A Simple Mechanism for Resolving Conflict*

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Abstract

In Conflict Resolution situations where two parties with opposed preferences need to make a number of decisions simultaneously,we propose a simple mechanism that endows agents with a certain number of votes that can be distributed freely across issues. Its novelty, and appeal, is that it allows voters to express the intensity of their preferences in a simple manner and with no use of monetary transfers; it allows agents to trade off their voting power across issues and extract gains from differences in the intensities of their preferences.

The appealing properties of such a mechanism may be negated by strategic interactions among individuals. In this paper we test its properties using controlled laboratory experiments. We observe that equilibrium play increases over time and truthful/honest play decreases over time. Subjects almost reach the welfare predicted by the theory. The latter result holds even when their behaviour is far from equilibrium. The fact that deviations from equilibrium do not do much damage to its welfare properties is a further argument in favour of the use of this mechanism in the real world.

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JEL Classification: C7, C9, D74

1 Introduction

It is common to find *Conflict Resolution* situations where two parties need to agree on multiple issues. An international dispute, a bilateral agreement in arms/pollution reduction, a country with two legislative chambers governed by opposing parties or a clash between the management and the union of a particular firm, are just a few examples.

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Inspired by Beggs *et al* (1997), we can think of two merchants that want to engage in a joint retail project to attract more customers and share costs. The merchants, although seriously interested in the idea, have concerns about several issues such as the advertising plan, the location of each store relative to the main entrance, the temperature of the facility, the number of clerks to be hired and trained and the distribution of the maintenance costs. While we acknowledge the importance of negotiations to reach joint decisions, in the present paper we test the properties of a simple mechanism that allow parties to trade-off their interests across different issues simultaneously and swiftly reach a joint decision.

As is stressed in the negotiation analysis literature, in conflict resolution situations parties need to assess trade-offs in terms of *how much to give up in [...] one issue in order to obtain a specified gain in another issue* (Keeney and Raiffa (1991), pg. 131). It is often the case that parties have differing relative intensities in their preferences, differing attitudes towards risk or differing patience and there are gains to be extracted from these differences. The negotiation analysis literature has offered several different approaches and techniques for settling such disputes by proposing specific algorithms that elicit, and then aggregate, agents' preferences. However, in multi-issue situations the literature has mainly focused on the candid/honest behaviour of parties.[1]

A mechanism that has received much attention is the Adjusted Winner by Brams and Taylor (1996 and 1999). Based on the work by Knaster (1946), Steinhaus (1948) and others, Brams and Taylor propose a *fair* (envy-free, efficient and equitable) mechanism to be used in the allocation of divisible goods among two parties. The divisibility of objects together with the honest behaviour of parties allows the mechanism to be fair because it makes it possible to compensate the party that does not receive the most valuable goods. Our approach differs from the Adjusted Winner in two main ways; we are thinking of a situation where objects are indivisible (issues that need to be approved or dismissed) and, most importantly, we analyse the strategic interactions among parties by characterising the equilibrium of the game; thus we do not assume honesty.

In the present paper we consider a situation where two parties have divergent views over a fixed number of issues. We want to allow them to have more influence on those issues they care relatively more about. It is a simple comparative advantage argument: in the same way that countries should specialise in those products they are relatively more productive at, parties should decide on those issues they feel relatively more intensely about. In this vein we propose a *simple* mechanism that allows parties to express the intensity of their preferences in a simple manner. Our study complements the study on *Storable Votes* by Casella (2005) and Casella et al (2006). Ultimately, we want to show the circumstances under which the strategic interactions between conflicting parties do not undermine the gains from taking into account the intensity of their preferences.

The mechanism endows each party with a budget of votes to distribute across the issues simultaneously (analogously to the Adjusted Winner and related mechanisms).[2] Parties have opposing

[1] In particular, see Raiffa *et al* (2002) where an analogous mechanism to the presented in this paper is introduced and not much discussed (point voting rule). Within the operations research literature see Phillips and Bana e Costa (2005) and references therein.

[2] Our mechanism has the flavour of a scoring rule (especially cumulative voting) though there is a crucial distinction. Scoring rules are used to elect one representative out of many; instead our mechanism deals with a situation

preferences so that one party wants all the issues to be approved and the opposing party wants them all dismissed. The party that invests most votes on a given issue is *decisive* on that issue. In case of ties, the issue is approved or dismissed with equal probability. By unilaterally trading off bargaining power from less preferred issues to more preferred ones parties can extract the gains from trade inherent in their differing valuations of the issues.

We design a series of experiments to examine the properties of our mechanism. We want to contrast the theoretical predictions with the experimental evidence and check whether deviations from equilibrium behaviour benefit or harm overall welfare. Our work complements the experimental work on Storable Votes (see Casella et al (2006)) by looking at a situation in which voters face the whole set of issues at once rather than voting on a single decision at a time –without knowing their own preferences over the decisions that are voted in subsequent periods. This key difference between our work and the one on Storable Votes also allows us to test whether subjects play *truthful strategies* where their actions match their relative preference across issues. This is a frequent hypothesis in the negotiation literature (see Keeney and Raiffa (1991)) but in our work we show that the subjects behavior is closer from equilibrium behavior than from truthful behavior. As compared to the existing literature, we also check the robustness of our results to a larger number of issues as we study situations with two, three or six issues while the literature on Storable Votes analyses situations with mostly three issues.

Characterising the equilibria of the game gives us a solid basis on which to discuss our experimental results. When there are only two issues, it is a dominant strategy for a party to invest all its votes in its most preferred issue. This strategy allows parties to be most influential on their most preferred issue and extracts all *gains from trade*. The theoretical solutions for the cases with three and six issues have been found computationally. From a theoretical perspective we are dealing with a non-zero sum Colonel Blotto game with incomplete information.[3] Recently, Robertson (2006) and Hart (2006) have provided a complete solution of the Colonel Blotto game when parties value all issues equally but the game has yet to be solved in our case where opposing parties have differing relative intensities (so there are gains to be extracted).

Our main finding is that the subjects' realised aggregate welfare matches that predicted by the theory and almost attains the efficient level of welfare –where efficiency is defined as maximising the sum of utilities.[4] In order to understand the source of these surprisingly good results we analyse subjects behaviour and observe that equilibrium bidding increases over time. The effect is specially pronounced in the two issues case: subjects play the dominant strategy equilibrium in 40% of the cases in the initial period, and in almost 90% of cases in the last period. We later

where there are N offices for which 2 candidates are running and voters can abstain in some elections cumulating their votes in the rest. We can also draw a parallel between our setting and an auction where two agents are endowed with token money to bid simultaneously towards various goods –Szentes and Rosenthal (2003) analyse a simultaneous auction for three objects in a setting with complete information. Unlike in our setting, they assume that parties have a common value for the objects.

[3] A Colonel Blotto Game can be described by a situation where two colonels are fighting over a number of regions and have to decide how to divide their forces; the one with larger forces wins the region and the winner of the battle is the one who wins the most territory. This is, unlike in our setting, a zero-sum game because both colonels value all regions equally.

[4] Our results are robust to considering alternative efficiency requirements such as Pareto efficiency.

turn our attention to the question of whether there is a need to analyse the mechanism's game theoretical framework, or whether we could have assumed honesty (as is usual in the fair division literature). We find strong evidence that subjects tend to follow the game theoretical predictions rather than the truthful behaviour ones.

