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Abstract: This paper discusses a two-dimensional jury model. It combines the idea of winning a maximum of votes in a voting game with utility maximization that derives from the winning proposition. The model assumes a first mover, the plaintiff, and a second-mover, the counsel of the defendant. Typically, these agents represent parties that have conflicting interests. Here they face a jury that consists of three groups of voters such that no single group has a majority of votes. Each group is characterized by homogeneous preferences on three alternatives that describe the possible outcomes. The outcome is selected by a simple majority of the jury members. The agents are interested in both gaining the support of a majority of jury members and seeing their preferred alternative selected as outcome. It will be demonstrated that equilibrium decision making can be derived for this model.

Keywords Condorcet's Jury Theorem, Voting Paradox, majority cycle, aggregation of preferences, agenda setting, collective decision making.

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1. Introduction

Condorcet's Jury Theorem says that (i) any jury of odd number of jurors is more likely to select the correct alternative than any single juror; and (ii) this likelihood becomes a certainty as the size of the jury tends to infinity. The theorem holds if (a) the jury N decides between two alternatives by voting under simple majority rule; (b) each juror *i* has a probability $p_i > ½$ to be correct; (c) $p = p_i$ for all *i* in N; and (d) each juror *i* decides independently. (See Boland, 1989; and Grofman et al., 1983.)[1]

Unfortunately, these four assumptions hardly ever (or, most likely, never) hold in reality and therefore increasing the number of jury members is not always a reliable instrument to come closer to the truth. As demonstrated by Kaniovski and Zaigraev (2011), the optimal jury size may in fact be a single juror if simple majority rule applies, all jurors are equally competent, but competence is low, and correlation between the jurors is high. Still, the Jury Theorem is well known among scholars of Law and Economics and references are ubiquitous. What is less known is that Condorcet tried to extend his probability approach to the aggregation of preferences, and failed.[2] However, this experiment left us with the Voting Paradox, Condorcet's second outstanding contribution. It did not only inspire Arrow (1963 [1951]) to write his *Social Choice and Individual Values*, but also triggered earlier work that is the core of this paper (Holler, 1980, 1982).

In principle, aggregation of preferences is not about finding some truth, but about summarizing the evaluation of feasible or available alternatives, such as social states. Therefore, the Jury Theorem does not apply and its probability calculation seems, at least at the first glance, to be vacuous. Black (1963, p.163) concludes "whether there be much or little to be said in favour of a theory of juries" that refers to probability calculation, "there seems to be nothing in favour of a theory of elections that adopts this approach." He adds "…the phrase 'the probability of the correctness of a voter's opinion' seems to be without definite meaning." However, Arrow (1963 [1951], p.85) gives a somewhat surprising interpretation of Rousseau's *volonté générale* and voting: "Voting, from this point of view, is not a device whereby each individual expresses his personal interests, but rather where each individual gives his opinion of the general will." And he concludes that this "model has much in

[1]For Condorcet's text see « Essai sur l'application de l'analyse à la probabilité des décisions rendues à la pluralité des voix » (Paris 1785, pp.119-136). Section 11 in "The Political Theory of Condorcet". Translated by Fiona Sommerlad and Ian McLean (manuscript 1989).

[2] See Black (1963, pp. 64ff.) for this judgement and the arguments.

common with the statistical problem of pooling the opinion of a group of experts to arrive at a best judgement…"[3]

This could be interpreted as a justification of using juries of experts to choose the winner in competitions in the fields of arts and sports. However, legal judgements are not always about finding or defining the truth. Often they are about what is good or bad, about the degrees of the goodness and badness of the alternatives to be judged, or what should be done and what should be omitted. Almost every member of the corresponding society is considered an expert in this field, although it cannot be denied that some justification for this can be found in the argument that relates Rousseau's *volonté générale* to voting.

