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Gathering support from rivals: the two agent case with random order

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Abstract

Which alternative is selected when voters are called to participate in a sequential voting? Does the ordering matter? The current approach is the first attempt to analyze these questions. Specifically, we propose a two-alternative sequential voting procedure in which two voters are randomly ordered. Each voter has complete information about the preference of both of them. The alternative is implemented if there is unanimity. We obtain that the most patient individual has some advantage in the election, but it is not enough to guarantee that his most-preferred alternative will be selected. The probability to vote first also plays a central role, since the election also depends on the voting order.

Keywords: Sequential Voting; Random order; Sub-game perfect equilibrium

1. Introduction

It is not difficult to find actual election situations where the voters are randomly ordered. For instance, suppose that an alternative is selected by "raising the hands those individual who prefer..." In this case, the ordering of voting is totally random, and each involved voter sees the choice made before him. Another example could be the *Doodle* questionnaires or achieving the commitment by e-mail messages. Each participant sees the choice made before him, and the ordering is random.

The current paper analyzes this kind of situations. As a first attempt, we propose a simple two-voter model with a two-alternative selection. Besides this, we consider a voting procedure where there are several stages until the decision is taken, such as jury trials, and the ordering of voting at each stage is random. The voting does not stop until the unanimity of the voters agree on the decision. Obviously, different voters have different preferences, so the main question is why and when voters agree to change their votes to reach an agreement.

In this framework, Baron and Ferejohn (1989) study a dynamic model of bargaining in legislatures, when at each round a randomly selected voter makes a proposal to vote by a committee, and it is shown that this voter has an advantage. Ponsatí and Sákovics (1996) show the uniqueness of equilibrium in a model with many players, two alternatives and delay costs. Furthermore, some researchers suggest that observing the actions of the other agents would induce individuals to believe that these agents are better informed and, therefore, these individuals are likely to imitate their behavior (see, for instance, Banerjee (1989), Herrera and Martinelli (2006), Battaglini et al. (2007), Dasgupta et al. (2008) and Rivas and Rodríguez-Álvarez (2012)). Finally, Bernheim (1994) states that the voters are willing to conform because they recognize that even small departures from the social norm will seriously impair their status. Despite this penalty, agents with sufficiently extreme preferences refuse to conform. In this regard, Compte and Jehiel (2010) study a committee formed by n members to determine the voters that have more impact on the decision under different majority rules. One of the interesting results is that, under unanimity, when proposals vary along a single dimension, the extremist voters (those with more intense preferences and therefore with the highest degree of patience) determine the final decision. Analogously, Kwiek (2014) assumes that alternatives are selected under a super-majority rule. He obtains the existence of a unique sub-game perfect Nash equilibrium in the first round. This outcome coincides with the alternative most-preferred by the pivotal voter with the greater indifference time (impatience degree).

Our approach assumes that voters are arranged in a random linear order. If the two votes are different, then the procedure goes into a new stage. The time is discrete. At every stage, each voter prefers the same alternative to the other and his utility is decreasing with stages, representing the cost of the delay. Each voter has an impatience degree that indicates when it is worth voting for the least-preferred alternative rather than voting for the most-preferred alternative in the following stage. Since both voters know their impatience degrees (reversal time), intuition suggests that the more patient voter will manage to get his most-preferred alternative. This paper tells that to be the most patient does not guarantee that the most-preferred alternative is chosen. The probability of being the first voting in the following stage also plays a central role, since the election also depends on the expected ordering.

The paper is organized as follows. Section 2 introduces the model and main notation. Section 3 provides the main results. Finally, Section 4 provides some final remarks.

2. The model

We analyze a two alternative election involving the set of alternative $\{A, B\}$. There are two individuals indexed by $i \in \{1, 2\}$. Choices are denoted by a fixed choice profile $c \in \{A, B\}$. Decision is made via a sequential unanimity voting.

At any discrete date $T = \{1, 2, \ldots, t, t+1, \ldots\}$, if a decision has not been made yet, the procedure goes to the next step. In each stage, each individual votes for one of the two alternatives following a random ordering. The voting procedure stops when both individuals vote for the same alternative.

2.1. Voting schedule

The individuals are engaged in a sequential voting procedure. The ordering of voters is represented by $V(t) = (v_{1,t}, v_{2,t})$. For each $i \in \{1, 2\}$, denote by p_i the probability that the individual i votes first at time t, $v_{1,t} = i$, such that $\sum_{i=1}^{2} p_i = 1$.

