3.2.1 Cooperative Games and Implementation of Cooperative Structures

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The main goal of this project is to shed more light on the nature of cooperative solution concepts and their final manifestation by either providing noncooperative foundations or by supporting them in a suitably designed market structure.

Topic:

Cooperative structures emerge in a variety of economic and social situations. Within this project, the focus will be put on cooperative games, allocation problems, models of coalition formation and of (social) network formation. Beyond the bare formulation of cooperation possibilities the literature offers solution concepts in each of these contexts. For instance, the notion of a *core* appears in all such models in appropriately modified versions but always relying on the same basic idea.

However, the formulation of a solution concept, and further, the analysis of existence and uniqueness, do not necessarily provide a recipe, how that solution can actually be achieved. More precisely, is there a way to obtain cooperation as a result of strategic interaction and without using peculiar knowledge of agents' characteristics? This problem is at the heart of mechanism design, which origins should be attributed to 2007 Nobel prize winner Leonid Hurwicz (see, e.g., Hurwicz (1972)). Even earlier, Nash (1953) already had stressed the point that the cooperative and the noncooperative games represent "two approaches, each of which helps to clarify and justify the other".

From classical mechanism design, we know several different variations of implementation, distinguished according to the noncooperative model and the solution concept employed for implementation. What is common to them is the method that the combination of a mechanism, i.e., rules for a game, and the agents' characteristics together induce a noncooperative game (e.g., in strategic or extensive form). One aim of this project is to complement this traditional scope with the design of underlying markets. The more precise question is the following one: Is it possible to achieve a cooperative solution by having agents interact in an appropriate market? Put in other words, can one design a market such that the desired result of cooperation is obtained in a market equilibrium? For example, determining the prices in an exchange economy shall now be viewed as part of the rules of the (market-)game, while utility maximization with respect to such prices yields the envisaged outcome.

To sum, the aim of this project is three-fold: We not only seek to contribute to the fields of cooperative structures and respective solutions on the one hand, and mechanism design on the other hand. We rather mainly head for establishing links between the two of them, thereby achieving a better understanding of each of the two important strands of game theory.

This generally stated aim shall be investigated in three overlapping areas: *NTU games / Bargaining, Coalition Formation / Matching, and Networks*. Researchers from Bielefeld and Paris have contributed to any of these areas. We believe that the project benefits from the different foci. Whereas the Bielefeld group has put more emphasis on mechanism design, bargaining theory, matching and network analysis, the Paris researchers contribute with their expertise in (N)TU solution concepts, competitive markets, and coalition formation.

State of the art, prior work, and research agenda:

NTU games / Bargaining:

The literature on implementation of bargaining solutions suffered for several years from an imprecise notion of the object to be implemented. Howard (1992) argues that the Nash bargaining solution (like other solutions) is not Nash implementable, as it does not satisfy Maskin monotonicity. According to him, therefore, there cannot be a noncooperative model that allows to obtain a bargaining solution in equilibrium. In their paper, Bergin & Duggan (1999) clarify the relation between the cooperative structure (e.g., NTU game) and social choice correspondences that reflect cooperative solutions along effectivity/supportability notions. In a series of papers on this topic, but with different foci Trockel (1999), Trockel (2002b), Trockel (2002a), Naeve (1999) and Haake & Trockel (2008) demonstrate positive implementation results for bargaining solutions. In particular, the lack of Maskin monotonicity can be overcome by an appropriate definition of the social choice correspondence. An open question is, whether there are "reasonable" mechanism for implementation. The constructive proofs in the general setup (see, e.g., Maskin (1999) or Yamato (1992)), do show existence, but the involved mechanisms can hardly be called applicable. Exploiting the structure of the cooperative model eventually leads to "better" mechanisms.

Starting with the contributions of Eisenberg (1961) and Chipman & Moore (1979), there is a well-established connection between various bargaining scenarios and underlying economies, so that the Nash bargaining solution prevails in Walrasian equilibrium of that market (see also Trockel (1996), Trockel (2000). The works Haake (2007), Haake (2008) analyze in how far solutions for bargaining games that stem from an object allocation problem can be achieved by looking at the underlying exchange economy. It turns out that, in the presence of two agents, prices can always be determined so that the utility allocation in Walrasian equilibrium coincides with the superadditive solution of Perles & Maschler (1981) (see also Ervig & Haake (2005)). As mentioned before, we do consider agents as price takers, but prices are not formed under competition but are part of this "Walrasian mechanism". In effect, we employ the Walrasian solution concept to implement a bargaining solution. In a similar way, the Kalai & Smorodinsky (1975) solution is achievable through the Walrasian equilibrium concept.

