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Face to Face Negotiation to Overcome the Nimby Syndrome: Theory and Experimental Design

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Résumé / *Abstract*

Lors de la localisation d'équipements générateurs de nuisances tels que les décharges ou les incinérateurs, la commune d'accueil subit l'ensemble des coûts tandis que les autres communes perçoivent des bénéfices. Ainsi, fréquemment, les riverains du projet s'opposent à l'implantation et les projets de localisation n'aboutissent pas. Confrontés à ce problème, les économistes ont utilisés de nombreuses méthodes telles que les loteries, les enchères ou les assurances. Cependant, tous ces mécanismes ne parviennent pas à réduire l'opposition des riverains. Par conséquent, nous proposons une approche basée sur une négociation face à face entre les représentants des communes. Dans le but de réduire les coûts de transactions, nous introduisons un arbitre qui propose des répartitions de surplus et une commune d'accueil. La question principale dans cet article est de déterminer quelle répartition ce dernier doit proposer pour obtenir un accord rapidement. Pour répondre à cette question, nous révisons la structure traditionnelle des jeux coopératifs et testons le pouvoir prédictif de trois concepts de solution généralisés grâce à la réalisation d'expériences en laboratoire.

> **Mots clés** : théorie des jeux coopératifs, économie de l'environnement, économie expérimentale, syndrome nimby, localisation d'équipements générateur de nuisances

In recent decade, community after community has refused to accept facilities that require large amounts of land and generate local environmental costs such as airports, trash disposal plants or waste incinerators. Faced with this problem economists have used several methods such as lotteries, auctions or insurance policies. However, all those mechanisms have theoretical shortcomings. Therefore, we propose an approach based on face to face negotiation between elected representative. In order to reduce transaction costs, we introduce an arbitrator that proposes surplus distribution and a host community. The main question in this paper is to determine which distribution it has to propose to quickly reach an agreement. To answer this question we revise the traditional structure of cooperative games and explore the predictive power of three generalized solutions by implementing laboratory bargaining experiments.

> **Keywords:** *cooperative game theory, environmental economics, laboratory experiments, nimby syndrome, noxious facility siting*

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1 Introduction

The siting of noxious facilities (such as trash disposal plants, landfills, hazardous waste facilities and waste incinerators) is usually a reason for conflict illustrated perfectly by what the Anglo-Saxons call the NIMBY (Not In My BackYard) syndrome: everyone knows the facility is necessary but no one is willing to host it. Faced with this problem economists and operations researchers have used several methods such as lotteries (Kunreuther and Portney [1991], Sullivan [1990]), auctions (Kunreuther and Kleindorfer [1986], Kunreuther *and al.* [1987], O'Sullivan [1993]) or insurance policies (Goetze [1982]). However, all those mechanisms have theoretical shortcomings.

Following Babcock *et al.* [1997], we propose a new mechanism, based on face to face negotiation with an "arbitrator", for siting noxious facilities when *few jurisdictions*[1] *negotiate* and when *each jurisdiction takes reponsibility for the waste generated within its boundaries.* Under these conditions, we can suppose *(i)* that each jurisdiction has complete information on the costs of a facility in its jurisdiction or in other potential host jurisdictions (Catin [1985]) and *(ii)* that property rights are clear or well defined. The Coase Theorem asserts that if there are no transaction costs and if property rights are clearly defined, the economy will achieve efficiency through voluntary negotiations between the involved agents even when there are externalities (Coase [1960]). Because of the complete information, the only transaction costs are delays and it is well known that negative externalities may cause delay in negotiation (Jehiel and Moldovanu [1995]). So, in order to reduce these potential delays, we introduce an arbitrator that proposes surplus distribution and a host community. But which surplus distributions does the arbitrator have to propose? that is the

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[1]By jurisdictions, we mean communities composed of individuals having the right to make decisions on their own behalf. That is State, region, district or city.

main question in this paper.

To answer this interrogation the pioneering study by Babcock *et al.* [1997] illustrates the necessity to revise the traditional structure of cooperative games: in this new cooperative game, the coalition values depend not only on the membership factor (the structure coalition) but also on who hosts the facility. Furthermore, the authors propose an experimental test in laboratory of the nucleolus as a solution to such a modified cooperative game. But we found an error in the model.

Hence, the main goal of this paper is triple: to correct the pioneering model, to enlarge the model to another classical solution concept -the Shapley value- and finally to explore the predictive power of the various theories in negotiation by implementing a new experimental study.

This paper is organized as follows: section 2 presents the new cooperative game. In Section 3, we generalize three classical solution concepts: the nucleolus, the Shapley value and the core. In Sections 4 and 5 we describe the experimental design and we retrace and interpret the experimental data. Finally, Section 6 presents some conclusions and comments on the shortcomings of our study.

2 The modeling of the siting problem

2.1 Hypotheses and example

To structure the siting problem with characteristic functions three hypotheses are made as follows. *(i)* Each jurisdiction takes reponsibility for the waste generated within its boundaries. *(ii)* The equipment market should be common knowledge. *(iii)* There are increasing economic return to scale for hazardous facilities. In this case, collective incentives for jurisdictions to cooperate to share a facility occur naturally and automatically. The scale economies are the key to cooperation. If there are not present, the problem of siting is simple: each one its own facility.

The following example illustrate, in a simple way, the siting problem submitted to analysis. Three French neighbouring towns, a, b, c produce household garbage. In order to respect the 13 Jun 1992 act relative to the elimination of garbage, it was decided to build one or more incinerators for the treatment of the garbage in these localities. A committee is therefore constituted. It is composed of experts (scientists, sociologists and economists) who evaluate the advantages and disadvantages of the construction of the public installation in question, but also of three individuals (called the negotiators) that represent each of the three communities. Table 1 furnishes the result obtained by the study. It shows the costs with respect to all of the possible situations. For example, if city a and city b construct a single facility sited in a, the cost for them is 137 jointly and if it is sited in city b the cost for them is only 132 jointly. Note that the geographical and economical differences between the localities create significant variations in costs. Furthermore, economies of scale appear.

Table 1. Cost matrix

	Host Community		
Coalition	a	b	c
stand alone	80	70	133
a and b	137	132	133
a and c	138	70	157
b and c	80	114	137
a, b and c	176	165	191

Table 1 can be charted from the viewpoint of surplus (see Table 1.r) This new presentation offers two advantages that are not negligible. Firstly, the game is in part normalized because $v(\{i\}) = 0$. This normalisation will simplify the calculations of theoretical solutions. Secondly, use the surpluses enables a faster visualisation of the gains tied to cooperation. Hence, if b joins a with a as host of the facility, the cost for them is 137. Compared to their status quo of total cost 150[2], they end up with a surplus of 13[3].

