Research Statement

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My research interest is the study of cooperation from an economic perspective. Typical questions I try to answer are: How self-interested individuals can reach an efficient outcome? How do institutions emerge? How fairness and stability criteria select a subset of the Pareto frontier? And so on so forth. Understanding cooperation is certainly a classical subject in economic theory, and especially in game theory that has its own subfield of "cooperative games." On the other hand, cooperative games are often associated to a specific model, viz. von Neumann and Morgenstern's (1944) "characteristic function," that has proven useful in some applications, but is too sketchy to provide more than a benchmark. To fully understand cooperation, it is important to master and apply many other tools as well, including the theories of mechanism design, general equilibrium, non-cooperative bargaining, distributive justice, repeated games, etc. My research is original, I believe, in that it extends the classical analysis of cooperative games to more realistic environments.

1 Random Objections and the Inner Core

The core of an exchange economy is the set of contracts that are both feasible when all the agents cooperate, and robust to coalitional objections, meaning that no set of agents can be made better off by seceding and trading their own resources instead. Contracts are assumed to be deterministic, while lotteries are prevalent in other parts of game theory (e.g. mixed strategies guaranteeing the existence of an equilibrium in normal-form games). In de Clippel and Minelli (2005), we investigate how the notion of core for exchange economies might change if agents had the possibility to agree on lotteries. Making the usual assumption that they are risk-averse von Neumann-Morgenstern utility maximizers, a simple answer might be that, in fact, nothing would change. Indeed, the expected value of any lottery defined over feasible contracts is a feasible contract that is at least as good as the expected utility of that lottery. It is certainly true that the grand coalition will not be able to improve on the satisfaction of all the agents. On the other hand, we believe that agents in subcoalitions might be able to use lotteries to further their interest, thereby creating new blocking opportunities and reducing the core. Formally, let x be a feasible allocation for the grand coalition, and let S be a coalition. A *random*

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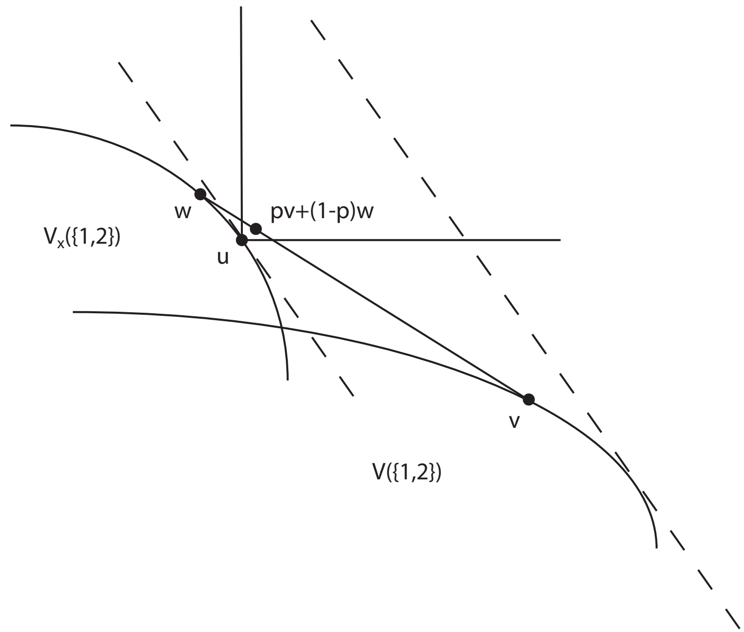

Figure 1

objection for S against x is a triple (y, z, p) where y is an allocation that is feasible for S when reallocating its members' initial endowments, z is an allocation that is feasible for S when reallocating x_S, and p is a probability (i.e. number between 0 and 1) such that all the members of S prefer to play the lottery that gives y, with probability p, and z, with probability $1-p$, rather than getting x for sure. Members of S can thus profitably "game" against x when such a random objection exists, by writing a binding confidential side-contract that requires them to throw a biased coin that falls head with probability p and tail with probability $1-p$, to secede and execute y if head obtains, and to agree with the status-quo with probability $1-p$, only to execute z after x has been realized within the grand coalition. A classical objection is equivalent to a random objection with $p=1$. Core allocations are also immune to random objections with $p=0$, since they are necessarily Pareto optimal. On the other hand, they need not be immune to random objections with $p \in]0,1[$, as the following example illustrates.

Example *Figure 1 represents a possible configuration in the utility space, focusing on payoffs for agents* 1 *and* 2*. We are testing a Pareto-optimal allocation x with associated utilities $u = (u_1(x_1), u_2(x_2))$. $V(\{1,2\})$ represents the set of utility pairs that are achievable via some reallocation of the initial endowments, while $V_x(\{1,2\})$ represents the set of utility pairs that are achievable through some reallocation of the tested allocation between the two agents. Coalition $\{1,2\}$ cannot improve on x, as $u \notin V(\{1,2\})$, and yet (y,z,p), where y (resp. z) is a reallocation of the initial endowments (resp. $x_1 + x_2$) that leads to v (resp. w), forms a random objection against x.*

The paper offers an interesting characterization of the set of feasible allocations that are immune to random objections for smooth economics (i.e. with differentiable preferences and interior endowments). Indeed, we show that it coincides with the inner core, a concept that was first introduced in Shapley and Shubik (1975). Formally, a feasible allocation x is robust against random objections if and only if there exists a vector λ of strictly positive weight (one component for each agent) such that

$$\sum_{i \in S} \lambda_i x_i \geq \max_{y \text{ feasible for } S} \sum_{i \in S} \lambda_i y_i,$$

for each coalition S of agents. The inequality for the grand coalition implies that λ is simply the vector that is orthogonal to the set of feasible utility profiles at the vector of utilities associated to x. We can see the characterization result at work on Figure 1. The first two components of λ are determined by the dashed line that is tangents to $V_x(\{1,2\})$ at u. The maximum weighted sum of utilities that the first two agents can achieve on their own is given by the other dashed line, and u clearly falls below it, meaning that there must exist a random objection against x, as shown indeed in Example.

2 The Type-Agent Core for Exchange Economies under Asymmetric Information

In de Clippel (2007), I study the allocation of scarce resources between agents that are asymmetrically informed about the fundamentals of the economy at the time of contracting.