Finally, we present some further results and then simulate the subjects' behaviour under alternative voting rules. We find that the efficiency gains arise mainly from playing *weakly monotone strategies* –i.e. strategies that never invest fewer votes in an issue that is valued higher. In our setting, it is suboptimal not to play such actions given that all issues are symmetric and preferences are uniformly distributed. We find that as we increase the number of issues, the use of weakly monotone strategies realises all efficiency gains. We therefore conclude that, when conflicting parties are able to allocate their voting/bargaining power freely across a set of issues, potential welfare gains can be realised even in complex games with strategic agents.[5] Our simple mechanism is robust to the subjects' idiosyncratic behaviour whenever their strategies satisfy the condition that more votes are invested in those issues they value higher.

The paper is organized as follows. In the remainder of this section we relate our work to the existing literature. In Section 2 we introduce the theoretical model. In Section 3 we describe the experimental design and in Section 4 we characterise the theoretical predictions for our specific design. Section 5 analyses the voting behaviour of our subjects and the welfare they achieved, and in Section 6 we present further analysis of the subjects' behaviour and various robustness checks. Section 7 discusses how our experimental results can be generalised to a situation with an arbitrary number of issues and Section 8 concludes.

1.1 Related literature

The literature on conflict resolution is very large and can be found in a variety of fields including international relations[6], political economy, game theory, experimental psychology and experimental economics. Nevertheless most literature focuses on unidimensional situations like the Rubinstein bargaining model (1982), the ultimatum game (see the seminal reference Guth *et al* (1982) or Thaler (1988) for a review) or the models on arbitration (see for instance the review by Brams, Kilgour and Merrill (1991)).The analysis of fair division assumes honest behaviour and tries to aggregate the truthfully revealed preferences into outcomes that are fair (see Brams and Taylor (1996), (1999)). The experimental literature on fair division (see for instance Daniel and Parco (2005) or Schneider and Kramer (2004)) has already shown that agents may not always reveal their information truthfully. The absence of a theoretical framework means they cannot interpret these

[5] When designing our experiment, we were initially concerned that it might be too complex. The experimental literature on multidimensional voting models offers opposing views on this question. McKelvey and Ordeshook (1981) show that an increase in strategic complexity, through the provision of better information on the other subjects' preferences, leads to worse outcomes for subjects. However, Yuval (2002) shows that an increase in complexity, through an increase in the size of the agenda, leads voters to act more sincerely and so achieve better payoff overall. We abstract from the former informational effect in our analysis and do not observe more sincere play when we increase the number of issues.

[6] See the excellent survey by Avenhaus and Zartman (2007).

deviations from truthful behaviour. In this paper we can clearly identify the subjects behaviour even when they depart from truthful behaviour.

Our analysis deals with a multidimensional *strategic* situation with non-divisible goods and without monetary transfers –an area where little research has been done.

From a theoretical perspective, there are two papers closely related to our work. Casella (2005) proposes a system of *Storable Votes* to be used in situations where voters have to decide over the same binary decision repeatedly over time and shows its superiority with respect to MR in a particular setting. Hortala-Vallve (2007) complements her work because he considers situations where the full preference profile is known at the time of voting and voters cast all their votes over all the issues simultaneously. Instead, in her work there is a temporal dimension and voters do not know their preferences on future decisions. Inspired in Casella (2005), Jackson and Sonnenschein (2007) prove that "the utility costs associated with incentive constraints typically decrease when the decision problem is linked with independent copies of itself." Both works have been tested in the laboratory.

Most closely related to our experiment is the experimental study of storable votes by Casella, Gelman and Palfrey (2006). The authors show that the subjects' welfare is remarkably close to theoretical predictions even when players do not follow the theoretical equilibrium predictions exactly. This apparent puzzle can be rationalised in our setting; deviations from equilibrium do not reduce welfare by much as long as subjects play weakly monotone strategies. In our setup, agents know their full preference profile so we can test whether their actions approach a truthful revelation of preferences. This behaviour is indeed assumed when authors have proposed different mechanisms for resolving conflict resolutions situations (see for instance Brams and Taylor (1996)). Finally, Engelmann and Grimm (2006) study the Jackson and Sonnenschein (2007) linking mechanism and show that constraining the number of cases where a player can declare a high preference captures nearly all possible efficiency gains. The source of the gains we observe in our model is analogous to theirs but the design of their mechanism is complex and relies heavily on the prior distribution of subjects' preferences.

2 The model

Two agents have opposing views over N issues that need to be approved or dismissed. Monetary transfers are not allowed. Each agent privately knows his preferences and the prior distribution from which they are drawn is common knowledge.

Agents and issues are denoted $i \in \{1,2\}$ and $n \in \{1,2,...N\}$, respectively. Agent i's valuation towards issue n is denoted $\theta_n^i \in \mathbb{R}^+$. The preference vector of agent i is denoted $\theta^i = \left(\theta_1^i, ..., \theta_N^i\right) \in \Theta \subseteq \mathbb{R}^N$ and his payoff on issue n is described as follows,

$$\begin{cases} \theta_n^i \text{ if his will is implemented in issue } n \\ 0 \text{ if his opponent's will is implemented in issue } n \end{cases}$$

The total payoff is the sum of the individual payoffs across the N issues.[7]

Agents are endowed with V votes that can be freely distributed between the issues. The action space is the collection of *voting profiles*:

$$\mathcal{V} := \left\{(v_1, ..., v_N) \in \{0, 1, ..., V\}^N : v_1 + ... + v_N = V\right\}$$

Our simple mechanism allows each agent to implement his will on issues where he invests more votes than his opponent. Ties are broken with the toss of a fair coin. That is,

$$\begin{cases} v_n^1 > v_n^2 & \Rightarrow \quad \text{Agent 1 decides on issue } n. \\ v_n^1 < v_n^2 & \Rightarrow \quad \text{Agent 2 decides on issue } n. \\ v_n^1 = v_n^2 & \Rightarrow \quad \text{Each agent decides on issue } n \text{ with probability } \frac{1}{2}. \end{cases}$$

3 Experimental design

We run a total of 9 sessions with 18 subjects per session. Students are recruited through the online recruitment system ORSEE (Greiner (2004)) and the experiment takes place on networked personal computers in the LEEX at Universitat Pompeu Fabra between April 2006 and October 2007. The experiment is programmed and conducted with the software z-Tree (Fischbacher (2007)).[8]

The same procedure is used in all sessions. Instructions (see Appendix) are read aloud and questions answered in private. Students are asked to answer a questionnaire to check their full understanding of the experimental design (if any of their answers are wrong the experimenter refers privately to the section of the instructions where the correct answer is provided). Students are isolated and are not allowed to communicate. At each period subjects are randomly matched into groups of two.[9] The sessions consist of 50 periods. The only difference across sessions is the number of issues on which players have to vote (2, 3 or 6).

Preferences are induced by assigning a valuation in terms of euro cents to each of the issues. Valuations are drawn from a uniform distribution of vectors with elements being positive multiples of 50. No issue is valued zero, and the valuation in each vector sum to 600.[10] The purpose of the constant total valuation is twofold. First, it ensures comparability across games and avoids framing effects.[11] Second, with normalised preferences all subjects are weighted equally when we calculate our efficient outcome.