Judgements on values presuppose the existence of a scale of values, i.e., a social welfare function, or a mechanism that brings about an evaluation scale or the choice of a particular alternative. A jury is such a mechanism. On the one hand, juries are used to decide on rank orders in competitions. On the other hand, they decide on guilty and non-guilty, or select from a bundle of alternatives these duties that a convict has to accomplish. However, Arrow (1963 [1951]) demonstrated that there is no social welfare function, i.e., a "process or rule" that maps the set of individual preferences profiles into the set of social preference orderings, both defined on the same sets of alternatives, such that it satisfies two well-known axioms and five "reasonable" conditions.

The conditions are: (i) "unrestricted domain" which says that none of the possible preference profiles on the given set of alternatives should be excluded; (ii) "monotonicity" which refers to Paretian efficiency ("Since we are trying to describe social welfare and not some sort of illfare, we must assume that the social welfare function is such that the social ordering responds positively to alterations in individual vales" (Arrow 1963 [1951], p. 24).), (iii) "independence of irrelevant alternatives", (iv) "citizen sovereignty" which in Arrow's words implies that the social welfare function is not "imposed", i.e., it derives from individual preferences; and (v) "non-dictatorship." Condition (v) says that there is no decision maker *i* whose preferences are identical with the social preferences, irrespective of what the preferences of the other members of the society are.

Arrow postulates that the social welfare function should satisfy the very same axioms that define individual preference orderings: "connectivity" and "transitivity" where "connectivity" implies both "completeness" and "reflexivity" which are standard for the definition of an individual preference ordering. To restate, his theorem says that there is no social welfare function that satisfies these properties and the five conditions listed. In this

[3] Later, the relationship of voting and Rousseau's common will was excessively discussed. See Grofman and Feld (1988) and the literature given in this article.

paper we will analyse a situation and a procedure of preference aggregation that is conclusive inasmuch as it selects a winning alternative for almost all preference profiles of the jury. Sections 2 and 3 will summarize the model and the major results that derive from it. In section 4 we compare the assumptions and results with the axioms and condition of Arrow's Theorem.

2. The model

This paper discusses a two-dimensional jury model. The model is based on the Holler-Steunenberg model discussed in McNutt (2002, pp. 282ff) and applied to European decision making in Holler and Napel (2007). The model had its roots in Holler (1994) and Steunenberg (1994). It assumes a sequential structure of decision making that is quite similar to the ultimatum game. There is a proposer and a responder. However, the game below endogenizes the judgements that characterize these empirical results of the ultimatum game that indicate a deviation from the subgame perfect equilibrium (when utilities are assumed to be linear in money). What is attributed to concerns of justice and envy in the interpretation of the ultimatum game is institutionalized by a jury. In fact, this is perhaps the most important function of juries: to institutionalize judgements that are meant to be based on justice (or truth).

The model combines the idea of winning a maximum of votes in a voting game (i.e., the jury) with utility maximization that derives from the winning proposition. The model assumes a first mover *A*, the agent of the plaintiff, and a second-mover *D*, the counsel of the defendant. It what follows we call *A* the "plaintiff" or proposer, and *D* the "defendant" or responder. Typically, *A* and *D* are agents of parties that have conflicting interests. They face a jury that consists of three groups of voters, J = {1,2,3}, such that no single group has a majority of votes. Each group is characterized by homogeneous preferences on the alternatives u, v, and w. The set of alternatives is given by Ω = {u,v,w}. Its elements describe the possible outcome selected by a simple majority of the jury members (i.e., the voters), subject to the alternatives presented by *A* and *D*. For simplicity we assume that each group of voters in J is a singleton so that we have three voters.