First defined in the absence of uncertainty, the core specifies the set of contracts that are immune to coalitional objections. Particularly, the core of an exchange economy with complete information is the set of feasible allocations such that no group of agents can improve their satisfaction by reallocating their initial endowments (as in the previous section). Besides its many economic applications, the core also allows to justify the price-taking assumption underlying the concept of competitive equilibrium. Debreu and Scarf (1963) indeed proved that the core shrinks towards the set of competitive equilibria when the economies are replicated.

The concept of contingent good introduced by Arrow and Debreu allows to extend the previous analysis (i.e. core, competitive equilibrium and convergence result) to exchange economies with uncertainty, as long as the agents have the same information at their disposal.

Important conceptual issues arise when the agents are asymmetrically informed. Two different aspects must be distinguished: (1) If the agents are asymmetrically informed at the time of contracting, then we have to describe how their bargaining strategies depend on their information; (2) If the agents are asymmetrically informed at the time of implementing the contracts, then we need to discuss which contracts are feasible (a contract may depend on the private information of the agents only if it gives the right incentives to the agents to reveal their information truthfully).

I focus on situations where the true state of the economy is commonly known when the contracts are implemented. Incentive and measurability constraints are therefore irrelevant. Many economic examples fit in this category. The payment of an insurance contract for instance depends on the observable losses incurred. The payment of a financial asset (e.g. equities or options) is contingent on the realization of some observable events. In addition, the model could serve as a benchmark to understand more complex problems where the agents are still asymmetrically informed at the time of implementing the contracts.

The main reference for core concepts in this framework is Wilson (1978). An agreement specifies a way to split the endowment of the economy among the agents in each state. Such a function is called a feasible allocation rule. Wilson discusses various notions of objection against given feasible allocation rules. They differ by the amount of communication that is permitted between the agents. Two polar notions emerge: coarse objections are based on events that are common knowledge among the members of the coalition; fine objections are based on events that can be discerned by pooling the information of the members of the coalition. Every coarse objection is a fine objection. Hence, the fine core is a subset of the coarse core. Serrano et al. (2001) showed that neither the coarse nor the fine cores converge towards any reasonable notion of price equilibrium when the economies are replicated.

The agents are cooperating on their own in Wilson's theory. Objections emerge from coalitions. I study an alternative approach where uninformed intermediaries help the agents to coordinate in an attempt to make some profit. They compete a la Bertrand. The intermediaries correctly anticipate the set of agents that are going to buy the contracts (net trade vectors) they offer. Even without communication, this set may vary with the future state of the economy as each agents decision is based on his own private information. This leads to an endogenous determination of the coalition that is going to form as a function of the state. In other words, I extend the competitive screening argument of Rothschild and Stiglitz (1976) to coalition formation.

The set of subgame-perfect equilibrium outcomes associated with the competitive screening game constitutes an interesting new solution concept. I prove that it coincides with the core (as usually defined thanks to the Arrow-Debreu contingent goods) of a fictitious exchange economy with uncertainty and symmetric information. The fictitious agents are defined as in the type-agent representation of Bayesian games suggested by Harsanyi (1968) in order to define the concept of Bayesian equilibrium. My new solution is therefore called the *type-agent core*.

The type-agent core is always a subset of the coarse core, and may even be a strict subset of the fine core in some examples. Although the fine core may be empty, the type-agent core is never empty. Wilson defined a notion of constrained market equilibrium as a technical tool to prove the non-emptiness of the coarse core. I show that, under mild conditions, the set of constrained market equilibria is a subset of the type-agent core and that the type-agent core shrinks towards the set of constrained market equilibria as the economy is replicated. Such a convergence result is rather unexpected as Serrano et al. (2001) showed that neither the coarse nor the fine cores converge towards the set of constrained market equilibria when the economy is replicated. More than that, they show that the negative result is robust against many alternative definitions of both the core and the price equilibria.

3 Mutual Evaluations and Impartial Division

How should a dollar, or any amount of any divisible commodity, be divided if subjective claims are to be respected? If the claims are objective, the most common rule is proportionality. No such simple rule is available, however, when the claims are at least in part subjective and there is no impartial observer who can resolve disagreements.

In de Clippel et al. (2008), we propose division rules for aggregating possibly conflicting evaluations of claims by eliciting individual reports that we call *impartial* in view of the following two properties:

- everyone reports an evaluation of the (relative) shares that *other* agents deserve; no one makes any statement about *her own* share of the dollar;
- the share of any participant is determined *exclusively* by the reports of other agents, her own report has *no influence* on her own share.

The first property takes literally the old adage that a man is never a good judge of his own cause. It eliminates *overt* partiality, whereas the second property rules out the *covert* form of partiality whereby a strategic participant uses her report to indirectly increase her share. For an agent who cares only about her own share, it is a weakly dominant strategy to report truthfully her evaluation of others' relative claims.

We call our third requirement the *consensus* property:

- if the profile of opinions points to a *consensual* division (if there is a way to divide the dollar that agrees with all individual reports), then this is the outcome.

Of the three properties above, only the third links the substantive content of the reports to the actual shares of the dollar. It is a very weak link, because it puts no restriction on the outcome when there is even a modicum of disagreement among the participants. Yet, in combination with the first two properties, the consensus property has much bite.

Our model is very general, in that it requires no assumption about the nature of individual claims or about the origin of the disagreement. Individual claims may be derived from effort applied toward the creation of the surplus (think of partners dividing a profit at the end of the year); they may measure the relative needs for the resource (relief distribution after a catastrophic loss); or represent exogenous rights (contestable claims in a bankruptcy or inheritance situation); or a combination of these factors. Objective claims may exist yet be imperfectly known (some records are lost), requiring the participants to make educated guesses. Finally we may be dividing a *cost*, in which case the claims turn into individual *liabilities*, with a similar array of possible interpretations.

Our problem bears a tenuous relation to the Condorcet Jury Problem and more generally to the literature on the pooling of expert opinions. There like here, one aggregates conflicting impartial opinions; but in our case the “experts” themselves are the beneficiaries of the outcome. Our approach is orthogonal to bargaining theory, where individual messages are explicitly partial, meant to improve one’s share of the dollar.

