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# Simple Mechanisms to Resolve Conflicting Interests and to Share the Gains

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# "Simple Mechanisms to Resolve Conflicting Interests and to Share the Gains"

**David Pérez-Castrillo**[*]

## 1. Introduction

Reaching a joint decision that concerns several people, organizations or countries, is always a difficult task. Preferences about different candidate outcomes may vary from one agent to another. This *opuscle* discusses existing mechanisms that may allow agents to reach efficient decisions that affect all of them. It also proposes a new mechanism, called the *multibidding mechanism* and analyzes its properties. Finally, it shows that the multibidding mechanism can help sharing the benefits from cooperation in an equitable manner.

The leading example that I will often use concerns the decision about the location of a large international research infraestructure. The decision about the city that should host such a facility is always the subject of hot debate among the candidates and other interested countries.

In 2002, the European Commission set the European Strategy Forum on Research Infrastructures (ESFRI) whose scope is "to support a coherent and strategy-led approach to policy making on research infrastructures in Europe and to facilitate multilateral initiatives leading to a better use and development of research infrastructures." Examples of research infrastructures include libraries, databases, biological archives, communication networks, research vessels, satellite and aircraft observation facilities, coastal observatories, telescopes, synchrotrons, and particle accelerators.

ESFRI has developed a strategic roadmap for Europe in the field of research infrastructures. The aim of this roadmap is to describe the scientific needs for research infrastructures for the next 10-20 years, on the basis of a methodology recognised by all stakeholders, and taking into account input from relevant intergovernmental research organisations as well as the industry. In its 2006 Report, ESFRI presented a first roadmap which identifies 35 projects for new, large-scale research infrastructures.

A number of criteria are used to select the research infrastructure projects that are able to enter in the European roadmap and their inclusion implies that they are supported by at least one European member state and have great potential at the pan-European level. In general, each research infrastructure is supported by several states and also several states put forward their own candidacy to host it.

Although ESFRI is instrumental in the identification of the projects, it is silent about how the interested countries should decide the location of the facility. However, this is a very difficult decision that involves many scientific, economic, and social issues. For each project, supporting countries should work out a procedure to choose the host of the facility. Therefore, they must decide first about a mechanism and then use the procedure to elect the hosting city.

Many other examples fit the type of situations I will discuss. A very relevant one is the location of noxious facilities, such as dump-sites, environmentally hazardous plants, prisons, nuclear power generators and the like. All the municipalities in a



certain area may agree that they need a dump-site. Also, they all may share the view that one dump-site is enough for all of them and that building just one site is the most efficient decision. However, trouble appears when they have to decide where to locate the facility since no municipality wants to host it. Indeed, such facilities suffer strong opposition by communities since they usually generate relatively little new employment and provide limited additional taxes in relation to their perceived negative impact. The problems are so severe and so common that an acronym is used to refer to them: NIMBY (Not In My Back Yard).[1]

A highly contentious NIMBY situation that illustrates the difficulty of reaching a decision about location concerns nuclear-waste repository in the USA. After many years of discussion and studies, the US Senate decided in February 2000 that nationwide nuclear waste would be shipped to the Yucca mountain site in Nevada (conditional to it being approved as a high-level nuclear waste repository). Despite the attractive compensation package, the state of Nevada voiced vehement opposition. President Clinton vetoed the bill, and in May 2000 the Senate failed to overturn it. In July 2002, president George W. Bush allowed the Department of Energy to take steps in establishing a safe repository in the Yucca mountain, and the Department proposed 2017 as the date to open the facility. However, Nevada Senator Harry Reid, a long time opponent of the repository, has became the Senate majority leader and is working very hard to block the completion of the project.

As a final example, consider the debate whether to transfer water from rivers in the north of Spain to the arid southern regions. The parties involved have conflicting interests with regard to the best project or the size of the transfer payments that would compensate the localities that would be relinquishing part of the water supply.

The previous examples and many other cases belong to a class of problems in which a group of agents has to choose one out of several projects. In some situations, the set of projects coincides with the set of agents, as it is the case if a group of municipalities meet to choose one of them to host a dump-site. In another context, the set of agents is larger than the set of projects. This is typically the case when countries or institutions build a large international research infrastructure: the number of parties involved in the choice of the location is larger than just the candidate cities or states.