Yet, certain aspects deserve further investigation. From bargaining theory (see Perles (1982)), we know that there is no superadditive bargaining solution on the class of all bargaining games that involve three or more agents. However, Pallaschke & Rosenmüller (2007) do in fact construct a superadditive solution on a subclass. What is missing is an underlying model of an economy that allows us to get the cooperative solution as a market equilibrium.

While there are open questions in the bargaining context, the situation is totally unclear in the case of NTU games. Here, Rosenmüller (2007) provides an extension of the Maschler-Perles solution. The key property that characterizes this value is conditional superadditivity. Again, an immediate question is, whether there is an appropriate market model that allows us to establish a connection between value and market solution. Such a link would certainly provide further insights in the nature of the cooperative concept. In this respect the works Bonnisseau, Florig & Jofré (2001) and Florig (2004), that analyze the Walrasian equilibrium correspondence of linear economies, shall be relevant for this endeavor.

In the attempt to understand the fundamental features of the relation between various solution concepts of cooperative games and market equilibria one can even be more radical and follow Shapley & Shubik (1969, 1975) and others in analyzing games by considering them directly as specific economies ("direct markets") . Utility possibility sets of coalitions defined by the coalitional (or characteristic) function - in fact a correspondence in the case of NTU - games are considered as production possibility sets for "producing" utility for the coalition's members. Such an approach led to the characterization of the Nash bargaining solution as the limit of a shrinking core of a sequence of naturally induced "bargaining economies" by Debreu-Scarf type arguments in Trockel (2005).

The relation between specific game theoretic solutions and competitive allocations may help not only to determine (utility) allocations but simultaneously the underlying coalition structure. For the special case of TU-games interpreted as coalition production economies and by the use of an adaptation of the core to this goal (c-core) Sun, Trockel & Yang (2008) have recently provided such a result. An analogon for NTU games, however, presently appears to be out of reach. Yet this is a very promising alternative approach to coalition building that we address in our project from various angles (see below).

In Bonnisseau & Iehlé (2007), Bonnisseau and Iehlé prove the non-emptiness of the core of an NTU game satisfying a condition of payoff-dependent balancedness, based on transfer rate mappings. They also define a new equilibrium condition on transfer rates and they prove the existence of core payoff vectors satisfying this condition. This work is strongly related to the work of Predtetchinski & Herings (2004). The additional requirement of transfer rate equilibrium refines the core concept and allows the selection of specific core payoff vectors. They also study the class of parametrized cooperative games introduced by Ichiishi. This new setting and its associated equilibrium-core solution extend the usual cooperative game framework and core solution to situations depending on an exogenous environment. A non-emptiness result for the equilibrium-core is also provided in the context of a parametrized cooperative game. In particular, they show that the existence of a core allocation in an exchange economy with non-ordered preferences from Border can be deduced from an equilibrium-core allocation of a well-suited parametrized cooperative game.

The proofs borrow mathematical tools and geometric constructions from general equilibrium theory with non convexities. In some sense, they reveal a hidden link between the core allocations and the equilibrium allocations for a production economy with only two producers. Conversely, we can remark that in Herves Beloso & Moreno (2008), it is shown that the Walras equilibrium allocation of an exchange economy is the Nash equilibrium allocation of a two-player game.

Three directions for further research can be initiated from concepts and results of Bonnisseau & Iehlé (2007): core of a possibly non-convex economy, core with asymmetric information and core selections.

In a non-convex economy, the payoff-dependent balancedness enlarges the geometric possibilities to get a non-empty core. The negative result of Scarf (1986, Theorem 5 p.426) delimits however the range of new results. In a convex economy with production, Florenzano (1989) uses a direct proof to show the core non-emptiness under a balancedness assumption which holds on the production sets of the economy. In her setting where no cooperative game structure is defined, one should restate payoff-dependent balancedness by defining transfer rates directly on the fundamentals of the economy.

In the setting of parametrized games, the main result of Bonnisseau & Iehlé (2007) allows to show the non-emptiness of the incentive cores with asymmetric information (Ichiishi & Idzik 1996, Ichiishi & Radner 1999) and the non-emptiness of the α-core (Kajii 1992, Scarf 1971). To show these results, one makes only use of the standard balancedness. In future research, one could exploit the flexibility of the payoff-dependent balancedness, to get additional existence result of core allocations for a larger class of games.