The voting procedure unfolds in a series of (potentially unending) stages. Specifically, at the beginning of each stage, the ordering of voting is randomly chosen and declared. That is, with probability p_1 the voter who votes first at time t is 1 ($v_{1,t} = 1$), and $v_{1,t} = 2$ with probability p_2.

Let vector $C(t) = (c_1(t), c_2(t))$ denote the choice of the voters at time t. The outcome $X(t)$ of the stage t consists of the declared choice of the voters at the stage t, $X(t) = (c_1, c_2, t)$ such that $i \in \{1, 2\}$, $c_i \in \{A, B\}$, and $t \in T$. A stage t^* is considered as an **agreement stage** if both individuals vote for the same alternative ($c_1 = c_2$). Let T^* denote the set of all the agreement stages.

Therefore, the procedure represents the collective decision mechanism by means of which individual carry on voting until they reach an unanimous decision.

2.2. Preferences

We assume that the individuals' preferences are common knowledge, that is, each individual knows the preferences of both of them. For each $i \in N$, let $u_i(c, t)$ be the individual i's utility function and $U(c, t) = (u_1(c, t), u_2(c, t))$. Note that the individuals obtain their utilities only if there is an agreement at the stage t. If there is no alternative chosen, the procedure continues till the earliest stage where the agreement is met $t^* = \min\{t \in T^*\}$. So, $U(c, t) = (u_1(c, t), u_2(c, t))$ if $t \in T^*$; otherwise, either $U(X(t)) = U(X(t^*))$, if this t^* exists, or $U(X(t)) = U(c, \infty)$.

We require that the individual i's utility functions should satisfy the following axioms. The first axiom, called persistence, says that each individual always prefers the same alternative. Hence, at each time t the same alternative is always most-preferred to the other. Let α_i and β_i denote the individual i's most-preferred and least-preferred alternatives, respectively.

Axiom 1 (Persistence (PER)). *For each individual $i \in N$ and each stage $t \in T$, $u_i(\alpha_i, t) > u_i(\beta_i, t)$.*

Next, impatience states that the time delays induces losses to the individuals. That is, the more the time passes to make a decision, the smaller is the corresponding utility. For instance, plane or train tickets become more expensive with time, or, the savings deposited in a bank checking account that affected by inflation. Therefore, utility is decreasing with time.

Axiom 2 (Impatience (IMP)). *For each individual $i \in N$, each alternative $c_i \in \{a, b\}$, and each stage $t, t' \in T : t < t'$, $u_i(c, t) > u_i(c, t')$.*

The third axiom, reversion, implies that for each individual i, there is a time t_i where i prefers the least-preferred alternative β_i at t_i than the most-preferred one α_i in the immediate posterior stage $t_i + 1$. Intuitively, t_i represents the moment at which i loses his patience: it no longer pays to wait for the possibility of obtaining in the future the most-preferred alternative by disregarding the possibility of obtaining now the least-preferred alternative. When there is a cost of delay (as time passes, the individual's utility decreases), the individuals would rather agree with taking a decision now than to wait and continue losing utility.

Axiom 3 (Reversion (REV)). *For each individual $i \in N$, there is a reversal stage $t_i \in T$, such that, for each $t \geqslant t_i$, $u_i(\beta_i, t) > u_i(\alpha_i, t+1)$, and for each $t' < t_i$, $u_i(\beta_i, t') < u_i(\alpha_i, t'+1)$*

Finally, each individual i prefers to stop the procedure at some stage than never stopping. So the utility obtained in such situation should be smaller than the utility of obtaining any other outcome. Note that any voting procedure induces some costs, so it is clear that the individuals would prefer to stop the procedure rather than to incur these costs at every stage.

Axiom 4 (Termination (TER)). *Let $\varnothing$ designate the outcome of a non-terminating procedure, then for each individual $i \in N$, each alternative $c_\in \{a, b\}$, and each stage t, $u_i(c, t) > u_i(\varnothing)$.*

3. Result

Our main result is based on the following lemmas. The first one states that if both individuals prefer to reach the agreement at the stage t, rather than continue the procedure, then, the first voter's most-preferred alternative is chosen.

