Reallocating Wasted Votes in Proportional Parliamentary Elections with Thresholds

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Joint work with Rupert Freeman, Jérôme Lang, Jean-François Laslier and Dominik Peters

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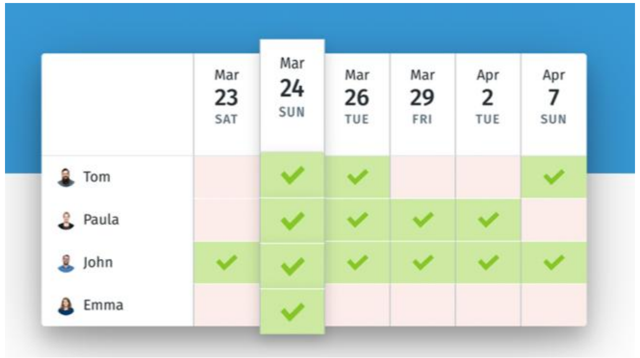
1. Computational Social Choice

Social Choice Theory:

Designing and analyzing methods for collective decision making

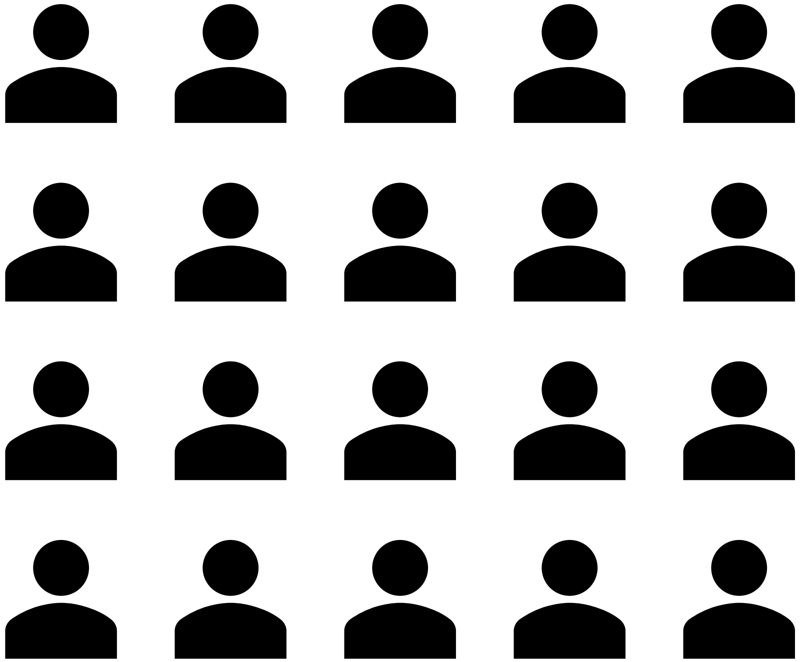
Political election



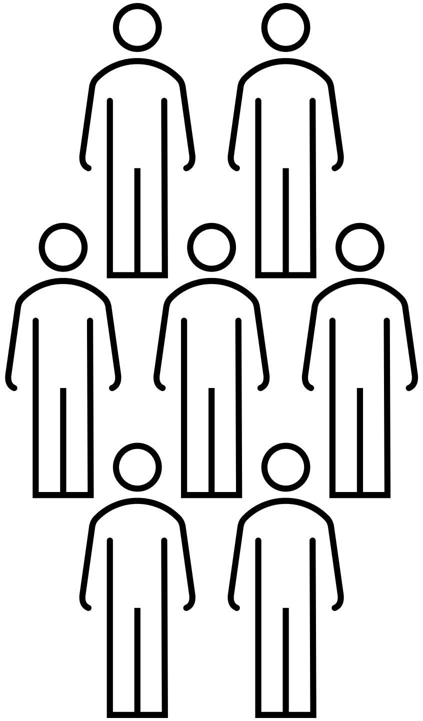
Decide on a date

Jury decision

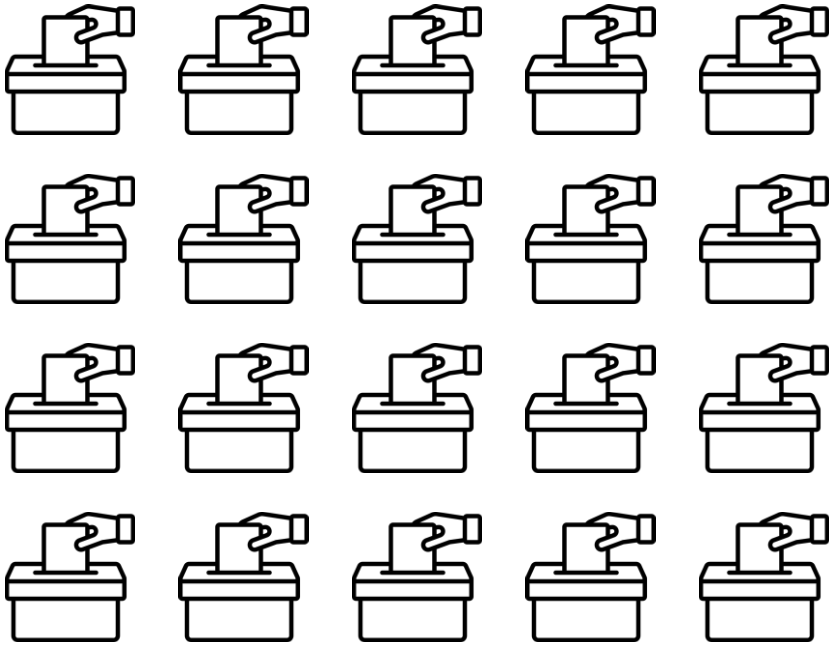
Voters



Candidates



Voters give their preferences over candidates



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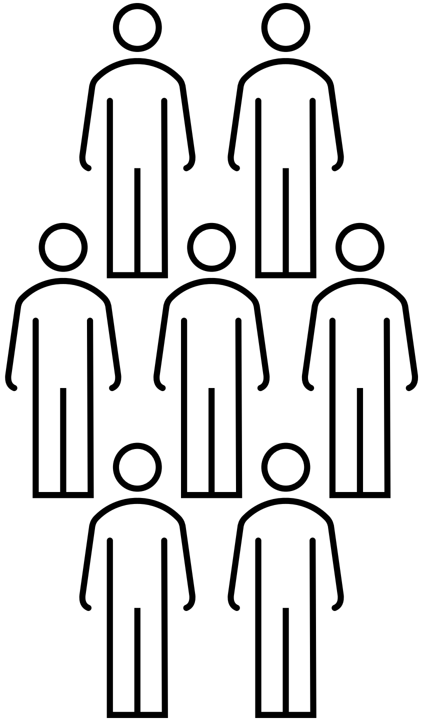

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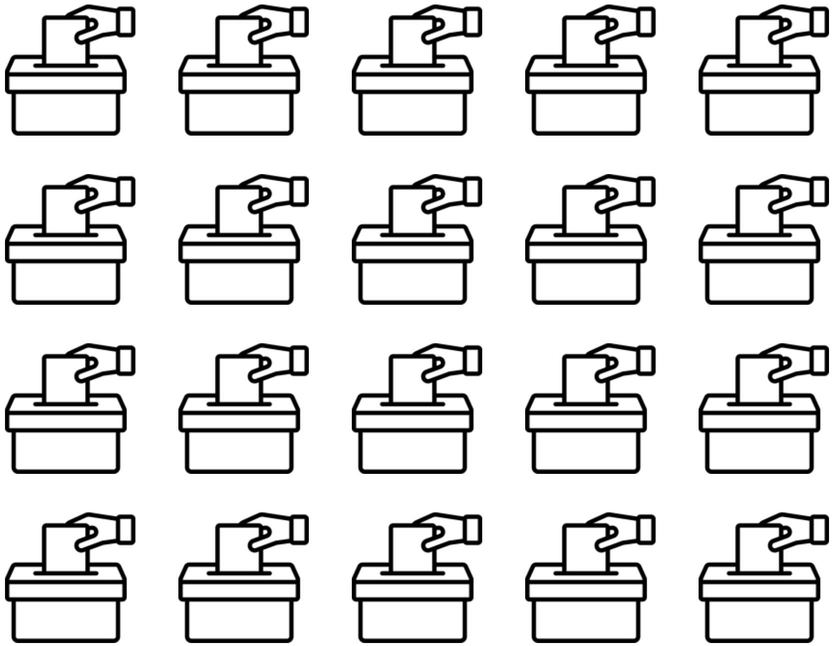
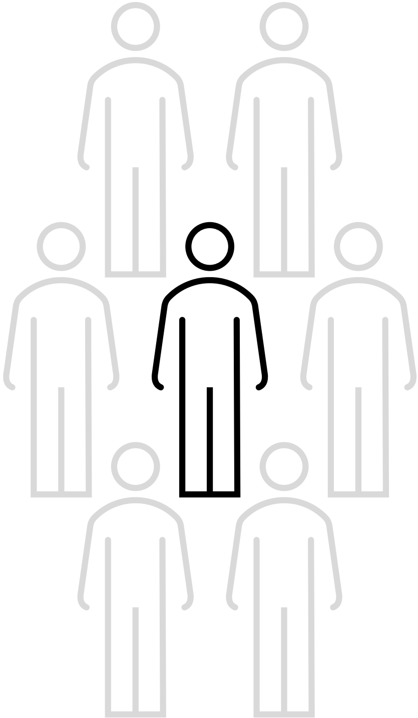
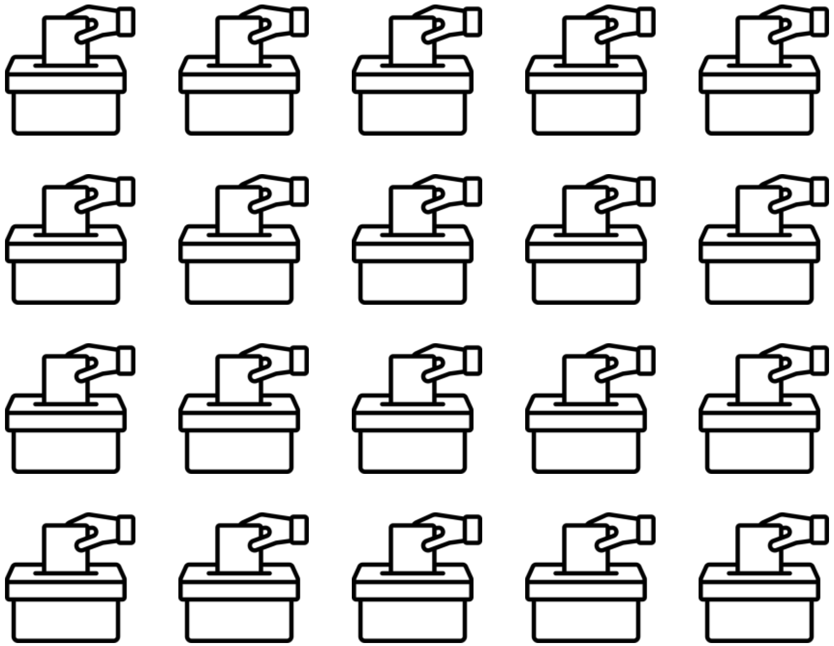