The "social" objective would be to carry out a project among the efficient ones, that is, a project that maximizes the aggregate welfare of all the agents. In addition, the decision may (or should) involve monetary transfers from some agents to others so that the final outcome can be considered "fair" to everybody.

In the next sections, I will describe some mechanisms that may help the agents reach joint decisions and analyze their main properties. First, in Section 2 I will discuss some previous contributions. Section 3 will be devoted to introduce and discuss the properties of the multibidding mechanism that David Wettstein (from Ben-Gurion University of the Negev) and I developed to address this type of questions. Finally, in Section 4 I will show that the multibidding mechanism can also be part of decision methods that allow for sharing benefits from joint decisions in an equitable manner.

## 2. Review of some previously suggested mechanisms

Imagine the decision faced by a group of countries concerning the location of a large international research infrastructure supported by ESFRI. From this group, some countries have presented their candidacy to host the facility (imagine the remaining countries are not interested, or that the location is required to meet some criteria that only a few places satisfy).

Candidate countries want to host the facility because of the benefits it affords in terms of scientific spillovers, job creation, etc. One easy way to express countries' preferences is through their willingness to pay for an extra share of the construction and maintenance cost of the research infrastructure.[2] Also non-candidate countries have preferences concerning the location, since they may prefer, for example, easier-to-reach cities than far-away locations. However, each country is willing to accept a location that is bad from its point of view if the decision is accompanied by a good compensation package. Also, they are ready to contribute to convince some other countries to support their preferred location. How much they are ready to contribute might depend on the identity of the hosting country, the number of national scientists interested in the research infrastructure, the *per capita* income, or any other factor.

Imagine that every country knows the willingness to pay of all the others. Further, to clarify the problem at hand, consider the simplest scenario, where ESFRI (as the "planner") also has this information. Then, reaching an efficient outcome is trivial: the planner should compute benefits and losses for each of the candidate cities/countries hosting the research infrastructure. Finally, it should choose the location with the highest global benefits; and it should typically set a compensation scheme from the countries that benefit the most (including the hosting country) to the others so that they are all treated in a fair way.

However, in real examples, most often the parties concerned possess much more information than the planner (the European Union, in the previous example). Hence, the planner faces a non-trivial problem of optimally choosing one of the projects. Moreover, from a normative point of view, even if the planner has all the information, it is easier to justify the use of a fixed procedure to reach a decision than to modify the procedure for various cases in light of information disclosed or already available to the planner. That is, given that ESFRI is supporting several research infrastructures, public opinion would prefer that ESFRI proposes a mechanism to be used to choose the location of all them to a procedure where ESFRI unilaterally decides on each of the location using an unknown and possibly different mechanism each time. "Anonymous" mechanisms, that is, mechanisms that are applied independently of the identity of the agents involved, are perceived as fairer (and they are also more immune to lobbying and rent-seeking) than mechanisms where one body decides on a one-to-one basis.

Several (anonymous) mechanisms are available for the problem of choosing one from a set of projects. One class of methods embraces the so-called *voting schemes*. Concerned agents meet and vote so that the chosen alternative is, somehow, the most preferred. I briefly describe two of the most popular voting schemes. Another class of methods consists of various types of auctions.

## 2.1. Voting schemes

Under "*plurality voting*", each agent (voter) is allowed to vote for only one candidate and the project with the highest number of votes is selected. The winning project does not have to receive the majority of the votes: it only needs to be chosen by a larger number of agents than any other project. Plurality voting is often used to elect executive officers or members of a legislative assembly that is based on single-member constituencies. It only requires information about each agent's most preferred candidate, all other information is irrelevant. Therefore, plurality voting may end up selecting a project that is the most preferred by some agents but it is very harmful for many others. Indeed, a project may be carried out because majorities outvote minorities, although it can be the case that the gain of the majority from a project is clearly smaller than the loss of the minority.

