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IMPLEMENTATION THEORY AND ETHICS

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1.INTRODUCTION.

Game theory and ethics- or parts of them- provide us with reasons for choosing in certain ways amongst alternative actions,outcomes,rules,or institutions . The emphasis of game theorists is on "rational" and "self-interested " choice in an interactive environment, where the relevant notion of "self-interest" is in principle amenable to a broad interpretation which does not rule out altruistic or "higher-level" preferences . On the other hand, ethical analysts dispute over,but insist upon criteria of "rightness","goodness" or "morality" of choice. All in all, the scope for potential conflict between "rational - strategic" and "ethical" prescriptions is large enough, especially when it comes to assessing basic social arrangements, institutions and rules of conduct.

In order to prevent the possibility of any such disturbing conflict between "rationality" and "morality",the most obvious -and drastic- strategy is commitment to some sort of "reductionism". Namely, a game-theoretically minded "reductionist" will typically maintain that only choices which are consistent with some appropriate solution concept as applied to the relevant game can ultimately count as morally "right" (see e.g. Binmore(1990)). A strictly related but different kind of "reductionism" obtains if one claims that the relevant "moral game" is - essentially- a game against nature (many proponents of some version of "contractarianism" advocate this approach: see e.g. Harsanyi(1955,1977a,1977b) and Rawls(1971)). Under this view, the role of strategic interaction is in turn taken over by some suitable decision-theoretic foundations ,either of the orthodox bayesian variety (e.g. Harsanyi' s argument for utilitarianism) or of a more unconventional sort (e.g. Rawls' s leximin-based second principle of justice). To be sure the utilitarian version of this contractarian approach may not be "reductionist" in a strict sense, in that it can be maintained that the plausibility of utilitarianism somehow presupposes a "moral" criterion of impartial benevolence since genuine interpersonal utility comparisons are involved in it (see e.g. Harsanyi(1977b)).In any case,under those contractarian approaches the advocated theory of individual rational choice under uncertainty-or ignorance- is defended on a purely decision-theoretic ground,with no appeal to "moral" criteria.

On the other side of the theoretical spectrum, one could also conceive of an "ethical reductionism", namely of a view maintaining that only choices which are consistent with some suitably defined criterion of "moral correctness" do qualify as fully rational . To put it in other terms, a sensible rational solution concept should accomodate the relevant "moral" considerations (that view could perhaps be ascribed to Gauthier(1986)).

Be it as it may, the reductionist approaches do not exhaust all the interesting theoretical ways to deal with concurrent ethically-oriented and game-theoretically-oriented prescriptions. As a matter of fact,a considerable amount of the current game-theoretic literature is devoted to implementation theory,which amounts to a consistency-test between performance criteria (which may well be ethically motivated) and the rational strategic behaviour of individual players and/or coalitions.

The aim of the present paper is to provide a selective survey,and a critical discussion of the relevant results in this area,which is at the interface of game theory and normative (ethical,political,economic) system evaluation.

I shall consider two kinds of normative evaluation criteria,namely i) welfarist consequentialist criteria and ii) rights-oriented (non-welfarist) criteria .

Also,I shall adopt an unconventionally broad view of implementation theory ,taking into consideration two main implementation devices, namely i) mechanism design and ii) repetition .

It will be argued that

1) Generally speaking, the typical performance criteria from the two classes mentioned above (say,efficiency and symmetry) turn out to be consistent with rational "self-interested" strategic behaviour on the part of individual players and/or coalitions. Namely,the relevant incentive constraints -perhaps unexpectedly- are not really binding with respect to the implementability of most ethically significant performance criteria: a clever mechanism design activity can,in principle,guarantee the required consistency between rational "self-interested" strategic behaviour and the prescribed performance .

To put it in other-slightly looser- terms,it turns out that incentive constraints only restrict the choice of the institutions by which one can achieve a certain systemic performance,as opposed to the choice of the implementable performance criteria themselves.

Repetition can be a partial substitute for clever mechanism design, but that only to a quite limited extent.

2) By contrast,significant restrictions on the range of implementable performance criteria do arise when rational "self-interested" strategic behaviour is coupled with further assumptions reflecting "factual" realities -such as informational decentralization and its extent- , or existing institutions (e.g. markets or bureaucracies,perhaps in a highly idealized version). These assumptions amount to implicit restrictions on the class of institutions which are taken as feasible, and (perhaps) on the admissible rational solution concepts, so that it should not come as a surprise that significant impossibility - i.e. non-implementability- results obtain.

But then it seems to be reasonable to conclude that it is just this sort of "factual" restrictions (which may well be ,at least in some cases,context-dependent or historically contingent) that precipitates this inconsistency between "ethical" performance criteria for institutions and rational "self-interested" strategic behaviour.

The conclusions will expand upon this interpretation and its consequences.

2. SOCIAL ETHICS AND PERFORMANCE CRITERIA.

As mentioned in the introduction ,we shall consider instances of both welfarist consequentialist criteria and rights-based criteria (see e.g. Sen(1987) for a thorough discussion of the main issues related to such a classification of normative evaluation criteria).

Consequentialist criteria assess the performance of the relevant system by focusing on outcomes or end-results, as opposed to the processes or procedures which bring them about (for a given convenient description of the outcome space).

Welfarist criteria assess the performance of the relevant system according to some direct welfare-indicator of the relevant social units (e.g. the individual preferences or utilities as opposed to , say,educational level ,income or health insurance).

Rights-based criteria assess the performance of the relevant system in terms of fulfillment of a certain set of individual or collective rights: e.g. the right to choose freely among options pertaining to a suitably defined "personal" sphere,the right to an equal maximal freedom, or the right to an equal a-priori voting power on matters of common concern. Rights-based criteria are perhaps best viewed as non-consequentialist in character,but they can also be given a consequentialist formulation. Also, they typically embody a kind of information on the relevant social units which is in principle publicly observable or verifiable (as opposed to welfarist criteria,which typically rely on the elicitation of some essentially private information).

The performance criteria we shall take into considerations are the following:

I) Efficiency,or Pareto Optimality (PO): the outcomes of the given system should be such that feasible changes making some player better off should only be possible at the cost of worsening the condition of someone else. This is the prototype of a consequentialist and welfarist criterion,and the core of current welfare analysis in economics and related disciplines. Efficiency is consistent with many ethical principles,including utilitarianism. To be sure,if one subscribes to the conventional bayesian expected utility theory under uncertainty and to Harsanyi's version of the contractarian "moral game" ,then it can be shown that efficiency is essentially equivalent to utilitarianism (see Harsanyi(1955)). However,it should be immediately noticed that these are no minor requirements. Moreover, it has been shown that this equivalence result does not hold if a more general skew-symmetric bilinear utility theory is used (see Fishburn,Gehrlein(1987)).

II) Individual Rationality (IR): the outcomes of the given system should be such that each player is at least as well off as she would have been by not taking part into the relevant social interaction. This is another consequentialist and welfarist criterion, which requires the specification of a "status quo" and amounts to a necessary condition for voluntariness of social interactions . Therefore, IR also expresses - in an indirect way- a minimal requirement of freedom of choice among the available options.

III) Symmetry or Anonymity Criteria (S) : this is a generic label for a class of criteria requiring the invariance of the outcomes of the relevant collective decision procedure with respect to all the permutations of the players . We shall focus on a) a symmetry requirement for simple games ,which amounts to a rights-based criterion requiring the allocation of an equal decision power to each player (this is so regardless of the power-index chosen,since virtually all the relevant power-indices reflects all symmetries of the simple games they are applied to : see Owen(1982))) and b) a symmetry requirement for economies with private goods (namely the symmetry of individual preferences with respect to any permutation of the personal bundles of goods as determined by a given allocation,which amounts to a "fairness- as-no-envy" criterion).

Thus,we are going to disregard those welfarist criteria which require interpersonal comparisons of preferences. The main reason for that is our persuasion that those criteria require a measurement and elicitation technology which is (much more sophisticated than that required by most typical non-welfarist criteria and welfarist criteria without interpersonal comparisons of preferences, and,also, are more likely to be controversial , because of the additional structure they embody (but see Harsanyi(1955,1982),Sen(1987),Roemer(1989) for more optimistic views on the feasibility and significance of interpersonal comparisons of preferences). Furthermore, most welfarist criteria with interpersonal comparisons (e. g. utilitarianism and related criteria) typically entail non-ordinal preferences while game theoretical solution concepts are, mostly, ordinal so that the corresponding implementation problem does not make sense.

3. IMPLEMENTATION THEORY.

Implementation theory is best viewed as a representation theory. It deals with the representability of performance-related objects by means of game-theoretical objects. Its main ingredients may be described as follows: the environment, the objects to be represented, a theory of rational strategic behaviour,and a suitable class of games to be used in the representation exercise.

A) The environment.

The environment -or domain- is a description of the entire class of conceivable states of the world to be taken into consideration. The choice of the relevant environment may reflect a concern for the "realism" of assumptions and/or elements of a prescriptive theory of rational behaviour (the latter most typically consisting of restrictions imposed upon admissible individual preferences) , or technical considerations of mathematical tractability. In any case,the environment typically includes a space

consisting of admissible profiles of individual characteristics (e.g. preferences,endowments,information structures,..),and is sufficiently "rich",in order to represent a reasonably large set of contingencies. These profiles of individual characteristics are then used as costitutive elements into the definition of the relevant implementing games to be described below. It is assumed that any given domain is common knowledge among the players which are part of it (we shall disregard here all the subtleties and difficulties attached to such a notion). By contrast,the (true) individual characteristics of any player are typically meant to be private information of that player,unless otherwise specified.