The transfer rate rule condition introduced via the payoff-dependent balancedness opens the possibility for selecting core payoff vectors. Other contributions in various fields deal with core selections, see for instance Herings, van der Laan & Talman (2006), Ichiishi & Idzik (2002), Kannai & Wooders (2000), Page & Wooders (1996), or Reny & Wooders (1998). The incorporation of appropriate transfer rate rules might lead to a unified treatment to describe core selections.

In case a market was involved in the research agenda described by now, we do not impose restrictions on characteristics of the traded commodities. Hence, parallel to the investigations, it seems worthwhile to limit the scope to markets, in which all or some objects are indivisible and ask, which results can be retained. Inoue (2005, 2008) considers an exchange economy where all commodities are indivisible. In such an economy, Inoue (2005) shows that a stronger version of the core coincides with the set of Walrasian allocations. Because of the indivisibilities, this core may be empty in some economies. Inoue (2008) gives a sufficient condition for the nonemptiness of the (usual) core. In an economy with indivisible commodities, as the number of feasible allocations is finite, a core allocation can be found in a finite number of steps. An open issue is to clarify which class of economies has an efficient algorithm to compute a core allocation. Another unsettled issue is to clarify the relation between Walrasian allocations and other cooperative solution concepts in an economy with indivisible commodities. Phrased differently, what cooperative solution is “implemented” by the Walrasian mechanisms, when goods can only be consumed in integer quantities?

The search for an implementing mechanism actually can be seen as the search for finding stable states of the world, independent of how agents' preferences look like. A good theory of stability (possible implementation) should also be accompanied by a theory of instability. For example, stability is a highly desirable property for political systems and the modeling of political interactions has to take this stability requirement into account. In coalitional models, stability is defined as the possibility of achieving, for any preference profile, a state that no coalition would oppose. In strategic models, this amounts to the existence, for any preference profile, of an equilibrium (solvability). However it is commonly known that most political systems are unstable in this sense. In mathematical social sciences, results known as impossibility theorems reflect the fact that stability (or solvability) is rather hard to obtain. Therefore it is interesting to investigate the properties of *unstable mechanisms*.

First, his investigation can be carried out in a general setting (see Abdou & Keiding (2003) for the general notion of effectivity structure). We are interested in defining a notion of stability index and investigate whether such an index gives information about the probability of conflict in the strategic or cooperative mechanism. The notion of index is defined in relation with the notion of cycle which is a generalization of the Condorcet cycle.

Second, concerning the bargaining set (with its variants) we are interested in the stability of effectivity functions for bargaining sets. More precisely given an effectivity function our aim is to find necessary and sufficient conditions so that the bargaining set be non-empty for all preference profiles of the players. This work is known as the stability problem when the solution concept is the core (Abdou & Keiding 1991).

Finally, we address a specific, seemingly more applied question. Cooperative solution concepts are frequently routinely employed to model labor market outcomes. The bargaining outcome is analyzed in the space of the crucial economic variables: wages and employment. While this approach is reasonable from an economic perspective, it is nevertheless unsatisfactory, as the solution concepts are defined in terms of utilities. And the link between these two ‘worlds’ seems to get lost. More precisely: Does the economic model of negotiations between a labor union and an employers' federation in fact constitute a bargaining problem in the sense of the bargaining theory? If so, how do the defining axioms of the various solutions concept, which are formulated in terms of utility, translate into the space of economic variables? For example, what do the axioms of *Independence of irrelevant alternatives* and *Monotonicity* imply in economic terms? And conversely, what are the consequences for the formal bargaining problem, when the parties on the labor market negotiate about wages, employment or about both? And what if these negotiations take place sequentially?

While it has been shown by Gerber & Upmann (2006) that union-employers negotiations over wages and employment constitute a bargaining problem in the sense of the bargaining theory, the other question are still unexplored. Haake and Upmann therefore commenced to scrutinize the connections between formal solution concepts and labor market negotiations. This work will illuminate and thus lead to a more comprehensive understanding of the fundamentals of labor market negotiations. On grounds of this work we shall then be able to investigate and understand in more depth specific aspects on labor markets such as joint negotiations and labor unions mergers, minimum wages and, more broadly, the effects of institutional changes on the labor market, again bridging bargaining theory and mechanism design.