The "*Borda count*" is a more flexible voting system. Under this mechanism, agents rank projects in order of their preference. Then, the Borda count determines the winning project by giving each alternative a certain number of points corresponding to the position in which it is ranked by each agent. For example, if there are four projects, the highest rank would receive 3 points, the next one 2, and so forth. Once all votes have been counted, the project with the highest number of points is chosen. The Borda count sometimes elects "broadly" acceptable candidates, rather than those that are the most preferred by some agents, so it is often described as a consensus-based system (it is similar to the system used, for example, to elect the winner at the Eurovision Song Contest).

Voting schemes have the advantage that they do not involve monetary transfers, that in some circumstances might be difficult to implement. Nevertheless, the use of mechanisms that do not use money creates in general large problems. Such mechanisms do not allow for compensating "losers" properly. They forbid those agents who would greatly benefit from some particular alternative to pay other agents that would be happy to "change their mind" in exchange to some reasonable compensation. Because of these problems, the outcome generated by voting schemes typically is not efficient.

## 2.2. Auctions

*Auctions* are the most common mechanisms allowing agents to express their preferences (their willingness-to-pay) in environments where the issue is the allocation of a good (like a painting, a lot of fish, or a UMTS license). Auctions have also been suggested in the literature for some of the situations that I analyze, in particular for siting noxious facilities, settings where the number of agents coincides with the number of projects. Analyses have been developed in environments where each agent knows his own preferences but does not know the preferences of the other agents. The idea applied to the example of several municipalities deciding the location of a noxious facility is to try to elicit the municipalities' cost if they obtain the facility and also their willingness to pay for someone else to assume this burden.

A *simple sealed-bid auction*, suggested and analyzed by Kunreuther and Kleindorfer (1986), is the following. Each municipality only has to make a "bid" that indicates the compensation that it should receive in case it is designated as the host of the facility. The bid simultaneously settles the amount the municipality pays if some one else is the host. For example, if there are 5 municipalities and municipality *A* makes a bid of 40, then it will receive 40 if it is the winner of the auction (hence, it hosts the facility). Otherwise it has to pay 10 (40 divided by the number of outside municipalities) if some other municipality wins the auction (independently of the bid that *the other municipality* made). An outside agency collects all the data and allocates the facility to the municipality with the lowest bid (that is, the one that requires the least money to host the dump-site). Given that the other municipalities' bids were higher than the winning bid, the sum of the payments the others make covers the compensation due to the winner and is likely to create a surplus for the agency. That is, the auction provides the means to compensate the hosting municipality.

The proposed sealed-bid auction has some good properties if the municipalities use maximin strategies, which are "prudent" strategies meant to ensure a reasonable outcome "in the worst-case scenario".[3] In environments where each municipality is indifferent about the location of the facility as long as it is not the host, the auction provides an efficient location when the municipalities follow maximin strategies.[4] The mechanism also leads to efficient locations if municipalities play strategically when only two municipalities are involved in the decision (and the parameters reflecting the costs of hosting the facility for the two cities are independently drawn; see O'Sullivan, 1993). However, the sealed-bid auction leads to inefficient location of the dump-site in more complex environments. The main reason behind the inefficiencies is that each municipality does not have any room to express different preferences for the location of the facility in other municipalities.

I will not comment on more sophisticated schemes that approach the siting problem from a mechanism design point of view (see, for instance, Rob, 1989 and Jehiel, Moldovanu and Stacchetti, 1996). Apart from their complexity, they are very sensitive to the particulars of the environment to which they are applied.

# 3. The multibidding mechanism

In the paper with David Wettstein (2002), we address the problem of reaching an efficient decision by suggesting a new mechanism. We construct a *multibidding mechanism*, which can be seen as a particular form of auction. In the multibidding mechanism, each agent submits a bundle composed of a bid for each project instead of just one bid. Thus, we propose a more flexible mechanism than the traditional auction that allows the agents to "fine-tune" their strategy. Bids can be positive or negative. Each bid can be interpreted as the amount of money the agent is willing to pay if that project is chosen. When country *A* submits a bid of 20 for project $l_A$ (meaning that the research infrastructure is located in country *A*), then country *A* should be ready to pay 20 in case it hosts the facility.[5] When, at the same time, *A* submits a bid of –15 for project $l_B$, then country *A* should receive 15 if the facility is located in country *B*. The only restriction imposed on the bids submitted by an agent is that they have to sum up to zero. That is, bids try to reflect relative, rather than absolute, worth whereby more desirable projects receive a larger bid.