The environments we shall take into consideration include the following:

i) The Linear-Ordering Domain : The characteristics of each player reduce to his/her preferences on the set X of all conceivable alternatives. The preferences of each player i are represented by an arbitrary linear ordering r(i) (i.e. a total ,transitive and antisymmetric binary relation) of X. A profile of individual characteristics is therefore the assignment of a linear ordering to each player : if N is the set of the players,and L(X) the set of all linear orderings of X, a linear profile is a function r:N-->L(X). The linear domain of N and X is the set of all such profiles, to be written **L**(N,X) (a strictly related and very much studied environment,the Total Preordering Domain, obtains from the foregoing definition by deleting "antisymmetric") .

ii) The Standard Domain of Repeated-Game Components : The characteristics of each player i consist of a non-empty compact and convex set A(i) - the action space of i - and a continuous real-valued utility function u(i): $\prod$ A(i) —> $\mathbb{R}$ such that u(i)(.,a(-i)) is quasi-concave for any a(-i) $\in \prod$ a(j) . A standard repeated-game profile is an assignment ((A(i),u(i)), i $\in$ N (where N is the finite set of the players). The standard repeated-game components domain for N is the set of all such profiles, to be written G(N).

iii) The Neo-Classical Domain : The characteristics of each player amount to her endowments -a finite l-dimensional real vector with components representing the quantities of each of the l distinct private goods she controls- and preferences as defined on her own (net) consumption set X(i) (a bounded from below,closed,convex subset of $\mathbb{R}$ containing the origin). The preferences of each player i are selfish and represented by an arbitrary continuous,convex,strictly monotonic total preordering r(i) (i.e. a total transitive binary relation) defined on the set of all feasible (net) consumption assignments $\prod_i$X(i) .

A neo-classical profile of individual characteristics for a finite set N of players is then a standard neo-classical pure exchange economy e=e(N). The neo-classical domain of N is the class of all such economies, to be written $\mathcal{E}$(N) (we shall also write $\mathcal{E}$(N,$\prod$X(i)) to denote the subclass of $\mathcal{E}$(N) corresponding to a fixed assignment of (net) consumption sets or of endowments).

iv) The Bayesian Domain : The characteristics of each player consist of an information set (or type) t(i) ,a prior probability distribution q(i) defined on the set $T=\prod T(i)$ of all admissible assignments of information sets to the players, an utility function $u(i):TxX \rightarrow R$ (where X is the set of feasible outcomes ,which is assumed to be fixed across T). Those primitive characteristics induce in a natural way a parametric set of conditional preference relations $\{r(t(i)) \ / \ t(i) \in T(i)\}$ defined on the set $F(N,T,X)=\{ f \ / \ f: T \rightarrow X\}$ of social choice functions (or allocation rules) for (N,T,X) (where N denotes,as usual, the set of the players): briefly,i prefers -at t(i)- social choice function f to f' iff the (q(i),u(i))-induced expected utility of f over type assignments in T which are consistent with t(i) -i.e. the information set of i- is greater .

A Bayesian profile of individual characteristics is an assignment of such an information set,probability distribution,and utility function to each player. The Bayesian Domain of N and X is the set of all possible Bayesian profiles ,to be written $\mathcal{B}(N,X)$. Furthermore , $\mathcal{B}(N,X)$ is said to be an Economic Bayesian Domain if it also satisfies the following property (see Jackson(1991)): for any admissible profile t of information sets and any feasible allocation rule f , at least two distinct players i,j strictly prefer to f -according to r(t(i)) (r(t(j)) ,respectively) - a whole set of feasible allocation rules $\{h(S) \ / \ t \in S \subseteq T\}$ ($\{h'(S) \ / \ t \in S \subseteq T\}$,respectively) which are derived from f by the following rule: $h(S)(t')=f(t')$ if $t' \in S$,and $h(S)(t')=x \in X$ otherwise (similarly, $h'(S')(t')=f(t')$ if $t' \in S$ and $h'(S)(t')=y \in X$ otherwise). To put it in more intuitive terms,a Bayesian Domain is Economic if it admits at least one profile such that it is not the case that all the players can simultaneously be granted their most preferred feasible alternative : implicitly, resource scarcity and the possibility of conflicting preferences are assumed (these properties obtain immediately if one considers a standard domain of economies with limited resources and private goods).

B. The performance-related objects.

As mentioned above,the performance-related objects are the objects to be represented,i.e. implemented. They typically embody the relevant -ethically motivated- prescriptions,or part of them. We shall take into consideration the following objects:

i) Symmetric proper simple games : A symmetric proper simple games is a pair (N,W),where N is the set of the players and $W \subseteq \mathcal{P}(N)$ the (non-empty) set of winning coalitions,which satisfies the following restrictions : a) (monotonicity): a coalition which admits a winning subcoalition is winning; b) (properness): The complementary coalition of a winning coalition cannot possibly be winning ; c)(symmetry): Any two coalitions with the same number of players are bound to be either both winning or both losing. A symmetric proper simple game is a model of a democratic collective decision procedure,in that it embodies an equal-decision-power requirement. (The concept of a symmetric proper simple game is amenable to several interesting extensions,the most widely used among them being anonymous regular monotonic effectivity functions; libertarian constraints for collective decision

procedures as introduced by Sen(1970) can also be regarded as objects of a similar kind,namely as suitable non-neutral effectivity functions).

ii) Efficient and individually-rational social choice correspondences : A social choice correspondence for a fixed (finite) set N of players, a fixed set $\Theta' \subseteq \prod \Theta(i)$ of admissible profiles of individual characteristics for players in N (the domain) , and a fixed set X of outcomes(or alternatives) , is a function $F:\Theta' \rightarrow \mathcal{P}(X)\backslash\{\emptyset\}$ mapping profiles into non-empty sets of alternatives such that any outcome in X is uniquely selected for some profile in Θ'. Obviously,any profile $\theta \in \Theta'$ is meant to include a profile $r=r(\theta)$ of individual preferences defined on X. The social choice correspondence F is efficient (PO) iff for any profile $\theta \in \Theta'$, any alternative selected by F is Pareto-Optimal w.r.t. $r(\theta)$ (i.e. $F(\theta) \subseteq PO(r(\theta))$,where $PO(r(\theta))$ is the set of Pareto-Optimal alternatives in X , according to $r(\theta)$). Moreover, F is individually rational (IR) -w.r.t. "status quo" $x \in X$ -iff for any player $i \in N$ and any admissible profile θ of individual characteristics, F guarantees that any alternative selected at θ cannot possibly be worse than x according to her preferences $r(\theta,i)$ at θ (hence it is at least conceivable that the players are both rational and free to decide whether to take part into the relevant social interaction process or not,which in turn entails that participation may be regarded as voluntary and rational).

iii) A special class of efficient and individually-rational social choice correspondences : the Walrasian correspondences . A Walrasian correspondence for a set N of players and a set $X \subseteq R$ of feasible net allocations is a social choice correspondence $W:\mathcal{S}(N,X) \rightarrow \mathcal{P}(X)\backslash\{\emptyset\}$ defined on the neo-classical domain and such that for any economy $e \in \mathcal{S}(N,X)$ with preference profile $r=r(e)$,an allocation is selected by W -i.e. $x \in W(e)$ - if and only if an h-dimensional price vector $p \in R$, $p \neq 0$ exists at which it turns out that for any player i there is not another net allocation y which is both compatible with her budget constraint as induced by p (i.e. $py(i) \leq 0$) and strictly preferred than x according to her prevailing preferences r(i) (i.e. $(y,x) \in r(i)$ and $(x,y) \notin r(i)$) . If the weaker claim is made that $x \in W(e)$ if and only if an h-dimensional price vector $p \in R$,$p \neq 0$ exists at which for any player i there is not another net allocation y which is strictly preferred to x, and compatible both with her budget constraint as induced by p and with the total amount of feasible resources of the economy e , then W is a constrained Walrasian correspondence. Of course, $W(e) \neq \emptyset$ at any $e \in \mathcal{S}(N,X)$ follows from standard Walrasian equilibrium existence theorems ,so that W is in fact a well-defined social choice correspondence . It is well-known that W -in both versions- is efficient and individually-rational (the "status quo" is,of course,the initial endowment) . Also,it satisfies a conditional symmetry property - sometimes called "equal treatment"- (i.e. at any Walrasian allocation any two players having the same characteristics get the same individual allocation), and the well-known "non-biasedness" condition to the effect that any strictly positive Pareto-optimal allocation of the economy $e \in \mathcal{S}(N,X)$ is a Walrasian allocation of another economy $e' \in \mathcal{S}(N,X)$ which can be obtained from e through a suitable redistribution of the endowments. This long list of appealing properties explains why W is so commonly used in economic theory as a benchmark to assess the performance of a given economic system. More often than not, W is also assumed to be a good model of the behaviour of an economic system as coordinated through perfectly competitive markets: this is,however, a highly questionable contention ,in any standard environment with a finite number of players (of course, I am implicitly assuming here that a definition of "perfect competition" which allows for a finite number of players is both desirable and feasible).