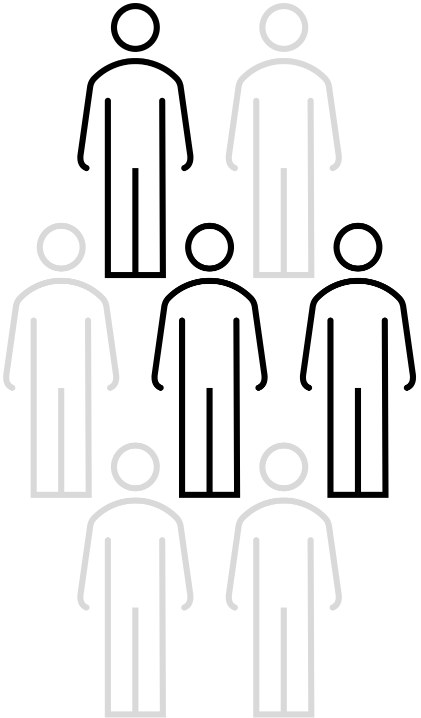
A **winner** is selected



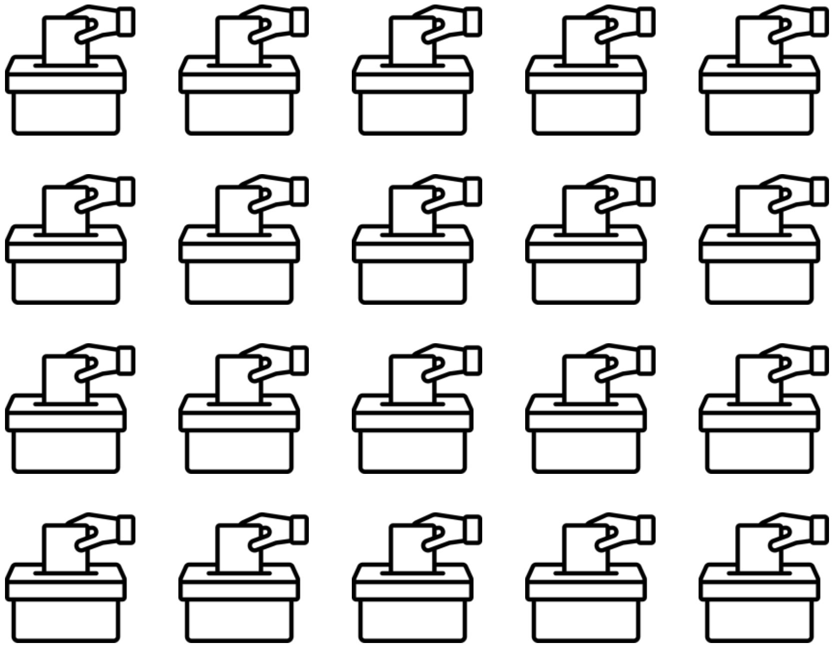
Voters give their preferences over candidates



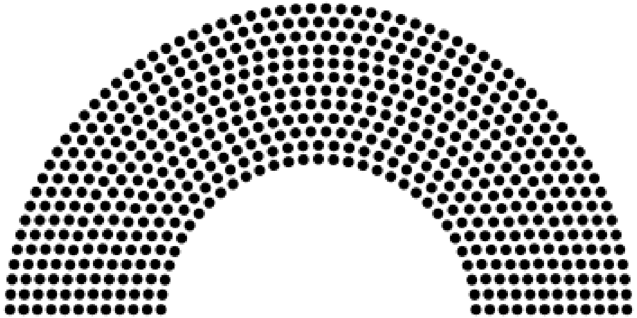
A **committee** is selected



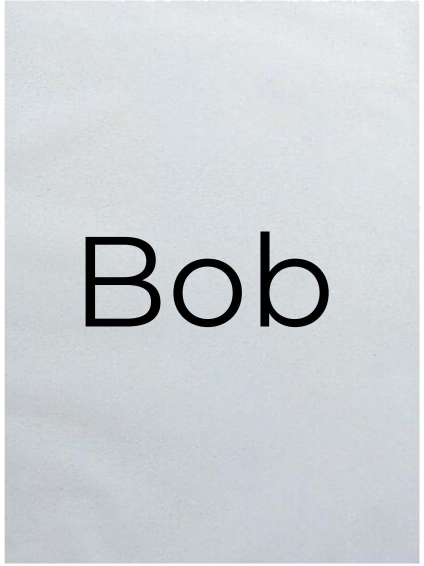
Voters give their preferences over candidates



A **parliament** is selected

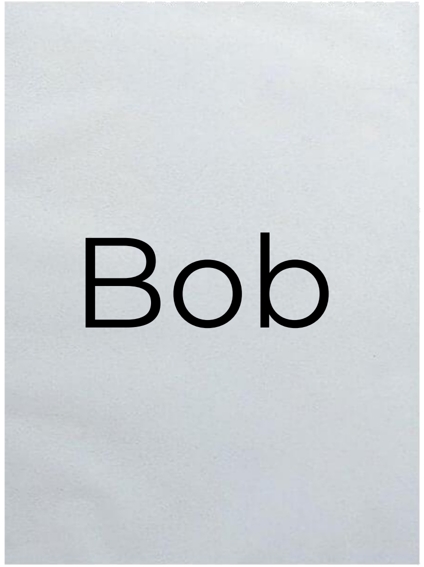


Ballot formats



Uninominal Ballots

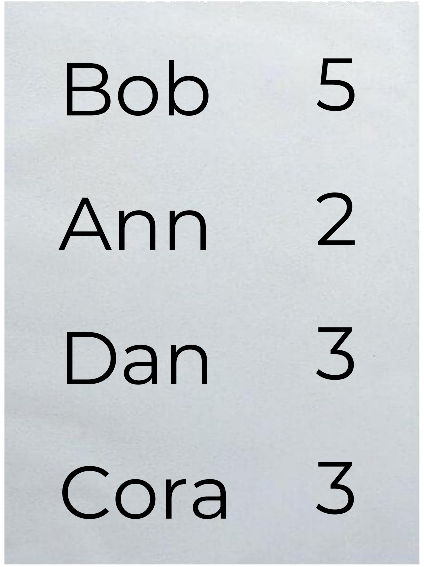
Ballot formats



Uninominal Ballots

Rankings

Approval Ballots



Scores

2. Single-winner voting with rankings

We have:

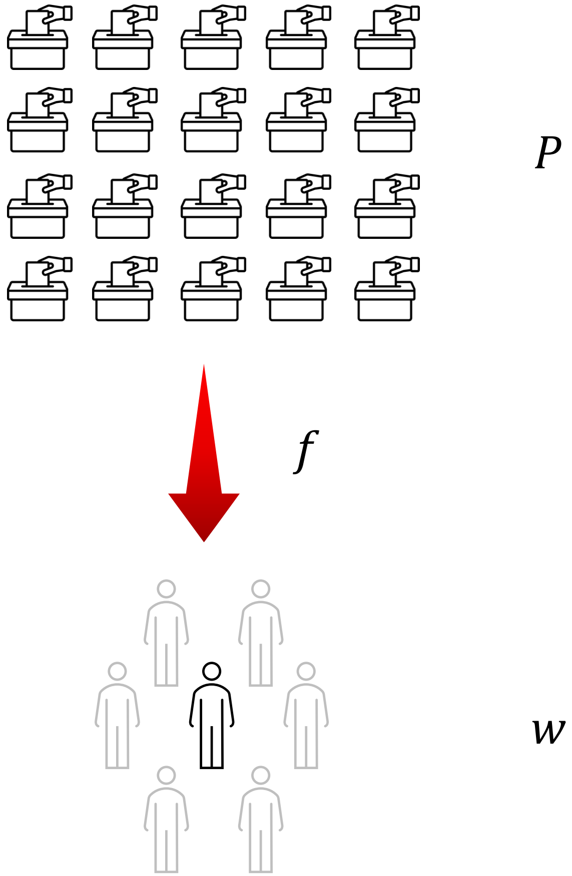
- A set of **voters** $\boldsymbol{V} = \{\mathbf{1}, \mathbf{2}, \dots, \boldsymbol{n}\}$.
- A set of **candidates** $\boldsymbol{C} = \{\boldsymbol{c}_{\mathbf{1}}, \dots, \boldsymbol{c}_{\boldsymbol{m}}\}$.
- A preference **profile** $\boldsymbol{P} = (\succ_{\mathbf{1}}, \dots, \succ_{\boldsymbol{n}}) \in \mathcal{L}(\boldsymbol{C})^{\boldsymbol{n}}$ of rankings of voters over candidates.

We want:

- A **winning candidate** $w \in C$.

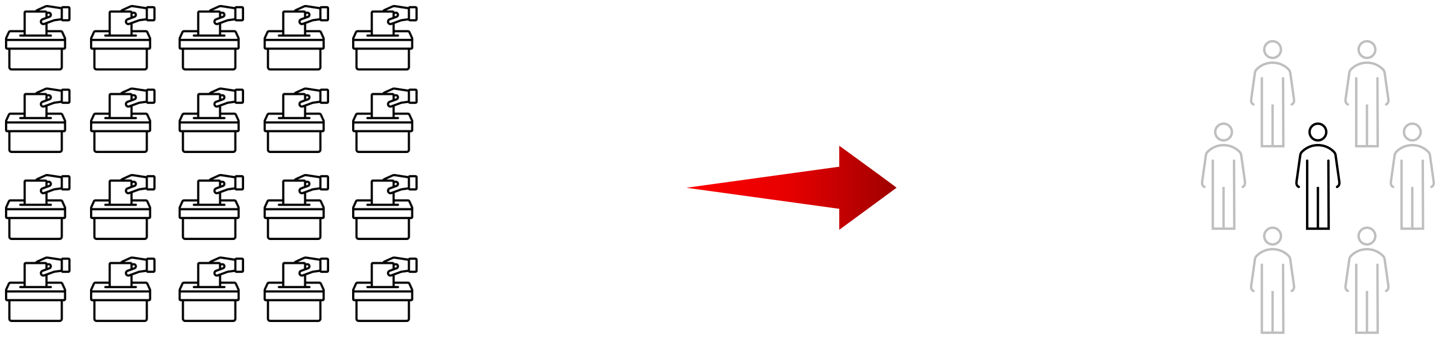
For this, we use:

- A **voting rule** $f: \mathcal{L}(\boldsymbol{C})^{\boldsymbol{n}} \to \boldsymbol{C}$.



Formal model

Profile P | Rule f | Winner w



Question: which voting rule should we use?

Different approaches of Computational Social Choice

Question: which voting rule should we use?

1. **Design** rules, analyze their complexity, and propose algorithms to compute them.
2. Check the **normative properties** (the *axioms*) satisfied by these rules.
3. **Run simulations** of the rules on real or synthetic preference data.