Lemma 1. *For each $i \in \{1, 2\}$, and each $t \in T$, if $u_i(\beta_i, t) > u_i(X(t^*))$, then $X(t) = (\alpha_{v_1}, \alpha_{v_1}, t)$.*

Proof. For each $i \in \{1, 2\}$, and each $t \in T$, suppose that $u_i(\beta_i, t) > u_i(X(t^*))$. At the stage t, either (i) with probability p_1, $v_{1,t} = 1$: or (ii) with probability $1 - p_1$, $v_{1,t} = 2$. By IMP and $u_i(\beta_i, t) > u_i(X(t^*))$, the individual who votes at the second place always prefers to agree with individual who votes first. By PER, the individual who votes first selects his most-preferred alternative at the stage t. Therefore, either, with probability p_1, $X(t) = (\alpha_1, \alpha_1, t)$; or, with probability $1 - p_1$, $X(t) = (\alpha_2, \alpha_2, t)$. That is, $X(t) = (\alpha_{v_{1,t}}, \alpha_{v_{1,t}}, t)$.

q.e.d.

The second lemma establishes that if at the stage t an individual prefers to stop and the other one prefers to pass to the next stage, the latter individual's most-preferred alternative at t is chosen, independently of the ordering of voting.

Lemma 2. *For each $i, j \in \{1,2\}$ with $i \neq j$, and each $t \in T$, if $u_i(\beta_i, t) < u_i(X(t^*))$ and $u_j(\beta_j, t) > u_j(X(t^*))$, then $X(t) = (\alpha_i, \alpha_i, t)$.*

Proof. For each $i, j \in \{1,2\}$ with $i \neq j$, each $c \in \{A, B\}$, and each $t \in T$. With loss of generality, suppose that $i = 1$.

(a) $v_{1,t} = 1$. By IMP and $u_2(\beta_2, t) > u_2(X(t^*))$, the individual 2 will always agree with individual 1. So, individual 1 always chooses his most-preferred alternative α_1, and $X(t) = (\alpha_1, \alpha_1, t)$.

(b) $v_{1,t} = 2$. If the individual 2 chooses the individual 1's most-preferred alternative, then the latter one will be agreed, by PER and IMP, so $X(t) = (\alpha_1, \alpha_1, t)$. On the other hand, if the individual 2 selects his most-preferred alternative, by PER and $u_1(\beta_1, t) < u_1(X(t^*))$, individual 1 prefers not to reach the commitment, and pass to the next stage $t + 1$. Given this, since $u_2(\beta_2, t) > u_2(X(t^*))$, individual 2 will choose the individual 1's most-preferred alternative at stage t, hence, $X(t) = (\alpha_1, \alpha_1, t)$. Since $c_1 = c_2$, the stage t is an agreement stage and $X(t)$ is an agreement outcome.

q.e.d.

The third lemma tells that there is no agreement at stage t, if the individuals prefer to postpone the commitment till the closest agreement stage instead of obtaining his least-preferred alternative at the current stage.

Lemma 3. *For each $i \in \{1,2\}$, each $t \in T \backslash T^*$, if $u_i(\beta_i, t) < u_i(X(t^*))$, then $X(t) = (\alpha_1, \alpha_2, t)$.*

Proof. For each $i \in \{1,2\}$, and each $t \in T \backslash T^*$. By $u_i(\beta_i, t) < u_i(X(t^*))$, at t each individual selects his most-preferred alternative independently the ordering of voting. Therefore, $X(t) = (\alpha_1, \alpha_2, t)$ and it is not considered as an agreement outcome.

q.e.d.

Note that, up to this point, in all possible agreement either some alternative is chosen independently from the order, or some alternative is chosen depending on the order of the voters. Moreover, as introduced previously, if at the current stage no alternative is chosen, then the outcome of this stage coincides with the outcome obtained at the next agreement stage. The next lemma states that at the stage t the voter would prefer to postpone the commitment rather than obtain the least-preferred utility only if t precedes the individual's reversal time t_i.

Lemma 4. *For each $i \in \{1,2\}$, and each $t \in T$, $u_i(\beta_i, t) < u_i(X(t^*))$, only if $t < t^* \leqslant t_i$.*

Proof. For each $i \in \{1,2\}$, and each $t \in T : t < t^* \leqslant t_i$, since at the stage t^* an agreement is reached, then, $u_i(X(t^*))$ may be by Lemma 2, either (i) $u_i(\alpha_i, t^*)$, or (ii) $u_i(\beta_i, t^*)$; and, by Lemma 1, (iii) $u_i(\alpha_{v_{1,t^*}}, t^*)$. Note that, by PER, $u_i(\beta_i, t) > u_i(\beta_i, t^*)$.