Ranking	Voter 1	Voter 2	Voter 3
High	*u*	*v*	*w*
Middle	*v*	*W*	*u*
Low	*w*	*U*	*v*

Table 1: Preference profile of the jury members

Table 1 represents the preference profile of the jury members. Voter 1 prefers *u* to *v* and *v* to *w*, and so on. Figure 1 demonstrates that the preferences of the voters are not single peaked (i.e., they are intransitive).[4] Note that Table 1 represents a selection of jury members with a maximum of diversity in their preferences. Pairwise comparison of alternatives implies cyclical majorities as there is no Condorcet winner if voters vote sincerely, i.e., if they vote in accordance to their preference orderings expressed in Table 1. As a consequence, if agent *A* proposes alternative s $\in\Omega$ there is always an alternative t $\in\Omega$ that is preferred to s by a majority of jury members if presented by agent *D*.

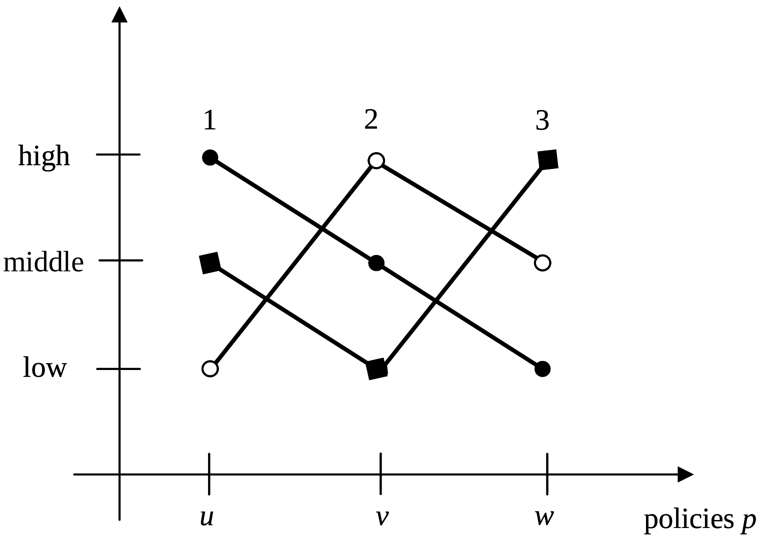

Figure 1: Non-single peaked preferences

If *A* is interested in winning a majority and thus to win the case, and *D* has the same target, then its intentions will be frustrated whatever alternative *A* proposes. However, in general, legal cases are not only about winning, but also about outcomes. The clients of A and D have preferences with respect to the elements of Ω and their agents *A* and *D* have to take these

[4] There is no ordering of u, v, and w such that the preferences of all three groups of voters are single peaked. Thus, preferencs are non-single peaked (see Black, 1948).

preferences into account. We assume that *A* and *D* represent the preferences $w > u > v$ and $u > v > w$, respectively. (Here, symbol > represents the binary relationship "better.") This defines the first dimension of the agents' preferences.

The second dimension of their preferences is indeed defined by "winning," "losing," and "compromise." We assign the numbers 1, 0 and ½ to these events. Given a particular outcome k $\in\Omega$, both *A* and *D* prefer event 1 to event ½ and event ½ to event 0. Often, in a legal case, the losing party has to pay fees to the court and cover the legal expenditures of the winning party. Therefore, winning the case is beneficiary *per se*.

More general we can write the preferences of the two agents *A* and *G* in the form of utility functions $u_i = u_i(m, p)$, i = *A, D.* Here $m \in M$ = {0, ½,1} expresses the probabilities of winning of a majority of votes in the jury which is assumed to be ½ in the case of the indifference of the decision-makers or in the case of non-decisiveness (ties) in the voting body. Or, it signals that both parties agree on a specific alternative. This alternative can be understood as a compromise with the consequence that the case will be closed and no vote is taken. Thus, there will be no loser and no winner. The variable p is defined by $p \in P$ = $\{u,v,w\}$. Here *P* describes the *discrete* set of alternatives that the agents can choose. We assume that this set is identical to the set of alternatives that can be submitted to a vote. Thus sets P and Ω are identical.[5]