iv) "Fair" and efficient social choice correspondences : Several notion of "fairness" have been proposed following the pioneering definition of "fairness as no-envy" due to Foley. The common aim of those "fairness" criteria consists in the attempt at introducing prescriptions related to some notion of "distributive justice" without invoking interpersonal comparisons of utility. We shall focus on (efficient) egalitarian- equivalent allocations (EEEA) for economies of the neoclassical domain with free disposal. An allocation is EEEA if it is efficient and such that for some egalitarian (possibly infeasible) allocation each player is indifferent between that allocation and the bundle of goods she receives under the allocation under consideration (see Pazner,Schmeidler(1978),Suzumura(1983), Thomson,Varian(1985)).

v) Sets of (ex-ante ,interim, or ex-post) efficient and individually-rational social choice functions: A social choice function is a single-valued social choice correspondence (see the definition above,under point ii). The ex-ante,interim and ex-post qualifiers for efficiency (and,possibly,for individual rationality with the "no trade" constant allocation rule as the "status quo") typically apply when a Bayesian Domain (see A.iv above) is considered. Those qualifiers refer to the amount of private information which is embodied in the relevant profile of individual preferences over alternative social choice functions. Namely, "ex-ante" refers to such individual preferences when the players disregard any private information they possibly have about their own "true" type; "interim" refers to individual preferences which are conditional on the private information of players who (privately) know their own type; "ex-post" refers to the individual preferences of players who know the "true" profile of types , and reduce ,therefore, to individual preferences over outcomes. Sets of social choice functions are the natural object to be implemented whenever a Bayesian Domain is considered, because the relevant alternatives in such an incomplete information environment are state-contingent allocations (hence social choice functions) ,as opposed to fixed allocations or outcomes. Thus, sets of social choice functions are the Bayesian counterpart of social choice correspondences as defined on other domains.

Of course one can extend both the Walrasian correspondence and the constrained Walrasian correspondence to a Bayesian Domain. If the emphasis is on "ex-ante"-preferences then the (constrained) Arrow-Debreu equilibrium-allocation correspondence for state-contingent commodities is the "right" version of the (constrained) Walrasian correspondence W . By contrast,if "interim" preferences are taken into consideration,then a suitable rational expectations (Walrasian) equilibrium correspondence is the "right" extension of W.

vi) Binary (or"rationalizable") social choice rules : A social choice rule for a set N of players, a set X of alternatives, and an environment Θ (i.e. a set of admissible profiles of individual characteristics) is a function $\mathcal{J}: \Theta \dashrightarrow \mathcal{C}(X)$ mapping profiles into the set of choice functions on X . A choice function on X is a function $C:D \dashrightarrow \mathcal{P}(X)$ (where $D \subseteq \mathcal{P}(X)$,$\{\emptyset\} \neq D \neq \emptyset$ is the set of admissible agendas,or issues) which satisfies a) $C(Y)=\emptyset$ only if $Y=\emptyset$,and b) for any $Y \in D$, $C(Y) \subseteq Y$.

It should be noticed that a social choice rule $\mathcal{J}$ determines in a natural way a family $\{\mathcal{J}(Y) \ / \ Y \in D(C)$ for some $C \in \mathcal{J}(\Theta)\}$ of social choice correspondences (see the definition above),where for any such Y,and for any profile $\theta \in \Theta$, $(\mathcal{J}(Y))(\theta)=(\mathcal{J}(\theta))(Y)$.

Therefore, efficiency and individual rationality of a social choice rule $\mathcal{J}$ are easily definable as equivalent to the efficiency and individual rationality of any social choice correspondence determined by $\mathcal{J}$.

A choice function $C:D \dashrightarrow \mathcal{P}(X)$ is said to be binary (fully binary) if a binary relation (a total preordering) $R \subseteq X\mathrm{x}X$ exists such that for any issue $Y \in D$ $C(Y)=\mathrm{Max}(R \cap Y\mathrm{x}Y)$,i.e. C may be "rationalized" as the selection of R-maxima from any admissible set of feasible alternatives. A social choice rule $\mathcal{J}: \Theta \dashrightarrow \mathcal{C}(X)$ is binary(fully binary) if, for any $\theta \in \Theta$, $\mathcal{J}(\theta)$ is binary (fully binary).

Binary social choice rules arise in a natural way when the matter of concern is the capability of a collective decision method to produce a "consistent" pattern of choice across different issues. In fact,"consistency" of collective choices is a sensible requirement if a pathological amount of strategic agenda manipulation is to be prevented (otherwise it could well be the case that the focus of strategic interaction is the description of the feasible set of alternatives,i.e. the agenda formation process,an aspect which is typically taken as exogenous in most relevant models). Unfortunately,if other restrictions -such as efficiency and symmetry- are imposed on the decision method ,then impossibility results may obtain (an exhaustive discussion of symmetry properties in a social choice-theoretic setting is provided by Campbell,Fishburn(1980)). The celebrated Arrow's impossibility theorem (Arrow(1963)) for efficient,nondictatorial and independent social welfare functions is the best known case in point (a social welfare function is a fully binary social choice rule $\mathcal{J}$ defined on the total preordering domain-or on the linear ordering domain- such that for any $\theta \in \Theta$, $D(\mathcal{J}(\theta))=\mathcal{P}(X)$,i.e. with no nontrivial agenda formation rule; a social welfare function $\mathcal{J}$ is independent iff it is locally determined by the preference profile as restricted to the feasible set of alternatives,namely $(\mathcal{J}(\theta))(Y)=(\mathcal{J}(\theta'))(Y)$ ' for any $\theta,\theta' \in \Theta$ and any $Y \subseteq X$ such that $\theta(i) \cap (Y\mathrm{x}Y)= \theta'(i) \cap (Y\mathrm{x}Y)$ for each player $i \in N$).

Two remarks on the foregoing sample list of performance-related objects are in order.

First,it should be noticed that a sharp distinction can be drawn between symmetric proper simple games (and related notions) and the other objects considered above. In fact ,the former class of objects is defined with respect to a set of players ,without any reference to spaces of individual characteristics. By contrast, all the other objects of our list do refer to such spaces. This distinction can be sensibly summarized by defining the objects of the first class as pure rights-based objects,i.e. objects embodying (only) rights-based performance criteria. On the contrary,the other objects may embody welfarist performance criteria,and definitely represent criteria of a consequentialist kind.

Second, proper simple games (and related notions) can be attached in a natural way to objects from the other classes listed above (e.g. a proper simple game is defined out of a social choice correspondence by defining as winning the coalitions that can force -at any profile-the choice of whatever alternative they agree upon,by means of a suitable coordination of their members' behaviour: see Peleg(1978)) . As a result, symmetric proper simple games and similar rights-based objects can be related in a natural way to welfarist objects. This makes it easier to combine several performance criteria of a different nature into the same implementation test.

C. Theories of rational strategic behaviour.

That is where game theory enters. As models of strategic interaction,games come in a large variety of formats. The most relevant to the ensuing analysis are the following .

a) Abstract Games. These are the simplest conceivable game-theoretical model ,reducing to a binary relation - or 1-digraph- (X,R) , where X is the set of states and $R \subseteq X x X$ is a "dominance" relation summarizing the relative "strenght" of support for the alternatives as a result of the power and the preferences of the players. It should be noticed that abstract games can be attached in a natural way to virtually any game-theoretic construct.

b) Coalitional Form Games. A game in coalitional form is an array $g=(N,X,v,r)$, where N is the set of players, X is the sey of feasible outcomes , $v:D \subseteq \mathcal{P}(N) \dashrightarrow \mathcal{P}(X)$ is a function attaching to any admissible coalition of players $T \in D$ the set of outcomes it can obtain by a suitable coordination of its members' behaviour, and r is a profile of individual preferences defined on X . In particular,if the grand coalition N is the only admissible coalition ,then we shall refer to g as a grand coalitional game: hence , a grand coalitional game reduces to a triple (N,X,r). Again, it should be noticed that coalitional form games can be attached in a natural way to most game-theoretical models (except for abstract games). Also, coalitional game forms obtain from coalitional games by omitting the preference profile.

c) Strategic and Normal Form Games. A game in strategic form $g=(N, (S(i))i \in N, X, h, r)$ consists of a set N of players ,an assignment $((S(i))i \in N$ of sets of strategies to players, an outcome space X, an outcome function $h:\prod S(i) \dashrightarrow X$ attaching an outcome to any strategy profile,and a profile $r=(r(i))i \in N$ of individual binary preference relations on X (they are typically assumed to be representable orderings so that a suitable profile $u=(u(i))i \in N$ of real-valued utility functions on X is usually substituted for r) . Of course, a preference profile r' (an utility profile u') is induced by r (u)

and h on the set $S=\prod S(i)$ of strategy profiles . If one take the profile r' (or u') as a primitive,ignoring the outcome space X,outcome function h,and profile r (or u) which give rise to it, then a normal form game obtains. Generally speaking a game in normal form $g=(N,(S(i))i \in N, u)$ consists of a set of players, an assignment of strategy sets to players ,and a preference (or utility) profile defined on the set of strategy profiles. Pseudogames in strategic or normal form obtain whenever the strategic possibilities of each player are not explicitly specified - i.e. if the list $(S(i))i \in N$ of strategy sets is replaced with a single set S of alternatives- or strategy profiles- (which may not be a cartesian product of sets). Obviously,pseudogames generalize games (any game is,up to a natural bijection, a pseudogame,while the converse does not necessarily hold).

d)(Perfect Information) Extensive Form Games . A game in extensive form models interactive decision problems with a sequential structure. Moreover,perfect information obtains whenever at any point the player who has to choose her move knows -and recalls- all the previous moves of the players in the present play. Thus, an extensive game of perfect information reduces to $g=(N, T, (P(i))i \in N, r)$, where N is the set of players , $T=(X,\mathcal{A})$ is a rooted tree (the decision tree, with nodes $x \in X$ representing move positions and arcs $a \in \mathcal{A} \subseteq X x X$ representing alternative moves which are feasible at the move position attached to their starting nodes; the root is the initial move position , while the nodes which are not starting points of any arc of T constitute the set $Z \subseteq X$ of final nodes or outcomes), $(P(i))i \in N$ is a partition of $X \backslash Z$ (the set of nontrivial move positions) among the players -which establishes who has to move when- , $r=(r(i))i \in N$ is a profile of individual binary preference relations defined on Z (usually they are assumed to be suitably representable orderings so that r can be replaced by an utility profile u). A set of pure (mixed) behavioural strategies can be defined for each player i. It consists of functions mapping each of i's move positions into a move starting from that position (to a probability distribution over moves starting from that position): if mixed behavioural strategies are allowed ,then the utility functions have to be extended to lotteries on Z . Moreover,a rooted subtree of T with root x is attached to any node x of the decision tree of g. The extensive form game $g'(x)$ which obtains when restricting g to any such subtree is a subgame of g . Extensive form pseudogames can also be defined along the same lines as normal and strategic pseudogames (see point b above). General extensive form games are obtained by specifying the chance moves,the information sets of the players and a suitable partition of their possible choices into moves (the behavioral strategies are accordingly defined as functions mapping information sets into moves).