1 **Design** rules: *Plurality*

Plurality: The winner is the candidate that is ranked first by the most voters.

40%	$A \succ B \succ D \succ C$
25%	$B \succ C \succ D \succ A$
20%	$C \succ B \succ D \succ A$
15%	$D \succ C \succ A \succ B$

→ **Winner:** A

1 **Design** rules: *Veto*

Veto: The winner is the candidate that is ranked last by the fewest voters.

40%	$A \succ B \succ D \succ C$
25%	$B \succ C \succ D \succ A$
20%	$C \succ B \succ D \succ A$
15%	$D \succ C \succ A \succ B$

Winner: D

1 **Design** rules: *Borda*

Borda: Voters give $m-1$ points to the first candidate, $m-2$ to the second, and so on. The winner is the candidate with the highest score.

40%	A	$\succ B$	$\succ D$	$\succ C$
25%	B	$\succ C$	$\succ D$	$\succ A$
20%	C	$\succ B$	$\succ D$	$\succ A$
15%	D	$\succ C$	$\succ A$	$\succ B$
	+3	**+2**	**+1**	

Winner: B

1 **Design** rules: The family of *Scoring rules*

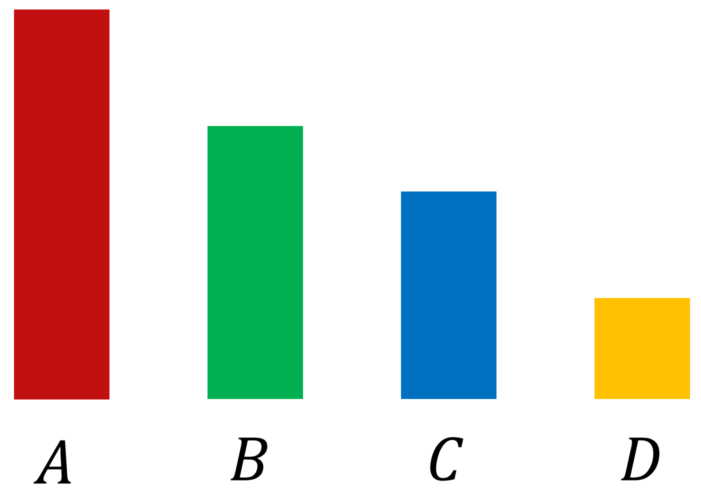
Ballot	Plurality	Borda	Veto
1 Bob	→ 1	→ 3	→ 1
2 Ann	→ 0	→ 2	→ 1
3 Dan	→ 0	→ 1	→ 1
4 Cora	→ 0	→ 0	→ 0

Plurality **Borda** **Veto**

1 **Design** rules: *Instant Runoff Voting* (IRV/STV)

Instant Runoff Voting (IRV): Repeatedly eliminate the candidate with the fewest 1st-place votes until one candidate gets 50% of the votes.

40%	$A \succ B \succ D \succ C$
25%	$B \succ C \succ D \succ A$
20%	$C \succ B \succ D \succ A$
15%	$D \succ C \succ A \succ B$



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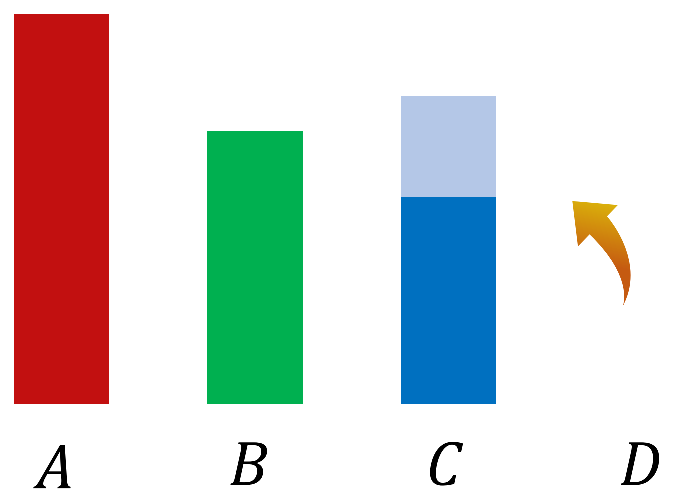

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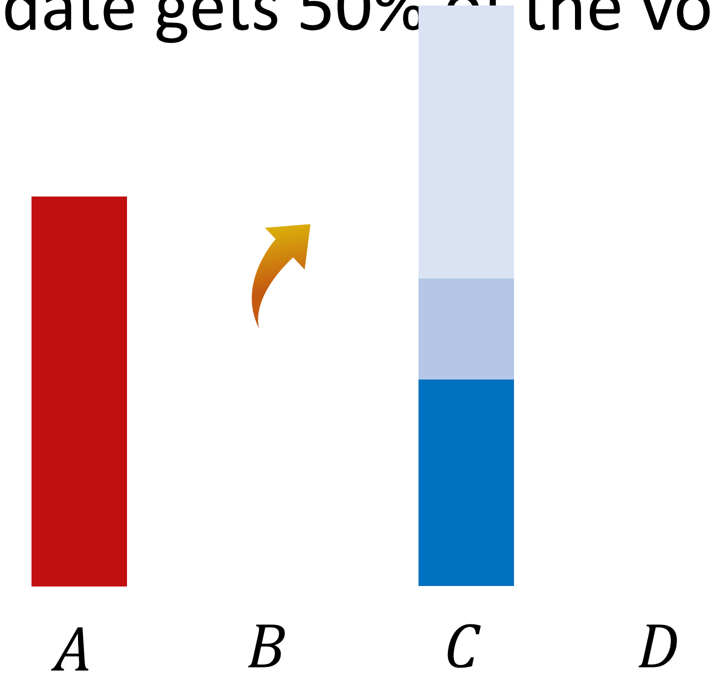
Instant Runoff Voting (IRV): Repeatedly eliminate the candidate with the fewest 1st-place votes until one candidate gets 50% of the votes.

40% $A \succ C$

25% $C \succ A$

20% $C \succ A$

15% $C \succ A$



2 Check the **normative properties** (the *axioms*).

Axiom: Reinforcement

If a candidate wins in a profile P_1 and in a profile P_2, it also wins in the profile $P_1 + P_2$.

Characterization Theorem *(Smith and Young, 1973)* **: Scoring Rules** are the only voting rules that satisfy **reinforcement**, neutrality, and anonymity.

2 Check the **normative properties** (the *axioms*).

Axiom: Strategyproofness

A voter cannot obtain a better winner by misreporting their preferences.

$$4 \times \; A \succ B \succ D \succ C$$
$$3 \times \; B \succ C \succ A \succ D$$
$$2 \times \; C \succ B \succ D \succ A$$
$$2 \times \; D \succ C \succ A \succ B$$

The plurality winner is A.

$$4 \times \; A \succ B \succ D \succ C$$
$$3 \times \; B \succ C \succ A \succ D$$
$$2 \times \; B \succ C \succ D \succ A$$
$$2 \times \; D \succ C \succ A \succ B$$

The plurality winner is now B.

2 Check the **normative properties** (the *axioms*).

Axiom: Strategyproofness

A voter cannot obtain a better winner by misreporting their preferences.

Impossibility Theorem *(Gibbard and Satterthwaite, 1973)* **:** There exists no rule that satisfies **strategyproofness**, resoluteness, non-imposition and non-dictatorship.

3 **Run simulations** with the voting rules.

We need preference data for the simulations:

- Generate **synthetic data** from probabilistic models.
- Use data from **online libraries** of datasets (e.g., Preflib).
- Design **voting experiments** and collect data.

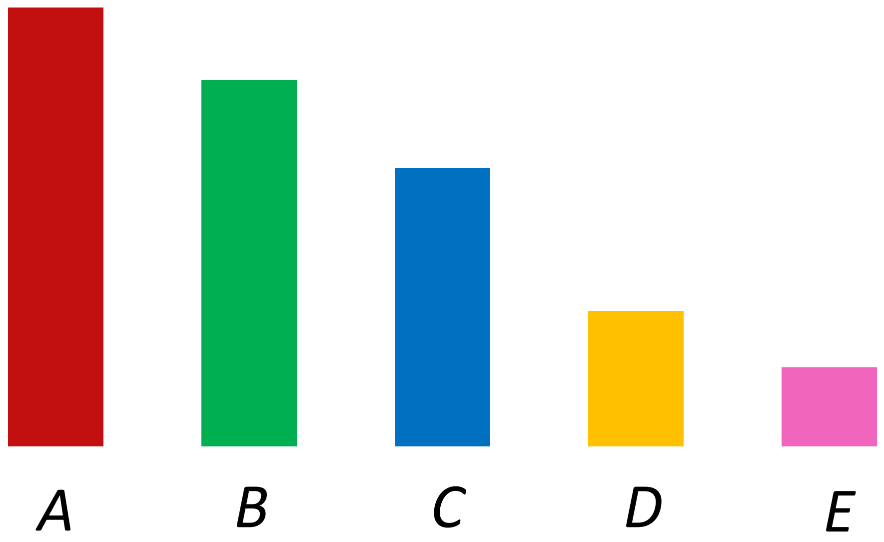
3. Proportional Parliementary elections with Threshold

Voting systems for parliamentary elections

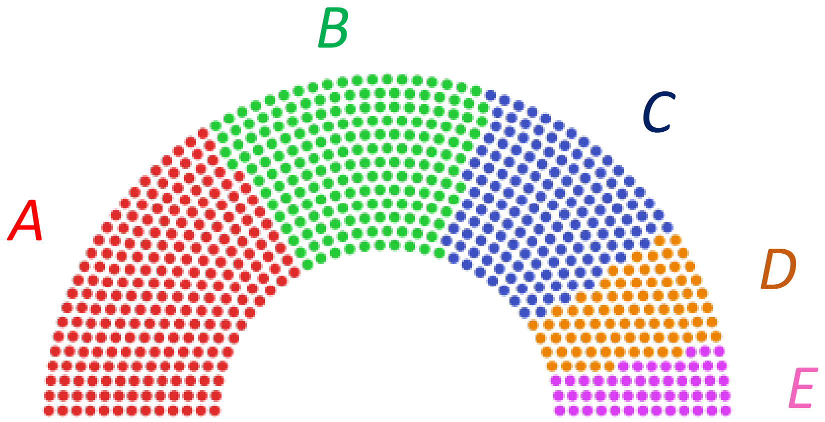





Voters vote for one party.