Our model requires at least three agents. With exactly three, there is a unique impartial and consensual division rule, but that rule distributes *exactly* the dollar only when the three reports are consistent; otherwise it distributes strictly less. By contrast, with four or more agents, we propose many anonymous, impartial and consensual rules that always distribute the dollar exactly.

The first step toward this result is to construct a family of inexact, wasteful rules (distributing one dollar or less), in which agent i’s share is derived from aggregate reports on the ratio of j’s share to i’s share for all $j \neq i$. Different methods can be used to aggregate the reports (e.g. median, maximum, geometric mean and arithmetic mean). We offer a characterization of these rules based on a separability property reminiscent of Gorman (1968).

We construct exact rules from inexact ones by dividing the dollar into n equal parts (n is the number of agents), designating for each part a different *residual* agent i, dividing inexactly that part among the $n-1$ other agents while ignoring agent i’s opinion, and giving the residual share to agent i.

4 Marginal Contributions and Externalities in the Value

Since the path-breaking work of Shapley (1953), much effort has been devoted to the problem of “fair” distribution of the surplus generated by a collection of people that are willing to cooperate with one another. More recently, the same question has been posed in the realistic case where externalities across coalitions are present. This is the general problem to which de Clippel and Serrano (2008a) contributes. The presence of such externalities is an important feature in many applications. In an oligopolistic market, the profit of a cartel depends on the level of cooperation among the competing firms. The power of a political alliance depends on the level of coordination among competing parties. The benefit of an agent that refuses to participate in the production of a public good depends on the level of cooperation of the other agents (free-riding effect), and so on.

In the absence of externalities, Shapley (1953) obtained a remarkable *uniqueness* result. He characterized a unique solution using the axioms of efficiency, anonymity, additivity and null player. Today we refer to this solution as the Shapley value, which happens to be calculated as the average of marginal contributions of players to coalitions. This comes as a surprise at first glance: uniqueness is the consequence of four basic axioms, and nothing in those axioms hints at the marginality principle, of long tradition in economic theory. In the clarification of this puzzle, Young (1985) provides a key piece. He formulates the marginality principle as an axiom, i.e., that the solution should be a function of players' marginal contributions to coalitions. He drops additivity and null player as requirements. The result is that the only solution satisfying efficiency, anonymity and marginality is again the Shapley value.

In our extension of the theory of the Shapley value to settings with externalities, we shall also pursue an axiomatic analysis (strategic considerations and issues of coalition formation are available in the companion paper de Clippel and Serrano (2008b)). In our axiomatic analysis, we will find that appealing systems of basic axioms that were used in problems with no externalities do not suffice to yield a unique solution. Thus, *multiplicity* of solutions seems essential to the problem at hand (this is confirmed by previous studies, in which authors must resort to new additional axioms to get uniqueness). Despite the multiple solutions, the novelty of our approach is to provide refined predictions based on payoff bounds implied by the axioms.

In order to tackle the question in axiomatic terms, we sort out the effects of *intrinsic marginal contributions* of players to coalitions from those coming from *externalities*. The model we shall employ is that of partition functions, in which the worth of a coalition S may vary with how the players not in S cooperate. In the model, $v(S,\Pi)$ is the worth of S when the coalition structure is Π, S being an element of Π. To define player i's marginal contribution to coalition S –a trivial task in the absence of externalities–, it is now crucial to describe what happens after i leaves S. Suppose i plans to join T, another coalition in Π. The *total effect* on S of i's move is the difference $v(S,\Pi) - v(S \setminus \{i\}, \{S \setminus \{i\}, T \cup \{i\}\} \cup \Pi_{-S,-T})$. This effect can be decomposed into two. First, there is an *intrinsic marginal contribution effect* associated with i leaving S but before joining T, i.e., $v(S,\Pi) - v(S \setminus \{i\}, \{S \setminus \{i\}, \{i\}\} \cup \Pi_{-S})$. And second, there is an *externality effect*, which stems from the change in the worth of $S \setminus \{i\}$ when i, instead of remaining alone, joins T, i.e., the difference $v(S \setminus \{i\}, \{S \setminus \{i\}, \{i\}\} \cup \Pi_{-S}) - v(S \setminus \{i\}, \{S \setminus \{i\}, T \cup \{i\}\} \cup \Pi_{-S,-T})$. (Note how this latter difference is *not* a "partial derivative," a marginal contribution of player i to coalition S.) Our results follow from exploiting this decomposition.[1]

Assuming that the grand coalition forms, we investigate the implications of efficiency and anonymity, together with a weak version of marginality.[2] According to this last property, the solution may depend on all the total effects –the sum of the intrinsic marginal contribution and the externality effects. We find the first noteworthy difference with respect to the case of no-externalities, because in our larger domain these axioms are compatible with a wide class of linear and even non-linear solutions. However, despite such a large multiplicity of solutions, our first result shows that if the partition function can be written as the sum of a symmetric partition function and a characteristic function,

[1]In this decomposition, we are focusing on the "simplest path", i.e., that in which player i leaves S, and stays as a singleton before joining T. As we shall see, the singletons coalition structure acts as a useful origin of coordinates from which externalities are measured.

[2]Similar results can be established for any exogenous coalition structure, if the axioms are imposed atom by atom in the partition.

a unique payoff profile is the consequence of the three axioms. As will be formally defined in the sequel, this class amounts to having *symmetric externalities.*

But for general partition functions, as a result of our first finding, we seek the implications of strengthening the weak version of marginality, and we do so in two ways. First, we require monotonicity, i.e., a player's payoff should be increasing in all the total effects –the sum of his intrinsic marginal contribution and externality effects. Then, we are able to establish useful upper and lower bounds to each player's payoff. And second, complementing this result, we require a marginality axiom, according to which a player's payoff should depend on the vector of intrinsic marginal contributions, not on the externality effect. The result is a characterization of an "externality-free" value on the basis of efficiency, anonymity and marginality. In a second characterization result, this solution is obtained using a system of axioms much like the original one due to Shapley (with a strong version of the dummy axiom that also disregards externalities).[3]

The externality-free value thus appears to be a natural reference point. Obviously, an analysis based solely on the externality-free value is not desirable in a model of externalities. This is why we do not insist on uniqueness, and accept the multiplicity of solutions inherent to the problem. The combination of both kinds of results –the externality-free value benchmark and the obtention of bounds around it– is a way to understand how externalities might benefit or punish a player in a context where normative principles are in place. In effect, the two results together provide a range for acceptable Pigouvian-like transfers (externality-driven taxes or subsidies among players) when efficiency is accompanied by our other normative desiderata.