The multibidding mechanism can be applied to any scenario where a group of agents has to choose one out of several projects; the set of agents does not have to necessarily coincide with the set of projects (as it was the case in the environments where municipalities decide on the location of noxious facility). It follows simple rules and it is easy to use; its design does not require any knowledge of the particulars of the environments; and it satisfies appealing efficiency and strategic properties. Hence, I would like to advocate the multibidding mechanism as a scheme that, for example, could be proposed by ESFRI to be applied to choose the location of all the research infrastructures in its roadmap.

Once all the bids are made, the planner (say, ESFRI) picks one project and a system of transfers as follows. Define the "aggregate bid" for a project as the sum of bids made for this project by all the agents. The project with the highest aggregate bid is chosen.[6] The agents pay the promised bid corresponding to this particular project (hence, those agents whose bid for the winning project is positive pay while those whose bid is negative receive some transfer), it is carried out, and any surplus is shared equally among the agents (the surplus of the project with the highest aggregate bid is always non-negative as the sum of all the aggregate bids must be zero). The system of transfer payments serves, in part, to compensate those agents who are not pleased with the chosen project.

To clarify the functioning of the multibidding mechanism, imagine that five countries, *A*, *B, C, D*, and *E* have to choose the location of a research infrastructure. The three candidate cities to host the facility are $l_A$, $l_B$, and $l_C$, located in countries *A*, *B*, and *C*. Countries like hosting the facility and, otherwise, may also have preferences for the facility to be located in nearby cities rather than in faraway cities. Taking into account their preferences (and possibly playing strategically), imagine that the countries choose the following vectors of bids: $b^A = (30, -10, -20)$, $b^B = (-5, 20, -15)$, $b^C = (0, -15, 15)$, $b^D = (-5, 5, 0)$, and $b^E = (-10, 5, 5)$ where, for example, $b^A = (30, -10, -20)$ means that the bid made for *A* in case city $l_A$ is chosen is $b^A(l_A) = 30$, while country *A*'s bid if $l_B$ or $l_C$ hosts the facility is $b^A(l_B) = -10$ or $b^A(l_C) = -20$, respectively. As required by the mechanism, the sum of all the bid components in a vector is zero.

In this example, the aggregate bid for each of the three locations is $B(l_A) = 10$ ($10 = 30 - 5 + 0 - 5 - 10$), $B(l_B) = 5$, and $B(l_C) = -15$. Since the aggregate bid for location $l_A$ is the largest, i.e., $B(l_A) > B(l_B)$ and $B(l_A) > B(l_C)$, the mechanism selects city $l_A$ as the host for the facility. Given this choice, countries should exercise their bids for this location: Country *A* committed to pay 30, while countries *B, C, D*, and *E* asked to receive, respectively, 5, 0, 5, and 10. However, since there is a surplus of 10 over the table, it is shared and each of the five countries receives 2. Hence, country *A*' final contribution is 28, while countries *B, C, D*, and *E* finally receive a compensation of, respectively, 7, 2, 7, and 12. Clearly, how happy each country is with the outcome of the multibidding mechanism will depend on both the money it contributes/receives and the satisfaction it obtains with the research infrastructure being located in city $l_A$.

The first appealing property of the multibidding mechanism is that an agent is at least as well off when participating in it as he is when staying out of the process. That is, if an agent concerned with the issue is given the option of not to participate in the mechanism, he will not take this option. Indeed, bidding zero for all the projects is better than not participating: the bid will not influence the result but the agent can obtain a share of the surplus, if there is any.