We further assume that agent *A* knows the preferences of *D*, and agent *D* knows the preferences of *A*, and both know the preferences of the jury members as shown in Table 1. The assumption that *A* and *D* know the preferences of the other party is perhaps not far away from most real-world settings. However, knowing the preferences of the jury members seems to be more daring. However, given these assumptions, the game model that is discussed in the following is characterized by complete (and perfect) information. We now derive the optimal choices of *A* and *D* in this game. This problem is "solved" for a subgame-perfect equilibrium by backward induction. Agents *A* puts himself into the "shoes" of *D* and ask how will *D* react if *A* presents u, v, or w, alternatively. The choices of *A* are represented by u^*, v^* and w^* in Figures 2 and 3. What are the best replies of *D*, given the choices u^*, v^* and w^*?

[5] The variable m represents the standard vote maximizing objective that public choice theory assumes for political agents, while p is a close relative to the utility maximization suggested in Wittman (1973) that becomes relevant if the incumbent (i.e. the proposer) faces cyclical majorities and thus cannot win an election.

3. The optimal choices

The potential best reply set of agent *D*, illustrated in Figure 2, shows the outcomes which derive from the choices of *A* and *D* for the given preferences.[6] If *A* chooses $w*$ and *D* selects v, voters 1 and 2 will vote for v and 3 will vote for w (see Figure 1). Thus *D* will win a majority of votes $(m=1)$ and v will be the outcome.

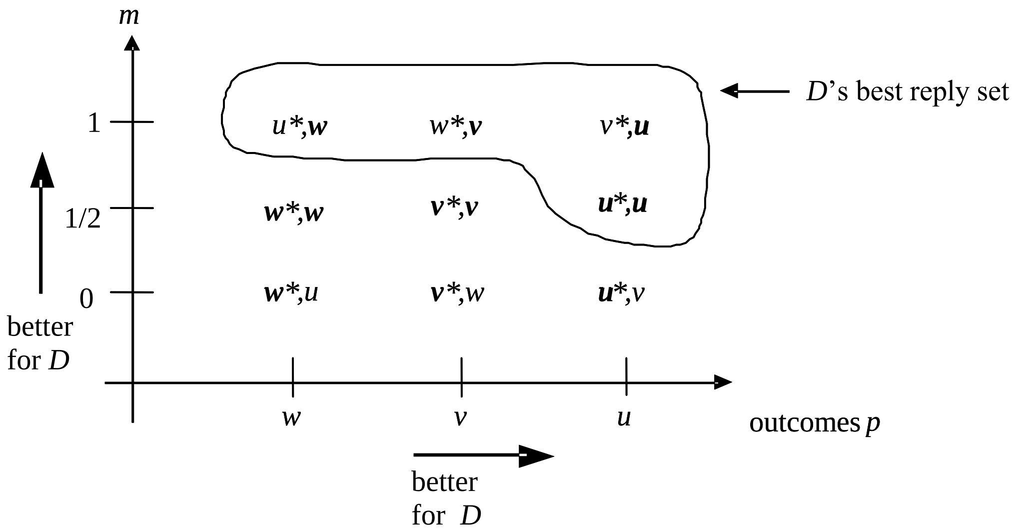

Figure 2: Best reply set of agent *D*.

The ranking of *D* on the pairs (m,p) is illustrated in Figure 2. For example, *D* prefers the outcome $(1,v)$ to $(1,w)$ which results from the choices represented by $(u*,w)$. However, *D* prefers $(1,u)$, which results from the choices $(v*,u)$ to $(1,v)$. Given $m=1$, Figure 2 reflects the Condorcet Paradox: *D* will win with certainty and no $s \in \Omega$ exists which can prevent D from winning. The pair $(u*,u)$ says that both *A* and *D* select policy u and thus there is a 1 in 2 chance of each of them winning the vote.