5 Non-Welfarist Characterizations of the Nash Bargaining Solution and the Equal Surplus Sharing Rule

Most contributions in axiomatic bargaining and social choice are phrased in "utilities." It is thus assumed, most often without justification, that two problems must have the same solution if they coincide in the utility space. Roemer (1986, 1988) was first to argue that this *welfarist* assumption lacks both a clear normative and positive content, and is thus hard to accept as an axiom. The existence of appealing contextual solutions (e.g. fairness or egalitarian equivalence) also shows that the welfarist assumption is far from being innocuous. To be precise, I am not arguing that a solution is unappealing because it is welfarist. Instead, I suggest that the axiomatic approach should be applied more systematically to explicit economic and social environments. Some properties that were incompatible in the utility space may lead to the characterization of new (necessarily contextual) solutions. In other cases, welfarism will come as a consequence of axioms,

[3]Straightforward adaptations of the principle of balanced contributions (Myerson (1980)), of the concept of potential (Hart and Mas-Colell (1989)), and of some bargaining procedures (Hart and Mas-Colell (1996); Pérez-Castrillo and Wettstein (2001)), once applied to the larger domain of partition functions, lead to the externality-free value as well.

hence giving us a deeper understanding of traditional solutions. The papers described in the next two subsections belong to the second category.

5.1 Axiomatic Bargaining on Economic Environments with Lotteries

Nash's (1950) bargaining model and the solution he derived axiomatically have had a great impact on economic theory. Yet the contribution may seem at odd with the major trend of the field in the second half of the twentieth century because his arguments are phrased in the space of utilities. The standard, instead, has been to work with more primitive concepts such as strategies, economic or social outcomes, and the participants' preferences. In de Clippel (2009a), I show how Nash's theory can be rephrased to meet these standards in a model where agents can choose lotteries over simple economic outcomes, while evaluating those lotteries with ordinal von Neumann-Morgenstern preferences (which, of course, are also the cornerstone of non-cooperative game theory and information economics).

Following Nash, a bargaining problem is a couple (U, d), where U is a compact convex subset of $\mathbb{R}^2$ that represents the set of utility pairs that are achievable through cooperation, and $d \in U$ is the utility pair that prevails in case of disagreement. A solution associates a feasible utility pair to each bargaining problem. Nash proved that there exists a unique solution that satisfies the properties of Efficiency, Symmetry, Scale Covariance, and Independence of Irrelevant Alternatives (IIA). It is obtained by maximizing the product of the participants utility gains over U. A large literature ensued, some papers establishing alternative characterizations of the Nash bargaining solution, other introducing alternative axioms to characterize new solutions (see Thomson (1994) for a survey).

A bargaining problem in this sense is simply a representation of the underlying economic or social problem via some utility functions that encode the bargainers' preferences. As pointed out by Nash himself, the convexity of U follows from the idea that bargainers can agree on lotteries over basic outcomes, provided one restricts attention to utility functions that are linear in probabilities. Of course, there is no loss of generality in representing the options available to the bargainers and the final agreement in the space of utilities. One is also free to use linear utility functions if the bargainers have von Neumann-Morgenstern preferences. On the other hand, restricting bargaining solutions to take convex utility possibility sets as argument, instead of the underlying economic or social environments, is a significant assumption. Indeed, it presupposes that the image of the economic or social problems through linear representations of the bargainers' von Neumann-Morgenstern preferences is sufficiently informative to determine the solution. I will call this a property of 'Cardinal Welfarism' (C-WELF). It is related to the notion of welfarism introduced by Roemer (1986; 1988), except that it emphasizes in addition the key role that linear representations play in Nash's theory.

C-WELF is not appealing as a postulate, because it is hard to understand what it entails in terms of the primitives, namely the set of available agreements and the bargainers' preferences. It is easy to construct problems that are very different in their economic description, but happen to have the same image in the space of utilities. The resulting agreements must thus be related (in the sense of coinciding in utilities) in Nash's cardinal welfarist framework. I do not argue that a solution that satisfies this property is necessarily unappealing. On the other hand, there is no straightforward argument in its favor.

Pushing the reasoning further, observe that conducting the analysis of bargaining problems in the space of utilities, that is assuming C-WELF *a priori*, is at best confusing and at worst misleading, because it creates a mismatch between the axioms' interpretation and their formal content. Consider for instance the axioms of scale covariance and IIA. The information retained when representing bargaining problems in the space of utilities is just too scarce to determine whether what looks like a scale transformation, or a reduction in the set of available contracts is not actually obtained by considering completely unrelated problems. Similarly a problem may appear symmetric in the space of utilities for some representation of the bargainers' preferences, while in reality the bargainers' preferences are unrelated, and the set of economic outcomes is non-symmetric.

Nash's theory seems to be build on some cardinal notion of utilities. Indeed, his solution is at best scale covariant, and the convexity of the sets of feasible utilities is justified only when applying linear utility functions. Nash's appeal to von Neumann-Morgenstern's expected utility theory to justify these assumptions may be slightly misleading. Indeed, while traditional axioms guarantee the *existence* of linear representations, a preference relation in that theory is an *ordinal* concept. von Neumann and Morgenstern's and subsequent arguments do not favor linear over any other form of representation: any increasing transformation of a linear representation of a von Neumann-Morgenstern preference is another valid representation of the same ordering, though usually not linear. One comes to wonder then whether the axiomatic justification behind the Nash bargaining solution relies crucially on the possibility of measuring intensities of preferences. It would seem so in a welfarist context. Indeed, we know since Shapley (1969) that it is impossible to find a solution in the space of utilities that is efficient, strictly individually rational, and ordinally invariant. Therefore, if one believes in welfarism (which is required to accept Nash' theory in its original and since then standard formulation), then one must necessarily rely on other theories of preferences that are not ordinally invariant. While there are some interesting theoretical foundations of cardinal utility functions (see chapter 6 of Fishburn, 1970, for a survey), the consensus so far in mainstream Economics is that they have no practical meaning because they cannot be deduced by observing choices.