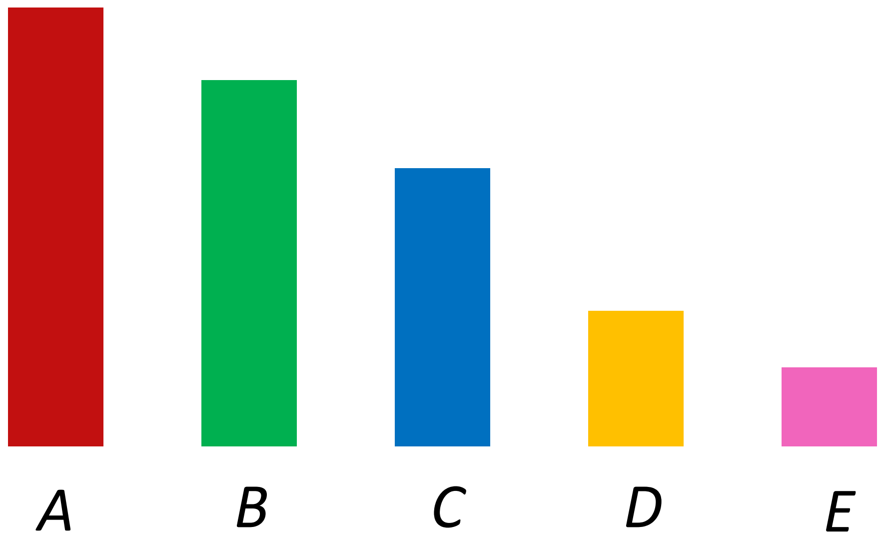


Seats are allocated to parties **proportionally to their scores**.



Proportional representation

Voters vote for one party.



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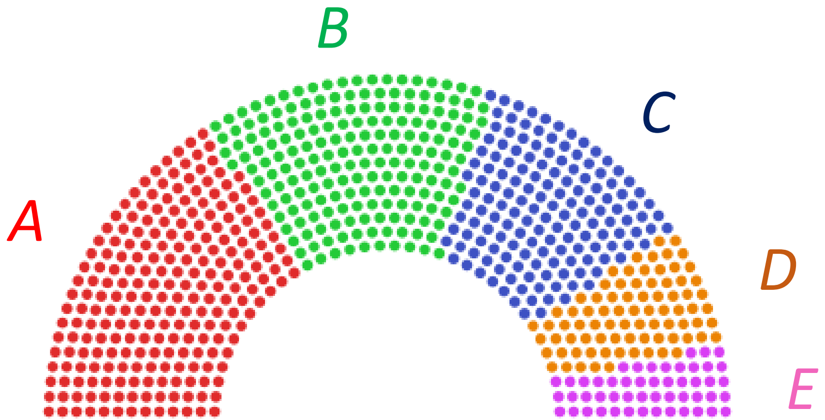
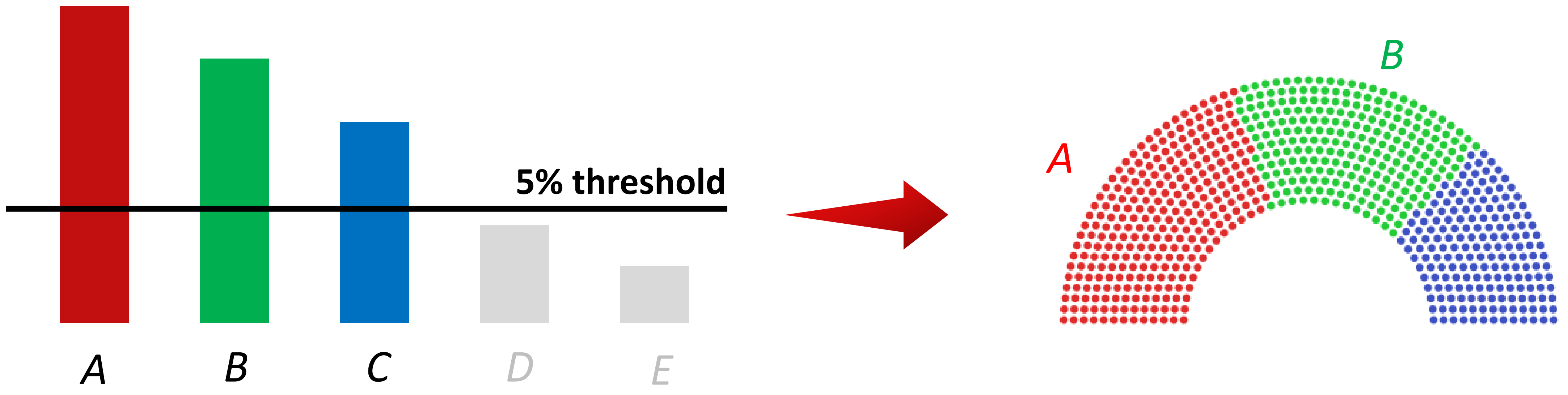
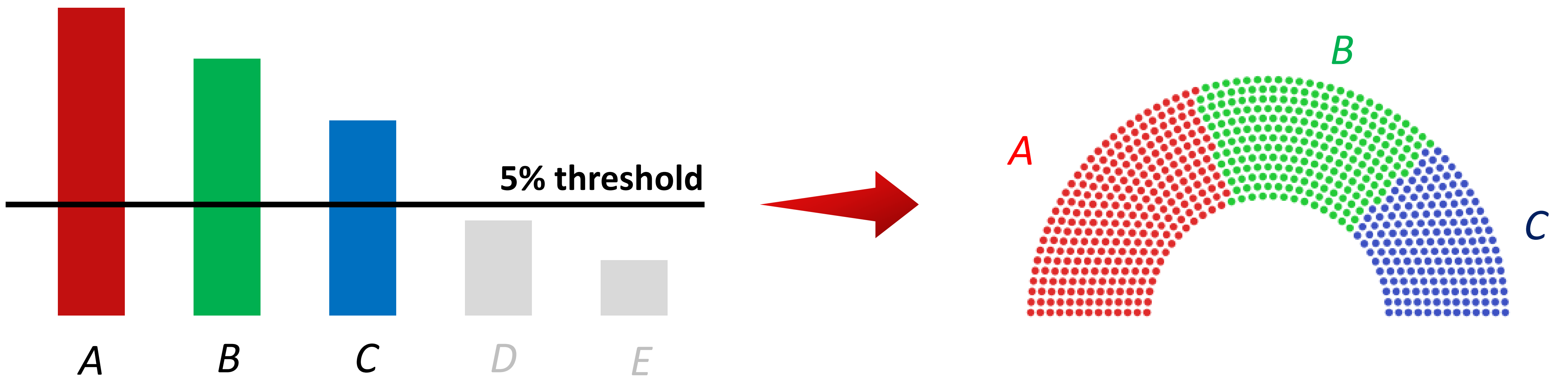


Problem: possible political fragmentation (many parties get a seat).

Many countries impose an **electoral threshold** to reduce political fragmentation.



Proportional representation *with threshold*



- **Some votes are "lost":** *D* and *E* supporters have no influence on the seat distribution.
- This incentivizes forms of **tactical voting.**

The “lost” votes

		Threshold	“Lost” votes
	2019 election of the French *representative to the EU Parliament.*	5%	20%
	2025 election of the *Bundestag* members.	5%	14% (increasing in recent decades)
	2002 election of the *Turkish Parliament* members.	10%	46%

Idea: a *replacement vote*

We could let voters **indicate a second choice** to be used in case their first choice does not reach the threshold.

Idea: a *replacement vote*

We could ask voters to rank **two parties**

1 Party B
2 Party D

We could even ask for a **truncated ranking**

1 Party B
2 Party D
3 Party A
4 Party C

Idea: a *replacement vote*

We could ask voters to rank **two parties**

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We could even ask for a **truncated ranking**

1 Party B
2 Party D
3 Party A
4 Party C

Question: how to decide which parties are “above the threshold”?

A *not-so-easy* problem

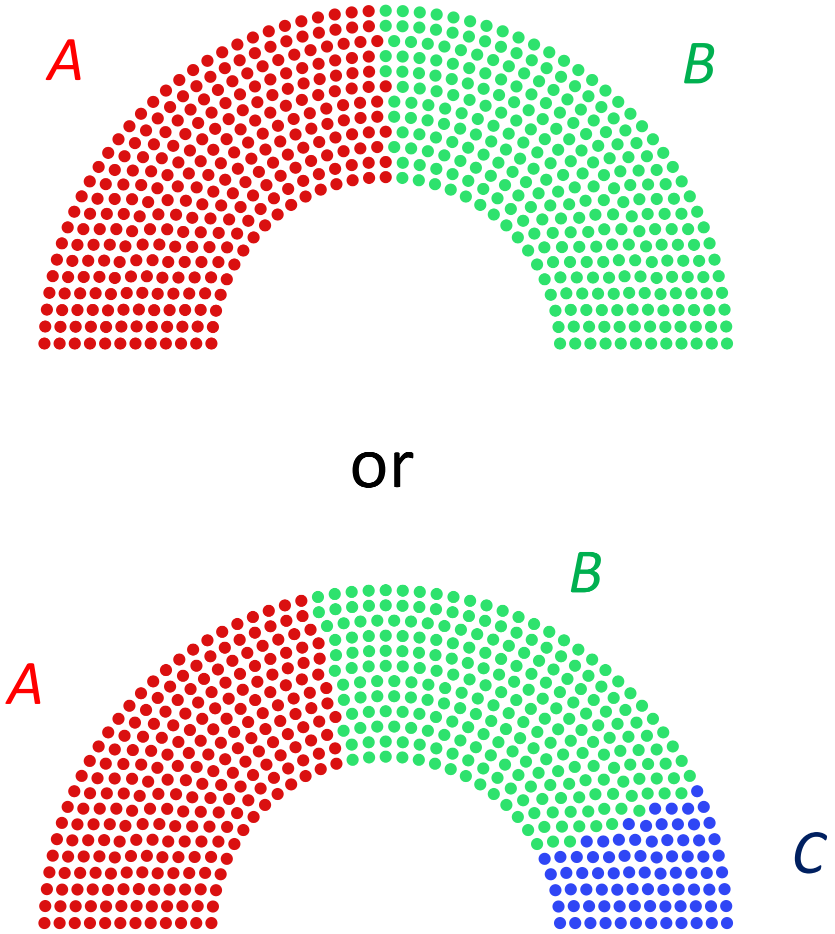
$43\%\ A$

$43\%\ B$

$4\%\ C \succ D$

$2\%\ D \succ C$

5% threshold



We have:
- Sets of **voters** $\boldsymbol{V = \{1, 2, \dots, n\}}$ and **parties** $\boldsymbol{C = \{p_1, \dots, p_m\}}$.
- A preference **profile** $\boldsymbol{P = (\succ_1, \dots, \succ_n)}$ of truncated rankings of voters over parties.
- A given **threshold** τ (absolute number of voters).

We want:
- A set of selected parties $S \subseteq C$, called the **outcome**.
- Voters are **represented** by their most-preferred party in S (if any).
- An outcome S is **feasible** if every party represents at least τ voters.
- We assume that parties in S get a **number of seats proportional** to the **share** of voters they represent.

- Profile P:

$\mathbf{6} \times \quad \boldsymbol{A} \succ B \succ D \succ C$

$\mathbf{4} \times \quad B \succ C \succ E \succ \boldsymbol{A} \succ D$

$3 \times \quad C \succ B$

$\mathbf{3} \times \quad D \succ E \succ B \succ \boldsymbol{A} \succ C$

$\mathbf{2} \times \quad C \succ \boldsymbol{A} \succ E$

- Threshold $\tau = 5$.