Theories of rational strategic behaviour -or solution concepts- refer to classes of games. They prescribe the rationally admissible solutions of games in a certain class (obviously,they also predict the possible outcomes of such games if the players are fully rational in the relevant sense). However,a theory of strategic rationality may fail on certain games of its domain, giving rise to an empty set of solutions: we shall call it partial in that case and complete otherwise. There are many available theories of rational strategic behaviour,though some theories are more popular than others. This plurality of theories

reflects both differences among various game-theoretical formats and substantial disagreements.
We shall focus on the following theories:

a) Von Neumann-Morgenstern Stable Sets and Related Solution Concepts. This is a theory of rational strategic behaviour which is defined on the class Γ of abstract games. A von Neumann-Morgenstern (henceforth VNM) stable set of an abstract game $g=(X,R) \in \Gamma$ is a set of states $Y \subseteq X$ satisfying the following requirements:

ai) (internal stability): for any $x,y \in Y$, $(x,y) \notin R$ (two states of a stable set cannot be related by dominance);

aii)(external stability): for any $x \notin Y$, a $y \in Y$ exists such that $(y,x) \in R$ (any state outside a stable set must be dominated by some state of this stable set).

The VNM-solution attaches to any abstract game g the collection VNM(g) of its VNM stable sets (a VNM-selection VNM* attaches to any abstract game g at most one of its VNM stable sets,denoted-if it exists- by VNM*(g)). It is well-known that any strictly acyclic abstract game (X,R) admits exactly one VNM-stable set ((X,R) is strictly acyclic iff $R(k)=\emptyset$ for some positive integer k,where R(k) is the k-th composition of R with itself)): hence the VNM solution is a complete theory for the class of strictly acyclic abstract games, coinciding thereupon with its unique VNM selection.

Both refinements and extensions of VNM-stable sets have been proposed. Strictly stable sets (see Harsanyi(1974)) are sets of states $Y \subseteq X$ satisfying external stability and a strenghtened version of ai), namely

ai') (strict internal stability) : for any $x,y \in Y$, $(x,y) \notin \bigcup R(k)$.

Quasi-stable sets (or subsolutions ,according to the original terminology of Roth(1976)) are sets of states $Y \subseteq X$ satisfying internal stability and

aii') (self-protective maximality) : for any $x \in X$, $x \in Y$ iff for any $z \in X$,$(z,x) \in R$ entails (y,z) for some $y \in Y$.

b) Core . This is another theory of rational strategic behaviour which refers to the entire class of abstract games . The core of an abstract game $g=(X,R)$ is the set of R-maximal states. Of course, strict acyclicity of g (see the definition above) is sufficient to guarantee that $Core(g) \neq \emptyset$. Other,weaker, sufficient conditions to ensure a nonempty core are also known.

c) Nash Equilibrium . This is a noncooperative theory of rational strategic behaviour (i.e. it implicitly refers to games which do not allow for binding agreements). Hence its ultimate aim is to identify the class of self-enforcing agreements. It can be referred both to the class Γ' of normal form games (including ,up to isomorphisms,the class of strategic form games),and to the class $\Gamma*$ of (perfect information) extensive form games.

For any normal (extensive) game g with preference profile r , a strategy profile (a behavioural strategy

profile) $s=(s(i))i \in N$ is a Nash equilibrium if and only if for any player $i \in N$ and any $s'(i) \in S(i)$ $(s,s/s'(i)) \in r(i)$.

A similar definition applies to games induced by the profiles of a Bayesian domain(see the definition above). In that case, a Nash equilibrium is sometimes referred to as a Bayesian (Nash) equilibrium.

The Nash equilibrium theory of a certain class $\mathcal{G}$ of games attaches to any game $g \in \mathcal{G}$ the set NE(g) of its Nash equilibria. Nash equilibrium theory is a complete theory for several large classes of games,including the standard domain of repeated-game components (see the definition above,and Nash(1951)).

d) Refinements of Nash Equilibrium. It is well-known that for certain games some Nash equilibria entail an unreasonable choice of strategy on the part of some players: for example,some Nash equilibria of certain normal and extensive games are weakly dominated (a player can do better and cannot do worse by changing her strategy,whatever the reactions of the other players), other Nash equilibria of certain extensive games involve non-credible (i.e. self-damaging) threats . A refinement of Nash equilibrium is a theory of rational strategic behaviour which is aimed at a systematic elimination of any such unreasonable equilibrium while retaining the nice existence properties of Nash equilibrium (hence selecting a suitable non-empty subset of Nash equilibria for every relevant game). Two general principles seem to be essential to any such attempt at defining a good refinement of Nash equilibrium. Those are the "backward induction principle" (an agreement is self-enforcing only if it is consistent with deductions about the present behaviour of rational players,which are based on their predictable future rational behaviour) and the "forward induction principle" (an agreement is self-enforcing only if it is consistent with deductions about the future behaviour of rational players,which are based on their past rational behaviour) . The weakest refinement of Nash equilibrium for extensive form games are subgame perfect equilibria : Nash equilibria which induce a Nash equilibrium on any subgame of the given game. This is perhaps the most obvious example of a refinement which is tailored to satisfy the backward induction principle. (If, moreover, a suitable "internal consistency" is imposed upon subgame perfect equilibria of repeated games to the effect that a continuation strategy profile which is Pareto-dominated by another one is ruled out as non-credible, then a further refinement obtains,namely renegotiation-proof equilibrium :see Van Damme(1987),Farrell,Maskin(1989)).

It turns out that the backward and the forward induction principles are not easy to reconcile with each other. As a matter of fact ,most proposed refinements (including subgame perfect equilibrium, sequential equilibrium , and trembling-hand perfect equilibrium) are somehow tilted towards the "backward induction principle" and thus tend to perform quite poorly with respect to the "forward induction principle" (we refer to Van Damme (1987) or Kohlberg(1990) for excellent and comprehensive surveys of the entire topic).Currently,the best compromise between the two principles is the notion of stable sets of equilibria , a solution concept due to Kohlberg and Mertens(see Kohlberg,Mertens(1986),Van Damme (1987),Mertens(1988), Kohlberg(1990), Hillas(1990)). A stable set of equilibria of a normal or extensive game g is a closed set s(g) of Nash equilibria of g which is minimal with respect to the following property : for each suitably defined "perturbation" of the reduced normal form of g a Nash equilibrium of g exists which is arbitrarily close to $s(g)$ (the reduced normal form of a game g is the game which obtains after deleting from the normal form of g all the strategies which are duplicates or mixed combinations of other strategies). Stable sets of equilibria exist for any game of the standard domain of repeated-game components as defined above(see Kohlberg,Mertens(1986),Mertens(1988),Hillas(1990)).

e) Coalitional Nash Equilibrium. This is a theory of rational strategic behaviour which implicitly assumes a high potential for coordination as made possible by unlimited communication among the players (this solution concept was first introduced in Aumann(1959)) . A coalitional (or strong) Nash equilibrium of a normal game $g=(N,(S(i))i \in N,r)$ is a strategy profile $s=(s(1),..,s(n))$ such that for any coalition $T \subseteq N$ and any strategy profile s' with $s'(i) \neq s(i)$ iff $i \in T$: $(s',s) \in r(j)$ for some $j \in T$ (the definition can be extended to strategic and extensive form games).

The main problems with coalitional Nash equilibrium are,arguably, a certain lack of internal consistency (why coalitional deviations which are vulnerable to further deviations by some subcoalition should be taken into consideration?) and ,above all, the stringent conditions which are needed in order to ensure its existence (see e.g. Ichiishi(1982)). Thus, coalitional Nash equilibrium is at best a very partial theory of rational strategic behaviour. On the other hand, coalitional Nash equilibria enjoy a very nice property in that their outcomes are,by definition, Pareto-optimal . In the social choice theoretic literature a refinement of coalitional Nash equilibrium - called exact coalitional Nash equilibrium - is sometimes used when analysing revelation games in strategic form (i.e. games with strategy sets consisting of spaces of admissible individual characteristics). Namely,a coalitional Nash equilibrium r' of a game g with (true) preference profile $r=r(\theta)$ and outcome function h is exact if $h(r)=h(r')$ (see e.g. Peleg(1984),Holzman(1986b)).