On the other hand, I already argued that welfarism is not appealing as a postulate. So I propose to re-phrase Nash's ideas in an explicit economic environment, allowing (selfish) bargainers with von Neumann-Morgenstern preferences to agree on lotteries. As expected, numerous non-welfarist solutions also satisfy his axioms in that setting. One of the main contribution of the paper is to show that all these alternative solutions violate a simple property of independence with respect to preferences between unfeasible alternatives (IPUA). This provides an axiomatic justification for the Nash bargaining solution that is based on the ordinal concept of von Neumann-Morgenstern preferences, the use of linear representations coming now as a consequence of the axioms, instead of being a prerequisite. The result also deepens our understanding of the Nash bargaining solution, IPUA being logically weaker, and more straightforward to understand than C-WELF.

As hinted by its name, IPUA requires that the solution of two problems that differ only in the bargainers' preferences over outcomes that are not feasible coincide. Interestingly the axiom is not really new, but I believe it is the first time that it is explicitly applied to bargaining environments with lotteries. As far as I can tell, the first explicit mention of a similar property can be found in Karni and Schmeidler (1975).[4] They show its close relation (together with IIA) to the maximization of a social welfare ordering that satisfies Arrow's independence property. This type of independence property has been rather often invoked in various models of the social choice literature since then, but it has surprisingly never been found to be sufficient to recover Nash's axiomatic result on economic environments with lotteries.

5.2 No Profitable Decompositions in Quasi-Linear Allocation Problems

In de Clippel and Bejan (2009), we consider situations where a group of people have to share a bundle of perfectly divisible private goods. We assume that compensations can be achieved through monetary transfers (quasi-linear framework). As often, instead of solving each specific problem in isolation, we study allocation rules that may be applied in many different instances. For most allocation problems and most rules, some participants can gain by decomposing the stakes in some way, requesting for instance to allocate good l before l', or to share a proportion of the total amount of goods available before allocating what remains. Of course, such decompositions often lead to an efficiency loss, which is not desirable. Even when there is no efficiency loss, a gain for one participant must result in a loss for another one when the allocation rule selects efficient outcomes. Hence the normative appeal of a rule may be lost if stakes are decomposed when implementing it. Finally, one advantage of agreeing on an allocation rule is to reduce conflict when it comes to solving particular problems. This advantage may be limited when implementing rules that are subject to such profitable decompositions, as participants will have conflicting preferences when it comes to setting the agenda. For all these reasons, we are interested in studying rules that satisfy a property of "No Profitable Decompositions" (NPD), requiring that no individual can gain by decomposing the problem into sequences of subproblems.

The main result of the paper establishes that NPD, once combined with other standard axioms, characterizes the allocation rule that corresponds to an equal split of the maximal total surplus among the participants. Equal surplus sharing being probably the simplest notion of microeconomic justice, one would think that there exist numerous axiomatic characterizations of this solution in bargaining and social choice theory. In reality there are only relatively few such results. The reason is that most contributions in axiomatic bargaining and social choice are phrased while taking utilities as primitive. Equal surplus

[4]Karni and Schmeidler themselves refer to a 1969 *mimeo* written by A. Gibbard.

sharing follows trivially from the properties of anonymity and efficiency in quasi-linear environments under this welfarist assumption. Most of the literature focuses instead on finding extensions of the equal surplus sharing solution to environments that are not quasi-linear. Unfortunately, as already argued both at the beginning of the section and in the previous subsection, the welfarist assumption lacks a clear normative and/or positive content, and is thus hard to accept as an axiom or postulate. It is worth noting that NPD cannot even be phrased under the welfarist assumption, since the set of utilities that are feasible in the subsequent step of a decomposition depends on the economic description of the problem. This set may be strictly smaller than, and unrelated to, the set of utilities that are achievable when solving the problem in its entirety.

Beyond usual properties of anonymity, efficiency, and continuity, the result requires an axiom of independence with respect to preferences over non-feasible allocations (IND). As hinted by its name, IND requires that the solution of two allocation problems that differ only in the participants' perferences over outcomes that are not feasible coincide (same as in the previous subsection, but without the use of lotteries, which makes the property only even more appealing). Though IND may appear completely innocuous at first sight, we must point out that it rules out Pazner and Schmeidler's (1978) egalitarian equivalent solutions.

We can now provide some intuition for our main characterization result. Consider various countries that have an equal claim over a newly-discovered field of natural gas. A total quantity Q is available to share. Let v_i be the function that measures the net social surplus for country i, as a function of the share it receives.[5] These functions are most likely to vary across countries because of different transportation costs and different needs (e.g. existence of alternative sources, and use of different technologies that make the resource more or less productive). NPD is more restrictive when it applies to many decompositions of the original problem. Consider for instance the case where the division of Q is tested against the iteration cubic meter by cubic meter of the solution. Suppose that $Q' < Q$ cubic meters have already been shared (combined with some monetary transfers). Given the possibility of monetary compensations, the efficient allocation of Q' prescribed by the solution must equalize the marginal social surplus across countries (assuming for simplicity that we have an interior solution). When considering the additional cubic meter to be shared in the next iteration of the decomposition, all the countries look identical, because a cubic meter is essentially an infinitesimal quantity when compared to Q, and the countries' social surplus functions over quantities that are larger than this infinitesimal amount must be irrelevant under IND. In order to be anonymous (a minimal requirement for equitability), the solution should give an equal share to each country of the additional total surplus generated by the additional cubic meter to allocate. Iterating

[5]The story is of course rather stylized, the objective being to emphasize the argument behind the main result of our paper. Still, the model is more general than it may seem at first sight. For instance, the costs of extraction seem to be overlooked, but they can possibly be expressed in terms of the energy required to extract the gas, which itself can be obtained from a fraction of the natural gas extracted. Q can then be interpreted as the *net* quantity available in the field. Also, our story does not incorporate time explicitly, but the functions v_i can be reinterpreted as the net present value of streams of resources to be extracted.

the process, it follows that the total surplus associated to Q should be shared equally across countries. The formal reasoning is more general (e.g. allowing for multiple goods, and without restricting attention to functions v_i that guarantee interior solutions), but also requires to focus on solutions that are regular (formalized in an axiom of continuity) in order to make the argument at the margin complete.