Moreover, even a naïve and very risk-averse agent can do better than bidding zero. He can choose a vector of bids so that he guarantees himself a certain final benefit irrespective of the choices made by other agents (that is, he can follow a maximin strategy). The agent can in fact secure for himself a payoff always equal at least to his *average worth*, that is, to the average of this agent's worth of all the projects. To see how to do it, let us come back to the example of the location of a large international scientific facility. Suppose that the worth for country $A$ of the three projects $l_A$, $l_B$ and $l_C$ is 45 (if location $l_A$ is selected), 15 (if $l_B$ is selected) and 0 (if $l_C$ is selected). Imagine that country $A$ chooses the vector of bids $b^A = (25, -5, -20)$. If it selects these bids, country $A$ obtains a final worth of at least $45 - b^A(l_A) = 45 - 25 = 20$ if, given the other countries' bids, the mechanism selects location $l_A$. Note that 20 is the average worth of the projects for country $A$ (20 is one third of $45 + 15 + 0$). By similar calculations, $A$ also obtains at least a worth of 20 if any of the other two locations is selected, independently of the bids chosen by the other agents. If fact, country $A$ may end up with a worth higher than 20 if the aggregate bid of the chosen location is strictly larger than zero, since it gets its fair share of the surplus.



To explain further strategic properties of the multibidding mechanism, I distinguish two informational set-ups. In the first environment, participating agents have complete information (although the planner does not). This could be a reasonable description, for example, of a situation where the planner is the university president and the agents, members of a department, one of whom should be designated as a chairman. In the second environment, agents hold private information regarding their valuation of the projects. This may better describe reality when agents do not know well each other's interest in the projects, as it may be the case when countries decide on the location of a facility involving countries from all over the world.

### 3.1 The multibidding mechanism when there is complete information

Consider first the *complete information environment*. The first question is: How are agents expected to bid if they take decisions strategically, each looking only for their interest? The most accepted view is that agents playing strategically will end up in a Nash equilibrium. A Nash equilibrium is a set of strategies (bids, in our case), one vector of bids for each agent, such that no agent has incentive to change his action unilaterally. Agents are "in equilibrium" if no change in the strategy by any one of them would lead him to earn more than if he remained with his current strategy.

It is clear that, in every Nash equilibrium of the multibidding mechanism, the final utility of any agent is greater or equal to his average worth: otherwise, this agent should follow his maximin strategy!

The most important property concerning the implications of agents playing the multibidding mechanism is that all Nash equilibrium outcomes of this mechanism are efficient. That is, the project chosen in equilibrium satisfies that the sum of the worth of this project for all the agents is the highest among all the projects. This is the crucial property we require from a good decision rule: it should lead us to the best global outcome, even though the authorities in charge lack precise information on the benefits associated with each project.

The intuition for the efficiency property is the following. If the project chosen in equilibrium was not efficient, then it would be possible to increase the aggregate utility of the agents by choosing an alternative project. This would certainly improve the situation of at least one agent and that agent could, by slightly modifying his strategy, attain a better outcome, in contradiction to the fact that the choice of the project was an equilibrium outcome.

How the agents share the gains from the efficient decision will depend on the particular Nash equilibrium that will be played. It is indeed the case that, under complete information, there are typically a set of Nash equilibria; hence, it is difficult to predict the one that will be played by the agents (and the multiplicity of equilibria may lead to some coordination failure). On the other hand, when there is some asymmetry of information between the agents (as in Section 3.2), the equilibrium is unique and can be identified in a similar way as in the classic auction theory.

Finally, one concern regarding the realization of efficient outcomes via Nash equilibria is that the results are often not immune to coalitional manipulations. That is, even if a single agent can not improve by unilaterally modifying his strategy, a subset of the agents could possibly improve their situation through a joint deviation. For example, two countries, say *A* and *D*, could talk and jointly decide about their bids in a way that would benefit both. However, this can not happen in the multibidding mechanism: it is immune to this type of deviations. (In game theory jargon: all Nash equilibria are also strong Nash equilibria.) This property adds further credibility to our efficiency results and makes the mechanism more attractive for policy makers since it will achieve efficient outcomes also in environments where agents might collude and coordinate their bids, which may often be the case in real-world situations.

