations. In this case we pose “what has to be?” or “what must be?” questions and we measure the efficacy of the answers we obtain with their compliance with the preferences and the assumed full or bounded rationality of the individuals.

For what concerns the levels we note how at the **microlevel** we consider the interactions among the individuals as independent entities acting as singletons. In this case the individuals are not seen as rational but rather they are seen as selfish, self interested and endowed with a bounded rationality ([98]) owing to time or resource constraints. In any case, at this level, we have no (either stable or instable) structure among the individuals.

At the **macrolevel** we consider the whole set of the individuals as forming a **society** and try to derive their collective behavior so to compare it with an either normatively or prescriptively intended collective behavior. If the two behaviors coincide, within an interval of tolerance and a physiologic quantity of free-riders, we may deduce that the norms or the prescriptions do not collide with the interests and values of the individuals. If they do not coincide, with the posed caveats, we must investigate if it may be better to resort to coercive tools or if it is better to modify norms and prescriptions since there is no way to align the two behaviors that is not too costly or too time consuming or both.

Last but not least, at the **mesolevel** we consider the possible presence of coalitions or groups among the individuals ([89]). We refer to chapter 5 for a full treatment of such concepts and of their relevance in our context. For the moment we focus our attention on the more classical concept of coalition.

A **coalition** ([89], [85], [40]) is any group of individuals that join together and share a common goal and interests. The players of a coalition interact with those of the other coalitions as if they were single players. Once the interaction has given rise to the definition of a solution and of the payoffs for the involved players/coalitions there is the sharing of the various payoffs among the members of each coalition. The individuals are not required to join a coalition and they do that only if they are able to find a profitable coalition otherwise they act as singletons.

A given coalition may be **stable** if its members have no incentive in leaving the coalition and the non members have no incentive in joining it otherwise it is termed **unstable**. If at the mesolevel we have coalitions this feature is reflected at the macrolevel where the society is seen as a collection of interacting coalitions and possibly singletons rather than a homogeneous set of individuals.

Assumptions and basic notations

Though we have inserted three supplementary chapters (Appendix A, Appendix B and Appendix C) with some background materials the present dissertation is by no means completely self contained but it rests on a bulk of “folk knowledge” and some concepts that belong to the common intuitive knowledge so that there is a little sense in trying to give them a formal definition of any sort. In such cases we limit ourselves to informal and colloquial definitions either within the text or through ad hoc short footnotes.

In the thesis we make use of some concepts derived from Game Theory and Negotiation Theory, among the others, but, for obvious reasons, we cannot cover such disciplines in any detail so that we use Appendix A and footnotes as reminders whenever it may prove necessary.

In any case, in this section, we make some comments on some terms that we are going to use diffusely in the thesis.

With the term **individual** we denote a generic entity that acts as a singleton, is a bearer of values and interests and may be endowed with variable levels of rationality ([98]) owing to constraints due to the availability of knowledge, time, computational and reasoning capabilities. If such constraints are fully relaxed (so that an individual has at least an imperfect knowledge in the sense of Game Theory, suffers no time bounds and has full computational capabilities) we have **rational agents** otherwise we have agents with a more bounded rationality the more such constraints are binding.

An individual is a **real agent** that inhabits models (at various levels of abstraction) of the real world (where “blood and flesh” individuals live and act) as opposed to the agents that inhabit the simulated environments that we may devise to verify our theories and predictions.

Depending on the context we may need to specialize such term as either a **player** or a **decider** or a **stakeholder**.

We use the term **player** whenever we want to stress the role of an individual in a Game Theory context of either complete or incomplete or imperfect information ([91], [89], [85], [18] and [19]) so whenever we use this term it is to be expected the use of some form of equilibrium as a collection of behaviors from which no player or no collection of players has an interest to unilaterally deviate.

We use the term **decider** as a synonym of **decision maker** whenever we want to stress the active role of an individual, its capability to select one of the available alternatives in a decision process⁶ ([59], [94], [68]) or in a

⁶As a first approximation, apart from other differences, we can say that a decision process involves only one decider whereas a negotiation process involves at least two deciders.

negotiation process ([93]).

Last but not least we use the term **stakeholder** whenever we want to stress the rather passive role of an individual. In this case such an individual has no active role in a decision process but can only suffer the decision taken by the deciders (see Figure 1) though he can get organized and exert pressures on the deciders (see Figure 1) either through voting mechanisms or through opinion and pressure movements.