6 Reason-Based Choice: a Bargaining Rationale for the Attraction and Compromise Effects

Many of the decision problems we face are complicated by the fact that there is no single dimension or criterion for evaluating the available alternatives. For example, when searching for an apartment or a house, the ranking of the available options may be very different depending on whether the criterion we use is price, size, proximity to work or quality of schools. Similarly, when choosing a car, there are several different criteria or dimensions that one may use such as price, safety, gas efficiency, size, color or esthetics. Also, in deciding between academic job offers there is no one obvious criterion to use as one may consider the ranking of the department, the number of faculty members in one's field, the financial terms, the location, etc. Often there can be many different dimensions or criteria that one may use, making it difficult, if not impossible, to take all of them into account. This often leads us to focus only on a limited number of dimensions, which we deem most important. However, we are still faced with the difficult task of resolving the trade-off between these dimensions.

If we were fully rational, as is typically assumed in economics, then first, we would be able to take into account all possible dimensions, and second, we would be able to consistenly make the necessary trade-offs across dimensions. However, numerous studies in economics, psychology and marketing provide overwhelming evidence that individuals exhibit systematic departures from rational choice, especially in those situations where there is no obvious single criterion for evaluating the available options. This suggests that individuals often find it difficult to resolve the conflict about how much of one dimension to trade off in favor of another, and hence, they resort to simple heuristics that lead to systematic violations of rationality. Among the most studied and robust violations are the *attraction* and the *compromise* effects.

The attraction effect was first demonstrated by Huber, Payne and Puto (1982), while the compromise effect was introduced by Simonson (1989).[6] The attraction effect refers to the ability of an asymmetrically dominated or relatively inferior alternative, when added to a set, to increase the choice probability of the dominating alternative. The compromise effect refers to the ability of an "extreme" (but not inferior) alternative, when added to a set, to increase the choice probability of an "intermediate" alternative. To illustrate these two effects, consider two options, A and B. Suppose there are two dimensions or criteria

[6]These studies have sprung a whole literature devoted to replicating and extending these effects to various decision problems, including real, monetary choices. For references see Shafir, Simonson and Tversky (1993), Kivetz, Netzer and Srinivasan (2004) and Ariely (2008).

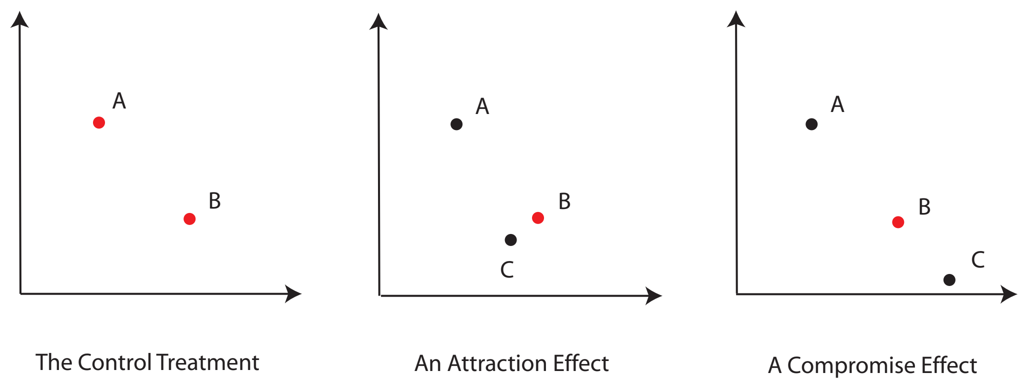

Figure 2

for evaluating these options such that B is better than A along the first dimension while A is better than B along the second dimension (see Figure 2). For example, suppose A and B are two equally priced apartments, but one is closer to work while the other has better schools. In a typical experimental study (which uses a between-subjects design), both A and B are chosen - usually in equal proportions - by a control group of subjects. The attraction effect is observed when a third alternative, C, is added to the set such that it is dominated by only one of the other two options (say, B, as in Figure 2). When subjects are asked to choose from $\{A, B, C\}$, the vast majority of them tend to choose B. The compromise effect occurs when C is added such that it is even better than B along the first dimension but worse than it along the second dimension (i.e., according to the first dimension, C is better than B, which is better than A, while the opposite ranking is obtained according to the second dimension). In such a case, most subjects again tend to pick B. These findings may be interpreted as systematic violations of the Weak Axiom of Revealed Preferences (WARP) by considering a choice correspondence that selects both A and B from $\{A, B\}$, but chooses B alone from $\{A, B, C\}$.

The introduction of these two effects has generated a huge literature in marketing aimed at understanding the source of the effects and their implications for positioning, branding and advertising (see Kivetz, Netzer, and Srinivasan (2004)). One important question that arises is whether the two effects may be viewed as just "snapshots" of a more general choice procedure, which may lead to more significant violations of WARP across various decision problems. In de Clippel and Eliaz (2009), we attempt to address this question by proposing and characterizing a choice procedure that generates both the attraction and the compromise effects. Our choice procedure is motivated by the interpretation of these two effects as instances of "reason-based choice" (see Simonson (1989), Tversky and Shafir (1992) and Shafir, Simonson and Tversky (1993)). According to this interpretation, in the absence of a single criterion for ranking available options (what is often referred to as "choice under conflict"), choices may be explained "in terms of the balance of reasons for and against the various alternatives" (see Shafir, Simonson and Tversky (1993)).[7] To formalize this interpretation, we envision the decision-maker as trying to reach a compromise between conflicting "inner selves", representing the different attributes or dimensions of the available options. We then propose to view the final choice (i.e., the "balancing of reasons for and against") as a *cooperative* solution to a bargaining among the different selves. In the spirit of the literature on dual-selves (e.g., the $\beta - \delta$ models of present bias, Benhabib and Bisin (2004), Eliaz and Spiegler (2006), Fudenberg and Levine (2006)), we focus our analysis on decision problems that give rise to two selves.