### 3.2 The multibidding mechanism when there is incomplete information

The complete information framework that I discussed before is sometimes a reasonable approximate representation of the problem at hand. This would be the case, for example, for those location decisions where each of the countries (or institutions) concerned by the construction of a research infrastructure has enough information about the preferences of the other countries with respect to where to locate the facility. In those cases, the analysis developed so far gives a good indication about what to expect if the multibidding mechanism is put in practice.

Other situations seem better characterized by the existence of asymmetric information about the agents, each agent having private information concerning his preference with respect to the project chosen. I report here the conclusions obtained by Róbert Veszteg (forthcoming), who studies how the multibidding mechanism performs when agents hold private information and are uninformed about others' preferences. In particular, he analyzes environments where agents are *ex ante* identical and risk neutral, and they have to choose among two projects.

Remember that a crucial objective of the multibidding mechanism is that bids reflect relative, rather than absolute, worth. That is, the objective is that an agent should make a larger bid on more desirable projects. A first property of the working of the mechanism when there is private information is that it succeeds in extracting individual private information on the relative worth of the projects. Indeed, at the symmetric Bayes-Nash equilibria agents' bids depend on the difference between the (privately known) worth for the alternatives.[7] Only relative worth, rather than absolute worth, matters when agents choose their bids. As intuition suggests, the equilibrium bidding function is strictly increasing (and continuous). That is, if the difference between the worth of locating the facility in cities $l_A$ and $l_B$ increases, then the difference between the bids a country chooses for these cities also increases.

In this environment with uncertainty, the multibidding mechanism is efficient when there are only two agents (and the prior distributions are symmetric), and also when the number of agents is large. Hence, if the multibidding mechanism is used to select among two candidate cities, it is very likely that the project that emerges is the one that maximizes the total surplus when there are either only two or many agents.

Efficiency is not guaranteed when the number of agents is larger than two but not too large. However, simulations suggest that the efficiency of the multibidding mechanism is very large for any number of agents, at least when there are only two candidate projects. For example, Róbert Veszteg (forthcoming) compute that, for the case in which uncertainty is captured by the uniform distribution, the proportion of efficient decisions is always very large. The lowest percentage of efficient decisions is 98.6% and it happens when there are only three agents. As the number of agents increases, the proportion of efficient decisions also increases (see the table).

| Number of agents | 2 | 3 | 5 | 10 | 20 |
|---|---|---|---|---|---|
| Efficient decisions | 100% | 98.6% | 99.1% | 99.5% | 99.6% |

Therefore, the multibidding mechanism has appealing properties also in environments where agents hold private information.

### 3.3 Experimental evidence on the multibidding mechanism

As shown, the rules of multibidding mechanism are easy to explain. The action that each agent must take is simple and the outcome is a straightforward function of the actions taken by the agents. Also, from a theoretical point of view, the mechanism has very good properties. In particular, it induces the agents to make, at equilibrium, efficient decisions in a variety of environments. A final test to advocate its use in real economic situations is checking how people behave when confronted with the mechanism. In a joint paper with Róbert Veszteg (2007), we take this challenge and provide and analyze evidence of its functioning in laboratory experiments.

We conducted four sessions of experiments at three universities, with a total of 76 participants. We implemented a treatment involving decisions by groups of two agents, while we arranged the agents in larger groups (8 to 10 agents per group) for a second treatment. In both treatments, the agents had to choose between two projects. The worth of two projects for each subject was his or her private information.

First, we checked to what extent agents' bids reflect their relative worth of the projects. Indeed, the multibidding mechanism is designed so that agents are able to convey their relative worth. In the experiments, the bids submitted by the individuals do follow this pattern. Hence, the mechanism does a good job, also in practice, at extracting the information concerning agents' relative worth.

Second, efficient projects were selected in roughly three quarters of the cases across the eight experimental treatments. Moreover, the larger the difference between the projects, the higher is the probability of an efficient decision. That is, observed inefficiencies tended to occur in cases in which the projects were similar, causing a relatively small drop in realized efficiency. In fact, the "realized efficiency", that is, the ratio between the value of the chosen project and the best project, is above 90% in all of our treatments.