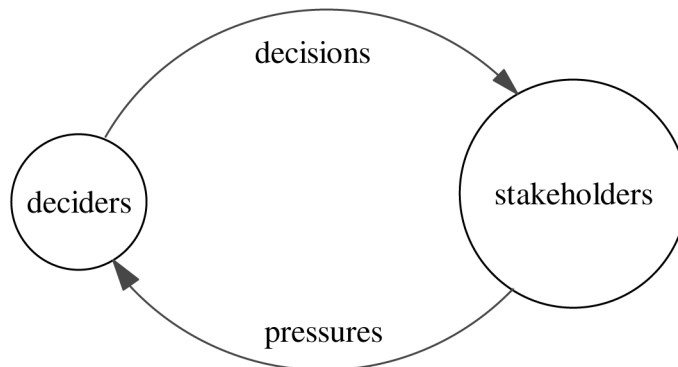


Figure 1: *Interactions between deciders and stakeholders*

We note how in Figure 1 we have used two ovals of different sizes to stress the fact that the deciders are usually less than the stakeholders than they influence with their decisions. It is obvious how in many cases both stakeholders and deciders belong to the same set of individuals (if the decisions influence also the deciders themselves) whereas in other cases they can belong to distinct sets (if the decisions do not influence the deciders themselves).

Other terms that we can use to specialize the term individual are **auctioneer**, **bidder**, **buyer**, **seller**, **producer** and **consumer** but such terms have classical meanings for which we refer to the literature (see for instance [78] and [90]) so we do not further comment on them here.

On the other hand, for what concerns **the notation** that we are going to use we underline how it is mostly of classical type so that it should not create problems of any kind nor cause any trouble of interpretation. In the thesis we are going to use preference relations represented through symbols such as \succ , \succeq or \sim (or the like) and endowed with classical (and intuitive) properties ([96]) though we are mostly interested in transitivity⁷. In many cases we perform comparisons of quantities belonging to the set of the real numbers \mathbb{R}

⁷We recall that a binary relation R on a set A is transitive if and only if for any triple of elements $a, b, c \in A$ we have that from aRb and bRc we derive aRc .

with the classical operators $>$, \geq or $=$ (or the like) whereas the comparisons of vectors in \mathbb{R}^n are performed through the use of classical concepts such as Pareto efficiency and Pareto dominance.

In all the cases where we deal with a set S we denote as $|S|$ its cardinality or the number of its elements and with I the set of the indexes of its elements where $I \subset \mathbb{N}$ is any subset of the natural numbers \mathbb{N} . As an example we can have:

$$S = \{s_i \mid i \in I\} \tag{1}$$

where $I = \{1, 2, 3, 4\}$.

Other mathematical concepts that we are going to use in the thesis will be defined, if it is believed to be necessary, through ad hoc footnotes in the due place.

Last but not least a short notice about the use of gender qualifying terms. In order to avoid the cluttering of the text with forms such as he/she or (worse) [s]he we generally use the male form but in cases where we can meaningfully alternate, as it happens, for instance, in all the cases where we have two deciders so that we can use he (and related forms) for one and she (and related forms) for the other.

The title

The title of this dissertation “Top-down and bottom-up interactions between individual and collective behaviors” contains the main keywords that characterize the thesis itself and that deserve some short comments.

Though we are going to examine in detail such keywords in the chapters of the thesis we think it is important to stress since now their relevance.

In this thesis we are concerned with how certain collective behaviors derive mainly from either a **normative** or a **prescriptive** approach. In both cases we have some **social planners** that try to guide the individual behaviors according to a **top-down approach** in order to obtain some desired collective behaviors.

On the other hand the **individuals** take their decisions on the basis of their (somehow constrained) free will and the interactions of their decisions cause the arising of collective behaviors according to a **bottom-up approach**.

The constraints that affect the individuals may be of cognitive or of economical type or of other types that we will investigate in the thesis and that affect their behavior.

The constraints that affect the individuals may be of cognitive or of economical type or of other types that we will investigate in the thesis and that affect their behavior.

We may have, for instance, a social planner that devises some rules for garbage collection and disposal but such rules may conflict with the habits or the will of the members of a society. Those members, therefore, take decisions that produce individual behaviors that conflict with the desired collective behavior.

In this case we may have, for instance, that the selected garbage collection mode fails and the garbage is either deposited in the wrong places at wrong times or is disposed of in illegal ways. If this occurs or is supposed to occur there is the need to set up a surveillance system that has costs, does not always succeed and may give rise to legal clashes.

Other examples include, but are in no way limited to:

- the institution of restricted traffic area or pedestrian roundabouts and their violation with unauthorized vehicles or with accesses through the unmonitored exit ways;
- the definition of parking area dedicated to disabled persons and their abusive use through the use of forged authorizations or misused authorizations;
- the definition of open beaches and public parks and their getting dirty from their users and the lack of cleaning possibly owing to conflicts of competences among the various public authorities.

We can imagine, therefore, to have a line of implementation from the social planners to the society of the individuals and a line of abstraction from the individual behaviors to the collective behaviors that are shown by the society. An **individual behavior** is a set of actions, decisions and choices carried out by an individual. They depend on his knowledge of his environment, his capability to remember his past and to foresee at least his immediate future. On the other hand, a **collective behavior** is the behavior showed by a set of individuals that may comprise the whole society. Usually collective behaviors produce outcomes that are concisely described through numerical values such as averages, median values, standard deviations and so on.

In the foregoing discussion we have introduced the concepts of **social planner** and of the **members** of a **society**.