[7] Implicit in this definition of payoffs is the assumption that valuations are independent across issues. That is, there are no complementarities between them. If this assumption holds, results can be extended to any linear transformation of the payoffs.

[8] The data and programme code for the experiment are available upon request.

[9] We partition the subjects into three sets of six players so as to obtain three independent observations. We have analysed each observation separately and we see no remarkable difference between them.

[10] For example (300,300), (100,500), (500,100) or (550,50) are all equally likely.

[11] Framing effects imply that voters may behave differently when they are assigned payments (1,2) or (200,400). We want to abstract from such framing issues which have been broadly analysed in many different settings -see the seminal reference Kahneman and Tversky (1983).

In each period, players are told their valuations and are asked to distribute 6 votes among the issues. Note that we are implicitly assuming that the set of possible valuations is finer than the set of voting profiles. This is done to capture a realistic feature of our simple mechanism with discrete votes since actual preferences will, in general, be richer than the action profile.[12]

The program computes the outcome and the payoff of each period after all subjects cast their votes. Each subject receives the following information on each of the issues at the end of each period: (i) his valuations; (ii) his vote; and (iii) his opponent's vote. Finally, he is also told his payoff for that period. The final payment of the session is computed by adding the payoff obtained in three (randomly selected) periods. At the end of each session participants are asked to fill in a questionnaire on the computer and are given their final payment in private. The average final payment is 14.20 euros. Session length, including waiting time and payment, is around an hour and a half.

4 Theoretical predictions

The following table lists the possible valuation profiles that were induced in each session (ordered in decreasing order) together with the symmetric Bayesian Nash equilibrium action for each type of subject.

2 issues

θ_1	θ_2	v_1	v_2
300	300	3	3
350	250	6	0
400	200	6	0
450	150	6	0
500	100	6	0
550	50	6	0

3 issues

θ_1	θ_2	θ_3	v_1	v_2	v_3
200	200	200	2	2	2
250	200	150	3	2	1
250	250	100	3	3	0
300	150	150	4	1	1
300	200	100	4	2	0
300	250	50	3	3	0
350	150	100	5	1	0
350	200	50	5	1	0
400	100	100	6	0	0
400	150	50	5	1	0
450	100	50	6	0	0
500	50	50	6	0	0

6 issues

θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	v_1	v_2	v_3	v_4	v_5	v_6
100	100	100	100	100	100	1	1	1	1	1	1
150	100	100	100	100	50	2	1	1	1	1	0
150	150	100	100	50	50	2	2	1	1	0	0
150	150	150	50	50	50	2	2	2	0	0	0
200	100	100	100	50	50	3	1	1	1	0	0
200	150	100	50	50	50	3	2	1	0	0	0
200	200	50	50	50	50	3	3	0	0	0	0
250	100	100	50	50	50	3	2	1	0	0	0
250	150	50	50	50	50	3	3	0	0	0	0
300	100	50	50	50	50	4	2	0	0	0	0
350	50	50	50	50	50	4	1	1	0	0	0

Utility vectors and the corresponding Bayesian Nash equilibria for each of the 2,3, and 6 issues games.

Table 1

Whenever parties vote over 2 issues, they should invest all votes in their most preferred issue –it is a weakly dominant strategy to do so. The intuition behind this result is very simple and relies on the fact that there are only three implementable outcomes: ties on both issues, and two outcomes

[12] We should stress that the chosen parameter values (i.e. number of issues, grid size on the induced payments and number of votes) were chosen to offer a coherent and comparable set of experiments among the parameters that induced a game that was computationally solvable. What would happen if we were to vary such parameters in interesting ways (e.g. increasing the number of votes or the grid size) remains an open question. We believe that these questions rely on characterising the equilibrium of such games theoretically and hence remain out of the scope of the present paper.

where each subject decides on a different issue. A subject who is not indifferent between the issues likes best the outcome where he decides on his most preferred issue. Therefore, his action is driven by maximising the likelihood of being decisive on such an issue. In other words, he invests all his votes in his most preferred issue.[13] Subjects that value both issues equally are indifferent between any outcome. If they split their votes equally between the two issues they allow non-indifferent subjects to decide on their preferred outcome and so allow the mechanism to reach the only ex-ante optimal allocation –in Section 6 we check whether subjects play this strategy.

The difficulties of finding the equilibria theoretically in the cases with 3 and 6 issues have led us to characterise them computationally.[14] In both cases, there is a unique symmetric Bayesian Nash equilibrium (up to mixing over issues that are equally valued). The equilibria have very appealing properties that seem intuitive: indifferent subjects (those that care about all the issues equally strongly) distribute their voting power evenly and extreme subjects concentrate their voting power on their most preferred issue.[15] The case with six issues is specially interesting since the type with most extreme preferences does not invest all his votes in his most preferred issue in equilibrium. This occurs because it is very unlikely that anyone's opponent most prefers the same issue. Therefore, subjects gain from diversifying their voting power and increasing their chances of winning on more than one issue.

We can now compare the welfare that subjects reach in equilibrium to the efficient level. The efficient welfare constitutes an upper bound and is achieved by the outcome that maximises the sum of utilities of the conflicting parties. Not having monetary transfers makes our setting a non transferable utility one, thus looking at the sum of utilities may seem meaningless. However, because preferences are uniformly distributed, the average of our efficiency requirement can be interpreted as the measure agents would use at a constitutional stage. It corresponds to an ex-ante evaluation where all possibilities are equally weighted and preferences are not yet known. In Section 6 below we show that all our results are robust when we consider the weaker concept of Pareto efficiency (as usual, an outcome that maximises the sum of utilities is Pareto efficient).

The efficient welfare does not usually coincide with the welfare achieved in equilibrium. For instance, whenever two subjects have valuations (50,550) and (250,350), equilibrium strategies lead to ties in both issues and a total welfare of 600. In contrast, to achieve the efficient welfare the first (second) subject must decide on the second (first) issue. This yields a total welfare of 800.

We want to compare our results with the baseline the level of welfare that would arise if no agreement was reached on any decision and the mechanism simply played a fair lottery on each issue. Note that this would be the outcome if subjects were not allowed to cumulate votes across issues but had to vote on each issue one by one. Subjects would then achieve a welfare of 300 in all cases.[16] We define the *score* that a particular mechanism achieves by considering the welfare

[13] See Hortala-Vallve (2007) for a formal proof of this result.

[14] The C++ programme code is available upon request.

[15] Note that some of the types are playing mixed strategies given that they invest a different number of votes in issues they equally value. See for instance the player with preferences (250, 100, 100, 50, 50, 50). For simplicity, our algorithm assumed that such types mixed uniformly across the available strategies. This assumption implies that all issues are ex-ante identical.

[16] This value also coincides with the expected welfare that subjects would attain if they played randomly i.e. if

gains over our baseline welfare and normalising with respect to the maximal gain. That is, given a mechanism that achieves a welfare W, $score := \frac{W-300}{EfficientWelfare-300}$.

	2 issues		3 issues		6 issues	
		score		score		score
Equilibrium Welfare	368.18	*82*	398.04	*97*	390.04	*98*
Efficient Welfare	383.33	*100*	401.25	*100*	391.47	*100*

Ex-ante theoretical equilibrium welfare and ex-ante efficient welfare.