Now, consider that $t^* \geqslant t+1$, then, by REV, $u_i(\beta_i, t) < u_i(\alpha_{v_{1,t^*}}, t^*) = p_i u_i(\alpha_i, t^*) + (1-p_i) u_i(\beta_i, t^*)$ holds only if $u_i(\beta_i, t) < u_i(\alpha_i, t^*)$. By PER, $u_i(\beta_i, t^*) < u_i(\beta_i, t^*-1) < ... < u_i(\beta_i, t) < u_i(\alpha_i, t^*) < u_i(\alpha_i, t^*-1) < ... < u_i(\alpha_i, t)$, which, by REV, holds only if $t < t^*-1 < t_i \Rightarrow t < t^* \leqslant t_i$.

q.e.d.

Our main result establishes a double implication. Either some alternative is chosen independently from the voting order, and then it happens at the first stage immediately; or, the alternative most-preferred by the voter who votes first is chosen, what may happen at the first stage or may be delayed up to the smallest reversal time.

If at some stage t there is an individual who prefers to reach the agreement now, rather than to continue and even to obtain his most-preferred alternative at the next agreement stage, and the other one prefers to enter to the next stage if he cannot get his most-preferred right now, the latter individual's most-preferred alternative will be selected at the first stage. And the selection does not depend on the voting order.

If at the first stage both voters prefer to stop the procedure now with any outcome rather then to pass to the next stage, then the sub-game perfect equilibrium is that the alternative most-preferred by the voter who votes first chosen at the stage 1.

The sub-game perfect equilibrium can be delayed to some agreement stage in the future, if both voters would rather prefer to continue voting expecting to get at this agreement stage something greater than the least-preferred alternative immediately. The decision can be delayed maximum till the smallest reversal time.

Proposition 1. *Assuming PER, IMP, REV and TER, and for each* $i, j \in \{1,2\}$*, with* $i \neq j$*, each* $c_i \in \{A, B\}$*, and each* $t \in T$*,*

(i) the individual i*'s most-preferred alternative is selected at the stage* 1*, if there exist* $t : u_i(\beta_i, t) < u_i(X(t^*))$*, and* $u_j(\beta_j, t) > u_j(X(t^*))$*;*

(ii) the first voter's most-preferred alternative is selected at the stage k*, if either* $u_i(\beta_i, k) < u_i(X(t^*))$ *for* $k : 1 < k \leqslant min\{t_1, t_2\} - 1$*, or* $u_i(\beta_i, k) > u_i(X(t^*))$ *for* $k = 1$*.*

Proof.- Assuming PER, IMP, REV and TER, and for each $i, j \in \{1, 2\}$, with $i \neq j$, each $c_i \in \{A, B\}$, and each $t \in T$.

Note that if $\alpha_1 = \alpha_2$, then it is straightforward to see that their maximum utility is reached if both vote for their most-preferred alternative at the stage 1.

Consider $\alpha_1 \neq \alpha_2$ (so $\alpha_1 = \beta_2$, $\beta_1 = \alpha_2$) and the stage t. Firstly, we prove that $T^* \neq \emptyset$. Assume that $T^* = \emptyset$, so $t^* = \infty$. By TER, $U(c, t) > U(c, \infty)$, so both individuals prefer to stop the procedure, the second voter being always agreed with the choice of the first voter. Consequently, an agreement stage t^* exits, and $X(t^*) = (\alpha_{v_{1,t^*}}, \alpha_{v_{1,t^*}}, t^*)$.

Next, consider $t < t^*$. By IMP, for each $i \in N$, $u_i(\alpha_i, t) > u_i(\alpha_i, t^*)$, and, by PER and IMP, $u_i(\alpha_i, t) > u_i(\beta_i, t) > u_i(\beta_i, t^*)$. Consequently, for each voter $u_i(\alpha_i, t) > u_i(X(t^*))$. Therefore the question is to compare the $u_i(\beta_i, t)$ with $u_i(X(t^*))$.

1. $u_i(\beta_i, t) > u_i(X(t^*))$.
2. $u_i(\beta_i, t) < u_i(X(t^*))$ and $u_j(\beta_j, t) > u_j(X(t^*))$.
3. $u_i(\beta_i, t) < u_i(X(t^*))$.

What will the voter i prefer? To obtain his least-preferred alternative at t, or to obtain something different at the next stage?

(1) At the stage $t_g = \max\{t_1, t_2\}$, by PER, IMP, REV and TER the condition $u_i(\beta_i, t) < u_i(X(t^*))$ never holds for any voter. Therefore, by Lemma 1, $X(t_g) = (\alpha_{v_{1,t_g}}, t_g)$.