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[2] 150=80+70
[3] 13=150-137

Table 2. Surpluses matrix

	Host Community		
Coalition	a	b	c
stand alone	0	0	0
a and b	13	18	0
a and c	75	0	56
b and c	0	89	66
a, b and c	107	118	92

Faced with this surplus matrix, the second part of the committee, composed of negotiators have to choose the host city and the sharing of surplus.

2.2 Formal approach

In order to reduce the duration of the negotiations, we introduce an arbitrator. He proposes a host city and a sharing of surplus. But which sharing of surplus does the arbitrator have to propose to "quickly" reach an agreement? For Sharing problems, cooperative games provide an operational scheme for conceptualization. A game in a characteristic form expresses itself by the data of a group of players N and an application $v(.)$, which at each coalition of agent $C \subseteq N$ associated a real number, leading to a value for the coalition. Following this, the function v is supposedly monotonous:

$$R \subseteq S \Rightarrow v(R) \leq v(S), \quad \forall R, S \subseteq N . \qquad (1)$$

A coalition cannot produce more than the coalition which includes it. Considering the siting problem of equipment which can be a public nuisance, $v(C)$ represents simply the surpluses generated by the cooperation.

But traditional cooperative games only take into account the coalition value due to membership. In our problem, the coalition values could vary and depend on who is the host of the facility. So, it is first necessary to enlarge the possibilities of coalition, taking into account the new factor, called the "host factor". We therefore obtain a characteristic function in the form of:

$$v^i : T = \{(i, C) | i \in C, \ C \subset N\} \rightarrow R^+ \qquad (2)$$

The function v^i is defined in a "cooperation set" $n(n+1)$. By convention, $v^i(R)$ represents the surplus of the coalition R when the facility is sited in community i. In this context, the payoff of the communities is represented by $X = \{x = (x_1 \ldots x_i \ldots x_n),\ x_i \in \mathbb{R}^+\}$ with $\sum_{i=1}^n x_i = \max_{j \in N} v^j(N)$. So, in order to reflect the existence of economies of scale during the construction of the equipment, we impose a specific condition of superadditivity, derived from the condition of the same name in the traditional cooperative game theory:

$$\max_{i \in R} v^i(R) + \max_{j \in S} v^j(S) \leq \max_{k \in R \cup S} v^k(R \cup S),\ R \cap S = \emptyset,\ R, S \subset N \qquad (3)$$

For laboratory bargaining experiments, we use three games. Table 3 represents the two asymmetric games, noted respectively (N, v_{a66}) and (N, v_{a10}) where the index a denotes that the cooperative game is asymmetric because of the explicit taking into account of the host factor:

$$v^i(\{ij\}) \neq v^j(\{ij\}), \forall i, ji \neq j \qquad (4)$$

The index 66 of the first game simply corresponds to the value $v^c(\{bc\})$ in this game. This value is reduced to 10 in the game (N, v_{a10}). This reduction reflects a decrease of the bargaining power of community c in this last game.

Table 3. Asymmetric games (N, v_{a66}) and (N, v_{a10})

Coalition	Host Community		
	a	b	c
a and b	13	18	0
a and c	75	0	56
b and c	0	89	66 or 10
a, b and c	107	118	92

The third game, (N, v_s), corresponds to a symmetric cooperative game. The "host factor" plays no role whatsoever (N, v_s) is presented in two different forms in the Tables 4 and 5. The first corresponds to a traditional representation. The second includes the "host factor", even if this last one has no influence on the

coalition values. We must also note that the two asymmetric cooperative games are issued of the same symmetric game.

Table 4. Symetric game (N, v_s) in reduced form

Coalition	Value
a and b	18
a and c	75
b and c	89
a, b and c	118

Table 5. Symetric game (N, v_s) in extensive form

Coalition	Host Community		
	a	b	c
a and b	18	18	0
a and c	75	0	75
b and c	0	89	89
a, b and c	118	118	118

3   Definition and computation of the solutions

In this study we consider two solution concepts: the nucleolus (Schmeidler [1969,1994]) and the Shapley value (Shapley [1953], Owen [1995]), as well as the general concept of the core.

3.1   The nucleolus and the generalized nucleolus

The method used for the computation of the generalized nucleolus can be summarized in the following manner: starting from a set of "cooperation" $T = \{(i, P) | i \in P, P \subset N\}$, we note $c(T) = P$ the coalition and $h(T) = i$ the host city inside this coalition. Then, for a payoff $x \in X$, define the excess of the coalition R as:

$$e(R, x) = v^{h(R)}(c(R)) - x(c(R)), \ R \in T, x \in X \ , \tag{5}$$

where $x(c(R))$ is shorthand for $\sum_{j \in c(R)} x_j$. If $e(R, x) > 0$, the excess can be interpreted as a measure of the sacrifice of the members in the coalition

$c(R)$, with $h(R)$ the host community, when the payoff x is realized. Inversely if $e(R,x) < 0$, it measures the gain that the members of the coalition receive. In this context, an objection of i to j is:

$$S_{ij}(x) = \max_{U}\{e(U,x)|U \in T, i = h(U), j \in N \backslash c(U), x \in X\} . \qquad (6)$$

S_{ij} is a measure of the dissatisfaction of i to the payoff that j receives. On the other hand, j can exercise a counter-objection against i as:

$$S_{ji}(x) = \max_{V}\{e(V,x)|V \in T, i \in N \backslash c(V), j = h(V), x \in X\} . \qquad (7)$$

The objection by i is considered justified if $S_{ij}(x)$ is greater than $S_{ji}(x)$. Given the payoff x, community i's net demand on all other communities is therefore:

$$D_i(x) = \sum_{j \in N} [S_{ij}(x) - S_{ji}(x)] . \qquad (8)$$

If $D_i(x) > 0$, i is underpaid and deserves more compensation. Inversely, if $D_i(x) < 0$, i is overpaid. When $D_i(x^*) = 0, \forall i \in N$, the payoff x^* is undefeatable by any subcoaltions and payoffs. In this way, we obtain an equilibrium point qualified as the generalized nucleolus, because it follows the same rules as in defining the nucleolus in the traditional cooperative game theory

$$N_a \equiv \{x \in X | D_i(x) = 0, \ \forall i \in N\} \qquad (9)$$

The nucleolus in its classical version is defined as follows:

$$N_s \equiv \{x \in X / D_i^s = 0, \ \forall i \in N\} , \qquad (10)$$

where:

$$
\begin{aligned}
D_i^s(x) &= \sum_{j \in N} [S_{ij}(x) - S_{ji}(x)] \\
S_{ij}^s(x) &= \max_{U} \{e(U,x) \mid U \in T, \ j \in N \backslash c(U), \ x \in X\} \\
S_{ji}^s(x) &= \max_{V} \{e(V,x) \mid V \in T, \ i \in N \backslash c(V), \ x \in X\} \\
\text{and } e(R,x) &= v(c(R)) - x(c(R)), \ R \in T, \ x \in X .
\end{aligned}
$$

To summarize, the generalization of the nucleolus proposed in this paper is essentially situated at the level of objections and counter-objections: a jurisdiction that exercise an objection must propose a new coalition inside which it will become the host city.