Outcome $\{A\}$ is feasible.

- Profile P:

$6 \times \quad A \succ B \succ D \succ C$

$4 \times$ $\quad B \succ C \succ \boldsymbol{E} \succ A \succ D$

$3 \times \quad C \succ B$

$3 \times$ $\quad D \succ \boldsymbol{E} \succ B \succ A \succ C$

$2 \times$ $\quad C \succ A \succ \boldsymbol{E}$

- Threshold $\tau = 5$.

Outcome $\{A\}$ is feasible.

Outcome $\{E\}$ is feasible.

Feasible outcomes

- Profile P:

$6 \times \quad A \succ B \succ D \succ C$

$4 \times \quad B \succ C \succ E \succ A \succ D$

$3 \times \quad C \succ B$

$3 \times \quad D \succ E \succ B \succ A \succ C$

$2 \times \quad C \succ A \succ E$

- Threshold $\tau = 5$.

Outcome $\{A\}$ is feasible.

Outcome $\{E\}$ is feasible.

Outcome $\{A, C\}$ is feasible.

Feasible outcomes

- Profile P:

$6 \times \quad \mathbf{A} \succ B \succ D \succ C$

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$2 \times \quad \mathbf{C} \succ A \succ E$

- Threshold $\tau = 5$.

Outcome $\{A\}$ is feasible.

Outcome $\{E\}$ is feasible.

Outcome $\{A, C\}$ is feasible.

Outcome $\{A, B, C\}$ is feasible.

- Profile P:

$6 \times \quad A \succ \mathbf{B} \succ D \succ C$

$4 \times \quad \mathbf{B} \succ C \succ E \succ A \succ D$

$3 \times \quad C \succ \mathbf{B}$

$3 \times \quad \mathbf{D} \succ E \succ B \succ A \succ C$

$2 \times \quad C \succ A \succ E$

- Threshold $\tau = 5$.

Outcome $\{A\}$ is feasible.

Outcome $\{E\}$ is feasible.

Outcome $\{A, C\}$ is feasible.

Outcome $\{A, B, C\}$ is feasible.

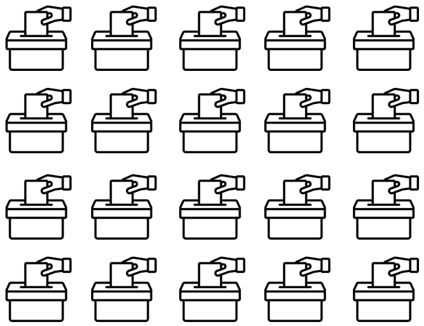
Outcome $\{B, D\}$ is not feasible.

! If $\tau > n/2$ and with full rankings, this corresponds to the **single-winner voting model** (if we additionally force a non-empty outcome).

(This is because when $\tau > n/2$, only one candidate can be part of the outcome since each candidate in the outcome needs to represent more than τ voters)

Summary of the problem

Profile P



⊕ Threshold τ

Party Selection Rule f

Feasible Outcome

$$S \subseteq C$$

4. Party Selection Rules

1^{st} Possibility: *Direct Winners Only (DO)*

Rule: Direct Winners Only (DO)

The selected parties are all those which receive more first-place votes than required by the threshold.

35% $A \succ C$

30% B

20% $C \succ E \succ A$

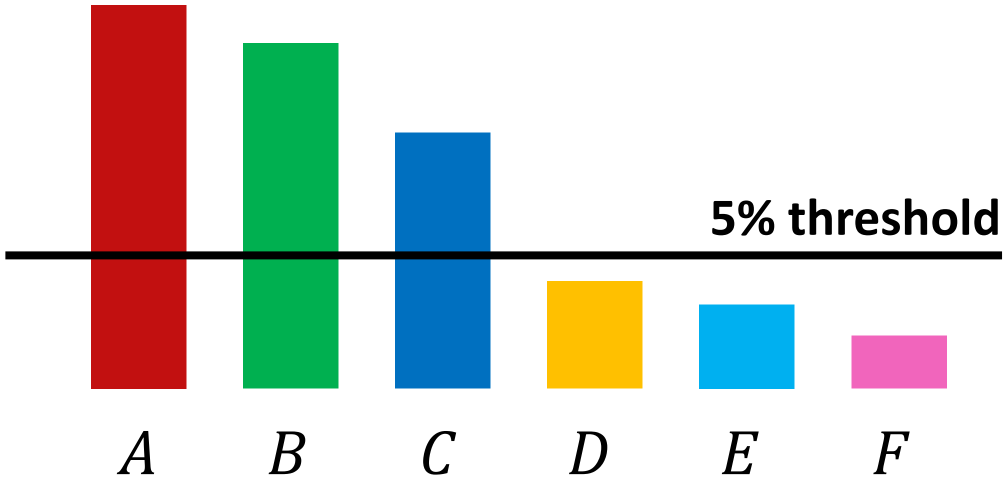
6% $C \succ A \succ B$

3% $D \succ E \succ F \succ C$

3% $E \succ F \succ A$

2% $F \succ E \succ D$

1% $D \succ F \succ B$



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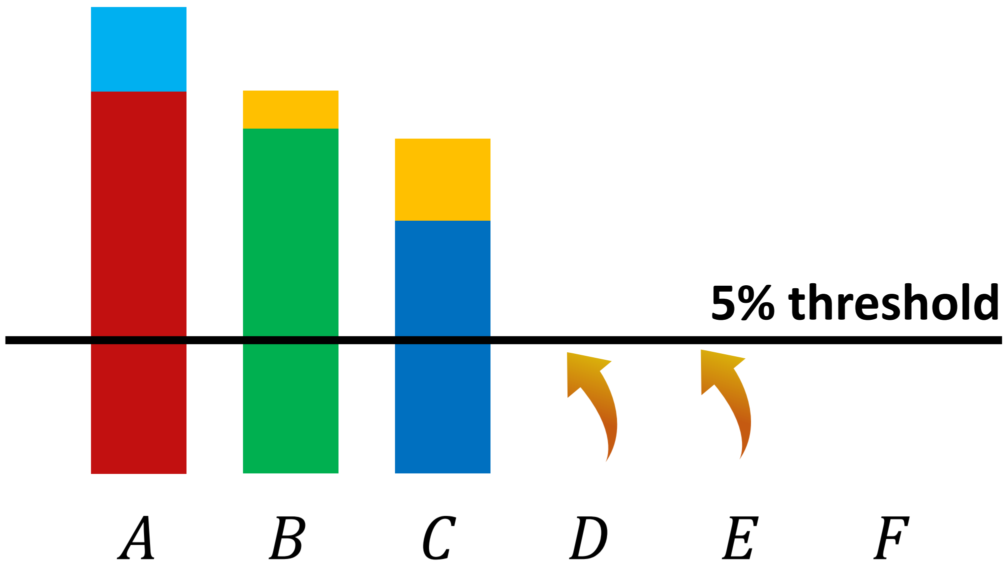

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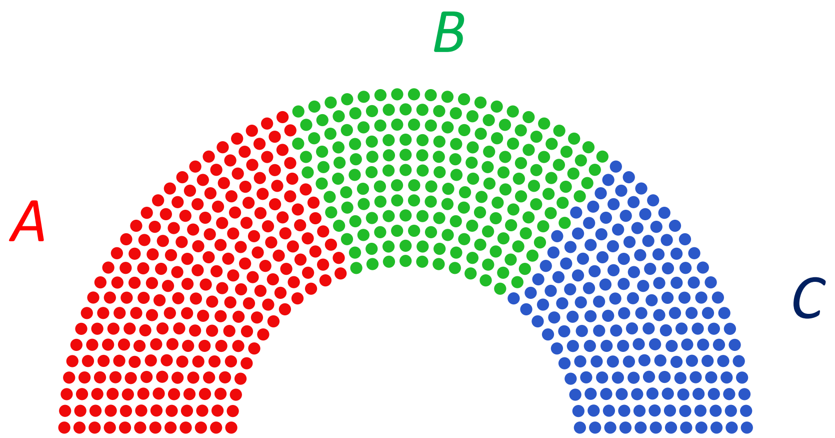
Rule: Direct Winners Only (DO)

The selected parties are all those which receive more first-place votes than required by the threshold.

35%	$A \succ C$	**3%**	$D \succ E \succ F \succ C$
30%	B	**3%**	$E \succ F \succ A$
20%	$C \succ E \succ A$	**2%**	$F \succ E \succ D$
6%	$C \succ A \succ B$	**1%**	$D \succ F \succ B$



2nd Possibility: *Single Transferable Vote (STV)*

Rule: Single Transferable Vote (STV)

Parties that receive the fewest votes are successively eliminated until all parties receive more votes than required by the threshold.

35% $A \succ C$

30% B

20% $C \succ E \succ A$

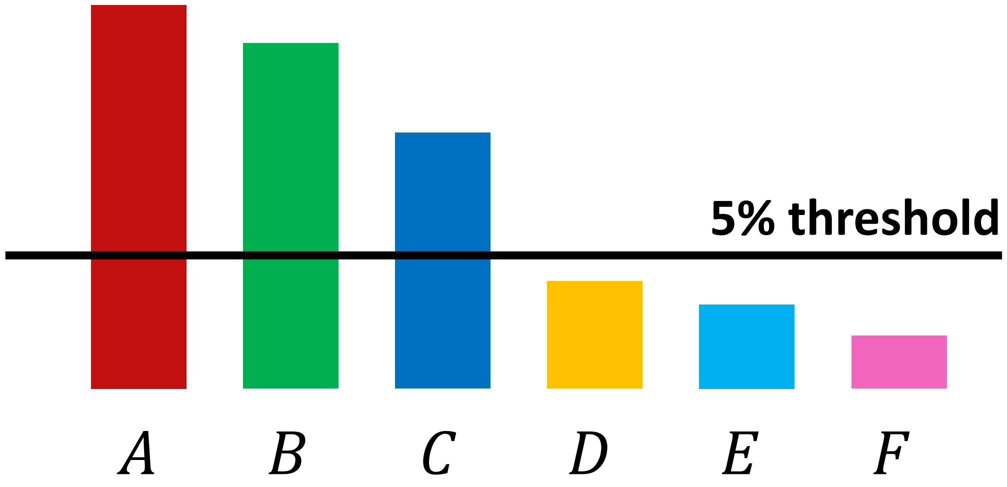
6% $C \succ A \succ B$

3% $D \succ E \succ F \succ C$

3% $E \succ F \succ A$

2% $F \succ E \succ D$

1% $D \succ F \succ B$



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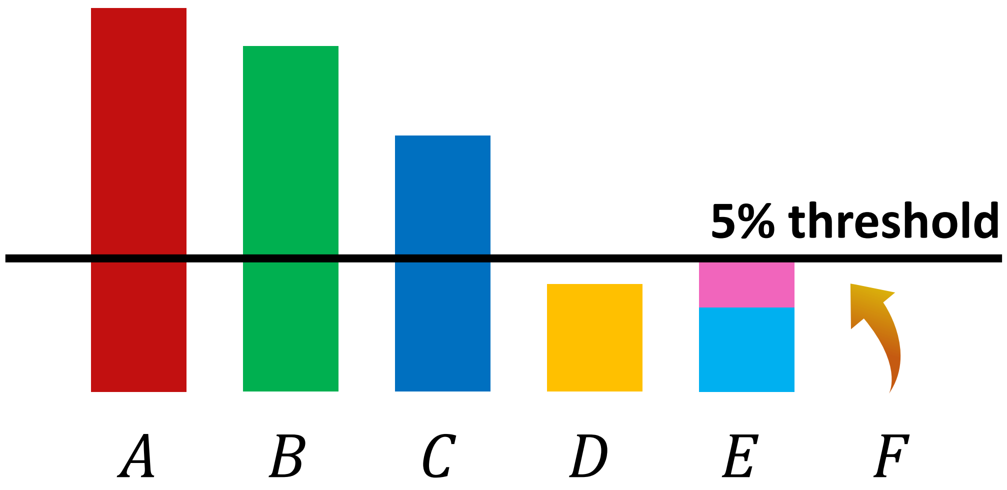
1% $D \succ F \succ B$