Table 2

Table 2 shows that Equilibrium welfares reach a very high score. This is a very good aspect of the simple mechanism we are proposing. Our goal in this paper is to check whether these impressive theoretical results are satisfied in practice.

5 Results

5.1 Welfare

We compare the welfare achieved by our subjects to the efficient level, and to that they would achieve if they followed the theoretical solution. Recall that the efficient welfare constitutes an upper bound and is achieved by the outcome that maximises the sum of the utilities of both conflicting parties.

Claim 1 ***The average score from all our sessions is above 80.***

they selected any of the voting profiles with equal probability independently of their announced valuations.

Whenever subjects play randomly there is a probability $p \in (0,1)$ that ties occur in any issue and there is a probability $(1-p)/2$ that any player decides in any issue. The expected payoff is

$$\sum_{n=1\ldots N}\left(\frac{1-p}{2}\cdot 1+p\cdot\frac{1}{2}+\frac{1-p}{2}\cdot 0\right)\theta_n^i = 300.$$

	2 issues		**3 issues**		**6 issues**	
		score		score		score
Realised Welfare	370.28	*80*	390.82	*87*	382.82	*90*
Equilibrium Welfare	371.30	*81*	401.31	*97*	390.21	*98*
Efficient Welfare	387.69	*100*	404.59	*100*	391.74	*100*

Realised welfare versus the efficient and equilibrium ones.[17]

Table 3

The most relevant finding from our experiment is the level of the realised welfare (i.e. our subjects reap most efficiency gains). This is a valuable property of our mechanism which, together with its simplicity, supports the case for using it in real world situations. When we look at the temporal evolution of welfare we observe no particular pattern; realised welfare is very close to the theoretical level for all periods of each session. These results parallel the ones obtained in Casella *et al* (2006) and Engelmann and Grimm (2006).

Does the closeness between the realised and equilibrium welfares arise from subjects playing equilibrium strategies? We answer this question in the next Section.

5.2 Individual behaviour

The game theoretical analysis from Section 4 above provides a framework for our experimental results. We also want to compare our theoretical predictions with the common assumption (within the fair division literature) that subjects truthfully reveal their preferences. Given that the set of possible payments is finer than the set of voting profiles, we assume that the truthful strategy is the voting profile that minimises the angle with the payment profile.[18] Table A1 in the Appendix lists the truthful strategies.

Claim 2 ***Equilibrium play increases over time.***

We estimate the probability of playing equilibrium strategies through a logistic regression for repeated measures, i.e. we use the method of generalised estimating equations in order to account for correlations among observations from the same subject. Table 4 shows that the probability of playing equilibrium strategies depends positively on the square root of the period number (the

[17] The equilibrium and efficient welfares are contingent on the valuations that were randomly assigned to our subjects. The close results between these results and the ones reported in Table 2 are reassuring.

[18] Any voting profile or payment profile is a vector of a 2, 3 or 6 dimensional space. Using the properties of the scalar product we know that the minimum angle between two vectors v and w is equal to

$$\alpha = \arccos\left(\frac{v \cdot w}{\|v\| \cdot \|w\|}\right) = \arccos\left(\frac{v_1 \cdot w_1 + ... + v_N \cdot w_N}{\sqrt{v_1^2 + ... + v_N^2} \cdot \sqrt{w_1^2 + ... + w_N^2}}\right).$$

coefficient is always positive and significantly different from zero at the 1% significance level for the cases with 2 and 3 issues and at a 10% significance level for the case with 6 issues).[19] In the case with two issues, there is a high rate of convergence towards playing equilibrium strategies, and most of the convergence takes place in the initial 15 periods, where the percentage of people playing equilibrium strategies grows from 47% to 83%, reaching its maximum during periods 42 where all subjects play the strategy predicted by the theory. The growth is less marked for the cases with 3 and 6 issues as can be seen by the magnitude of the estimated coefficient. In the former case, the maximum percentage was achieved in periods 26 and 37 where 26 out of 54 subjects played equilibrium strategies (48%). In the latter case, the maximum was achieved in period 41 where 36 out of 54 subjects played equilibrium strategies (67%).

Number of Issues	**Var**	**Coef**	**St.E.**
2	period sqrt	.57	.05
3	period sqrt	.10	.03
6	period sqrt	.04	.02

Logit regression for repeated measures of the probability of playing equilibrium strategies on the square root of the period number. 2 and 3 issues coefficients are significant at the 1% level, 6 issues coefficient is significant at the 10% level.

Table 4

Claim 3 ***Truthful play decreases over time.***

We use the same specification to test whether subjects acted truthfully. Table 5 shows that the probability of playing truthful strategies depends negatively on the square root of the period number (the coefficient is negative and significantly different from zero at the 1% significance level for the cases with 2 and 6 issues and is not significant at any reasonable level for the case with 3 issues).

Number of Issues	**Var**	**Coef**	**St.E.**
2	period sqrt	-0.13	0.02
3	period sqrt	-0.02	0.03
6	period sqrt	-0.12	0.03

Logit regression for repeated measures of the probability of playing truthful strategies on the square root of the period number. 2 and 6 issues coefficients are significant at the 1% level, 3 issues coefficient is not significant.

Table 5

[19] Motivated by the observation that learning mainly occurs in the first periods we regressed the fraction of subjects playing equilibrium strategies on the square root of the period number (results are robust but slightly weaker when we consider the period number rather than its square root).

The results in Tables 4 and 5 above are robust to considering the distance between observed and equilibrium (or truthful) strategies instead of the frequency with which subjects play each strategy.[20]

Having analysed the frequency with which each strategy is played, we now proceed to analyse how much subjects deviate from each strategy. By considering the minimum angle between each voting profile and the voting profile that assigns equal voting power to all issues (i.e. the vector that assign $\frac{V}{N}$ votes to all issues) we can order all voting profiles (see Table A2 in the Appendix). This measure captures the degree of *intensification* of each voting profile or, in other words, the extent to which our subjects concentrate their voting power on a few issues. Moreover, by close examination of Tables 1 and A1 we can see that the truthful action is always less *intense* than the equilibrium one. Therefore, we can classify all actions as belonging to one of the following 6 (self-explanatory) equivalence classes: LessThanTruth, Truth, BetweenTruthAndTheory, Theory, MoreThanTheory, and TruthAndTheory. Note that the last equivalence class needs to be defined because in some circumstances the equilibrium and truthful actions coincide (see for instance the preference profile (250,200,150)).

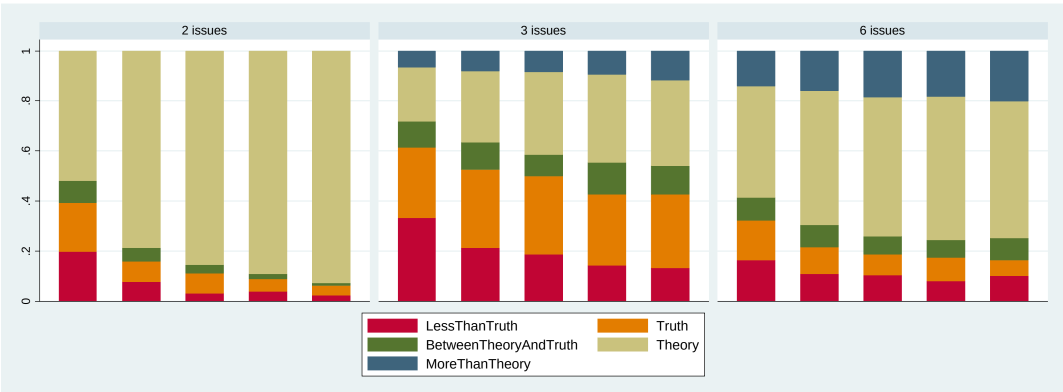


Figure 1: Frequency of play aggregated when the truthful and equilibrium actions do not coincide.