In order to calculate the nucleolus (N_s) and generalized nucleolus (N_a) an algorithm can be used. Given an arbitrary initial payoff x^0, cities perform the transfer as:

$$x_i^{m+1} = x_i^m + \lambda F(x_i^m), \ \forall i \in N, \ \lambda \leq \frac{1}{n}, \ m = 0, 1, 2, \cdots , \qquad (11)$$

where x^{m+1} denotes the new payoff resulting from the transfer, and:

$$F(x_i^m) = \sum_{j \in N} [S_{ij}(x^m) - S_{ij}(x^m)] . \qquad (12)$$

The transfer of equation (11) continues iteratively until $F(x_i) = 0$ for all $i \in N$. Table 6 presents the intermediary steps in the calculation of N_a in the game (N, v_{a66}):

Table 6. Calculation for the nucleolus in (N, v_{a66})

	x^0	x^1	x^2	x^3	x^4
payoff to community a	20	18	17	17	17
payoff to community b	20	21	27	29	31
payoff to community c	78	79	74	72	70
S_{ab}	-23	-22	-16	-14	-12
S_{ac}	-27	-26	-31	-33	-35
S_{ba}	-9	-11	-12	-12	-12
S_{bc}	-22	-21	-26	-28	-30
S_{ca}	-32	-34	-35	-35	-35
S_{cb}	-42	-41	-35	-33	-31
D_a	-9	-3	0	0	0
D_b	34	31	13	7	1
D_c	-25	-28	-13	-7	-1

The transfer enables to obtain the payoff vector $(17, 31, 70)$. The net demands are non-existent or close to zero. The procedure has also been used for the games (N, v_{a10}) and (N, v_s); we obtain the following payoff vectors:

$$N_{a66} = \begin{pmatrix} 17 \\ 31 \\ 70 \end{pmatrix} \qquad N_{a10} = \begin{pmatrix} 36 \\ 31 \\ 51 \end{pmatrix} \qquad N_s = \begin{pmatrix} 11 \\ 25 \\ 82 \end{pmatrix}. \qquad (13)$$

3.2 The Shapley value and generalized Shapley value

To calculate the Shapley value, we introduce the marginal contribution notion of one player. Let us imagine that, at the beginning of the game, a player teams with another to form an intermediate coalition of two players. Next, the two player are joined by a third. Let us suppose that, at each step, each player receives his marginal gain, that is, the differences between the coalition value already formed and that of the coalition with the new player. If we admit that the final coalition is as likely to form in one way or another (that is in any order), then the gain one player can hope to receive is equal to his Shapley value:

$$V_i(v) = \sum_{S \subseteq N - \{i\}} \frac{\mid S \mid !(\mid N \mid - \mid S \mid -1)!}{\mid N \mid !} \big(v(S \cup \{i\}) - v(S) \big), \qquad (14)$$

where $\mid X \mid$ represents the cardinal of X. With this method we calculate the Shapley value of the symmetric game without difficulty. The steps appear in table 7:

Table 7. Calculation for the Shapley value in (N, v_s)

	Community		
Coalition	a	b	c
$\{abc\}$	0	18	100
$\{abc\}$	0	43	75
$\{abc\}$	29	0	89
$\{abc\}$	18	0	100
$\{abc\}$	75	43	0
$\{abc\}$	29	89	0
Mean	25,1	32,1	60,6
V_s^i	25	32	61

The interpretation of the table 7 is as follows. For example, in the first line, the coalition is formed in the order a, b, c. So, at the start, city a is alone, it has a surplus equal to zero. Afterwards, city a forms a coalition with b and b receives its marginal contribution, that is $v(\{ab\}) = 18$. Finally, city c joins a and b, the value of the coalition become 118. c receives its marginal contribution $v(\{abc\}) - v(\{ab\}) = 118 - 18 = 100$.

To calculate the Shapley value in the asymmetric game (N, v_{a66}) et (N, v_{a10}), we proceed in the same manner as for the traditional Shapley value, but we take into account all possible coalitions. Table 8 is designed to show the steps of calculation of V_{a66}. The notations are as follows: $\{a\}^a; \{ab\}^a; \{abc\}^a$ represents the coalition formed in the following order abc, with a as host city. The V_a^{i*} do not correspond to the Shapley value because their sum is not equal to 118 but to the average of $v^i(\{ijk\})$. This average is noted m:

$$m = \frac{v^a(\{abc\}) + v^b(\{abc\}) + v^c(\{abc\})}{3} = \frac{107 + 118 + 92}{3} = 105,66 \ . \quad (15)$$

At the end of the procedure, we are therefore left with the allocation of a payoff equal to the difference between the 118 and the average of $v^i(\{ijk\})$. In the game (N, v_{a10}) and (N, v_{a66}), this difference d amounts to 12,33. The calculation of the Shapley value being based on the notion of marginal contribution, it therefore seems normal to allocate this sum proportionally to each marginal contribution. We note p_a^i the share of d given to community i in the asymmetric game (a): $p_a^i = \frac{V_a^{i*} \times d}{m}$. Finally, the generalized Shapley value is equal to: $V_a^i = V_a^{i*} + p_a^i$.

Table 8. Shapley value in the game (N, v_{a66})