D. The implementing games.

We shall take into considerations three main classes of implementing games,namely i) the games induced by a game form (for a given environment); ii) the games of a "social situation" ; iii) the repeated-games having games in the standard domain (see the definition above) as constituent games. Both i) and ii) pertain to "implementation through mechanism design", while iii) gives rise to "implementation through repetition".

i) The games induced by a game form and an environment.

Game forms model institutions ,i.e. rules for strategic interaction. Namely,a (strategic) game form for a set N of players and a set X of outcomes consists of an array $G=(N,(S(i))i \in N,X,h)$ where $S(i)$ is the

set of strategies of player i, and $h:\prod S(i) \rightarrow X$ is the outcome function (if the list $(S(i))i \in N$ is replaced by a single set S then G is a strategic quasi-game form). Normal game forms -quasi-game forms ,respectively- can also be defined in a natural way as an array $G=(N,(S(i))i \in N)$ ($G=(N,S)$ respectively).

Thus,a game form is a sort of game "without preferences". It represents a scheme of strategic interaction whose specification is independent of any information about (essentially) private individual characteristics: it can work for any profile of such characteristics. In fact,for any given environment Θ and any profile $\theta \in \Theta$, a game in strategic form $g=(G,\theta)$ can be attached in a natural way to G (this is the game induced by G on θ).

ii) The games of a "social situation" .

"Social situations" are a model of strategic interaction recently introduced by Greenberg(1990). A social situation is a set of grand coalitional games endowed with a set of game-specific admissible inputs (consisting of a proposed outcome and an "active" coalition) and a nondeterministic dynamics -called the "inducement correspondence"- which maps admissible game-inputs pairs into sets of games (the grand coalitional games which are reachable from the given grand coalitional game by a move of the input-specified coalition when the input-specified outcome is proposed). Namely, a social situation is a pair $\mathcal{J}=(\Gamma,d)$ where Γ is a class of grand coalitional games ,and d a correspondence mapping each triple (g,x,T) such that $g \in \Gamma$, $x \in X=X(g),T \subseteq N=N(g)$, into a set $d(g,T,x) \subseteq \Gamma$ of grand coalitional games. Notice that the games in Γ may have distinct sets of players. A social situation-form is a "social situation without preferences" i.e. it is a pair $\mathcal{S}=(G,d')$ where G is a class of grand coalitional game forms (including a grand coalitional game form consisting of the $\subseteq$-greatest player set in G and the $\subseteq$-greatest alternative set in G) and d' a nondeterministic dynamics defined along the same lines of the dynamics of a social situation (provided that Γ' is substituted for Γ). A social situation-procedure for a set of alternatives Y is a social situation-form $\mathcal{S}=(G,d')$ endowed with an outcome function $\mu:X(\Gamma) \rightarrow Y$.

If the dynamics d of a social situation $\mathcal{J}=(\Gamma,d)$ is independent of the preference profile of the relevant grand coalitional game(i.e. $d(g,,x,T)=d(g',x,T)$ for any $g,g' \in \Gamma$ such that $N(g)=N(g')$ and $X(g)=X(g')$) then the social situation $\mathcal{J}=(\Gamma,d)$ is uniquely determined by the environment $\Theta=\Theta(\Gamma)$ consisting of preference profiles of games in Γ, and the social situation form $\mathcal{S}=(\Gamma',d')$ (where $\Gamma'=\{(N,X) / (N,X,r) \in \Gamma$ for some $r \in \Theta\}$ and for any $(N,X) \in \Gamma'$ and $r \in \Theta(\Gamma)$ $d'((N,X),x,T)=d((N,X,r),x,T)$ if (x,T) is an (N,X,r)-admissible input for d, and undefined otherwise; such an $\mathcal{S}$ will be referred to as a situation-form for (N,X)).

It should be noticed that an abstract game $g(\mathcal{J})=(\mathfrak{S}(\mathcal{J}),\mathfrak{R}(\mathcal{J}))$ can be attached in a natural way to any social situation $\mathcal{J}=(\Gamma,d)$ by the following definitions : $\mathfrak{S}(\mathcal{J})=\{ (g,x) / g \in \Gamma , x \in X(g) \}$, and for any $(g,x),(g',x') \in \mathfrak{S}(\mathcal{J})$ $((g,x),(g',x')) \in \mathfrak{R}(\mathcal{J})$ if and only if $g' \in d(g,x,T)$ for some $T \subset N(g)$ and for any $i \in T$ $u(i)(g')(x') > u(i)(g)(x)$ (where $u(i)(g)$ and $u(i)(g')$ are utility functions representing the preference relations $r(i)$, $r'(i)$ of i in g and g',respectively) . As a result, the solution concepts defined for abstract games (see points C-a,b above) apply to social situations as well.

iii) Repeated games .

Many interactive decision problems tend to persist, and occur repeatedly over time. Repeated games are models of such interactive phenomena. Let $g=(N,(S(i))i \in N,u)$ be a standard constituent normal form game (see the relevant definition under point A-b above) . There are several kinds of repetitions of g one may conceive of ,depending on the number of repetitions to be considered (finite or infinite), the criteria by which the players are assumed to evaluate alternative sequences of outcomes,and the information about previous plays of the constituent (or stage) game the players have access to at any round We shall focus on models assuming -at any round- perfect information of the players about previous plays of the stage game.

The most widely used (perfect information) models include the following :

a) Infinitely repeated undiscounted games with the liminf-average payoff criterion. This kind of repetition amounts to assuming that the players are perfectly far-sighted in that they do not discount the future being only interested in the long-run average payoffs . Thus,in a sense they act as if they were eternal,an extreme assumption indeed. Namely,the preferences $R(i)=R(i)(LA)$ of a player $i \in N$ over sequences of payoffs $\langle u(i,t)\rangle,\langle u'(i,t)\rangle$, $t=1,..,\infty$ are defined by the following rule :

$$(\langle u(i,t)\rangle,\langle u'(i,t)\rangle) \in R(i) \text{ iff } \underset{T\to\infty}{\liminf}\Big(\sum_t u(i,t)\Big)/T \geq \underset{T\to\infty}{\liminf}\Big(\sum_t u'(i,t)\Big)/T \quad ,$$

where $\underset{T\to\infty}{\liminf}\big(\sum_t u(i,t)\big)/T=\sup_T \inf_{K\geq T}\big(\sum_t u(i,t)\big)/K$ (we recall that the use of liminf as opposed to the limit average payoff is due to the fact that the former is a well-defined finite real number,which may not be the case for the latter) .

The strategies of a player i in the repeated game of a standard constituent game g can be defined as functions $\sigma(i) \in \Sigma(i)$ mapping each possible finite history (or finite sequence of action profiles of g) into actions of i . Any strategy profile of the repeated game induces in an obvious way a sequence of time-indexed utilities or payoffs for each player. Thus, the preferences $R(i)$,$i \in N$ can be extended in a natural way to the strategy profiles giving rise to a normal (repeated) game that we shall denote -with a slight abuse of notation- by $g(\infty,LA)=(N,(\Sigma(i))i \in N, (R(i))i \in N)$.

The set of all infinitely repeated undiscounted games with the liminf-average payoff criterion - which have their constituent game in the standard domain $\mathbb{R}G(N)$ defined above- is denoted by $\Gamma(\infty,LA)$.

b) Infinitely repeated undiscounted games with the "overtaking" payoff criterion. This kind of repetition is meant to put a remedy on the most unrealistic feature of the liminf criterion model : in fact,under the latter criterion nothing happening in a finite time can really matter. By contrast,differences among finite subsequences of outcomes are taken into account by the "overtaking"-criterion induced preferences $R(i)=R(i)(OT)$, $i \in N$,defined as follows:

for any player $i \in N$ and any pair of utility sequences $\langle u(i,t)\rangle,\langle u'(i,t)\rangle$, $t=1,..,\infty$

$$(\langle u(i,t)\rangle,\langle u'(i,t)\rangle) \in R(i) \text{ iff } \underset{T\to\infty}{\liminf}\Big(\sum_t (u(i,t) - u'(i,t)\Big) \geq 0 \ .$$

An infinitely repeated undiscounted game with the "overtaking" criterion - having g as constituent game - is defined along the same lines as mentioned above under point a), and denoted by $g(\infty,OT)$.The set of all infinitely repeated undiscounted games with the "overtaking" payoff criterion- which have their constituent game in the standard domain $\mathbb{R}G(N)$ defined above - is denoted by $\Gamma(\infty,OT)$.

c) Infinitely repeated games with the discounted average payoff criterion. This kind of repetition models either i) players who discount time (at a constant rate δ) i.e. attach less importance to utilities accruing at later dates in the future or ii) players who are engaged in a finitely repeated game but are uncertain about the exact number of repetitions to occur, and attach -at any time- a common probability δ to the event that a further round takes place . Thus, the relevant preferences $R(i)=R(i)(\delta)$, $i \in N$ are defined as follows : for any player $i \in N$ and any pair of utility sequences $\langle u(i,t)\rangle,\langle u'(i,t)\rangle$,$t=1,..,\infty$

$$(\langle u(i,t)\rangle,\langle u'(i,t)\rangle) \in R(i) \text{ iff } (1-\delta)\sum_t \delta^t u(i,t) \geq (1-\delta)\sum_t \delta^t u'(i,t) \ .$$

An infinitely repeated δ-discounted game with constituent game g is defined along the same lines as mentioned above under point a), and is denoted by $g(\infty,\delta)$. The set of all infinitely repeated δ-discounted games with the (discounted) average payoff criterion -which have their constituent game in the standard domain $\mathbb{R}G(N)$ defined above - is denoted by $\Gamma(\infty,\delta)$.

d) Finitely repeated undiscounted games with the average -or total- payoff criterion. Those games model players who do not discount the future and are engaged in a finitely repeated game such that the number T of repetitions is common knowledge. The relevant preferences $R(i)=R(i)(T)$,$i \in N$ are defined as follows: for any player $i \in N$,and any pair $\langle u(i,t)\rangle,\langle u'(i,t)\rangle$,$t=1,..,\infty$ of utility sequences

$$(\langle u(i,t)\rangle,\langle u'(i,t)\rangle) \in R(i) \text{ iff } \sum_t u(i,t) \geq \sum_t u'(i,t)$$

(obviously, the preferences induced by the average payoff criterion are exactly the same).