Figure 1 shows the aggregated frequency of play of each equivalence class every ten periods when the equilibrium and truthful actions do not coincide.[21] It captures the results from our previous regressions where we see that equilibrium play increases over time. Most importantly, we can see that subjects tend to move away from truthful play not only by playing it less frequently but also by playing the Theory action or the MoreThanTheory actions more frequently. The fact that subjects are more likely to play the actions classified MoreThanTheory than the LessThanTruth can also be observed in Figure 2 where we have depicted the cases when equilibrium and truthful actions coincide (this corresponds to the 39% of observations in the case with two issues, 29% of observations in the case with 3 issues and 46% in the case with 6 issues). Note that subjects in the cases with 2 and 6 issues are most likely to choose the equilibrium (and truthful) actions.

[20] The results are preserved under different specifications of the metric such as the norm sub one (adding the absolute value of the difference between each coordinate), the euclidean distance or the minimum angle between vectors.

[21] Frequency graphs without aggregation across periods are included in the Appendix.

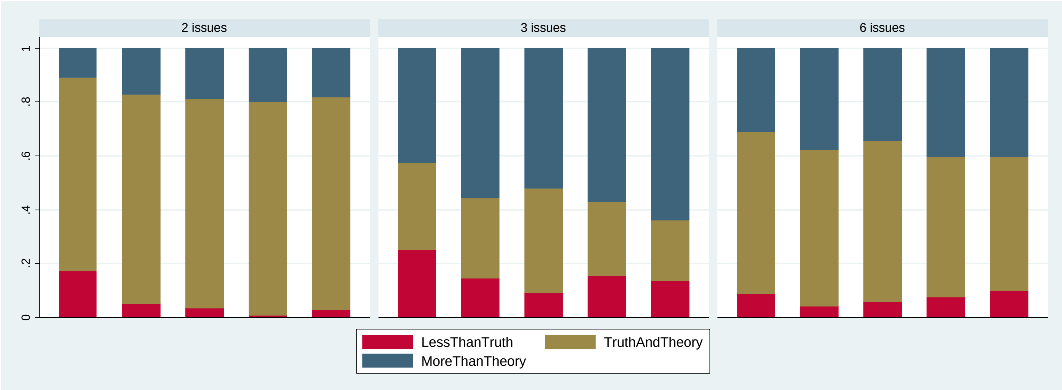


Figure 2: Frequency of play when the truthful and equilibrium actions coincide.

We estimate the probability of playing equilibrium or "more than equilibrium" through the same logistic regression for repeated measures as above. Table 6 shows the statistical significance of the results depicted in Figures 1 and 2. We see that the probability of playing Theory or MoreThanTheory depends positively on the square root of the period number (the coefficient is always positive and significantly different from zero at the 1% significance level). As can be seen in the graphs, the increase in play of these strategies is especially strong when we decrease the number of issues.

Number of Issues	Var	Coef	St.E.
2	period sqrt	.33	.02
3	period sqrt	.17	.02
6	period sqrt	.14	.02

Logit regression for repeated measures of the probability of playing Theory or MoreThanTheory strategies on the square root of the period number. All coefficients are significant at the 1% level.

Table 6

The analogous regressions where we estimate the probability of playing truthful or "less than truthful" strategies produce negative coefficients, all of which are significant at the 1% level.[22] As was mentioned earlier, the experimental literature on fair division shows that deviations from thruthul behaviour are common. However, not much could be said about them. We can now see that such deviations tend towards the behaviour identified in our equilibrium predictions, i.e. they tend towards a concentration of votes onto fewer issues.

[22] The coefficients are -0.29 for the 2 issues case, -0.18 for the 3 issues case and -0.13 for the 6 issues case.

6 Further results

6.1 The case with two issues

The case with two issues is specially appealing given that preferences are essentially unidimensional. This allows us to provide both a thorough study of the subjects' behaviour and a very clear graphical representation. Figure 3 draws attention to four specially selected subjects (called A,B,C and D). We map their value for the first issue into their vote on that issue. In order to have meaningful strategy mappings, we aggregate each individual's behaviour into groups of ten periods.

Figure 3: Individual behaviour for the 2 issues case.

A set of observed actions along the diagonal captures truthful voting behaviour where the subject matches his relative intensity to the vote ratio. In contrast, a step function depicts the equilibrium strategy where zero votes are invested in the first issue when the valuation is below 300 and 6 when it is above 300. Subject A represents the most commonly observed subject: a subject that starts playing a truthful strategy but, over time, learns to play the equilibrium. Subject B, instead, plays the equilibrium strategy from the very first periods. Subject C is learning to play the equilibrium strategy (like subject A) but in the first periods he splits his votes evenly regardless of his valuation. Finally, subject D starts by playing more votes in the issues he most prefers but without a clear pattern and moves towards a truthful strategy.[23]

When analysing equilibrium play in the case with 2 issues, we can see that the convergence is driven by the behaviour of less extreme subjects (i.e. players that value issues more similarly). Most extreme subjects have a high propensity to play the equilibrium strategy (invest all votes in most

[23] We can classify subjects according to their actions during the first and last ten periods (the information in between does not separate types given the rapid convergence to equilibrium play). 41% of our subjects played truthfully in the first ten periods and played according to theory in the last ten (like subject A in Figure 3); 54% played the theoretical solution throughout (like subject B in Figure 3); and, finally, three subjects (5%) cannot be categorised (two of them are depicted as subjects C and D in Figure 3).

preferred issue) from the very beginning. This is captured in Figure 4 where we observe increased play of equilibrium strategies mainly among the subjects that have non-extreme preferences (i.e. those that value their most preferred issue 350 or 400).[24]

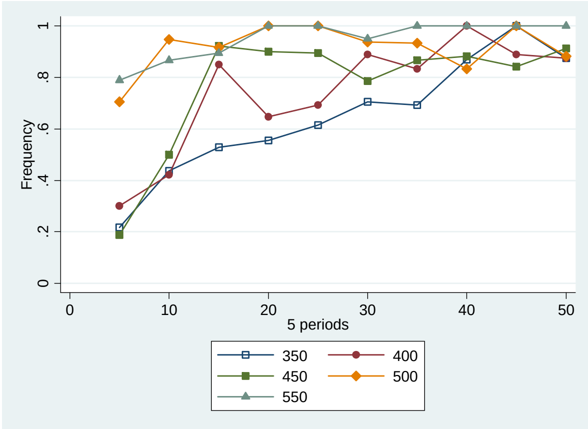


Figure 4: Relative frequency of subjects playing equilibrium strategies in the 2 issues case (disaggregated by value placed on their most preferred issue.)