	Community				Community		
	a	b	c		a	b	c
$\{a\}^a;\{ab\}^a;\{abc\}^a$	0	13	94	$\{b\}^b;\{bc\}^b;\{bca\}^a$	18	0	89
$\{a\}^a;\{ab\}^a;\{abc\}^b$	0	13	105	$\{b\}^b;\{bc\}^b;\{bca\}^b$	29	0	89
$\{a\}^a;\{ab\}^a;\{abc\}^c$	0	13	79	$\{b\}^b;\{bc\}^b;\{bca\}^c$	3	0	89
$\{a\}^a;\{ab\}^b;\{abc\}^a$	0	18	89	$\{b\}^b;\{bc\}^c;\{bca\}^b$	41	0	66
$\{a\}^a;\{ab\}^b;\{abc\}^b$	0	18	100	$\{b\}^b;\{bc\}^c;\{bca\}^c$	52	0	66
$\{a\}^a;\{ab\}^b;\{abc\}^c$	0	18	74	$\{b\}^b;\{bc\}^c;\{bca\}^a$	26	0	66
$\{a\}^a;\{ac\}^a;\{acb\}^a$	0	32	75	$\{c\}^c;\{ca\}^c;\{cab\}^a$	56	51	0
$\{a\}^a;\{ac\}^a;\{abc\}^b$	0	43	75	$\{c\}^c;\{ca\}^c;\{cab\}^b$	56	62	0
$\{a\}^a;\{ac\}^a;\{abc\}^c$	0	17	75	$\{c\}^c;\{ca\}^c;\{cab\}^c$	56	36	0
$\{a\}^a;\{ac\}^c;\{acb\}^a$	0	51	56	$\{c\}^c;\{ca\}^a;\{cab\}^a$	75	32	0
$\{a\}^a;\{ac\}^c;\{acb\}^b$	0	62	56	$\{c\}^c;\{ca\}^a;\{cab\}^b$	75	43	0
$\{a\}^a;\{ac\}^c;\{acb\}^c$	0	36	56	$\{c\}^c;\{ca\}^a;\{cab\}^c$	75	17	0
$\{b\}^b;\{ba\}^a;\{bac\}^a$	13	0	94	$\{c\}^c;\{cb\}^c;\{cab\}^a$	41	66	0
$\{b\}^b;\{ba\}^a;\{bac\}^b$	13	0	105	$\{c\}^c;\{cb\}^c;\{cab\}^b$	52	66	0
$\{b\}^b;\{ba\}^a;\{bac\}^c$	13	0	79	$\{c\}^c;\{cb\}^c;\{cab\}^c$	26	66	0
$\{b\}^b;\{ba\}^b;\{bac\}^a$	18	0	89	$\{c\}^c;\{cb\}^b;\{cab\}^a$	18	89	0
$\{b\}^b;\{ba\}^b;\{bac\}^b$	18	0	100	$\{c\}^c;\{cb\}^b;\{cab\}^b$	29	89	0
$\{b\}^b;\{ba\}^b;\{abc\}^c$	18	0	74	$\{c\}^c;\{cb\}^b;\{cab\}^c$	3	89	0
				Mean $= V_{a66}^{i*} \sim$	23	29	54

We obtain the following payoff vectors:

$$V_s = \begin{pmatrix} 25 \\ 32 \\ 61 \end{pmatrix} \qquad V_{a66} = \begin{pmatrix} 26 \\ 32 \\ 60 \end{pmatrix} \qquad V_{a10} = \begin{pmatrix} 36 \\ 27 \\ 55 \end{pmatrix} \qquad (16)$$

It must be noted that there are obvious differences between the nucleolus and the Shapley value. The two solution concepts both tend to answer the same question: how to allocate the benefits of the coalition between the communities? However, although these solutions are different, the bargaining power of the communities is analyzed in the same way. Figure 1 shows this property.

Figure 1: Nucleolus and Shapley value in the three games
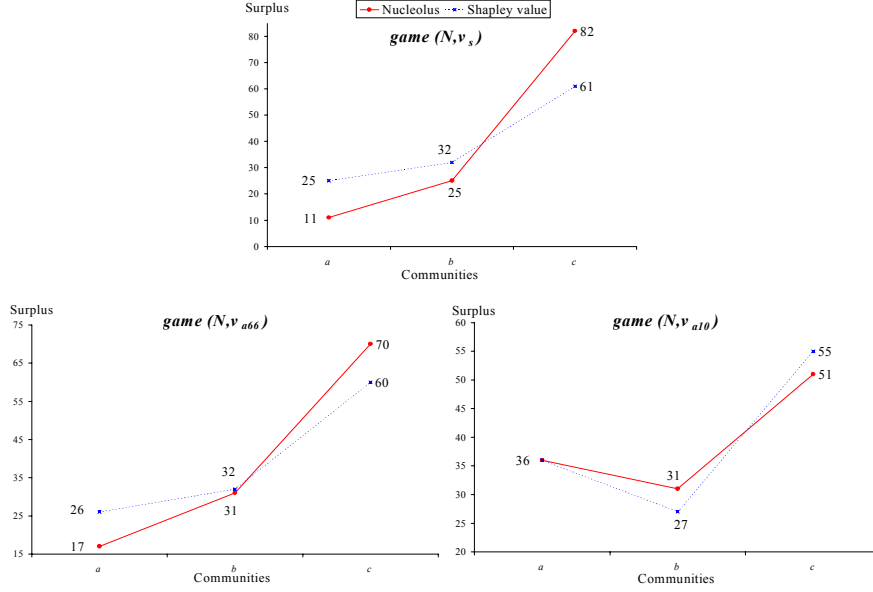
3.3 The core, the inner core and the outer core

We know that a division is called "coalitionally rational" if, and only if, the sum of the payoffs for any coalition is no less than the coalition value, a term coined by Aumann and Maschler (1964). This concept is also referred to as the "core" noted $\mathcal{C}$

$$x \in \mathcal{C} \text{ if } v(S) \leq \sum_{j \in S} x_j, \ \forall S \subseteq N \tag{17}$$

In a traditional game, $v(S)$ is unique and this concept can be applied without difficulty. However, when the value of $v(S)$ is not unique this concept must be modified as follows

$$
\begin{aligned}
x \quad &\in \quad \mathcal{IC} \text{ if } \sum_{j \in S} x_j \geq \max_{i \in S} v^i(S), \ \forall S \subseteq N \\
\text{and } x \quad &\in \quad \mathcal{OC} \text{ if } \left\{ \begin{array}{l} \sum_{j \in S} x_j \geq \min_{i \in S} v^i(S), \ \forall S \subset N \\[2ex] \sum_{j \in N} x_j \geq \max_{i \in N} v^i(N) \end{array} \right.
\end{aligned}
$$

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Where $\mathcal{IC}$ is the "inner core" and $\mathcal{OC}$ the "outer core". The inner core is by definition a smaller set of solutions than the outer core. Effectively, in the inner core, the communities form an optimal coalition, they look for a location which permits the receipt of a maximum surplus. In the outer core the cities are content with a payoff sum superior to the value of the minimal coalition, that is the one for which the surplus is the lowest. Figure 2 shows these two properties.