Coalition Formation / Matching:

In seminal works, Bogomolnaia & Jackson (2002) and Banerjee, Konishi & Sönmez (2001) analyze a coalition formation model and present various versions of *stable coalition structures*. Their models in fact go back to works of Greenberg (1978) and Dreze & Greenberg (1980). What is new, is that agents' preferences are purely hedonic, meaning that each agent only cares about the coalition he is a member of. In essence, the above papers provide sufficient conditions for existence of core stable coalition structures in such hedonic games. Later, Iehlé (2007) arrived at a condition that is necessary and sufficient. His work uses an approach inspired by Bonnisseau & Iehlé (2007) (see above).

Presumably, the most prominent application of coalition formation is the formation of governments after parliamentary elections. Shenoy (1979) introduces a model, in which he uses the Shapley-Shubik power index to derive a notion of a core stable government, i.e., a winning coalition in the underlying simple (TU-) game. Dimitrov & Haake (2006), Dimitrov & Haake (2008) extend Shenoy's model, formalize and characterize the notion of the *semistrict core* of a hedonic game. Preferences in the hedonic game are given by application of a cooperative solution concept to corresponding simple games. Finally, Barbera & Gerber (2003) introduce a stability notion that is also different from the core.

There are a couple of open issues in this area that deserve further investigation. So far, there are few works on implementation of the core of a hedonic game. Bloch & Diamantoudi (2006) demonstrate a positive implementation result for the subclass of totally balanced hedonic games. Sönmez (1996) obtains Nash implementability in a generalized matching problem. Strategic models for coalition formation in the parliament, such that the various versions of the core can be implemented, are still missing. Here, one might expect a positive result from exploiting the underlying specific structure of the hedonic games context.

Apart from questions of implementation, there also remain open problems on the cooperative side. For instance, the approach used in Dimitrov & Haake (2008) may be transferred to model coalition formation with an underlying arbitrary (N)TU game, instead of a simple game. More precisely, agents evaluate a coalition by what a particular cooperative solution concept assigns to them in the game played by that coalition. Of course, one should not expect positive results on the core for the class of all games, but for certain interesting subclasses, this should be possible. Another issue that needs to be settled is whether there is a necessary and sufficient condition for he existence of semistrict core stable coalition structures in order to better understand the nature of this concept.

A special case of coalition formation that has rather independently developed its own field of research is the theory of matching. Starting with Gale & Shapley's (1962) fundamental contribution to the analysis of stable matchings, stability (of a matching) can now be defined in various kinds of matching markets. Roughly ten years ago, Kara & Sönmez (1996, 1997) showed that the stable correspondence is Nash implementable (see also Haake & Klaus (2008) for an implementability result in a more general context). These results rest on a version of Maskin's (1999) mechanism and are far from being "realistic". Therefore, an interesting question would be, whether the well-known structure of matching markets and the stable correspondence can be used to derive "better" mechanisms that implement the stable correspondence.

Networks:

Similar to the issues raised in the above two sections, the area of network economics bears a series of unanswered questions, from which we focus on three particular ones.

First, Jackson (2005) introduces allocation rules for network games. Precursors of the model and solutions he uses are the works by Myerson (1977) or Owen (1986). Jackson also provides a method to transfer cooperative solution concepts to solutions for network games. However, this does not include a proper analysis within the context of network games. In particular, axiomatization results, such as for the transferred version of the nucleolus, should be added. As a next step, a strategic approach to allocation rules and hence an implementation result will definitely complement this part of the networks literature.

Besides the cooperative structures that stem from game theory, there are recent developments to utilize concepts from graph theory to define new allocation rules. For instance, Brandes & Erlebach (2005) or Borgatti & Everett (2006) survey centrality measures that, as the name says, indicate, how central an agent is in a social network. While there is an appealing interpretation for this concept in networks analysis, a theoretical foundation is again still open. Also, the incentives that the centrality concepts provides in network formation models build an object of active research. For a survey on network formation models see, e.g., Slikker & Van den Nouweland (2001) or Dutta & Jackson (2003).

Second, there are almost no works on network formation under incomplete information. Dimitrov & Haake (2007) take a first step into this direction. Specifications of the model for different relevant scenarios promise substantial progress in this respect.

PhD projects:

1. Market Design to implement solutions for NTU games.

2. Core and increasing returns to scale in production
3. Coalition formation in (N)TU games
4. Implementation of core stable coalition structures in hedonic games that are derived from (N)TU games
5. Mechanism design in matching markets
6. Implementation of allocation rules for network games
7. Network formation under incomplete information

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