Finally, how do the individuals bid? The analysis of bidding allowed us to identify four types of players. Almost half (47%) of the individuals were bidding according to the equilibrium. Another 17% bid in a similar manner, although in less aggressively way. A third group of individuals, accounting for another 17%, followed the safe strategy by bidding according to maximin strategies. Finally, we could not explain the bidding of approximately 20% of the individuals participating in the experiments.

Therefore, the multibidding mechanism also performs well in the laboratory.

## 4. Sharing benefits through the multibidding mechanism

In this section, I briefly indicate other possible applications of the multibidding mechanism. In particular, it can be used as part of more complex procedures whose aim is to achieve a "fair" or "equitable" sharing of the surplus arising from join decisions.

As an example of the type of environments I will be discussing, imagine that some firms working on different components of a product are deciding whether to merge. Merging increases joint benefits because the different production processes can be better coordinated, the final product can be finished quicker and with fewer errors, workers can learn better practices; that is, merging decreases the marginal cost of production. The question is how to share the benefits from cooperation. One could think, for instance, that equal sharing of the surplus is a reasonable rule. However, this might not be the fairest way because not only the benefits from the merger of all the firms must be taken into account. Indeed, any subgroup (any coalition) of firms could merge and obtain surplus. Even if the greatest surplus is attained when they all merge, the potential benefits coalitions could obtain otherwise should be taken into account as they reflect the "threats" or the potential contributions of any player.

One answer to the question of how to share benefits (or how to share costs of, say, a public good) was provided by Shapley (1953) and is now named the *Shapley value*. He proposed a value that is characterized as the only one to satisfy four "natural" properties: "efficiency" (all the surplus should be shared), "symmetry" (identical agents should obtain the same share), "dummy player property" (if an agent does not contribute to increase the worth of any coalition, then he should get nothing), and "linearity" (when a group of agents shares the benefits stemming from two different issues, how much each agent obtains should not depend on whether they consider the two issues together or one by one). The Shapley value is seen as a reasonable way of distributing the gains of cooperation among agents. It is the most studied and widely used single-valued solution concept in "cooperative game theory". It can be viewed as a normative proposal.

A natural question concerning the Shapley value is whether the agents can reach it through non-cooperative behaviour. In other words, if the agents can not commit to cooperate, is it still possible to find a mechanism that gives rise to the Shapley value as the result of equilibrium behaviour? This is part of the so-called "Nash program", which tries to provide a non-cooperative foundation for cooperative solution concepts.

Hart and Mas-Colell (1986) analyzed a natural bargaining mechanism. A simple version is the following.[8] Out of a set of agents, one is chosen at random as the "proposer". He is in charge of making a proposal about the division of the surplus. If the rest of the agents agree with the proposal, then it is carried out. However, if some agent disagrees, then the proposer is left on his own (maybe he did a bad job!) and he can not participate any longer in the mechanism. If this happens, then the rest of the agents apply again the same mechanism to share the new surplus but to the reduced group (all except for the removed proposer).

The bargaining mechanism proposed supports the Shapley value as each agent obtains, in average, his Shapley value. That is, if the probability of being the proposer is the same for all the agents, then the expected benefit each obtains is precisely the one advocated by the Shapley value.

However, the actual benefit of one particular agent strongly depends on the identity of the proposer. In some cases, being the proposer could prove to be beneficial, while in other cases it is preferable not to be the proposer. Even more, an agent may have strong preferences for one agent instead of another (both being different from himself) to be the proposer. Therefore, the actual sharing of the surplus may be quite different from the Shapley value. It may in fact end up being quite unfair.

One easy way to turn the previous mechanism into another that achieves the Shapley value in actual terms is to add a previous stage where the agents play the multibidding mechanism to decide the identity of the proposer (see my paper with David Wettstein, 2001). That is, we can view each potential proposer (each agent) as a "project"; we need to "locate", or rather, to allocate, the decision power about making a proposal. Once we view the problem of finding a proposer as a problem of deciding about a location, I have argued that the multibidding mechanism does a good job. Hence, adding this mechanism to the bargaining procedure proposed by Hart and Mas-Colell achieves efficiency and, in fact, all the agents obtain always their Shapley value, in equilibrium.