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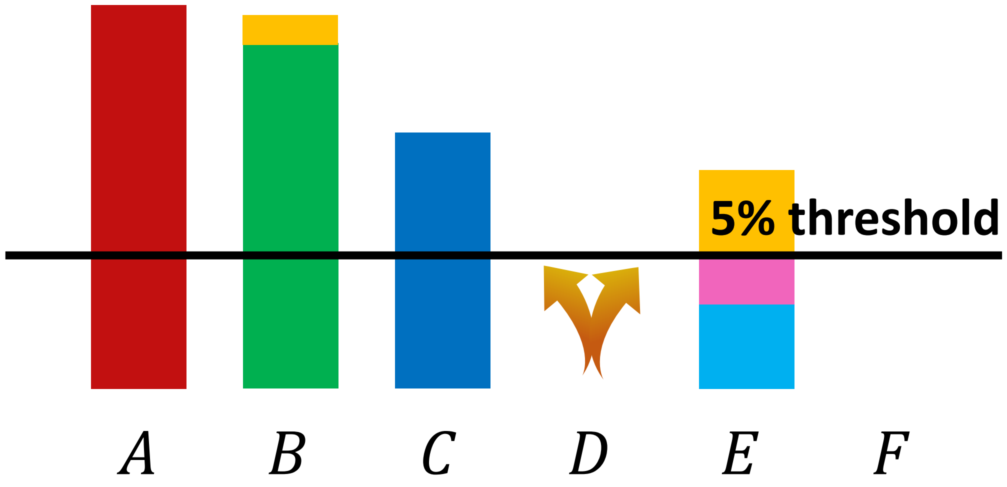

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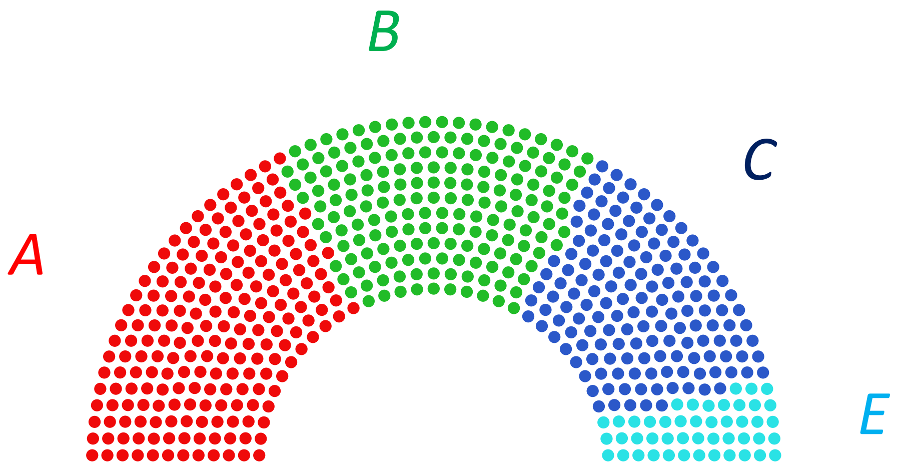
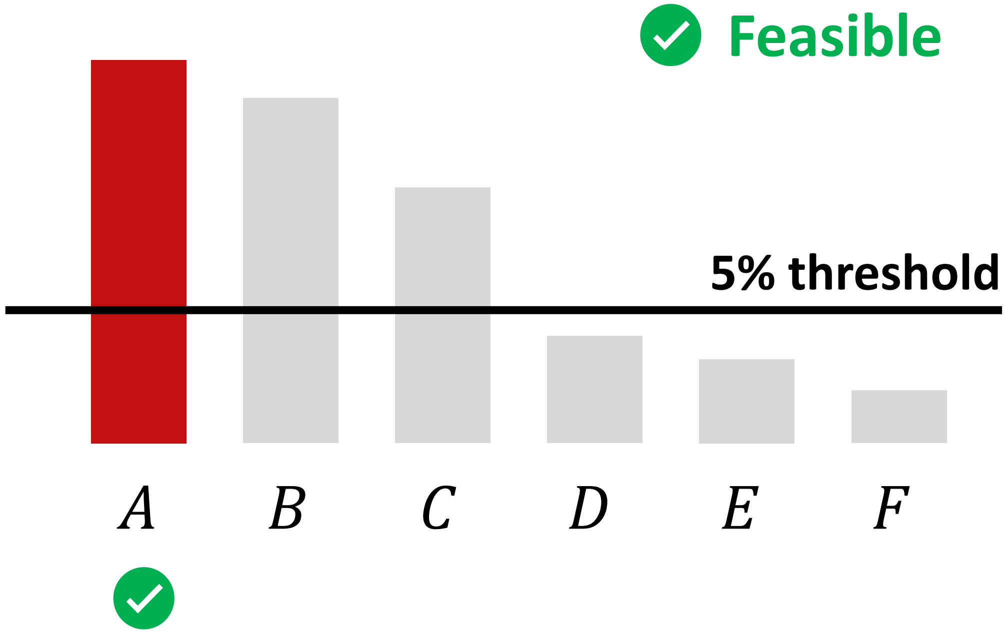


3rd Possibility: *Greedy Plurality (GP)*

Rule: Greedy Plurality (GP)

Parties are considered in decreasing order of plurality score, and added to the outcome if it remains feasible.

35%	$A \succ C$	**3%**	$D \succ E \succ F \succ C$
30%	B	**3%**	$E \succ F \succ A$
20%	$C \succ E \succ A$	**2%**	$F \succ E \succ D$
6%	$C \succ A \succ B$	**1%**	$D \succ F \succ B$

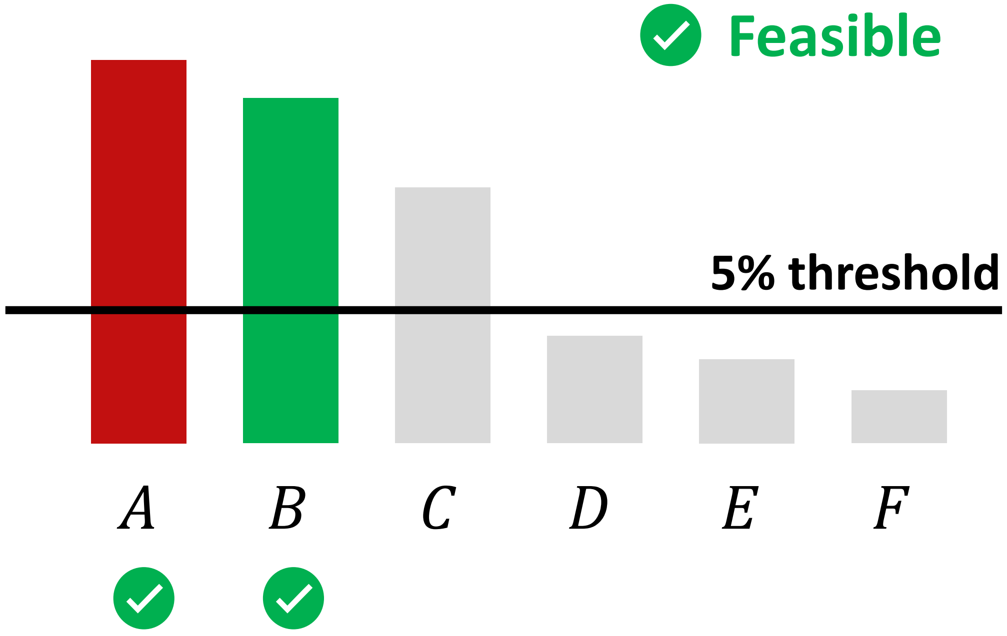


3rd Possibility: *Greedy Plurality (GP)*

Rule: Greedy Plurality (GP)

Parties are considered in decreasing order of plurality score, and added to the outcome if it remains feasible.

35% $A \succ C$	**3%** $D \succ E \succ F \succ C$
30% B	**3%** $E \succ F \succ A$
20% $C \succ E \succ A$	**2%** $F \succ E \succ D$
6% $C \succ A \succ B$	**1%** $D \succ F \succ B$



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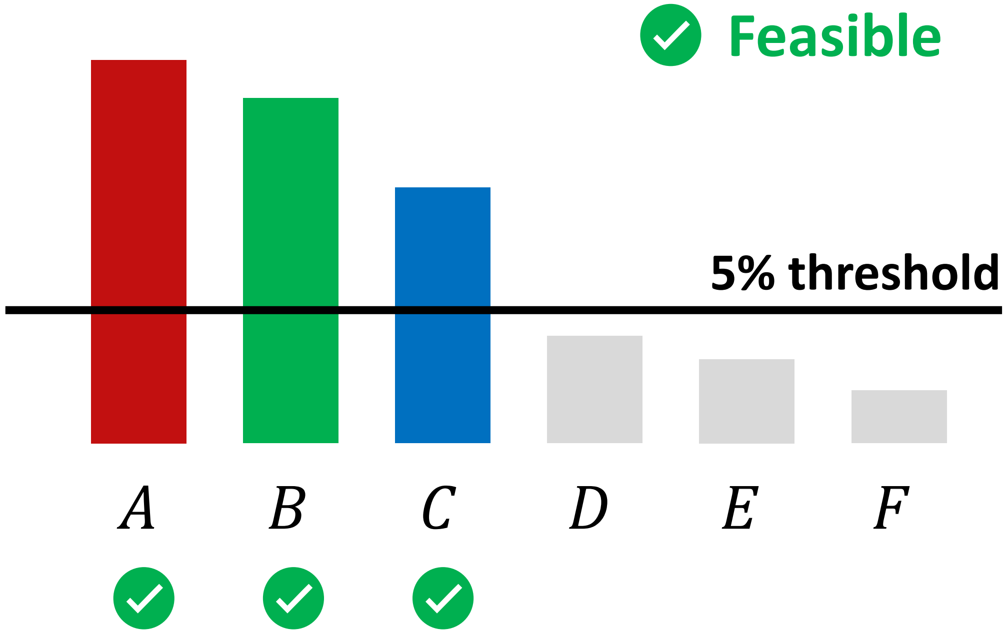