[6] These preferences result from applying the dominance relation, but do not consider trade-offs between *m* and *p*. For example, in *D*'s perspective *u* dominates *v* as a response to *A*'s choice of *u* (denoted by *u** in Figure 2). However, winning for sure (*m* = 1) with *w*, that is ceteris paribus the least desirable policy for *D*, may potentially be preferred to responding with *u* resulting in outcome *u* (indicated in bold in Figure 2) but only with *m* = 1/2.

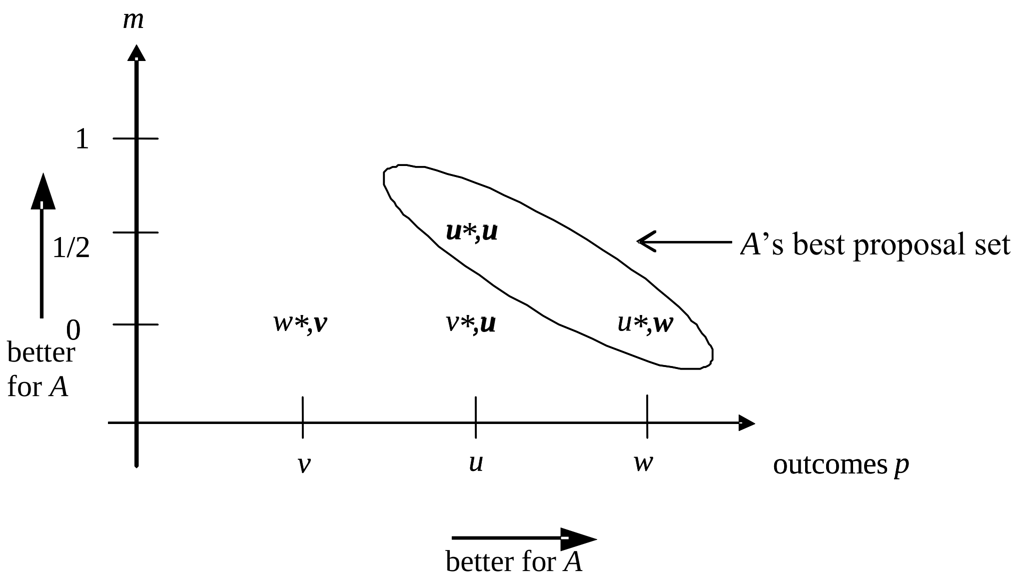

Figure 3: The best proposal set of agent *A*.

Obviously, seen from the perspective of agent *A*, there are elements in the potential best reply set of *D* that are dominated by another element in this set. Figure 3 illustrates *A*'s evaluation of the elements contained in *D*'s potential best reply set. Given *A*'s preferences, (w^*,v) and (v^*,u) are clearly dominated by (u^*,u) and (u^*,w). Thus, we can conclude that *A* will propose the alternative u^*. Whether *D* accommodates and proposes an identical policy or whether it selects w to defeat the proposed policy u^*, is a question of *D*'s preferences on (u^*,u) and (u^*,w). If we abstract from the case that *D* is indifferent as regards these two alternatives, then the outcome of the two-dimensional jury game is uniquely determined and corresponds to a subgame perfect equilibrium.

More generally, every finite sequential-move game of perfect information has a *unique* subgame perfect equilibrium if all players have strict preference orderings over the possible outcomes. This follows by backward induction.

Note that the social preferences, i.e., voting outcomes, are not cyclical although we dropped the assumption of one-dimensional single-peaked preferences. Note further that the voting outcome could be *u* irrespective of whether *A* or *D* is winning the election. Thus we conclude that there is a chance for a rather stable arrangement despite the fact that voter preferences are non-single peaked. The platform *u* can function as a substitute for the median position which is not defined for cyclical preferences. This implication of the above model is quite different from the standard result in the case of non-single peaked voter preferences which suggests that the winning outcome will strictly depend on the agenda in pairwise voting. For instance, given the preferences of the voters in Table 1 and no voter represents a majority of votes, w will be the outcome if u and v are submitted to voting in the first round and the winner, u, competes with w in the second round.