The multibidding mechanism has proven to be useful in several other environments. Two additional examples can be found in Begantiños and Vidal-Puga (2003) as well as in my paper with Inés Macho-Stadler and David Westtein (2006). In both cases, the problem dealt with is attaining Shapley-like values in environments that are more complex than the one I have presented. Also, it can be used to equalize the agents' gains when the solution that is considered "fair" is different from the Shapley value (see Ju and Wettstein, 2009).

## 5. Conclusion

Selecting the procedure to be used by a group of agents when they have to reach a decision that will affect all of them is a complex affair. The task is even more complex when we intend to have in place a mechanism that is anonymous, that is, it does not depend on the identity of the participants, and that can be used in very different scenarios concerning the amount of knowledge that each agent has with respect to the other agents' preferences. One problem that lies in this category is the design of a mechanism by the European Strategy Forum on research infrastructures that has the potential to help selecting the host of each of the research infrastructures.

I have discussed some advantages and disadvantages of some well-known methods to take decisions. Various voting methods have been proposed and they have the key advantage that they do not involve transfers. Hence, they may prove being a good solution when monetary transfers are unfeasible. However, I have argued that not using money to support some decisions creates in general large inefficiencies.

The use of simple auctions has also been suggested to deal with the siting of noxious facilities and it is a well-known and studied method that has some times good efficiency properties. However, in many of the situations that I have discussed in this *opuscle*, simple auctions fail to do a good job.

The multibidding mechanism adds flexibility to the properties of simplicity and anonymity of simple auctions as it allows each agent to submit a bid for each candidate project or location. It can be played in a very safe way, if the agent wishes to do so, and it leads to efficient outcomes when agents play strategically in a variety of environments. Also, it achieves good efficiency results when it has been taken to the experimental laboratory. Hence, it is a good candidate mechanism.



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## Notes

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*(1) Public's reaction to the siting process of noxious facilities is also expressed through the acronym LULU (Local Undesirable Land Use).*

*(2) In an international research infrastructure, countries typically pay construction and maintenance costs according to their use of the facility. If scientists from a country use 10% of the total time available in the infrastructure, the country is supposed to pay 10% of all the costs. If this country has a strong preference for the facility to be built in a particular location (for example, it wants to host the facility), then it is natural to express this strong preference in terms of the extra share of the costs that it is willing to cover (which, obviously, will result in the reduction of the shares covered by other countries). Similarly, if this country has a preference for the facility not to be located in a particular city, its preferences can be translated in terms of the reduction of its 10% share necessary to "compensate" this country if it is chosen as the final location of the facility.*

*(3) If a municipality follows a maximin strategy, it will obtain for sure a certain level of benefit, independently of the choice of the other cities.*

*(4) A short series of controlled laboratory experiments simulating this situation revealed that many subjects were using strategies not too far from maximin bids (Kunreuther and Kleindorfer, 1986).*

*(5) Bids can be made either in terms of shares or in terms of absolute money. That is, we can interpret the bid of 20 as country* A *offering to pay an additional 20% of the construction and maintenance costs, or as country* A *offering to pay, say, 20 million euros.*

*(6) To solve ties, each agent is also required to "select" one of the projects when he submits his bids. In case there are several projects with the highest aggregate bid, the winning project is randomly chosen from them among those that have also been selected by at least one agent. If there is no such project, the winning project is randomly chosen from those with the highest aggregate bid. Tie-breaking rules have relevance in some scenarios (see also Ehlers, 2009).*

*(7) In a game with incomplete information, when an agent chooses his action (his vector of bids, in the multibidding mechanism), he can not fully anticipate what the other agents will do, as he does not perfectly know their preferences. Therefore, each agent tries to anticipate the action of the others "for every possible preference profile" and then he uses the probability he assigns to all the possible profiles to compute his expected benefit. That is, an agent's decision is not represented by an action, but by a strategy: one action for each possible "type" of agent. A strategy profile (one strategy for each agent) is a Bayesian Nash equilibrium if every strategy in that profile is a best response to every other strategy in the profile; that is, there is no strategy that an agent could play that would yield a higher payoff, given all the strategies played by the other agents.*

*(8) See also Mas-Colell (1988)*

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