We also want to analyse the behaviour of subjects that value both issues equally and hence are indifferent between possible strategies. The way they play is relevant to our welfare analysis: only when they split their votes do they allow our simple mechanism to reach the ex-ante optimal incentive compatible allocation (i.e. allow their opponent to decide on his most preferred issue). Figure 5 shows that half of the indifferent subjects split their voting power evenly; around a third of the subjects display extreme behaviour and, unfortunately, this behaviour does not change over time. However, the existence of indifferent subjects that display extreme behaviour has almost no effect on the efficiency of outcomes (the average realised welfare if indifferent subjects split their votes evenly would increase from 370.23 to 372.33).

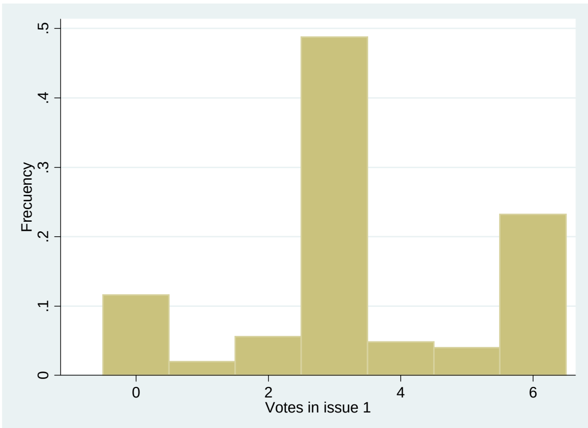


Figure 5: Relative frequency in voting patterns of indifferent subjects in the 2 issues case.

[24]The intuition of Figure 4 is supported by a logistic regression for repeated measures for each type of player –the McFadden R-Squared of such regressions is 0.246.

6.2 Weakly monotone strategies

In our experimental design, all issues are identical so we can assume that subjects' actions are independent of their labelling. This implies that the marginal distribution of the opponent's votes coincides in all issues, so a subject should never invest fewer votes in an issue that is valued higher -i.e. they should play *weakly monotone strategies* (WMS). Whenever the opposite occurs we say that they make an *Elementary Error*.[25] We understand the existence of such errors as a sign that subjects may not have perfectly understood the functioning of the experiment or the way payments were drawn, or did not figure out the rationale of our simple mechanism. Fortunately, we observe that only 4% of cases involved elementary errors, and half of them were made by only eight subjects. Moreover the mode of elementary errors per period occurs within the first three periods.

Nber of issues	*Periods*				
	1-10	*11-20*	*21-30*	*31-40*	*41-50*
2	7	8	2	4	6
3	60	33	39	39	31
6	26	17	18	16	20

Number of elementary errors by the number of issue and groups of ten periods (each cell corresponds to 540 observations).

Table 7

6.3 Alternative voting rules

In Section 5.1 we saw that the welfare achieved by our subjects is very close to the equilibrium and efficient levels even though subjects are far from playing equilibrium strategies. In the two issues case, we also see that the realised welfare outperforms the equilibrium one in the first periods of each session; this is mainly driven by some players deviating from equilibrium strategies and hence allowing players with more intense preferences to decide on their most preferred issue.

In order to understand the surprisingly good results in terms of welfare we compute the welfare that subjects would have obtained if they chose their strategies at random, while still keeping the condition that they never invest fewer votes in an issue they value higher –i.e. they play WMS.

[25] We cannot rule out equilibria where strategies are contingent on the labelling of the issues. In such cases Elementary Errors may occur in equilibrium. However, it seems implausible that subjects could coordinate on such equilibria.

Table 8 shows the average welfare that players would have obtained if they randomised.

	2 issues		**3 issues**		**6 issues**	
		score		score		score
Random-WMS Welfare	362.43	*71*	377.70	*74*	368.95	*75*

Averaged welfare if subjects uniformly randomise among the actions without elementary errors. The results show the average welfare across 50 independent realisations (results remain unchanged when we increase the number of realisations).

Table 8

Table 8 shows the impressive results in terms of welfare that a random action (without Elementary Errors) achieves. This is a further argument in favour of the use of our simple mechanism in Conflict Resolution situations. Subjects only need to order their voting profiles according to their preferences so that they never cast more votes in an issue they value less. By doing so their score is above 70 in all cases with 2, 3 or 6 issues.

Given the results above, we could also think of another rule where agents do not specify their relative intensities but simply declare their ordinal preference across issues (in case of indifference we assume that subjects play a uniform mixed strategy). Each issue would then be decided by the subject that ranks it higher.[26]

	2 issues		**3 issues**		**6 issues**	
		score		score		score
Ordinal-Preferences Welfare	364.63	*74*	387.92	*84*	385.34	*93*

Averaged welfare if subjects only declared their ordinal preference.

Table 9

Following the results we observed in Table 8, Table 9 shows the good results that subjects achieve if they declare their ordinal ranking sincerely. The welfare our agents can theoretically achieve by the use of this latter rule is still below the equilibrium welfare. The similarity in welfare between the ordered and equilibrium cases is mainly driven by our use of uniformly distributed preference profiles; in situations where subjects tend to have more polarised preferences, the wider range of available voting strategies offered by our simple mechanism would allow them to express their preferences better and hence may see their welfare improve more dramatically.

[26] This mechanism has a flavour of the scoring rule Borda Count (where agents give one point to their least preferred option, 2 points to the second least preferred, etc.). The differences between a scoring rule and our simple mechanism are highlighted in footnote 3.

6.4 Pareto efficiency

In Section 5.1 above we highlighted the fact that our efficiency criterion may be subject to criticism given that we are in a setting with non-transferable utility and hence any utilitarian approach is not invariant to rescaling. We now show that our results on welfare are robust to replacing our criterion with that of Pareto efficiency. The table below gives the percentage of cases where the final outcome is Pareto efficient.

	2 issues	**3 issues**	**6 issues**
Realised	94	89	67
Equilibrium	100	98	94
Random-WMA[27]	85	79	40
Ordinal-Preferences	91	85	78

Percentage of cases where the final outcome is Pareto efficient.

Table 10

The theoretical solution is the one that achieves the most Pareto outcomes (needless to say the efficient solution reaches 100% of Pareto outcomes). Subjects obtain results close to the theoretical predictions in the cases with 2 and 3 issues. They obtain significantly lower results in the case with 6 issues (this may be a consequence of the complexity of the six issues case together with the fact that with so many issues there are a lot more possibilities to get something that is not Pareto optimal). Finally, the use of alternative voting rules yields analogous results to the ones discussed above.

6.5 Envy-freeness

A common property that is tested in most fair division procedures is envy-freeness. “[A]n allocation is envy-free if every player thinks he or she receives a portion that is at least tied for largest, or tied for most valuable and, hence, does not envy any other player”.[28] In our setting this requires checking when a subject strictly prefers the allocation of his opponent (i.e. would prefer to have lost the issues he wins and won the issues he lost). The table below gives the percentage of subjects

[27] Percentage of cases where the final outcome is Pareto efficient when subjects uniformly randomise among the voting profiles without Elementary Errors. The results show the average welfare among 50 independent realisations (results remain unchanged when we increase the number of realisations).

[28] Brams and Taylor (1996, pg. 241)

that do not envy their opponent's allocation.

	2 issues	**3 issues**	**6 issues**
Realised	93	86	94
Equilibrium	100	89	96
Efficient	84	88	96

Percentage of cases where the final outcome is envy-free.