Holler (1982) analyzes all 36 cases that result from combining the possible preferences of a first mover A and a second mover D if the preferences of the two candidates have the structure of any of the three preference orders given in Figure 1. Each best proposal set of the corresponding proposer-responder game contains two undominated alternatives. One of these alternatives is characterized by a pair of identical propositions. This implies that there is a chance that the result will be the same, irrespective of the agent who wins a majority of votes. In the case discussed above, this of course presupposes that both agents prefer (1/2, u) to winning a majority "with certainty" but having to propose something less preferred than u. The latter possibility characterizes the second undominated alternative in the best proposal set.

From the analysis of 36 cases in Holler (1982) we can conclude:

(i) There is a second-mover advantage in the above game: being the first to present a proposal can never be preferred to being the second. If the proposal of A is acceptable to D, because it ranks high in D's preference order, then the latter can select an identical proposition, thereby gaining a 50% chance of winning the election. If the proposal of A is not acceptable to D, because it ranks low in D's preference order, D can present a different proposal and win a majority of votes.

(ii) However, there are combinations of preference profiles for jury members and agent's preferences on $\Omega = \{u,v,w\}$ such that the outcome of A presenting a proposal first and D second are identical to the outcomes of A presenting a proposal second and D presenting a proposal first. That is, the second-mover advantage is "weak."

4. Discussion

In this section we will discuss our results with reference to two standard models. First we relate them to Don Saari's observation that a majority cycle profile is not neutral when matched with other preferences. Then we ask the question whether our results are different from the standard observation that the agenda is decisive for the selection of the winner, given cyclical majorities.

Following Saari (1995)[7] we now combine our proposer-responder model with a jury whose preference profile is in a way complementary with the profile in Table 1 inasmuch as it consists of the "other" three preference orderings that can be formed out of three alternatives. (There are n! different orderings that can be formed out of n elements.) Not surprisingly, the preference profile in Table 1a implies cyclical majorities as well.

Ranking	Voter 1	Voter 2	Voter 3
High	*u*	*v*	*w*
Middle	*w*	*u*	*v*
Low	*v*	*w*	*u*

Table 1a: Preference profile with cyclical majorities.

Now let us see the (optimal) choices of *A* and *D* facing the jury represented by Table 1a. The best reply set of D is shown in Figure 4. Again it illustrates *D*'s best replies to the alternative propositions possibly brought forward by *A*. Starting from this result we derive the best proposal set for *A*. The result is illustrated in Figure 5.

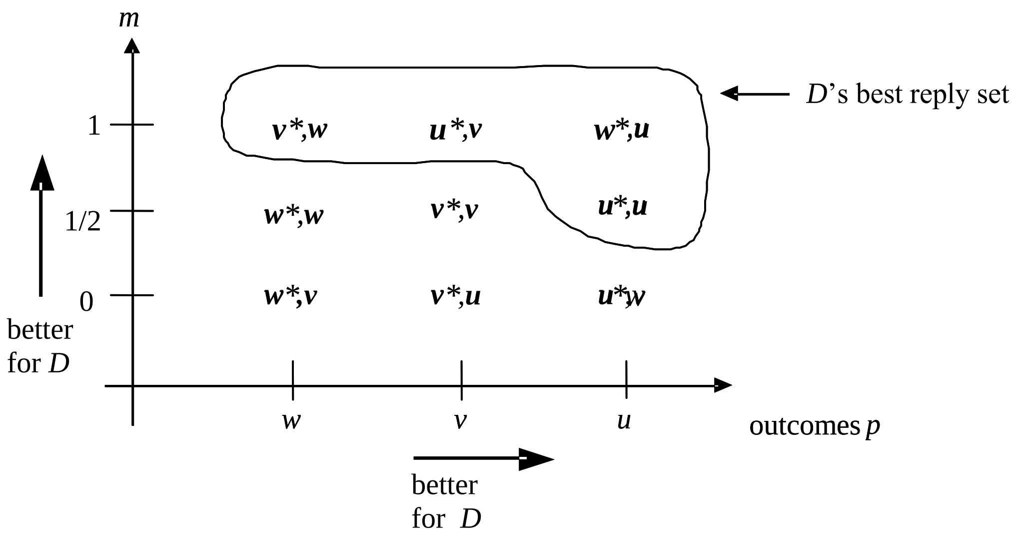

Figure 4: Best reply set of agent *D*.