Figure 2: Core, Inner Core and Outer Core
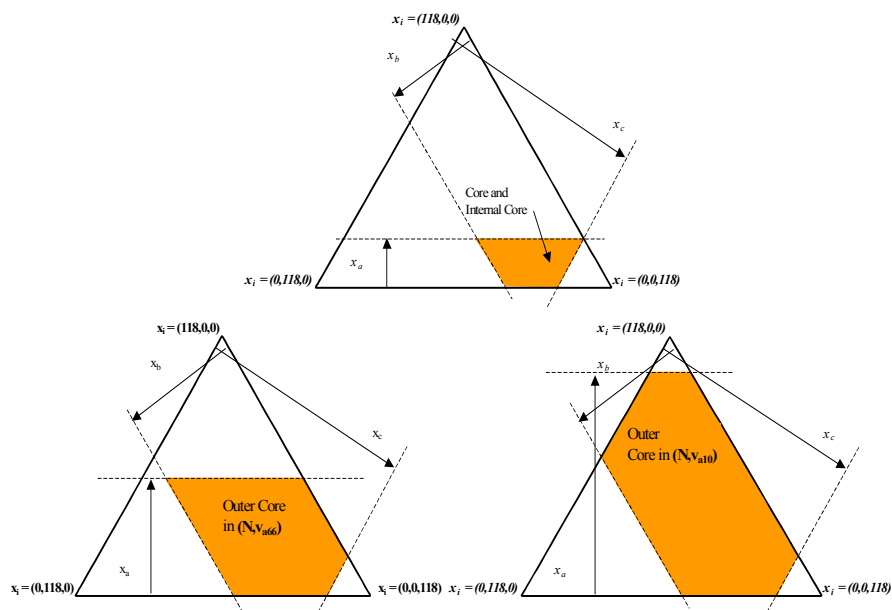
4 Experimental design

4.1 Questions tested

1: *Are the decisions made by the subjects similar in an asymmetric or symmetric game?*

$$H_0 \; : \; x_s^i \neq x_a^i \; ,$$

where x_s^i is the payoff of community i in the symmetric game and x_a^i the payoff of the same community in the asymmetric games. If the subjects have a different perception of the asymmetric and symmetric problem the null hypothesis H_0 will be rejected.

2: *Do the subjects use in a relevant way the information given by the asymmetric game?*

In the symmetric game the bargaining power of community c is very important because in forming a coalition with this community, a and b can hope to obtain the maximum surplus. The communities a and b can only obtain 18 whereas the coalitions ($\{ac\}$ and $\{bc\}$) earn respectively 75 and 89. From (N, v_s) to (N, v_{a66}), and then to (N, v_{a10}), the bargaining power of community c diminishes. If the subjects take into account the decrease of the bargaining power of community c the payoff of this town should be diminished from game (N, v_s) to game (N, v_{a66}), and once again from game (N, v_{a66}) to game (N, v_{a10}).Therefore two sets of assumptions have to be tested:

$$H_0 \quad : \quad x_{a10}^c < x_{a66}^c \ ,$$

$$H_0 \quad : \quad x_{a66}^c < x_s^c \ .$$

If hypothesis H_0 is accepted, we can admit that the subjects use the information given by the asymmetric game in a relevant way.

3: *Should one have to modify the nucleolus?*

$$H_0 \quad : \quad \|x_{ak}^i - N_{ak}^i\| < \|x_{ak}^i - N_s^i\| \quad \forall k = \{66 \ ; \ 10\} \quad \forall i = a, b, c \ ,$$

where $\|x_{ak}^i - N_{ak}^i\|$ represents the Euclidian distance between the observed payoff to community i in game (N, v_{ak}) and the predicted payoff of the nucleolus. If H_0 is accepted for all i and k, the distance between the prediction of the generalized nucleolus and the observed payoff of community i is inferior to the

distance between the prediction of the nucleolus and the observed payoff of community i. Consequently, we can admit that the predictive power of the generalized nucleolus is better than that of the nucleolus.

4: *Should one have to modify the Shapley value?*

$$H_0 \quad : \quad \|x_{ak}^i - V_{ak}^i\| < \|x_{ak}^i - V_s^i\| \quad \forall k = \{66 \; ; \; 10\} \quad \forall i = a, b, c \; .$$

If H_0 is accepted for all i and k, we can admit that the predictive power of the generalized Shapley value is better than that of the Shapley value.

5: *Which solution reflects in the best way the subject behavior in the symmetric game: the nucleolus or the Shapley value?*

$$H_0 \quad : \quad \|x_s^i - V_s^i\| < \|x_s^i - N_s^i\| \quad \forall i = a, b, c \; .$$

If H_0 is accepted for all i and k, the prediction established by the Shapley value is better than that established by the nucleolus.

6: *Which solution reflects in the best way the subject behavior in the asymmetric game: the nucleolus or the Shapley value?*

$$H_0 \quad : \quad \|x_{ak}^i - N_{ak}^i\| < \|x_a^i - V_{ak}^i\| \quad \forall k = \{66 \; ; \; 10\} \quad \forall i = a, b, c \; .$$

If H_0 is accepted for all i and k, the prediction established by the generalized nucleolus is better than that established by the generalized Shapley value.

4.2   Protocol description

Two laboratory bargaining experiments was used to test these six hypotheses. Thirty-six subjects (in four group of nine) took part in this experimental bargaining experiment. During the first study which was conducted with two groups of nine subjects, subjects were recruited on a voluntary basis amongst

the staff of the University of Economics of Montpellier (Engineers, Administrative staff and Technician). In the second experiment subjects were students (Economics and Arts) that had no experience in game theory. They were also divided into two groups of nine subjects. On average, the experiments were finished within an hour. Subjects were told that their reward depended on their performance in the negotiation of how benefits would be shared. Every point each subject received was worth \$0,15. In addition, subjects were paid a fixed payement of \$4 for participating in the negotiation. The following stages describe the procedure of each session which included two phases: an introductory phase and the experimental phase.

Introductory phase:

1. The nine subjects enter the room and each draws an identification number randomly.

2. They go to the table on which their number is marked.

3. On this table they find a form including a detailed description of the problem, an example of the surplus matrix, a bargaining simulation, an awareness to the fact that there exists some payoffs in which everyone is better off (that is the core), and the rules of reward which are applied.

4. When the subjects have read for ten minutes, the experimenter writes an example on the blackboard and subjects are invited to offer a payoff allocation to the three cities.

5. The experimenter answers questions.

Experimental phase:

6. Subjects gather at the tables in groups of three for face to face negotiating.

7. On each of the three tables they find a description of the game rules as well as the explanations necessary for the progress of the experiment.

8. Subjects participate in the three scenarios $((N, v_{a10}), (N, v_{a66})$ and $(N, v_s))$;

each one consists of three games, because subjects represent andomly each towns a, b and c. At the end of the session we therefore obtain 27 payoff allocations.

9. Subjects have five minutes to agree on who host the facility and how to share the surplus. If after five minutes is no agreement, subjects receive no reward.

10. Once subjects have finished the three games of scenario (N, v_{a10}), they pass on to scenario (N, v_{a66}) and next on to scenario (N, v_s). Subjects change negotiating tables each time the scenario change, so that they negotiate with different partners every time.