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3% $E \succ F \succ A$

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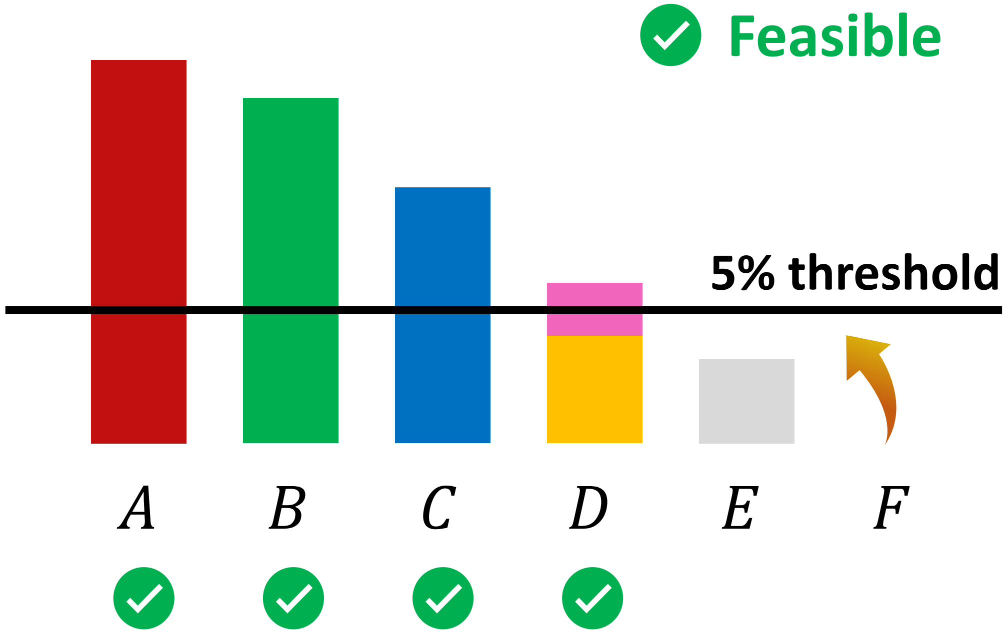

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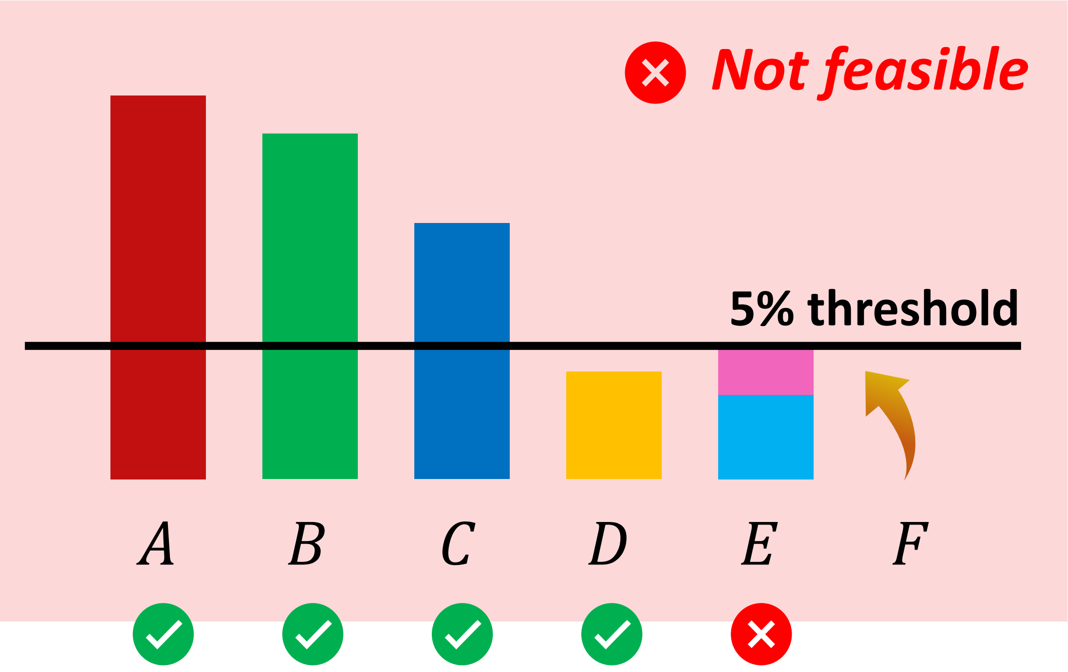

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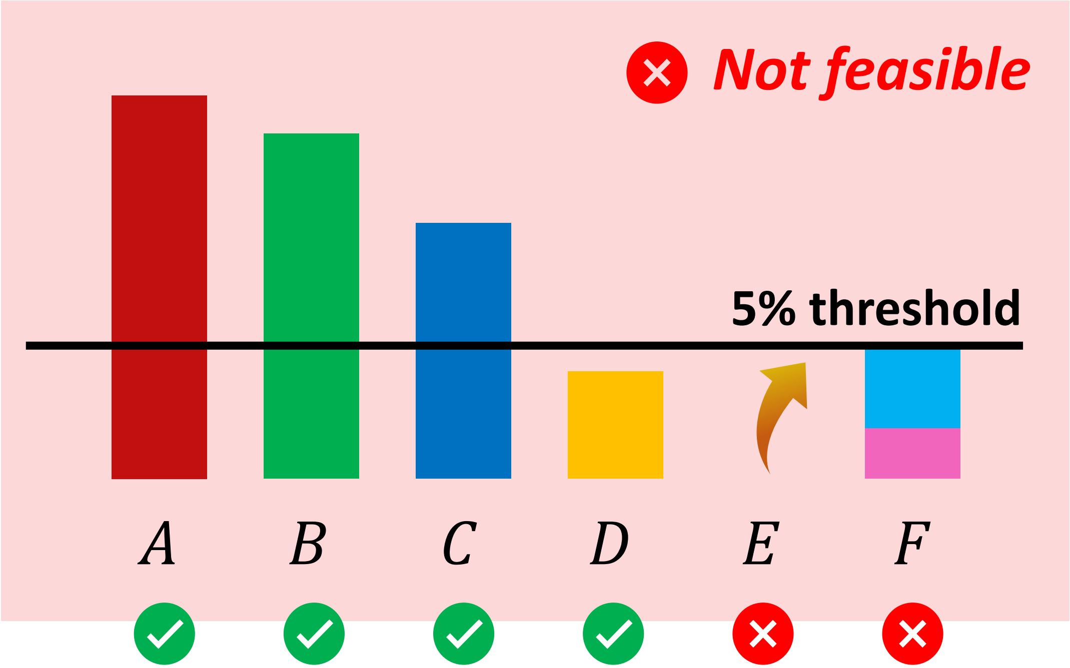

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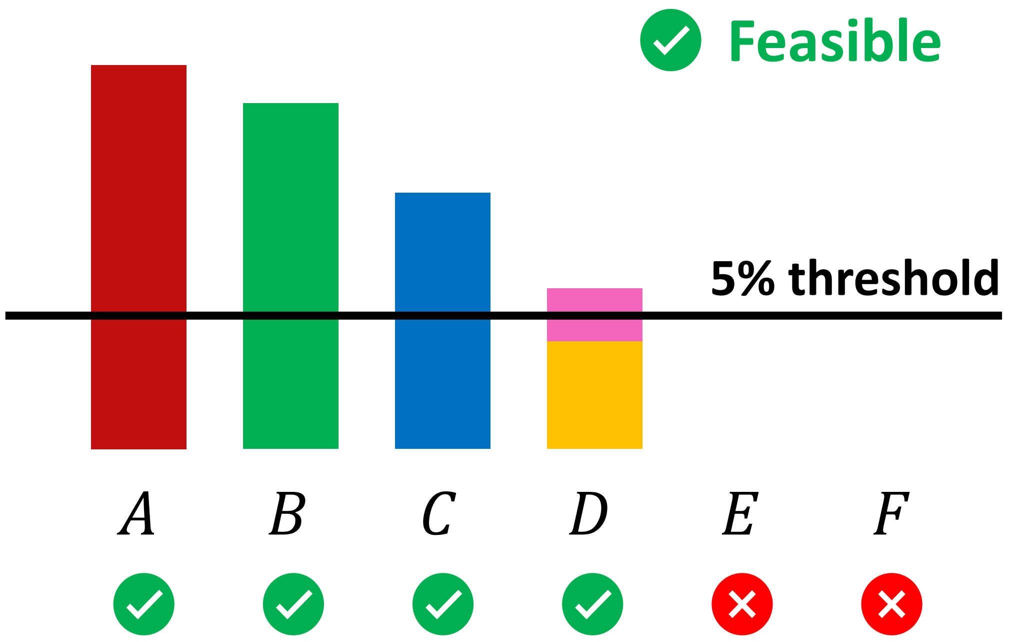

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Parties are considered in decreasing order of plurality score, and added to the outcome if it remains feasible.

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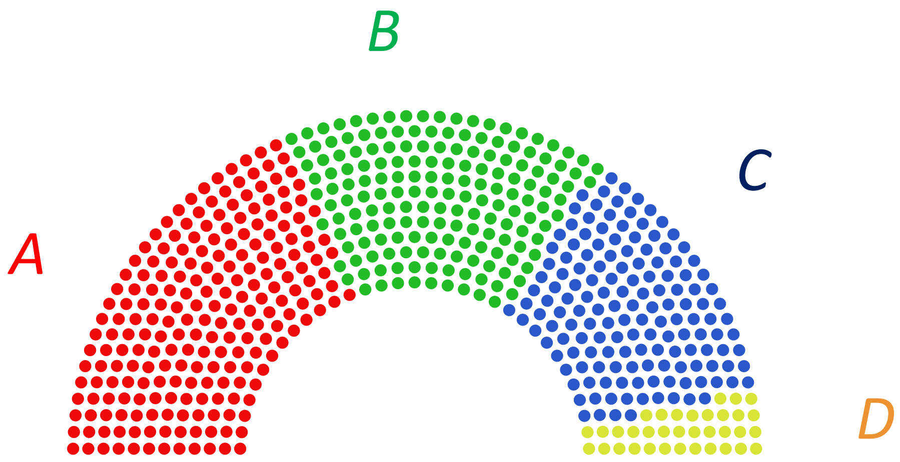


Rule: Maximum Representation (MaxR)

Return the feasible outcome that maximizes the number of voters that are **represented**.

Rule: Maximum Plurality (MaxP)

Return the feasible outcome that maximizes the number of voters that are **represented by their first choice**.