A T-repeated undiscounted game with constituent game g is defined along the same lines as mentioned above under point a), and is denoted by $g(T)$. The set of all such games -with constituent game in the standard domain $\mathbb{R}G(N)$ defined above- is denoted by $\Gamma(T)$.

We are now ready to describe a general implementation problem .

Let F be a social choice correspondence for a set N of players and a set X of alternatives,defined over an environment Θ. Let P be one of the performance-related objects described above under section B such that it "represents" F in a suitable sense (i.e. $P=f(F)$ for a suitably defined function f: f may be the identity function ,or the function mapping F to its simple game,or its effectivity function). Furthermore, let $\Gamma=\Gamma(\Theta)$ be the admissible class of implementing games, T a theory of rational strategic behaviour defined on Γ , $X[\Gamma] \supseteq T[\Gamma]$ the class of T-relevant solution objects (e.g. strategy profiles for normal or strategic games, states or sets of states for abstract games) , and H a suitable function mapping solutions into alternatives (e.g. the function selecting the outcome induced by -or the utility profile attached to- a strategy profile of the relevant game). Then **P** is **T**-implementable on Θ by means of Γ if and only if the following triangular diagram commutes :

$$\begin{tikzcd} \Theta \arrow[rr, "F"] \arrow[dr, "T"'] & & X \\ & X[\Gamma] \arrow[ur, "H"'] & \end{tikzcd}$$

Obvious specializations of the involved objects by suitable selections from the lists presented above under sections A,B,C,D result in the typical implementation problems studied in the game-theoretic literature. (In particular, a social choice rule is implementable if all of its induced social choice correspondences are).

As mentioned above, an implementation problem amounts to a sort of conditional consistency-test between a theory of rational strategic behaviour (**T**) and a criterion of good-performance for a system of social interaction (P) . That test is conditional upon the general hypothesis that only states of the world which are consistent with Θ may obtain. Thus ,if it turns out that P is T-implementable on the environment Θ , then one may conclude that the prescriptions embodied in P and in T are consistent , as long as Θ is a good (partial) description of the state of the world.

To be sure,other -weaker- notions of implementation are available (and sometimes used in the literature). In fact,the implementation concept can be weakened by requiring that the foregoing triangular diagram commutes when some subcorrespondence $F' \subseteq F$ is substituted for F (weak implementation : this weakening of the implementation concept is mandatory if one is interested in a single-valued solution concept ; see e.g. Harsanyi,Selten(1988)),or when some supercorrespondence $F' \supseteq F$ is substituted for F (partial implementation). Also, the implementation test can be weakened by requiring that the triangular diagram introduced above commutes when some correspondence F' which is " close to F "(in a suitably defined sense) is substituted for F (virtual implementation): see Matsushima(1988) . However,each of those weakened versions of the implementation problem has clear drawbacks of its own and adds a degree of arbitrariness into the problem, resulting in a definitely less significant consistency-test.

4. SOME IMPLEMENTATION RESULTS.

This section is devoted to a sample of implementation results. Both implementation by mechanism design and by repetition are considered . The implementation theorems described below are chosen in order to make clear the following point: most limitative theorems can be turned into possibility results i)by introducing restrictions on the institutional context,as opposed to the environment (i.e. the class of admissible individual characteristics) and/or ii) by varying the assumptions about the prevailing information structures. The chosen theory of rational strategic behaviour can also be consequential in that respect, but only to a smaller extent.

4.1 . Implementation by mechanism design .

4.1.1. : Symmetric simple games and efficiency: capacity theory.

As mentioned above ,(proper) simple games can be represented in a natural way by social choice correspondences having the same set of winning coalitions (see Peleg(1978,1983)). Social choice correspondences are to be considered as a model of the behaviour of a social decision mechanism : hence efficiency and strategic robustness (i.e. existence of some solution of the relevant kind at any admissible profile) are natural restrictions to be imposed upon the admissible representations of the given simple game. The capacity of a proper simple game G - for a fixed environment Θ,and a fixed theory of rational strategic behaviour **T**- is the maximum integer number $c=c(G,\Theta,T)$ such that the following obtains : c is the cardinality of a (finite) set X s.t. for any $Y \subseteq X$ a social choice correspondence $F:\Theta \dashrightarrow \mathcal{P}(X)\setminus\{\emptyset\}$ exists which is i) efficient ii) T-implementable on Θ by means of a suitable class Γ of games, and iii) a representation of G. Moreover,the capacity $c=c(G,\Theta,T)$ is said to be infinite if such a maximum c does not exist (see Peleg(1978,1984),Holzman(1986a),Vannucci(1991a)); it should be noticed that capacities can also be defined for infinite spaces, by substituting "dimension" for "cardinality").

Thus, the capacity of a simple game G is a measure of the maximum complexity of the decision problems that a collective decision mechanism with the power structure summarized by G is able to solve whatever the preferences of the players (provided that T is correct).

Obviously ,a further restriction to symmetric proper simple games is in order whenever the fulfilment of democratic rights to an equal decision power is the main concern. In that setting,a possibility theorem amounts to the statement that the capacity of some symmetric proper simple game is infinite (for a sensible choice of the environment Θ and of the solution concept **T**).

Following the standard approach,we shall take into consideration the case Θ=the linear ordering-domain (see the definition above under 3. A. i)). As it turns out ,for most choices of T , the essential distinction for capacity theory is the one between weak and non-weak simple games (a simple game is weak if and only if it has at least one veto player). Loosely speaking, weak proper simple games happen to have unbounded capacities,whereas non-weak proper simple games don't. Namely, the following holds true:

Theorem 1. Let $G=(N,W)$ be a proper simple game , X the universal alternative space , Θ the linear ordering domain on X ,Γ a suitable class of admissible implementing games,$\mathcal{T}$ a theory of rational strategic behaviour defined on Γ,and $c(G,\Theta,\mathcal{T})$ the capacity of G on Θ w.r.t. $\mathcal{T}$. Then :

i)(Nakamura(1979)) Let Γ be the set of coalitional games having N as player set, an arbitrary subset $Y \subseteq X$ as alternative space, a linear ordering profile on Y as preference profile ,and W as its set of winning coalitions . Moreover,let $\mathcal{T}$ be the core as defined on Γ. Then, $c(G,\Theta,\mathcal{T})$ is infinite if G is weak, and bounded otherwise.

ii) (Peleg(1984),Holzman(1986a),Dutta,Sen(1991)): Let Γ be the set of strategic games induced by arbitrary social choice functions $F:\Theta(Y) \rightarrow Y$ and linear preference profiles $\theta \in \Theta(Y)$ (where $Y \subseteq X$, and $\Theta(Y)$ is the linear ordering domain on Y with N as player set). Moreover, let $\mathcal{T}$ be an arbitrary selection of coalitional Nash equilibria (or the coalitional Nash equilibrium solution concept) defined on Γ. Then $c(G,\Theta,\mathcal{T})$ is infinite if G is weak, and bounded otherwise.

iii) (Vannucci(1991b)): Let Γ be the set of grand coalitional games attached to some situation-form $S=(G,d)$ for (N,Y) (cfr. the definition above under 3.D.ii) and the corresponding linear ordering profiles defined on Y (where Y is an arbitrary subset of X). Moreover,let $\mathcal{T}=\mathcal{T}(d)$ be any selection of quasi-stable sets as defined on Γ (thus $\mathcal{T}$ may be any selection of VNM-stable sets as defined on Γ). Then $c(G,\Theta,\mathcal{T})$ is infinite if G is weak, and bounded otherwise.

In particular,the foregoing theorem holds true if G is a symmetric (proper) simple game. Also,it should be noticed that unanimity simple games are both weak and symmetric. They represent the power structure attached to decision mechanisms based on a suitable allocation of some (typically limited)veto power to every player. On the other hand,symmetric non-weak simple games typically arise from majoritarian decision mechanisms. It follows that the foregoing theorem can be regarded as a positive (non-limitative) result as far as democratic performance criteria are concerned. Their limitative implications only refers to the institutions that can be used in order to satisfy such performance criteria. In fact,an impossibility theorem obtains if-and only if- one insists that any democratic decision method (including some majoritarian mechanism) should work. It should also be mentioned that focusing on smooth representations of simple games Theorem 1 can be easily extended to finite-dimensional manifolds of alternatives,along the lines of Schofield(1985) (see also McKelvey(1990)).