The **members** of a **society** are either the individuals or the groups or both depending on the level of analysis: at the microlevel we have only interacting individuals, at the mesolevel we have both coalitions or groups of individuals and individuals as singletons (or single member coalitions) and at the macrolevel we have also more or less static structures that survive to both individuals and coalitions and define what is usually defined as **society** ([107]).

On the other hand, stated briefly and rather informally, a **social planner** is an individual who has the role of designing mechanisms that the members of a society, other individuals, should follow in order to behave in an intended way so to produce some intended effects. These effects should represent a benefit for the whole society, benefit that is shared, in various degrees, among its members.

We spoke of **social planners** since, in general, we have more than one individual with that role. These individuals produce the foregoing mechanisms through negotiation procedures so that there is no guarantee that they produce either optimal or even only unambiguous mechanisms as we are going to show, at least in part, in the rest of the thesis.

Thanks

At this point I would like to thank all the people who have helped me in writing this dissertation. They are really a small bunch of people.

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methods for the solution of partial differential equations and Marina Massei for all the times we have friendly talked on various issues and all her precious e-mails. All the rest is to be sunk in oblivion.

Preface or the genesis

This thesis derives a good part of its contents from a rather casual event: my participation to a public lecture that Professor Marco LiCalzi held at the Scuola Normale Superiore in Pisa on June 8, 2011, and whose title was “E pluribus unum? Matematica della diversità” or “From multiplicity unity. The mathematics of the diversity”. The main topics of the lecture were the often unpredictable, counterintuitive and unwanted relations between individual behaviors and collective outcomes.

Such relations were presented through a certain number of paradoxical case studies that showed how the individuals may even be guided by sound principles but from their interactions may derive an outcome that is worse off for each of them than the one they could obtain by taking other and apparently worse decisions, at least for some of them.

At that time I was struggling with what was the intended topic of my PhD thesis and so auction models ([43], [42], [31], [33], [45], [46]), barter models ([44], [41]) and bargaining models ([47], [39]) but I was trapped in a stalemate with no clear ideas neither on the real novelty and relevance of my approaches nor on the possibility to use on my models the simulation techniques based on the use of multiagent system according to the guidelines laid down by Axelrod in his seminal works [12] and [13].

During the lecture Professor LiCalzi spoke briefly about also the book of Thomas C. Schelling “Micromotives and Macrobehavior” ([105]) and the book of J.L. Mackie “Ethics. Inventing Right and Wrong” ([79]) and in this way he was able to solve my stalemate by giving me a completely new (at least for me) set of topics and ideas on which I could have grounded my PhD thesis.

Of course not everything happened during that lecture neither immediately after it but anyway the seeds had been planted and, at the right time, they were able to sprout and produce the fruits that have been collected in the chapters of this thesis.

The first fruits ripened with my reading of the book “Micromotives and Macrobehavior”, together with a paper of the same author entitled “Ethics, Law, and the Exercise of Self-Command” ([106]).

By reading them I became aware of the conflicts between individual behaviors and collective outcomes (that, in their turn, affect and influence the individuals and their behaviors) and I started pondering how it could be possible to attain a convergence between the interests of the individuals and those of the society of which they are members without resorting to coercive and punitive tools and so to minimize the presence of the so called “free riders” or those individuals that get some benefits without paying the associated costs.

It is obvious, indeed, that such tools have costs in order to be implemented and maintained. Such costs must be borne by all the members in different degrees and, moreover, can intervene only ex-post when a violation has occurred and has been detected with further costs.

We have to note, moreover, how an excessive use of coercive and punitive tools may make subtler (and so harder to detect) the ways through which the individuals act as free riders and may even give rise also to collusive coalitions among them and among those individuals who, instead, should detect and punish the violations.

Other fruits ripened from the reading of the book of J.L. Mackie as well as of the book of Torbjörn Tännsjö “Understanding Ethics: An Introduction to Moral Theory” ([111]). Maybe such fruits do not represent a real novelty in the panorama of the social and moral sciences but for me they represented a real epiphany, as an oasis in the desert for a thirsty pilgrim.

From their reading I started to think about the possibilities for an ethics to pose soft constraints on the individual actions in order to convince the individuals to pursue the collective interest as a source of utility higher than the pursuing of each one’s individual (or selfish) interest.

Obviously this section is not the right place where we can state the answers to all these problems. The answers, if there are any, are scattered in the chapters that follow though, in many cases, we have no clear cut or definite answer but, rather, a certain number of hints, of “rule of thumbs” through which the individual actions do not clash too much with the desired collective outcomes.

And now let me close this preface as I closed the preface of my Pisa PhD thesis as a wish of good luck: and now “rise up the hem of the skirt, my Lord, since we are going to hell”⁸.

Note about the code

This thesis contains pieces of code that has been developed both with Vensim and with NetLogo for the purposes of the research activities that have been carried out during the writing of the thesis. This code is provide as it is without any warranty neither explicit nor implicit of correctness. It can be freely used but only for research or didactic purposes and only on condition that the source is mentioned.

⁸Williams Carlos Williams, freely back translated from his preface to the Italian version of “Howl and other poems” by Allen Ginsberg.

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