11. The groups for the first scenario are : $(1, 2, 3)(4, 5, 6)(7, 8, 9)$, for the second scenario : $(1, 4, 7)(2, 5, 8)(3, 6, 9)$, and for the third scenario : $(1, 6, 8)(2, 4, 9)(3, 5, 7)$.

12. At the end of the session each subject is paid anonymously in cash.

It is significant to note that, in the first experiment, the protocol we retained differed noticeably from what is described in point 8 : subjects represented *one by one* each of the towns. This procedure revealed itself to be erroneous because subjects had the opportunity to cancel each other out. Consequently, the result of the first experiment must be interpreted cautiously.

5   Experimental evidence

The data obtained in the first and second experiment are shown in Appendix (Tables 15 and 16). Before tackling nonparametric tests let us develop briefly three remarks on data obtained. Firstly, 8 percent of the coalitions are different from the grand optimal coalition (i.e. $v^b(\{abc\})$). We do not include these subcoalition allocations in our statistical analysis because the arbitrator has to propose an efficient division of the surplus. Secondly, 63 percent of the vectors do not belong to the inner core. At least two reasons can be produced for explaining this fairly large proportion of allocations outside the inner core: either the individuals are incapable of understanding or calculating the inner core (bounded cognitive or instrumental capacities), either factors, such as altruism

or reciprocity, influence the individuals' behavior. This second hypothesis is the most plausible. Indeed, the core was presented during the introductory phase. Thirdly, when the grand optimal coalition is formed there are no solutions outside of the outer core.

We realized nonparametric tests (Siegel and Castellan [1988]). We use the *Mann-Withney Rank-Sum test* when we analyse two independent samples (hypotheses 1 and 2) and we use the *Wilcoxon Signed-Rank test* for paired data (hypotheses 3 to 6). Note that these nonparametric tests permit only to test three hypotheses:

$$X \leq Y \quad ; \quad X \neq Y \quad ; \quad X \geq Y \, ,$$

but no straight: $X < Y$. Now, it is this type of hypotheses that we wish to test. So, We must realize two successive tests to accept or reject hypotheses 2 to 6, $H_0' : X \leq Y$ (named test A) and $H_0'' : X \neq Y$ (named test B).

1: *Are the decisions made by the subjects similar in an asymmetric or symmetric game?*

Table 9. Test 1

	Null Hypothesis	Sample size	U stat	p value	test 5%	test 10%
EXP 1	$x_s^a \neq x_a^a$	$n_{a10} = 17$; $n_{a66} = 32$	233	.4	H_1	H_1
	$x_s^b \neq x_a^b$	$n_{a66} = 17$; $n_s = 32$	215	.22	H_1	H_1
	$x_s^c \neq x_a^c$	$n_{a66} = 17$; $n_s = 32$	369	.038	H_0	H_0
EXP 2	$x_s^a \neq x_a^a$	$n_{a66} = 17$; $n_s = 33$	123	.001	H_0	H_0
	$x_s^b \neq x_a^b$	$n_{a10} = 17$; $n_{a66} = 33$	362	.09	H_1	H_0
	$x_s^c \neq x_a^c$	$n_{a66} = 17$; $n_s = 33$	417	.048	H_0	H_0

Table 9 is interpreted as follows. Let us consider, for instance the third line. We test hypothesis $H_0 : x_s^c \neq x_a^c$, in the first laboratory experiment. We have two samples of sizes 17 and 32. The test statistic for the Mann-Withney test is U. This value is equal to 369. The p-value is equal to 0,038 ($<$0,05): the

differences in the median values among the two groups are greater than would be expected by chance. We accept the null hypothesis. In the first experiment, we accept the null hypothesis only once. In the second experiment, we always accept H_0. It should be not forgotten that the result of the first experiment must be interpreted cautiously. So, we admit that the decisions made by the subjects are not similar in an asymmetric or symmetric game.

2: *Do the subjects use in a relevant way the information given by the asymmetric game?*

Table 10. Test 2

	Null Hypothesis	Sample size	W stat	p value	test A	test B
EXP 1	$x^c_{a10} < x^c_{a66}$	$n_{a10} = 17$; $n_{a66} = 15$	111	.73	H'_1	H''_1
	$x^c_{a66} < x^c_s$	$n_{a66} = 15$; $n_s = 15$	192	0	H'_0	H''_0
EXP 2	$x^c_{a10} < x^c_{a66}$	$n_{a10} = 17$; $n_{a66} = 17$	160	.19	H'_1	H''_1
	$x^c_{a66} < x^c_s$	$n_{a66} = 17$; $n_s = 17$	214	0	H'_0	H''_0

It is a one-sided test. Table 10 is interpreted as follows. Let us consider, for instance the second line. We wish to test hypothesis $H_0 : x^c_{a66} \neq x^c_s$, in the first laboratory experiment. In the first place, we test hypothesis $H'_0 : x^c_{a66} \leq x^c_s$. We have two samples of sizes 15 and 15. The test statistic for the Mann-Withney test (U) is equal to 192. The p-value is equal to 0,006 ($<$0,05): we accept the null hypothesis. We test then the second hypothesis $H''_0 : x^c_{a66} \neq x^c_s$. Once more we accept the null hypothesis[4]. Globally, it is reasonable to assume that subjects use in a relevant way the information given by the asymmetric game because hypothesis $H_0 : x^c_{a66} \neq x^c_s$ is always accepted. But, it should be stressed that hypothesis $H_0 : x^c_{a10} \neq x^c_{a66}$ is always rejected. So it would appear that the subjects do not make differences between the two asymmetric games.

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[4] For this test U and p-value do not appear in the Table 12.

3: *Should one have to modify the nucleolus?*

We use now *Wilcoxon Signed-Rank test*. The analysis of Tables 12 to 15 is the same as Table 11. W is the test statistic for the Wilcoxon test. The last column clarifies the dominant concept of solution (N_a or N_s). The null hypothesis is always accepted: the predictive power of the generalized nucleolus outperformed the nucleolus by a wide margin.