We start by considering the two relevant criteria or dimensions, and their associated rankings, as primitives of the model. This allows us to focus attention on how conflict could be resolved in the mind of a decision maker who is subject to both the attraction and compromise effects, while still satisfying some consistency properties. Also, it may be reasonable in some applications to consider that these primitives are indeed known to the modeler. As illustration, one may think for instance of the choice of product with two attributes such as price and quality, price and size, shipping rate and date of arrival, sugar and fat content, etc. Formally, our first model consists of a finite set of options X and a pair of linear orderings on this set, $\succ = (\succ_1, \succ_2)$. Each ordering is interpreted as the (known) preference relation of one of the individual's dual selves. A bargaining problem is defined to be a non-empty subset of options S. For a given preference profile $\succ$, a bargaining solution is a correspondence $C_\succ$ that associates with every bargaining problem S a subset of S.

Which cooperative bargaining solution can capture our dual-self interpretation of reason-based choice? This solution should first of all exhibit properties that capture the attraction and compromise effects. We interpret an attraction effect as the following property (ATT): whenever a set of options is expanded by adding an alternative that is Pareto dominated by some previously chosen element, then only those chosen alternatives that dominate the new alternative are selected from the new set. We view a compromise as an attempt to resolve conflicting preferences over a pair of alternatives by selecting an outcome that is ranked in between the two by both bargainers. A bargaining solution, therefore, exhibits a compromise effect, or what we call the "No Better Compromise" property (NBC), if whenever x and y are chosen from a set, then there cannot be an element in that set that both bargainers rank between x and y.

Our first main result establishes the existence of a unique bargaining solution that satisfies the above properties, in addition to a number of other properties that capture a notion of consistency across decision problems, the cooperative nature of the bargaining, immunity to framing and symmetry. To describe this solution, imagine that for every bargaining problem, each bargainer assigns each option a score equal to the number of elements in its lower contour set. Hence, each option is associated with a pair of scores. The bargaining solution selects the options whose minimal score is highest. This solution has been previously discussed in the literature under various names: "Rawlsian

[7] Note that reasons involving relationships to other alternatives may lead to violations of WARP.

arbitration rule" (Sprumont (1993)), "Kant-Rawls Social Compromise" (Hurwicz and Sertel (1997)), "fallback bargaining" (Brams and Kilgour (2001)), as well as "unanimity compromise" (Kibris and Sertel (2007)). An appealing feature of this bargaining solution is that it is purely ordinal and applies to any arbitrary finite set of options (in contrast to the Nash or Kalai-Smordinsky solutions).[8]

Next we consider an environment in which there is no obvious way to rank the options along two dimensions. We interpret our focus on only two dimensions as an assumption that the decision-maker can process only a limited number of dimensions or attributes. Thus, if the options are characterized by a large number of attributes, it may not be clear which two dimensions the decision-maker focuses on. Hence, an outside observer may not be able to infer what rankings the decision-maker uses to evaluate the options. Alternatively, there may be only two salient dimensions or attributes, but it is not obvious how a decision-maker would rank the options along each dimension (consider, for example, attributes such as color, taste, smell). In such an environment the only observations we may have about the decision-maker are the choices he makes (i.e., his choice correspondence). We ask the following question: what are the necessary and sufficient conditions for representing the decision-maker *as if* he has two selves (each characterized by a linear ordering on X), which make a choice according to the fallback bargaining solution?

Our second main result identifies these conditions. This result relies on the notions of "revealed Pareto dominance" and "revealed compromises". An option x is revealed to be Pareto superior to y if it is chosen over y in a pairwise comparison. An option y is revealed to be a compromise between x and z if no option in this triplet is revealed to be Pareto superior over another, and y is chosen uniquely from $\{x, y, z\}$. The necessary and sufficient conditions identified in our second result include the revealed versions of the relevant properties characterized in our first result, in addition to properties that capture the consistency of the revealed Pareto relation and the consistency of revealed compromises.

Because we need to simultaneously recover *two* preference relations, proving Theorem 2 requires a different approach than the one that is typically used in the choice theoretic literature. The difficulty arises when we observe that both x and y were chosen from $\{x, y\}$ and that both y and z were chosen from $\{y, z\}$. These choices reveal to us that the two selves disagree on the rankings of $\{x, y\}$ and $\{y, z\}$. The challenge we face is to determine whether the self who ranks x above y also ranks y above z.[9] We overcome this difficulty by constructing an induction argument in which the elements of X are added in a particular order. In particular, we partition the set of options into "revealed Pareto layers", and the elements in each Pareto layer are further partitioned into "revealed extreme layers" (where the most extreme layer includes elements that are never revealed to be compromises in that Pareto layer).

[8]Mariotti (1998) proposes an extension of the Nash bargaining solution to finite environments. However the extended solution still uses cardinal information as it is defined over sets of payoff vectors.

[9]Note that this difficulty does not arise in establishing the revealed-preference foundation of *non-cooperative* solution concepts, such as Nash equilibrium (Sprumont (2000)). There, we can isolate the preference relation of each player by fixing the action of the opponent.

This refined induction proves useful, not only in defining the selves' orderings and showing that they are transitive, but also in addressing the question of "identifiability": to what extent can we identify the set of preference profiles that are compatible with the observed choices? Clearly, exchanging the rankings between the two selves does not affect the bargaining solution. Our third main result argues that there is a sense in which any further multiplicity is with respect to "irrelevant alternatives". This means that for any given bargaining problem S, we can pin down the pair of preferences over the minimal set of options that Pareto dominate any option outside this set.

So far, we have interpreted our choice procedure as a solution to an *intra*-personal bargaining problem. Alternatively, we may interpret it as a solution to an *inter*-personal bargaining problem where two distinct individuals need to agree on an option. While most of the choice theoretic literature aims to characterize testable implications of models of *individual* decision-making, the same set of tools may be applied to models of *collective* decision-making. Since many collective decisions are achieved through bargaining, it seems important to identify the necessary and sufficient conditions for inferring the bargainers' preferences and for modelling their decisions as an outcome of cooperative bargaining. This paper takes a first step in this direction by studying situations in which two individuals bargain over some finite, arbitrary set of alternatives. We, therefore, focuses on *ordinal* bargaining solutions on finite domains. Among such solutions, the fallback bargaining solution has received much attention in the literature. Moreoever, this solution has a non-cooperative foundation, which is similar to the real-life bargaining protocol, that the Federal Mediation and Conciliation Service (FMCS) recommends to disputing parties.[10] Our last two results then provide testable implications of the fallback solution and characterize the extent to which the bargainers' preferences may be recovered from the data.