The prospects get slightly worse if one shifts to Nash equilibrium . Namely, the following theorem holds true:

Theorem 2 (Ferejohn,Grether,McKelvey(1982); Vannucci(1991a)) . Let $G=(N,W)$ be a proper simple game , X the (universal) alternative space, Θ the linear ordering domain on X, Γ the set of games in strategic form induced by some strategic game form with outcome set Y at linear preference profiles on Y (where Y is an arbitrary subset of X),$\mathcal{T}$ the Nash equilibrium solution concept ,as defined on Γ,and

$c(G,\Theta,\mathcal{T})$ the capacity of G on Θ with respect to $\mathcal{T}$. Then $c(G,\Theta,\mathcal{T})$ is infinite if G is either weak and s.t. $\#N \geq 3$ or dictatorial, and bounded otherwise.

Thus,choosing Nash equilibrium as the relevant theory of rational strategic behaviour implies an additional structural limitation on the capacity of any symmetric proper simple game ,to the effect that only committees with at least three players can solve decision problems of any size by means of some democratic method (when the linear ordering domain is the predictably prevailing environment): see also the influential Maskin(1977),and Moore,Repullo(1990) for a complete solution of the Nash implementation problem ,including the 2-player case. On the other hand, it turns out that a moderate amount of refinement of the Nash equilibrium solution (either of the "backward induction" or of the "forward induction" variety) is powerful enough to produce a substantial improvement of the situation. This is summarized by the following

Theorem 3 . (Moore,Repullo(1988), Abreu,Sen(1990), Palfrey,Srivastava(1991)) . Let $G=(N,W)$ be a proper simple game , X the (universal) alternative space, and Θ the linear ordering domain defined on X . Then

i) Γ (the set of implementing games) is the set of games in extensive form induced by some extensive game form with outcome set Y on the corresponding linear ordering domain $\Theta(Y)$ (where Y is an arbitrary subset of X),and $\mathcal{T}$ is the subgame perfect equilibrium solution concept as defined on Γ imply that $c(G,\Theta,\mathcal{T})$ i.e. the capacity of G on Θ w.r.t. $\mathcal{T}$ is infinite for both weak and (some) non-weak symmetric G,provided that $\#N \geq 3$.

ii) Γ is the set of games in strategic form induced by some strategic game form with outcome set Y on the corresponding linear ordering domain $\Theta(Y)$ (where Y is an arbitrary subset of X), and $\mathcal{T}$ is the undominated Nash equilibrium solution concept imply that $c(G,\Theta,\mathcal{T})$ is infinite for both weak and (some) non-weak symmetric G .

Thus, a theory of rational strategic behaviour which is only slightly more stringent than Nash equilibrium enables even majoritarian methods - if correct- to work well on the linear ordering domain (provided that there are at least three players : with two players, a restriction to domains allowing for a universally bad outcome seems to be unavoidable : see Moore,Repullo(1988,1990)).

Generally speaking ,the price to be paid for such an improvement on theorem 2 is a further enlargement of the strategy spaces of the relevant mechanisms. That is quite definitely a cost. A more precise evaluation of that cost and of the inherent trade-offs has,however, to wait for further developments in the theory of "bounded rationality" (see e.g. Simon(1987)) and for a detailed analysis of the role of mixed strategies in implementation theory (see the observations of Jackson(1991) on this point).

As a last remark ,it is worth noticing here that -as shown in Demange(1984)- using subgame perfect equilibrium as a solution concept makes it possible to implement the efficient egalitarian equivalent correspondence on the neo-classical domain $\mathcal{S}(N)$ (see the definition above) by means of a mechanism of the divide-and-choose type with a preliminary auction for the divider-role .

4.1.2 . Symmetry and efficiency cum "consistency" : social choice rules and agenda formation.

Some "consistency" across choices from different feasible sets is usually required in social choice theory under the name of "collective rationality". This terminology is suggested by the common view of individual rational as "consistency" i.e. rationalizability of choices as (local) maxima of a binary preference relation (possibly a total preordering) plus the idea that "collective rationality" should consist in replicating such "consistency" with respect to social choices . As an argument for requiring "consistency" for social choice rules this line of reasoning is far from compelling. In fact,it is by no means obvious that the same "rationality" criteria should apply to individual and social choices; moreover, the standard view of individual rationality as "consistency"-or maximization- is coming under growing attack (see e.g. Sen(1987b),and Simon(1987)). There is,however,a much more convincing argument - with a game-theoretical flavour- to support the requirement of such a "consistency" for collective choices. Namely, "consistency" guarantees that the introduction of "suboptimal" alternatives cannot induce the choice of a previously "suboptimal" alternative nor the rejection of a previously "optimal" one (see Suzumura(1983),and Vannucci(1990)) ,and thus it prevents the occurrence of a pathological amount of agenda manipulation on the part of the players.

As a result,it is apparent that - when it comes to "consistency" of collective choice- the crucial issue is the agenda formation process. Thus,it seems to be quite natural to introduce an explicit modelling of the latter. In particular,endogenous agenda formation rules may be defined in order to determine the domain of admissible agendas of a social choice rule (the term "endogenous" refers to the dependence of the admissible agendas on the parameters of the ensuing decision game ,e.g. the number of active players). Therefore,an agenda formation rule restricts the class of admissible social choice rules by restricting the domain of the choice functions in their range.Also, an agenda formation rule and a preference profile may induce in a natural way an agenda formation game . Moreover,symmetry criteria can be easily extended to agenda formation rules .

The following result obtains :

Theorem 4 (Vannucci(1989,1990,1991a); see also Grether,Plott(1982)): For some agenda formation rules (including some symmetric ones) and some theory of rational strategic behaviour (including VNM-solution theory), at any linear ordering preference profile the induced agenda formation games are such that the ensuing admissible social choice rules turn out to be trivially "consistent" or "rationalizable" (e.g. because no admissible agenda is properly contained in another one).

In particular, the foregoing proposition holds true if the relevant social choice rule consists of implementable social choice correspondences. It follows that the implementation problem and the agenda manipulation problem can be given a simultaneous and positive solution: a suitable agenda

formation rule makes the relevant social choice rule trivially consistent (see Vannucci(1989)). Obviously,this positive results extends to capacity problems (see the paragraph above).

It goes without saying that the framework outlined above is not the most popular one. The usual approach in the social choice theoretic literature on "consistency" takes the agenda formation process as an entirely exogenous phenomenon. As a result ,the most common -and natural- model consists of social choice rules whose values are choice functions defined on the entire power set of the (universal) alternative set X. That amounts,in a sense, to requiring that the pathological cases of agenda manipulation mentioned above are to be avoided whatever the specification of the agenda formation mechanism. This is, however,an exceedingly strong requirement,as testified by Arrow's theorem and the long list of related impossibility results (see Arrow(1963),Sen(1970),Suzumura(1983)). Once again, implicit institutional constraints play a decisive role in precipitating limitative results.

4.1.3. Implementation of Walrasian (and other efficient and individually rational) correspondences by Nash Equilibrium.

Informational assumptions play a major role in implementation theory on the neo-classical domain. Since virtually any economic system of interest has some degree of informational decentralization (i.e. some amount of relevant information is private and dispersed across different players) it is only natural to assume that each player is privately informed about her own individual characteristics (e.g. preferences and endowments). However,if private information about individual endowments is assumed (so that the set of feasible allocations is not common knowledge) some strong impossibility theorems immediately result (see e.g. Hurwicz,Maskin,Postlewaite (1983)). If the feasible set is publicly known while information about individual preferences is allowed to be private, more palatable positive results obtain,namely

Theorem 5. (Hurwicz(1979),Schmeidler(1980)): The constrained Walrasian correspondence W (defined on the neo-classical domain S(N)) is implementable w.r.t. Nash equilibrium (the implementing games being the games in strategic forms induced by a strategic game form on the economies of S(N)).

As shown by Reichelstein(1984) the foregoing result extends to any efficient and individually rational social choice correspondence which satisfies strong positive association (a monotonicity property that Maskin(1977) has shown to be a necessary condition for Nash implementability: as a matter of fact the Walrasian correspondence does not satisfy ;therefore it is not Nash-implementable).

It should be remarked that both Schmeidler's and Hurwicz's mechanisms (or game forms) endow the players with price-quantity strategies. Moreover,Hurwicz's game form- as opposed to Schmeidler's- is continuous. However,both of them share a most relevant feature: namely, they are incomplete (i.e. they may select allocations which are not consistent with the personal endowments when a strategy profile is not a Nash equilibrium). Hence they are in a sense essentially equivalent to pseudogames (incidentally,it is worth noticing here that the classic Arrow-Debreu existence theorem for Walrasian equilibria consists in showing that they are the Nash equilibria of a suitable pseudogame with an auctioneer).

Therefore, those game forms are best interpreted as models of a decentralized ex-ante coordination mechanism as opposed to decentralized ex-post coordination mechanisms (i.e. an equilibrium is first searched in an abstract space and then implemented: no adjustment takes place in the "real" allocation space).