(2) Consider that $X(t^*) = (\alpha_{v_{1,t^*}}, t^*)$. Hence,

- **(2.a)** by Lemma 1, if $u_i(\beta_i, t) > u_i(\alpha_{v_{1,t^*}}, t^*)$, $X(t) = (\alpha_{v_{1,t}}, \alpha_{v_{1,t}}, t)$;
- **(2.b)** by Lemma 2, if $u_i(\beta_i, t) < u_i(\alpha_{v_{1,t^*}}, t^*)$ and $u_j(\beta_j, t) > u_j(\alpha_{v_{1,t^*}}, t^*)$, $X(t) = (\alpha_i, \alpha_i, t)$;

(2.c) by Lemma 3, if $u_i(\beta_i, t) < u_i(\alpha_{v_{1,t^*}}, t^*)$, $X(t) = X(\alpha_i, \alpha_j, t)$.

Note that, by Lemma 4, **(2.b)** can happen only at some stage t, such that $t < t_j$; and **(2.c)** only if $t < t^* \leqslant t_i$ and $t < t^* \leqslant t_j$. Therefore, even at the first stage the equilibrium can be delayed up to $\min\{t_1, t_2\}$, if $u_i(\beta_i, 1) < u_i(\alpha_{v_{1,t^*}}, t^*)$.

(3) Consider that at stage t^* some alternative is chosen independently from the order of the voters. Without loss of generality, let $X(t^*) = (\alpha_1, t^*)$. At stage t^* the individuals 1 and 2 obtain $u_1(\alpha_1, t^*)$ and $u_2(\beta_2, t^*)$, respectively. By PER and IMP, $u_i(\alpha_i, t) > u_i(\alpha_i, t^*)$ and $u_i(\alpha_i, t) > u_i(\beta_i, t) > u_i(\beta_i, t^*)$. So, $u_i(\beta_i, t) > u_i(X(t^*))$. By REV and Lemma 4, $u_i(\beta_i, t) < u_i(\alpha_i, t^*)$, only if $t < t^* \leqslant t_i$. Therefore, by Lemma 2, $X(t) = (\alpha_1, \alpha_1, t)$, if $t < t^* \leqslant t_i$, and, since $u_i(\beta, t) > u_i(\alpha, t^*)$, by Lemma 1, $X(t) = (\alpha_{v_{1,t}}, \alpha_{v_{1,t}}, t)$.
At stage $t^* < t_g$, by Lemma 2, $X(t^*) = (\alpha_1, t^*)$, which, by Lemma 2, only holds if $t^* < t_1$. So, by REV $u_1(\beta_2, t) < u_1(\alpha_1, t^*)$. Therefore, by Lemma 2 $X(t) = (\alpha_1, \alpha_1, t)$.

q.e.d.

The result tells that at such a sequential voting the sub-game perfect equilibrium is not unique. Furthermore, it may be either at the first stage (independently of the voting ordering), or delayed (depending on the voting order). Obviously, in the latter case the probability matters: the greater is the probability to be the first voter, the more likely an individual gets his most-preferred alternative. So, the reversal time (patience) does not matter at all.

Regarding to the first stage equilibrium, note that it may occur independently from the ordering of voting. If at some stage t an individual prefers to stop the procedure (even if he gets his most-preferred alternative at the nearest agreement stage) and, at the same time, the other one prefers to continue, then the latter individual's most-preferred alternative will be selected at this stage, and, henceforth, at all the stages before. What favors these conditions? First of all, such conditions can happen only before the reversal time of this latter individual. It means that the greater patience favors these conditions, but does not guarantee them. As shown, the first voter's most-preferred alternative is chosen at the next agreement stage. Consequently, it also depends on the intensity of the preferences or on the probability to be first voter. Even if one of the individuals has extremely intense preferences, if his probability to vote at the first place is zero, he can never win.

Finally, the delay equilibrium is achieved when both individuals prefer to continue voting, since their expected utility is great enough, rather than to stop the procedure, and get his least-preferred alternative. Note that the expected utility depends on the intensity of the preferences and the probability to be first. Since both probabilities are complement each other, the equilibrium is delayed if (i) both voters have intense preferences, or (ii) there is one voter with highly intense preferences and extremely low probability to be first. So, the higher is the intensity of the preferences, the more likely the equilibrium will be delayed.

4. Concluding remarks

The current approach predicts that in a $2-$agents sequential voting procedure where the ordering of voting is random, the patience favors that the most-preferred alternative of an individual may be implemented, but it does not guarantee this. The intensity of the preferences (sometimes the patience is positively correlated with it) also plays an important role. The most crucial parameter is the probability to vote at the first place. *"The higher the probability to be the first voter, the more likely to be chosen my most-preferred alternative."*

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