[7] See Nurmi (2006, p.131) and the appendix for illustration and discussion.

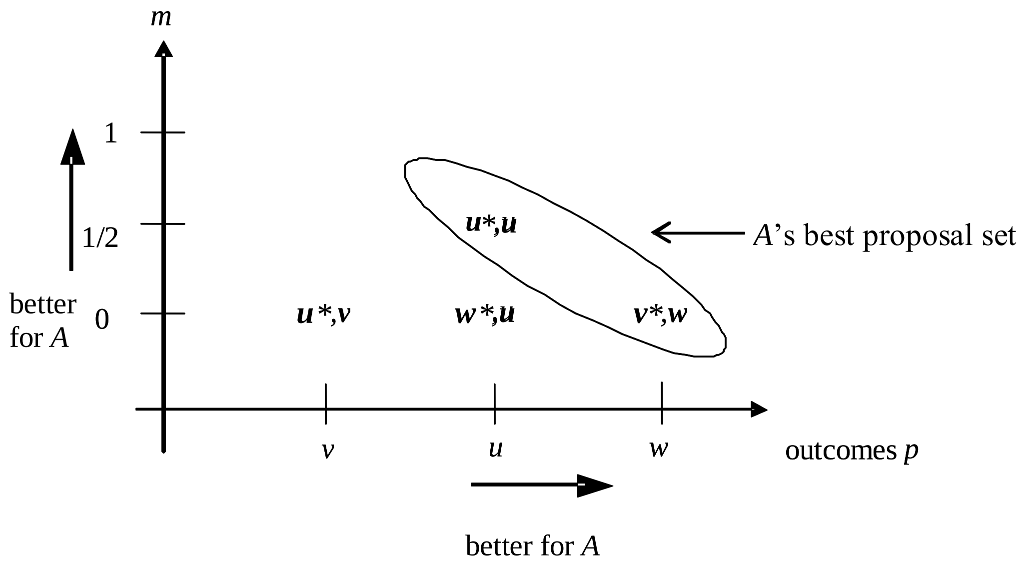

Figure 5: The best proposal set of agent *A*.

Figure 5 implies that *A* can initiate outcome (*u**,*u*) or outcome (*v**,*w*). If *A* prefers to achieve its highest ranking alternative at the expense of losing the case through jury voting, to achieving its second ranking alternative and a chance of ½ to win the case, then A will propose *v*. Correspondingly, *D* will react with *w* and *w* (and *D*) will win. If not, then *A* proposes *u*, the outcome will be alternative *u*, and *A* will win the case with probability ½. Obviously, given the jury's preference profile in Table 1a, *A* decides what alternative will result. This implies a first-mover advantage for *A*. Note, in case that the jury's preference profile is given by Table 1, *D* decides whether *u* or *w* will be the outcome. This confirms that Condorcet paradox profiles are *not neutral:* The jury can have an impact on the final outcomes even if the preferences of its members are intransitive.

It is well known that when facing a Condorcet paradox the agenda decides on the outcome in case of pairwise voting. Given a preference profile as in Figure 1 and none of the voters (or groups of voters) has a majority, alternative *u* will be the winner if *v* and *w* compete in a first round and *u* challenges the winner of this round. Similarly, *v* can be made winner if *u* and *w* compete in the first round. The above proposer-responder model endogenizes the agenda. It adds competition on selecting the alternatives. The competition results from the agents' interest in the resulting alternative and in the winning of a majority of votes. This model still allows a sequence of alternating alternatives to win, if *A* and *D* take turns, which can be interpreted as a cycle, however, it does not exclude a stable result as suggested by (u^*,u) in the above specification.