Table 11

As is common in the literature we can see the tension between efficiency and envy-freeness by realising that the efficient outcome is not the one that maximises envy-freeness. Note that the theoretical solution achieves the most envy-free situations, and subjects always obtain results close to the theoretical predictions.

7 Discussion

A natural question is whether our results would continue to hold in a general situation with an arbitrary number of issues to be decided. We can observe from our analysis above that when we move from 2 issues to 3 issues the score achieved by our subjects (and the equilibrium score) increases; the same occurs when we move from the 3 issues case to the 6 issues case. Is this a general property of the simple mechanism we have analysed so far?

In Section 6.3 we saw that the score achieved by uniformly randomising among the weakly monotone strategies is always below the realised and equilibrium scores. In order to show how our previous results extend to the case with an arbitrary number of issues we use the welfare of the Random-WMS as our baseline welfare. We know that very little is required from our subjects to achieve this welfare: they simply need to never invest less votes in those issues they value higher.

We assume that preferences are uniformly distributed in the $(N-1)$-dimensional simplex, $\Delta^{N-1} := \left\{v \in \mathbb{R}_+^N : v_1 + ... + v_N = 1\right\}$. We also assume that the set of voting profiles is the $(N-1)$-dimensional simplex. Both assumptions allow us to easily compute both the efficient welfare and the welfare achieved by uniformly randomising. The table below summarises our findings (note that the maximum attainable welfare is now 1 rather than 600):

Number of issues	2	3	4	5	6	7	8
Efficient Welfare	0.666	0.700	0.714	0.722	0.727	0.731	0.733
Random-WMS Welfare	0.625	0.659	0.677	0.690	0.698	0.704	0.709
Random-WMS Score	75	79	83	85	87	89	90

Ex-ante theoretical welfares and score when preferences are uniformly distributed in the $(N-1)$-dimensional simplex.

Table 12

Both welfares increase with the number of issues -when all issues are identically distributed, the likelihood of the parties' most preferred issues coinciding decreases with the number of issues. Note that the rate of increase of the Random-WMS welfare is higher than the one of the efficient welfare (this is captured by the increase in the score). As a matter of fact, when we increase the number of issues, the score of uniformly randomising among actions without elementary errors tends to 100. In other words, by playing weakly monotone actions, subjects are able to reap all possible gains and reach the ex-post efficient allocation.[29] This occurs because as we increase the number of issues, the set of actions with no elementary errors rapidly decreases relative to the set of all available actions. Therefore, randomising across the set of actions with no elementary errors does not depart much from the truthful strategy.

Overall, then, the welfare benefits of the simple mechanism we have analysed so far are not only restricted to the cases analysed in our experimental sessions and can be extended to an arbitrary number of issues as long as subjects avoid elementary errors.

8 Conclusion

This paper provides an experimental analysis of a simple mechanism for use in conflict resolution situations. In these situations, our mechanism allows parties to trade-off their voting/bargaining power and hence to be more decisive on those issues they care relatively more about.

Embedded in the proposal for a new and simple voting rule is the belief that it should attain a better outcome for the subjects than the mechanisms usually used (such as deciding on an issue by issue basis). Certainly, the welfare obtained is very close to the efficient level, even if many subjects do not fully converge to equilibrium predictions. These results lead to a highly favourable assessment of our mechanism; even when subjects do not play according to theoretical predictions, the realised level of welfare is very close to the efficient one. Moreover, we have shown that our experimental results can be extended to situations with any number of issues as long as subjects play weakly monotone actions.

[29] This result is reminiscent of Jackson and Sonnenschein (2007).

More generally, this paper contributes to the classical debate among researchers and policy makers looking to improve our political institutions and the mechanisms through which we can reconcile divergent views. Our mechanism is indeed a simple one whose properties in our controlled laboratory environment are favourable. It remains to be seen in future work whether these properties are preserved in more complex settings when we vary the informational structure or when we try to reconcile the views of more than two parties.

We are aware that our work opens more enquiries than it closes. Our aim has been to offer a first experimental study of a simple mechanism that we believe may smooth conflict resolution situations. We should now continue our endeavour and compare this mechanism with other methods of confl;ict resolution. Of special interest will be the comparison with non-structured negotiation where subjects freely communicate and propose binding agreements on all issues simultaneously.

9 Appendix

2 issues

θ_1	θ_2	v_1	v_2
300	300	3	3
350	250	4	2
400	200	4	2
450	150	5	1
500	100	5	1
550	50	6	0

3 issues

θ_1	θ_2	θ_3	v_1	v_2	v_3
200	200	200	2	2	2
250	200	150	3	2	1
250	250	100	3	2	1
300	150	150	3	2	1
300	200	100	3	2	1
300	250	50	3	3	0
350	150	100	4	1	1
350	200	50	4	2	0
400	100	100	4	1	1
400	150	50	4	2	0
450	100	50	5	1	0
500	50	50	5	1	0

6 issues

θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	v_1	v_2	v_3	v_4	v_5	v_6
100	100	100	100	100	100	1	1	1	1	1	1
150	100	100	100	100	50	2	1	1	1	1	0
150	150	100	100	50	50	2	2	1	1	0	0
150	150	150	50	50	50	2	2	2	0	0	0
200	100	100	100	50	50	2	1	1	1	1	0
200	150	100	50	50	50	2	2	1	1	0	0
200	200	50	50	50	50	2	2	1	1	0	0
250	100	100	50	50	50	3	1	1	1	0	0
250	150	50	50	50	50	3	2	1	0	0	0
300	100	50	50	50	50	4	1	1	0	0	0
350	50	50	50	50	50	4	1	1	0	0	0

Utility vectors and the corresponding truthful strategy for each of the 2,3, and 6 issues games.

Table A1

2 issues

v_1	v_2
3	3
4	2
5	1
6	0

3 issues

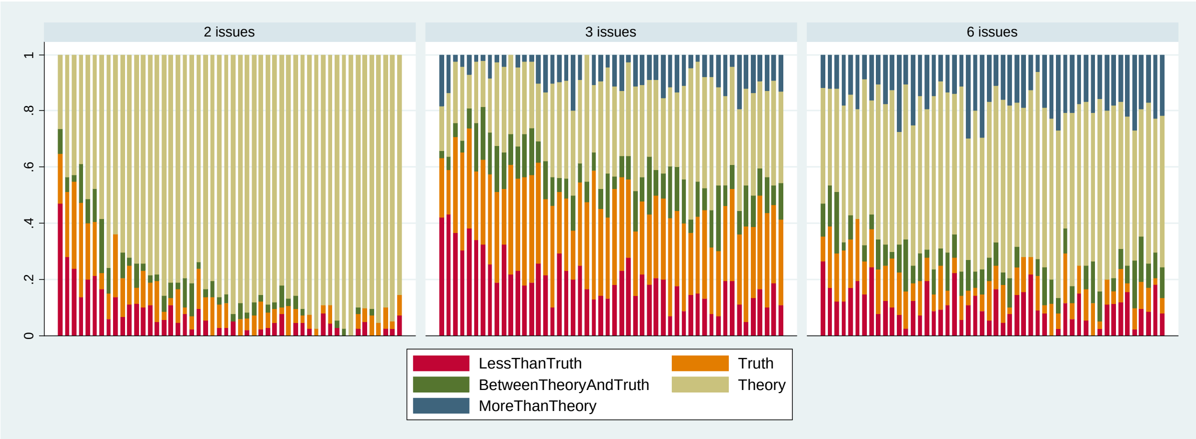
v_1	v_2	v_3
2	2	2
3	2	1
4	1	1
4	2	0
5	1	0
6	0	0