Table 11. Test 3

	Null Hypothesis	Sample size	W stat	p value	test A	test B	D.C.
E	$\|x^a_{a66}-N^a_{a66}\| < \|x^a_{a66}-N^a_s\|$	$n_{a66}=15$	0	$<.001$	H'_0	H''_0	N_a
X	$\|x^b_{a66}-N^b_{a66}\| < \|x^b_{a66}-N^b_s\|$	-	0	$<.001$	H'_0	H''_0	N_a
P	$\|x^c_{a66}-N^c_{a66}\| < \|x^c_{a66}-N^c_s\|$	-	1	$<.001$	H'_0	H''_0	N_a
	$\|x^a_{a10}-N^a_{a10}\| < \|x^a_{a10}-N^a_s\|$	$n_{a10}=17$	0	$<.001$	H'_0	H''_0	N_a
1	$\|x^b_{a10}-N^b_{a10}\| < \|x^b_{a10}-N^b_s\|$	-	9.5	.007	H'_0	H''_0	N_a
	$\|x^c_{a10}-N^c_{a10}\| < \|x^c_{a10}-N^c_s\|$	-	0	$<.001$	H'_0	H''_0	N_a
E	$\|x^a_{a66}-N^a_{a66}\| < \|x^a_{a66}-N^a_s\|$	$n_{a66}=17$	0	$<.001$	H'_0	H''_0	N_a
X	$\|x^b_{a66}-N^b_{a66}\| < \|x^b_{a66}-N^b_s\|$	-	0	$<.001$	H'_0	H''_0	N_a
P	$\|x^c_{a66}-N^c_{a66}\| < \|x^c_{a66}-N^c_s\|$	-	0	$<.001$	H'_0	H''_0	N_a
	$\|x^a_{a10}-N^a_{a10}\| < \|x^a_{a10}-N^a_s\|$	$n_{a10}=16$	0	$<.001$	H'_0	H''_0	N_a
2	$\|x^b_{a10}-N^b_{a10}\| < \|x^b_{a10}-N^b_s\|$		8.5	.005	H'_0	H''_0	N_a
	$\|x^c_{a10}-N^c_{a10}\| < \|x^c_{a10}-N^c_s\|$		0	$<.001$	H'_0	H''_0	N_a

4: *Should one have to modify the Shapley value?*

Note that for the scenario (N, v_{a66}), the predictions of V^b_{a66} and V^b_s are the same. Of the twelve hypotheses tested in table 12, only two are rejected. So, the predictive power of the generalized Shapley value outperformed the Shapley value.

Table 12. Test 4

	Null Hypothesis	Sample size	W stat	p value	test A	test B	D.C.
E	$\lVert x^a_{a66}-V^a_{a66}\rVert < \lVert x^a_{a66}-V^a_s\rVert$	$n_{a66}=15$	8	.008	H'_0	H''_0	V_a
X	$\lVert x^b_{a66}-V^b_{a66}\rVert < \lVert x^b_{a66}-V^b_s\rVert$	-	$V^b_{a66}=V^a_s$				$\sim$
P	$\lVert x^c_{a66}-V^c_{a66}\rVert < \lVert x^c_{a66}-V^c_s\rVert$	-	0	0	H'_0	H''_0	V_a
	$\lVert x^a_{a10}-V^a_{a10}\rVert < \lVert x^a_{a10}-V^a_s\rVert$	$n_{a10}=17$	55	.165	H'_1	H''_1	V_a
1	$\lVert x^b_{a10}-V^b_{a10}\rVert < \lVert x^b_{a10}-V^b_s\rVert$	-	139	.99	H'_1	H''_0	V_s
	$\lVert x^c_{a10}-V^c_{a10}\rVert < \lVert x^c_{a10}-V^c_s\rVert$	-	0	0	H'_0	H''_0	V_a
E	$\lVert x^a_{a66}-V^a_{a66}\rVert < \lVert x^a_{a66}-V^a_s\rVert$	$n_{a66}=17$	9	.003	H'_1	H''_0	V_a
X	$\lVert x^b_{a66}-V^b_{a66}\rVert < \lVert x^b_{a66}-V^b_s\rVert$	-	$V^b_{a66}=V^a_s$				$\sim$
P	$\lVert x^c_{a66}-V^c_{a66}\rVert < \lVert x^c_{a66}-V^c_s\rVert$	-	0	0	H'_0	H''_0	V_a
	$\lVert x^a_{a10}-V^a_{a10}\rVert < \lVert x^a_{a10}-V^a_s\rVert$	$n_{a10}=16$	16	.002	H'_0	H''_0	V_a
2	$\lVert x^b_{a10}-V^b_{a10}\rVert < \lVert x^b_{a10}-V^b_s\rVert$		127	.99	H'_1	H''_0	V_s
	$\lVert x^c_{a10}-V^c_{a10}\rVert < \lVert x^c_{a10}-V^c_s\rVert$		1	0	H'_0	H''_0	V_a

Note that for the scenario (N, v_{a66}), the predictions of V^b_{a66} and V^b_s are the same. Of the twelve hypotheses tested in table 12, only two are rejected. So, the predictive power of the generalized Shapley value outperformed the Shapley value.

5: *Which solution reflects in the best way the subject behavior in the symmetric game: the nucleolus or the Shapley value?*

Table 13. Test 5

	Null Hypothesis	Sample size	W stat	p value	test A	test B	D.C.
exp	$\lVert x^a_s-V^a_s\rVert < \lVert x^a_s-N^a_s\rVert$	$n_s=17$	0	<.001	H'_0	H''_0	V_s
1	$\lVert x^b_s-V^b_s\rVert < \lVert x^b_s-N^b_s\rVert$	-	0	<.001	H'_0	H''_0	V_s
	$\lVert x^c_s-V^c_s\rVert < \lVert x^c_s-N^c_s\rVert$	-	0	<.001	H'_0	H''_0	V_s
exp	$\lVert x^a_s-V^a_s\rVert < \lVert x^a_s-N^a_s\rVert$	$n_s=17$	19	<.001	H'_0	H''_0	V_s
2	$\lVert x^b_s-V^b_s\rVert < \lVert x^b_s-N^b_s\rVert$	-	0	<.001	H'_0	H''_0	V_s
	$\lVert x^c_s-V^c_s\rVert < \lVert x^c_s-N^c_s\rVert$	-	0	<.001	H'_0	H''_0	V_s

Results are clear: all of the six hypotheses tested in Table 13 are accepted. So, the predictive power of the Shapley value outperformed the nucleolus by a wide margin in the symmetric game (N, v_s) .