5. Conclusion

In Arrow (1963, p.1) we read that in “a capitalist democracy there are essentially two methods by which social choices can be made: voting, typically used to make ‘political’ decisions, and the market mechanism, typically used to make ‘economic’ decisions.” The procedure that we analysed above does not give a social ranking of the alternatives, but indicates a possible choice. Thus, strictly speaking, it does not define a social welfare function but a social choice function. However, this concurs with the result that we expect from applying voting procedures[8] and the function of making political decisions that Arrow assigns to them. Voting procedures involve the counting and adding up of votes. This implies cardinality and interpersonal comparison, irrespective of whether “one person, one vote” applies or votes are weighted like, for instance, in the council of ministers. There is a fundamental tension between Arrow’s project - a social welfare function that assumes ordinal preferences of the individuals and ordinality of the social ranking - and voting. There is. Moreover, a certain contrast between the obvious cardinality of voting, and the reference to voting as an aggregation procedure, and Arrow’s assertion “…that interpersonal comparison of utilities has no meaning and, in fact, that there is no meaning relevant to welfare comparisons in the measurability of individual utility …If we cannot have measurable utility…, we cannot have interpersonal comparability of utilities a fortiori” (Arrow, 1963 [1951], p.9).

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[8] There are however voting procedures that give a ranking of the alternatives that can be interpreted as a social welfare function (e.g. Borda count). Needless to say that such social welfare functions do not satisfy the Arrow’s axioms and conditions as stated in the introduction.

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Appendix

The following derives from Saari (1995). Table 2 represents a preference profile that has alternative *u* as an obvious majority winner. However, *u* is also a Condorcet winner as wins the support of a majority of votes in a pairwise comparison with any other alternative.

Ranking	7 Voters	4 Voters
High	*u*	*w*
Middle	*w*	*v*
Low	*v*	*u*

Table 2: Preferences with Condorcet winner u

It is easy to see that the preference profile in Table 3 does not produce a majority winner, if voters vote sincerely, and in fact implies cyclical majorities so that, in addition, no Condorcet winner exits. Since the frequencies of the three alternative preference orderings in Table 3 are just four times of what we have in Table 1, this should come as no surprise.

Ranking	4 Voters	4 Voters	4 Voters
High	*u*	*v*	*w*
Middle	*v*	*w*	*u*
Low	*w*	*u*	*v*

Table 3: Preference profile with cyclical majorities I.

However, if we now combine Table 2 and Table 3 for a unified preference profile and vote distribution, and we assume that voters vote sincerely, then alternative w is the Condorcet winner. This result demonstrates that a preference profile with cyclical majorities is not a *neutral element* to joining with additional voters. This is even more apparent when we combine Table 2 with the preference profile in Table 4 which is complementary to the profile of Table 3 inasmuch as it consists of the "other" three preference orderings that can be formed out of three alternatives. Not surprisingly, the preference profile in Table 4 implies cyclical majorities as well. However, if unified with the profile in Table 2, cyclical majorities still prevail and the voting game is inconclusive.

Ranking	4 Voters	4 Voters	4 Voters
High	*u*	*v*	*w*
Middle	*w*	*u*	*v*
Low	*v*	*w*	*u*

Table 4: Preference profile with cyclical majorities II.

A comparison of the combinations of Tables 2 and 3 and Tables 2 and 4 suggest that the inclusion of a profile of cyclical preferences may either change the outcome of a voting game or destabilize the situation.[9]

[9] Don Saari's concept of a "ranking wheel" allows for identifying the preference profiles that are characterized by a majority cycle, i.e., a voting paradox. (See Saari, 2011.)

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