6 issues

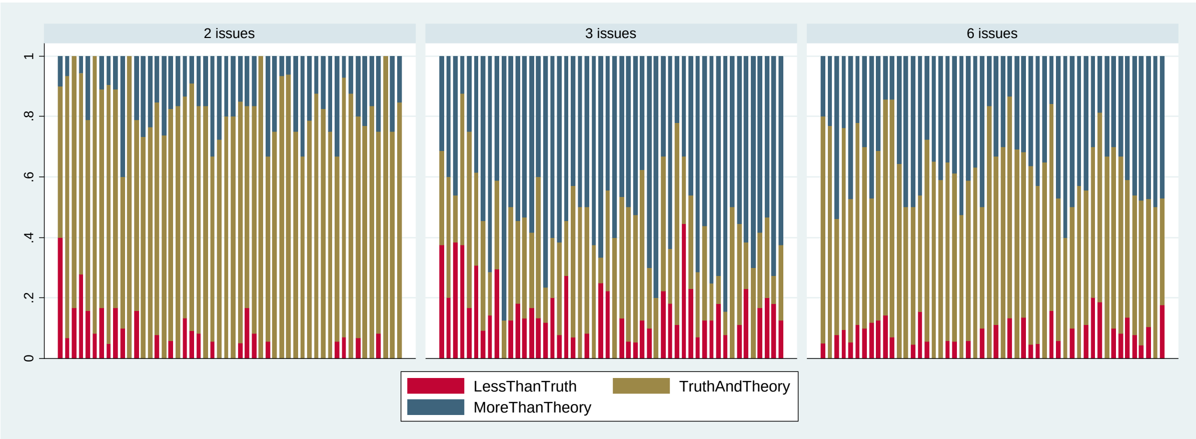
v_1	v_2	v_3	v_4	v_5	v_6
1	1	1	1	1	1
2	1	1	1	1	0
2	2	1	1	0	0
2	2	2	0	0	0
3	2	1	0	0	0
3	3	0	0	0	0
4	1	1	0	0	0
4	2	0	0	0	0
5	1	0	0	0	0
6	0	0	0	0	0

Voting profiles ordered according to the minimum angle with the vector $\left(\frac{V}{n}, ..., \frac{V}{n}\right)$.

Table A2



Frequency of play when the truthful and equilibrium actions do not coincide.



Frequency of play when the truthful and equilibrium actions coincide.

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INSTRUCTIONS

(Translated from the original Spanish instructions)

We are grateful for your participation and for your contribution to an Economics Department project. The sum of money you will earn during the session will be given privately to you at the end of the experiment. From now on (and until the end of the experiment) you cannot talk to any other participant. If you have a question, please raise your hand and one of the instructors will answer your questions privately. Please do not ask anything aloud!

These experiments consist of 50 periods. The rules are the same for all participants and for all periods. At the beginning of each period you will be randomly assigned to another participant with whom you will interact. None of you will know who the other participant is.

You and the other participant will simultaneously vote over a group of three questions. Each question has three possible results: 1) you win and s/he loses it; 2) you lose and s/he wins it; and, finally 3) ties occur. These results will determine the profits that yourself and the other participant will have in each period. Remember that the participant with whom you are interacting in each period is selected randomly in each period.

1. Information at the beginning of each period

At the beginning of each period you will be told your 'valuations' for each issue. You will only know your own valuations. The valuation of each issue specifies how much you earn when you win that issue. These valuations are expressed in terms of cents of Euro.

The possible valuations are summarised in the following table. You should consider all possible permutations. That is, looking at the first row, it is for instance possible that the valuations for issues 1, 2 and 3 are 50, 500 and 50 respectively (instead of 500, 50 and 50). As you can see, the valuations are multiples of 50 and add up to 600.

Issue 1	Issue 2	Issue 3
500	50	50
450	100	50
400	150	50
400	100	100
350	200	50
350	150	100
300	250	50
300	200	100
300	150	150
250	250	100
250	200	150
200	200	200

The valuations of each participant have been selected randomly by the computer. All possible combinations of valuations are equally likely. The valuations of each participant need not be equal; what is more, they will usually be different.

2. Voting procedure

In each period you will have six votes that you will have to distribute among the different issues. After doing so you should press the 'OK' key. The participant with whom you are matched at each period has the same number of votes.

3. Voting result

The result on each voting procedure will be resolved by the following rule: if the number of votes you have assigned to an issue is

- … higher than the number of votes of the other participant, you win the issue
- … smaller than the number of votes of the other participant, you lose the issue
- … equal to the number of votes of the other participant, ties occur

For instance, if you vote in the following way:

	Issue 1	Issue 2	Issue 3
Your votes	3	1	2
His/her votes	0	4	2

You win Issue 1 given that you have assigned more votes (3) than him (0) in that issue; you lose issue 2 given that you have invested less votes (1) than him (4); and you tie issue 3 given that you have both invested the same number of votes (2).

4. Profits in each period

In each period your profits will be equal to the sum of the valuations of all issue you win plus half the valuation of the issue you tie. For instance, if in the previous example your valuations are 350, 100 and 150, according to the assignation of votes in Section 3 your benefits will be: 350 in issue 1, 0 in issue 2 and 75 (half of 150) in issue 3. As you do not know the valuations of the other participants you will not know his profits.

5. Information at the end of each period

At the end of each period, as you can see in the previous screenshot, you will receive the following information:

- Your valuations in each issue
- Your votes in each issue
- The votes of the participant you have interacted with
- The issues you win, lose and tie
- Your profits

6. Final payment

At the end of the last period, the computer will randomly select 3 periods and you will earn the sum of the profits on those periods. Additionally you will be paid three euros for having taken part in the experiment.

7. Questionnaire

1. Circle the correct answer. When you have to vote….

    - ¿You know your valuations? YES NO
    - ¿You know the valuations of the participant you are matched with? YES NO
    - ¿Your own valuations and his can be different? YES NO
    - ¿You know who the other participant you are matched with it? YES NO

Imagine you have the following valuations and that you and the participant with whom you are matched vote in the way specified below

	Issue 1	Issue 2	Issue 3
Your valuations	150	250	200
Your votes	1	3	2
His/her votes	3	1	2

2. ¿Who wins issue 1?   YOU HIM TIES
3. ¿Who wins issue 2?   YOU HIM TIES
4. ¿Who wins issue 3?   YOU HIM TIES

5. ¿How much do you win in issue 1? ____________
6. ¿ How much do you win in issue 2? ____________
7. ¿ How much do you win in issue 3? ____________

8. ¿Which is your profit in this period? __________

9. ¿How many periods will determine your final payment?

10. Your valuations (50, 500, 50), (500, 50, 50), (200, 200, 200) y (200, 250, 150) have the same probability

    ☐ True
    ☐ False

11. In all periods you are matched to the same person

    ☐ True
    ☐ False

12. You know the identity of the participant you are matched with

    ☐ True
    ☐ False