7 Egalitarianism under Incomplete Information

The theory of social choice has been applied extensively to determine collective actions. A limitation to its applicability is that it has been developed under the assumption of complete information. In many practical scenarios, on the other hand, the participants already have some private information when they engage in the cooperative process. Developing models of cooperation under incomplete information has long been considered and remains a significant open problem in economic theory, as pointed out, for instance, by Professor Aumann in his first presidential address to the Game Theory Society (reproduced in Aumann, 2003). To be more precise, an impressive amount of work has already been devoted to understand which contracts are feasible under asymmetric information. Professors Hurwicz, Maskin, and Myerson were awarded the 2007 Sveriges riksbank prize in economic sciences in memory of Alfred Nobel for their path-breaking contributions on the topic. Yet, little is known about what specific contracts, among those that are

[10]See Section 1404.12, "Selection by Parties and Appointments of Arbitrators" in http://www.fmcs.gov/internet/itemDetail.asp?categoryID=197&itemID=16959

feasible, are socially desirable. Authors use the ex-ante utilitarian criterion, most often without justification, when they want to select a specific incentive compatible mechanism.Extending the theory of social choice to characterize selection criteria that will be applicable to the mechanism design problem is an important research agenda.

As a first step in that direction, I discuss in de Clippel (2009b) possible extensions of the egalitarian solution to environments with asymmetric information. More specifically, the objective is to find a solution that is anonymous, determines mechanisms that is interim incentive efficient, and that satisfies some form of monotonicity, a property that is known to be characteristic of the egalitarian principle under complete information (see Kalai, 1977, for instance). A first observation is that requiring monotonicity on the whole domain of social choice problems leads to an impossibility result. Contrary to the complete information case, this incompatibility remains valid even if one restricts attention to large sets of collective decisions that allow for transfers and prevent satiation. The reason is that incentive constraints may lead to feasible sets of interim utilities that are non-comprehensive (for instance, a type of an individual may beneficiate of an "informational rent" in any incentive efficient mechanism) and with the possibility of satiation, even in very well-behaved problems. This difficulty will be present throughout the paper, whereby axiomatic results are far more difficult to derive than under complete information.

Considering efficiency as a prime objective, and hence the equity criterion, captured mostly by the monotonicity property, will be weakened in order to escape the impossibility discussed in the previous paragraph. It may be unreasonable to require the monotonicity property when starting with a mechanism whose associated interim utilities belong to the relative boundary of the interim incentive Pareto frontier. In such cases, one cannot exclude that there exist alternative mechanisms that are more equitable, but were not selected because of they are not second-best efficient. On the other hand, one can be sure that efficiency-first is not a binding constraint when the interim utilities associated to the mechanisms in the solution of the original problem belong to the relative interior of the interim incentive Pareto frontier. Indeed, in such cases, infinitesimal compensations in all directions, i.e. for any type of any individual at the expense of others, can be realized at some rate by selecting alternative incentive compatible mechanisms. The restricted monotonicity axiom requires the monotonicity property to apply only in those interior cases. This weaker property is compatible with the properties of interim efficiency and anonymity. Actually, I present a partial axiomatic characterization of the lex-min solution applied to interim utilities after adding the axioms of "interim welfarism," "exhaustivity," and "merging identical types."

Not surprisingly, interpersonal comparisons of interim utilities comes as a consequence of the axioms, as it did under complete information. I react in three ways to this fact. First I apply the new criterion to classical examples in the mechanism design literature (public good and bilateral trade) under the assumption that utilities are quasi-linear, in which case interpersonal comparisons are easiest to accept. Many examples in mechanism design fall in that category, simply because characterizing incentive compatible mechanisms in the more general case can be very hard. Second, I pursue Harsanyi's

(1963) methodology (see also Shapley, 1969, and Yaari, 1981) of endogenizing interpersonal comparisons so as to reconcile the utiltarian and the egalitarian principles. Here I aim at combining the ex-ante utilitarian criterion (which is the natural extension of the utilitarian criterion to the interim stage, cf. Nehring, 2004) and my interim egalitarian criterion by rescaling the interim utilities. Interestingly, it turns out that this is always feasible, even while requiring the interim egalitarian criterion to hold with equality (no need to resort to the lex-min), it leads to a unique solution, and results in a characterization of Myerson's (1979) solution, maximizing Harsanyi and Selten's (1972) weighted Nash product over the set of interim utilities that are achievable through some incentive compatible mechanism (see Weidner, 1972, for a direct axiomatic characterization of that solution under the assumption of independent types). Third, in a companion paper (de Clippel et al., 2009), the solution is applied to utility gains that are measured endogenously in a way that extends Pazner and Schmeidler's (1978) concept of egalitarian equivalence to economies under asymmetric information. Though we do not have an axiomatic characterization of that solution, it has the advantage of being ordinally invariant and applicable to rational preference orderings that do not necessarily satisfy the expected utility hypothesis.

Examples show that some agents may feel that the outcome the interim egalitarian solution is actually biased in favor of some other individual *given the information they have*. This motivates another possible extension of egalitarianism in quasi-linear collective choice problems that selects the interim incentive efficient mechanisms that maximize the minimum of the type-agents ratios between their expected utility gains and the total surplus they expect the mechanism to realize. Since I do not have an axiomatic characterization of that second criterion, I only mention it in the concluding section, and study its properties in view of the axioms that have been introduced earlier. It interesting to observe that the presence of incomplete information does not only create difficulties in finding selection criteria that satisfy some normative properties because of the incentive constraints, but also leads to different normative criteria, distinguishing a notion of equity from the point of view of an impartial designer and a notion of equity as perceived by the participants themselves, a distinction that is of course irrelevant under complete information.

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