6: *Which solution reflects in the best way the subject behavior in the asymmetric game: the nucleolus or the Shapley value?*

Table 14. Test 6

	Null Hypothesis	Sample size	W stat	p value	test A	test B	D.C.
E	$\|x^a_{a66}-N^a_{a66}\| < \|x^a_{a66}-V^a_{a66}\|$	$n_{a66}=18$	120	1	H'_1	H''_0	V_a
X	$\|x^b_{a66}-N^b_{a66}\| < \|x^b_{a66}-V^b_{a66}\|$	-	120	75	H'_1	H''_0	V_a
P	$\|x^c_{a66}-N^c_{a66}\| < \|x^c_{a66}-V^c_{a66}\|$	-	136	1	H'_1	H''_0	V_a
	$\|x^a_{a10}-N^a_{a10}\| < \|x^a_{a10}-V^a_{a10}\|$	$n_{a10}=17$	$N^a_{a10}=V^a_{a10}$				$\sim$
1	$\|x^b_{a10}-N^b_{a10}\| < \|x^b_{a10}-V^b_{a10}\|$	-	12.5	.0007	H'_0	H''_1	N_a
	$\|x^c_{a10}-N^c_{a10}\| < \|x^c_{a10}-V^c_{a10}\|$	-	36	.028	H'_0	H''_1	N_a
E	$\|x^a_{a66}-N^a_{a66}\| < \|x^a_{a66}-V^a_{a66}\|$	$n_{a66}=17$	152	1	H'_1	H''_0	V_a
X	$\|x^b_{a66}-N^b_{a66}\| < \|x^b_{a66}-V^b_{a66}\|$	-	144	.99	H'_1	H''_0	V_a
P	$\|x^c_{a66}-N^c_{a66}\| < \|x^c_{a66}-V^c_{a66}\|$	-	153	1	H'_1	H''_0	V_a
	$\|x^a_{a10}-N^a_{a10}\| < \|x^a_{a10}-V^a_{a10}\|$	$n_{a10}=16$	$N^a_{a10}=V^a_{a10}$				$\sim$
2	$\|x^b_{a10}-N^b_{a10}\| < \|x^b_{a10}-V^b_{a10}\|$		8.5	.0005	H'_0	H''_1	N_a
	$\|x^c_{a10}-N^c_{a10}\| < \|x^c_{a10}-V^c_{a10}\|$		18	.003	H'_0	H''_1	N_a

Note that for the scenario (N, v_{a10}), the predictions of V^a_{a10} and N^a_{a10} are the same. Of the twelve hypotheses tested in Table 14, four are rejected. So, the predictive power of the generalized Shapley value outperformed the generalized nucleolus.

Globally we can then advance the following experimental evidence: (1) the introduction of the host factor in the framing of the siting problem affects the behavior of each individual. (2) The nucleolus and the Shapley value must be generalized to allow an accurate prediction. (3) The Shapley value supplies far better predictions than the nucleolus in the traditional symmetric game. (4) The generalized Shapley value supplies better predictions than the generalized nucleolus in the asymmetric games. (5) The subjects perceive a decreasing of the negotiating power of community c when changing from a symmetric game to an asymmetric game. (6) The negotiating procedure often leads to observed solutions outside the inner core, but as foreseen, there are no solutions exterior to the outer core.

6 Summary and conclusion

The main purpose of the present paper is to design a mechanism to overcome the impasses that often arise in the process of siting hazardous facilities. However, in voluntary exchange mechanism transaction costs prevent the negotiations from reaching the optimum. More particularly, siting procedures take time. To reduce transactions costs we introduce an arbitrator who proposes surplus distributions. The main goal of this paper is to determine which distributions it has to propose to reach an agreement. To this end, a new cooperative game is constructed to facilitate this cooperation. The game takes into account the selection of a host, which is the essential concern in siting, but also the coalition structure, the only factor considered in traditional cooperative game.

Two bargaining solutions are proposed for the game which yield the optimal site and the transfer payments among participating communities: Shapley value and nucleolus. These two classical solution concepts are studied after adaptation to the asymmetric context of the game. Furthermore the experimental results indicate that the presentation of the siting problem in its different formats (asymmetric or symmetric cooperative games) are different. In general the results are significantly different. Moreover, the experimental results show that the predictive power of the generalized Shapley value (more centred on efficiency) is better than the nucleolus (more focused on the equity) by a significant margin. The arbitrator must propose a generalized Shapley value solution to quickly reach an optimal agreement and thus overcome the NIMBY syndrome.

This paper identifies several opportunities for further works on mechanisms to facilitate the siting of noxious facilities. The first option is to generalize new solution concepts and maybe assume that players are not "rational". A second option is to explore the effects of the mechanism when participation is irra-

tional for some cities. Moreover, in this paper, we suppose that communities each have complete information on the costs of a facility in their jurisdiction or in other potential host jurisdictions. This hypothesis is realistic when few jurisdictions negotiate (Catin (1985)). But in the real world many jurisdictions can participe in such negotiations. So, a final option for extending the analysis is to consider that jurisdictions each have incomplete information on the cost of a facility in other potential host jurisdictions.

APPENDIX

Table 15. Results of the first experiment

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
(N, v_{a10})	a	28	28	28	27	38	30	40	37	47	38	37	39	30	30	35	28	28	28
	b	42	42	42	30	13	28	60	44	30	42	41	39	58	44	0	34	34	34
	c	48	48	48	50	56	34	18	37	30	38	40	40	30	44	40	56	56	56
						○	○	○	○	○	○	○	○	○	○	◇			
(N, v_{a66})	a	28	28	28	28	28	0	35	38	34	37	37	37	30	30	30	25	9	0
	b	42	42	42	42	42	49	56	50	54	42	43	43	46	46	46	43	9	42
	c	48	48	48	48	48	40	27	30	30	39	38	38	42	42	42	50	0	47
							◇	○	○	○	○	○	○	○	○	○	○	◇	◇
(N, v_{s})	a	28	28	28	31	28	28	28	34	40	30	30	30	28	0	30	30	30	30
	b	42	42	42	32	42	42	40	34	40	46	46	46	42	43	41	38	38	38
	c	48	48	48	55	48	48	50	50	38	42	42	42	48	46	47	50	50	50
					○				○	○	○	○	○		◇	○	○	○	○

Table 16. Results of the second experiment

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
(N, v_{a10})	a	38	37	35	38	38	50	30	39	43	30	35	29	28	28	0	38	40	39
	b	42	37	36	40	40	50	44	39	32	45	25	33	42	40	35	40	39	39
	c	38	44	36	40	40	18	44	40	43	43	58	56	48	50	54	40	39	40
		○	○	◇	○	○	○	○	○	○	○	○				◇	○	○	○
(N, v_{a66})	a	28	28	28	30	32	32	0	45	38	38	29	18	39	30	30	39	39	39
	b	42	42	42	46	45	38	0	28	40	35	41	45	39	44	44	40	39	40
	c	48	48	48	42	41	48	0	45	40	45	48	55	40	44	44	39	40	39
					○	○	○	◇	○	○	○		○	○	○	○	○	○	○
(N, v_{s})	a	25	26	24	33	30	28	40	0	18	35	39	30	29	18	8	10	23	21
	b	43	41	42	40	40	42	39	40	40	41	40	40	45	50	40	50	45	44
	c	50	51	52	45	48	48	39	49	60	42	39	48	44	50	70	58	50	53
					○	○		○	◇		○	○	○	○	○		○	○	○

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