Both Hurwicz's and Schmeidler's mechanisms can be improved upon in several respects. The dimension of their strategy spaces may be reduced (Reichelstein,Reiter(1988); see also McKelvey(1989)). Complete (and continuous) mechanisms which implement the constrained Walrasian correspondence can also be devised (see Hurwicz,Maskin,Postlewaite(1983),Hurwicz(1986)). However, if one insists on requiring the Nash-implementability of the (constrained) Walrasian correspondence by means of a decentralized ex-post coordination mechanism (i.e. a market-type mechanism) then he is bound to get into trouble. In fact, the informational assumptions underlying the Nash equilibrium concept are quite ambiguous. One may think of a Nash equilibrium a) as the outcome of a learning process with each player (initially) ignoring the feasible strategies and preferences of her opponents, or b) as the result of an one-shot ("rational") choice on the part of players who are informed of the relevant parameters of the given game (possibly an incomplete information game). If a) is the case, a "real" adjustment presumably takes place in the process of reaching a Nash equilibrium. But then the relevant alternative space consists of sequences of outcomes and ,thus,intertemporal preferences are the relevant ones in order to assess the efficiency of the alternatives selected by a mechanism. Since -as it turns out- under strict convexity of the individual preferences the only efficient sequences are the constant sequences made up of efficient outcomes (see Coughlin,Howe(1989)), it follows that virtually any learning process -as required by Nash equilibrium- is bound to result in an inefficient sequence of outcomes(if the mechanism is of the ex-post variety). If b) is the case ,then one is confronted with the fact that any known axiomatization of the Nash equilibrium concept makes it clear that it requires -inter alia- common knowledge of a common prior probability distribution on the possible choices of the players (or at least of a 'concordant' prior i.e. a prior which may only differ with respect to the probabilities the players attribute to their own choices): see Bernheim(1986),Aumann(1987),Brandeburger,Dekel(1987)). Anyway,public knowledge of essentially private (i.e. nonobservable) individual characteristics- namely, personal beliefs- is implied, contradicting the requirement of informational decentralization.

This point can be reinforced if an explicit formalization of the informational structure is allowed for. Let us then consider the case of a Bayesian environment .

Theorem 6. (Palfrey,Srivastava(1987)) : The expectational (constrained) Walrasian correspondence is implementable with respect to Bayesian Nash equilibrium on the subset of an economic Bayesian environment (see the definitions above) consisting of profiles with no exclusive information (i.e. the private information of each player can be acquired by the other players by pooling their own information).

The foregoing result shows that if no essentially private information exists then the Walrasian correspondence is implementable with respect to Bayesian Nash equilibrium. It turns out that this restriction is also necessary to the Bayesian implementability of the Walrasian correspondence (and of other interesting correspondences) as shown in Blume, Easley(1990) (see also Postlewaite,Schmeidler(1986), Palfrey,Srivastava(1989)). It follows that a proper decentralization of information rules out the Nash-implementability of the constrained Walrasian correspondence (with the implied efficiency properties) by means of a decentralized ex-post coordination mechanism. As implied by the discussion above,if decentralized ex-ante coordination mechanisms are allowed, then more positive prospects arise . Again, the point to be made is that implicit or explicit institutional constraints have a great import on implementability problems even in a standard economic setting.

4.2. Implementation by repetition.

In the literature on repeated games the typical (implicit) performance criterion is the correspondence attaching to any costituent game a set of (possibly all) its efficient and individually rational payoff vectors.An exception is the early work by Aumann (see Aumann(1959)) whose aim is providing a foundation for the use of the core solution concept for cooperative games. Therefore he concentrates on a version of the core for coalitional games - the so called β-core- (which is,obviously , an efficient and individually rational correspondence). His positive result can be paraphrased as follows:

Theorem 7. (Aumann(1959); see also Aumann(1976),Ichiishi(1987)) . Let us take the standard constituent game domain as the environment $\Gamma=\Gamma(N)$, the set of infinitely repeated undiscounted games with the lim-inf average payoff criterion (and constituent game in Γ) $\Gamma(\infty,LA)$ as the set of implementing games, and coalitional Nash equilibrium as the relevant theory of rational strategic behaviour T . Then the β-core correspondence defined on Γ is implementable with respect to T by means of $\Gamma(\infty,LA)$.

The limitations of this remarkable theorem are the following . First, the conditions ensuring the existence of coalitional Nash equilibria (or of a non-empty β-core) for a given game are quite stringent,so that in many cases of interest the theorem happens to be only trivially true (see Ichiishi(1982) for an example of such an existence theorem). Second, coalitional Nash equilibria implicitly assume communication and coordination facilities which may be considered too strong to be plausible (especially in a noncooperative setting: in fact ,as we mentioned above, the explicit aim of Aumann(1959) is a study of cooperative games)

As a matter of fact, the main focus of the current literature on repeated games has been on Nash equilibrium and its refinements. A long list of "folk theorems" has been shown to hold true (a "folk theorem" asserts that all the individually rational or strictly individually rational payoff vectors - whether efficient or not - are achievable by means of a certain kind of repetition of the basic game). From the point of view of our discussion any such "folk theorem" can be regarded as an impossibility theorem (see Fudenberg,Maskin(1986),Van Damme(1987),Sabourian(1989),Myerson(1991)).

The following is one of the very few positive theorems existing in literature (another one is presented in Greenberg(1990) , referring-however- to a coalitional social-situation setting) . It relies on a parametric class of 3-stage games derived from any repeated game g and called information-leakage games of g . At the first stage each player chooses her strategy for the repeated game g; at the second stage a chance move determines the outcome of a two- event lottery (e.g. the first event occurs with probability p and amounts to the fact that a certain designated player i gets informed about the choice of the other players). At the third stage the players may revise their strategies,and make the final choice . Moreover,it is assumed that changing strategy entails an infinitesimal but positive cost so that a rational player will change strategy - at stage 3- if and only if the new strategy ensures a strictly greater payoff.denote by g(3,i,p) such a 3-stage leakage game and by $\Gamma L(\infty,LA,3,i,p)$ the set of all such games when g ranges over the standard domain of constituent games.

Theorem 8. (Matsui(1989)). Let us take the standard domain of constituent games G(N) as environment, the set $\Gamma L(\infty,LA,3,i,p)$ of 3-stage leakage games as the set of implementing games (for some $i \in N$ and some p, $0<p<1$), and subgame perfect equilibrium (defined on $\Gamma L(\infty,3,i,p)$) as the relevant theory T of rational strategic behaviour. Then an efficient and individually rational social choice correspondence which is defined on G(N) and implementable with respect to T exists.

Unfortunately the foregoing result cannot be extended to a more symmetric context (e.g. if all the players can possibly get informed about each other's strategies the theorem fails). Also,it should be noticed that Theorem 8 is not about the effects of repetition alone, but rather underscores the beneficial effects of repetition as combined with a further transformation of the repeated game, which amounts to embedding it into a particular institutional context allowing for a peculiar kind of pre-play communication among the players. Repetition or pre-play communication alone are not -generally speaking- sufficient for the players to coordinate on efficient strategy profiles. Moreover,the refinements of the Nash equilibrium concept do not help in the repeated game setting.

In fact, "folk theorems" obtain with subgame perfect equilibrium (see e.g. Fudenberg,Maskin(1986)),with renegotiation-proof equilibria (i.e. a refinement which allows for some amount of communication through "cheap talk" among the players: see Farrell,Maskin(1989)),and - for

finitely repeated games - with a "strong" refinement such as stable equilibria (see Van Damme(1987,1989)). Even models of "bounded rationality" do not help to avoid the "folk theorems"(see Kalai(1990)) . This should be contrasted with the dramatic positive effect that even slight refinements of Nash equilibrium may have on implementation by mechanism design. Briefly, implementation by repetition turns out to be a tougher and less rewarding task than implementation by mechanism design is.

5. CONCLUSIONS .

The proposed implementation tests for the "ethical" performance criteria listed in section 2 are largely positive. Virtually all of them pass most of the relevant implementation tests. The impossibility theorems typically obtain when additional institutional constraints (e.g. some particular implementing mechanisms are implicitly or explicitly required) and/or factual assumptions are introduced (e.g. the extent of informational decentralization). Therefore, impossibility theorems appear to have little bearing on those performance criteria per se . The implementation test does not help very much to select among them , since all of them survive it.

Yet,we do not find those results disturbing in any respect. On the contrary,we maintain that they are very much in agreement with other interesting recent developments in ethics ,game theory,and economics.

To begin with, in recent years some versions of a moral "objectivism" or "realism" have been seriously considered or advocated by several scholars (see e.g. Parfit(1984),Gilbert(1990)). The main point made by this view is emphatically not to deny the role of subjective values in moral judgments or the admissibility of the ensuing disagreements and conflicts. Rather, it consists in insisting that moral judgments are not completely arbitrary in that a considerable amount of disagreement in moral evaluations arises from disagreements about "factual" propositions. It follows that ,under such an "objectivist" view, moral analysis can capitalize to a large extent on developments from other empirical disciplines As a result, the notion of a genuine moral "progress" is vindicated. Similarly ,the implementation results discussed above suggest that in most cases what seems to be a conflict between basic "ethical" criteria and rational strategic behaviour is in fact a more complex conflict between them and some (implicit) institutional assumptions,which can therefore-at least in principle- be removed.

Another point suggested by the foregoing implementation results is the idea that the standard theories of rational strategic behaviour are weak and perhaps (partially) incorrect. Again,this is no new idea. H.Simon's advocacy of models of bounded and procedural rationality is grounded on a strictly related view (see also Binmore (1987/1988) for a thorough discussion of the need for more procedural details in game theoretic models) . Moreover, it has been noticed that the notion of rationality commonly used in economics is in fact weak, and that other assumptions(say a complete information hypothesis, or the existence of complete markets,or an infinite number of players) are generally responsible for the strongest results of that discipline(see e.g. Ledyard(1986), Arrow(1987)).

It remains to be seen ,however, if and how the further development of theories of rational strategic behaviour of a more procedural kind can affect the implementation- tests considered in this paper.

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