Computational Complexity

Theorem : The outcome of DO, STV and GP can be computed in **polynomial time.**

Theorem : The problem of computing the outcome of MaxR and MaxP is **NP-hard.**

(proof by reduction to the independent set problem)

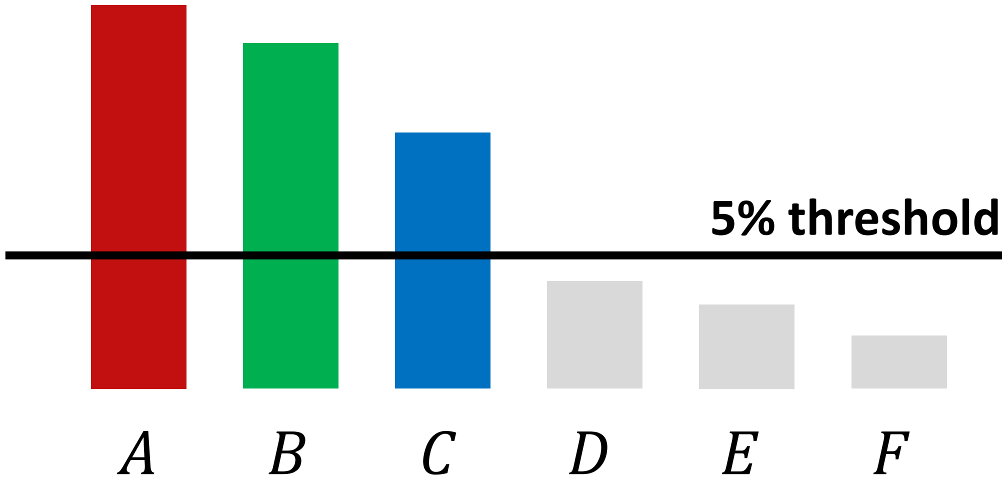
5. Axiomatic Analysis

Axiom: Inclusion of Direct Winners

If τ voters or more rank a party x on top of their rankings, this party should be selected.

✓ DO
✓ STV
✓ GP
✗ MaxP
✗ MaxR

35% $A \succ C$	**4%** $D \succ E \succ F$
30% B	**3%** $E \succ F \succ A$
26% $C \succ E \succ A$	**2%** $F \succ E \succ D$



Axiom: Representation of solid coalitions

If τ voters or more rank a set of parties T on top of their rankings, at least one of these parties should be selected.

Inspired by *Proportionality for Solid Coalitions* **[Dummet 94]**

✗ DO ✗ MaxP
✓ STV ✗ MaxR
✗ GP

35%	$A \succ C$	**4%**	$D \succ E \succ F$
30%	B	**3%**	$E \succ F \succ A$
26%	$C \succ E \succ A$	**2%**	$F \succ E \succ D$

= 5%

→ **Party E or F** should be part of the outcome.

Axiom: Threshold Monotonicity — ✓ DO ✓ STV ✗ GP ✗ MaxP ✗ MaxR

If a party is selected for threshold τ, then it is also selected for threshold $\tau' < \tau$.

Axiom: Ind. of Definitely Losing Parties — ✗ DO ✓ STV ✗ GP ✗ MaxP ✗ MaxR

Once some parties are losing at some threshold τ, then for all larger thresholds $\tau' > \tau$, the rule should behave as if none of the losing parties had been available.

Characterization Theorem : **STV** is the only party selection rule that satisfies inclusion of direct winners and independence of definitely losing parties.

Axiom: Reinforcement for Winning Parties

If a party is selected for profile P_1 with threshold τ_1 and for profile P_2 with threshold τ_2, then it should be selected for profile $P_1 + P_2$ with threshold $\tau_1 + \tau_2$.

✓ DO
✗ MaxP
✗ STV
✗ MaxR
✗ GP

Characterization Theorem : **DO** is the only party selection rule that satisfies inclusion of direct winners and reinforcement for winning parties.

Axiom: Representative-strategyproofness

Voters cannot cause a party to be selected that they prefer to all currently selected parties by misreporting their preferences.

Axiom: Share-strategyproofness

Voters cannot cause a party to be selected that they prefer to all currently selected parties by misreporting their preferences ***OR*** increase the share of voters represented by their most-preferred selected party.

No hope for strategyproofness in general.

(Gibbard-Satterthwaite impossibility result applies since single-winner voting is a special case of our model)

Say that a party is **(all with respect to a voter i)**…

- …**Safe** if it is always selected no matter how i votes.
- …**Risky** if it might or might not be selected depending on how i votes.
- …**Out** if it is always not selected no matter how i votes.

$\ll \tau$ votes	$\sim \tau$ votes	$\gg \tau$ votes
Out	***Risky***	***Safe***

1 maximum

$\ll \tau$ votes	$\sim \tau$ votes	$\gg \tau$ votes
Out	***Risky***	***Safe***

Proposition : GP, MaxP and MaxR satisfy representative-strategyproofness when there is *at most one risky* party from the perspective of each voter.
(DO and STV do not.)

Always one in top 2

$\ll \tau$ votes	$\sim \tau$ votes	$\gg \tau$ votes
Out	***Risky***	***Safe***

Proposition : DO satisfies share-strategyproofness when every voter has a *safe party as one of their two most-preferred* parties.
(GP, STV, MaxP and MaxR do not.)

In the (current) uninominal system, voters are incentivized to **vote for their favorite party among the ones that will be selected:**

32% $A \succ C$	32% $C \succ D \succ B$	32% $A \succ C$	32% $C \succ D \succ B$
32% B	4% $D \succ A$	32% B	4% $A \succ D$
	Unrepresented		Represented

Proposition : **DO** and **GP** satisfy share-strategyproofness under the restriction that voters can only misreport by promoting their most-preferred *selected* party into first place. (STV, MaxP and MaxR do not)

Summary

	DO	STV	GP	MaxP	MaxR
Set-maximality			✓	✓	✓
Inclusion of direct winners	✓	✓	✓		
Representation of solid coalitions		✓			
Threshold monotonicity	✓	✓			
Ind. of definitely losing parties		✓			
Ind. of clones		✓			✓
Reinforcement for winning parties	✓				
Monotonicity	✓				
Rep-SP (one risky party)			✓	✓	✓
Share-SP (safe 1st or 2nd)	✓				
Share-SP (rep. ranked 1st)	✓		✓		

6. Empirical Analysis

Context of the experiment

To collect appropriate preference data, we **ran a voting experiment** during the 2024 election of the French representative to the EU parliament.

Candidate parties: 38

Threshold: 5%

Parties above the threshold: 7

Lost votes: 12.1%

The experimental setup

1. Explanation of the issues caused by the threshold.
2. Presentation of the candidate lists.
3. **Vote with alternative voting methods.**
4. Questionnaire.

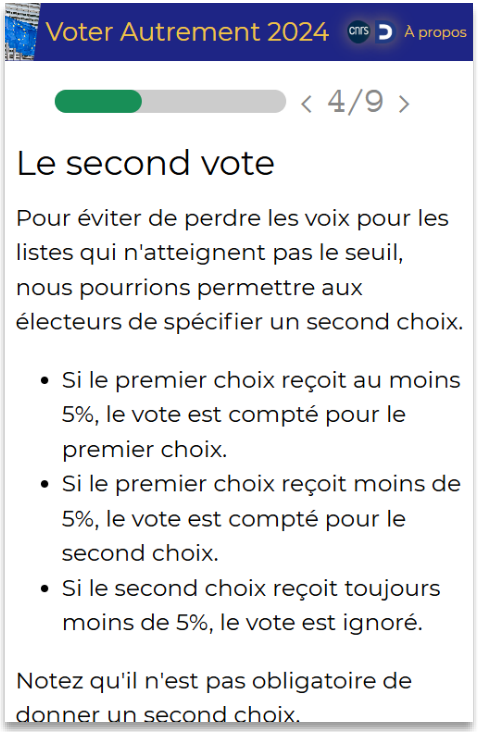


Fig. Screenshot of the website of the experiment conducted during the 2024 election of the French representative to the EU Parliament.

Two samples of participants

1 *Self-selected* sample

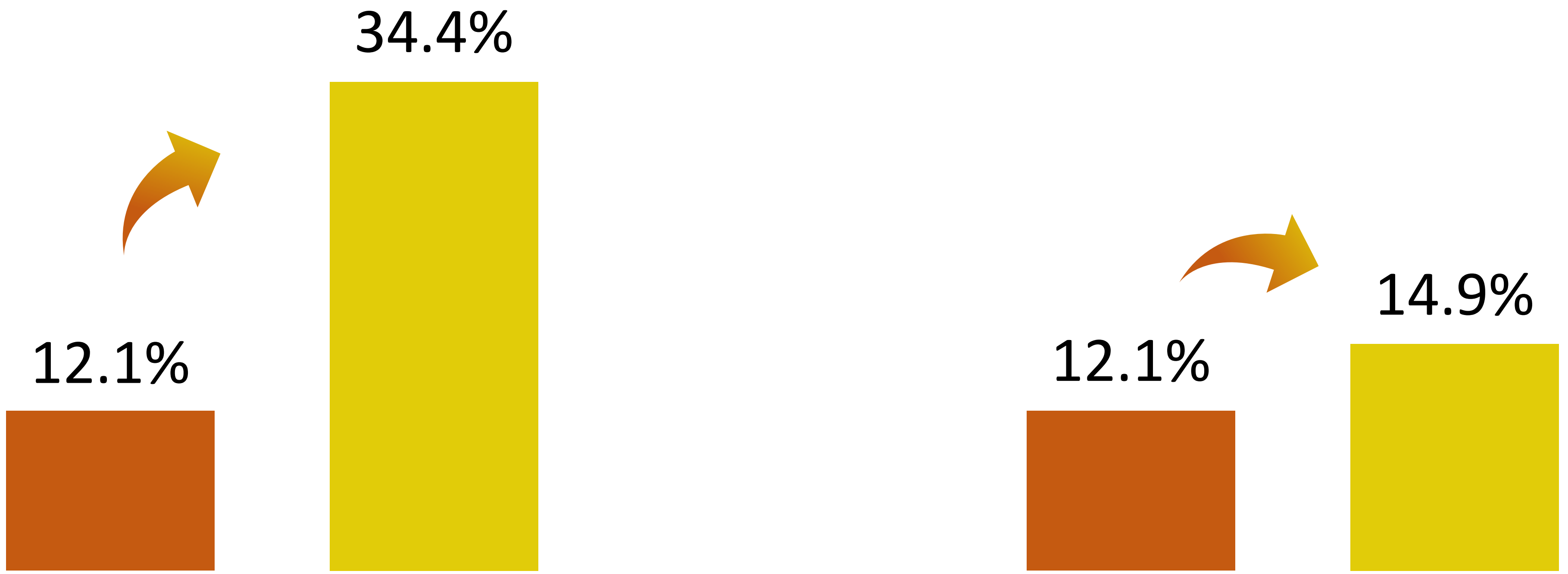
- 3 046 participants in a week.
- Recruited through social media, unpaid.
- Overrepresentation of left-wing, young and educated people.

2 *Representative* sample

- 1 000 participants.
- Recruited via a polling institute and paid a fixed amount to participate.
- Representative of the French population.

! **We assign weights to the voters to reduce the biases:** weights are selected based on the vote of the participant at the actual election, to match the share of votes received by each party.

1st Observation: more votes for “small” parties

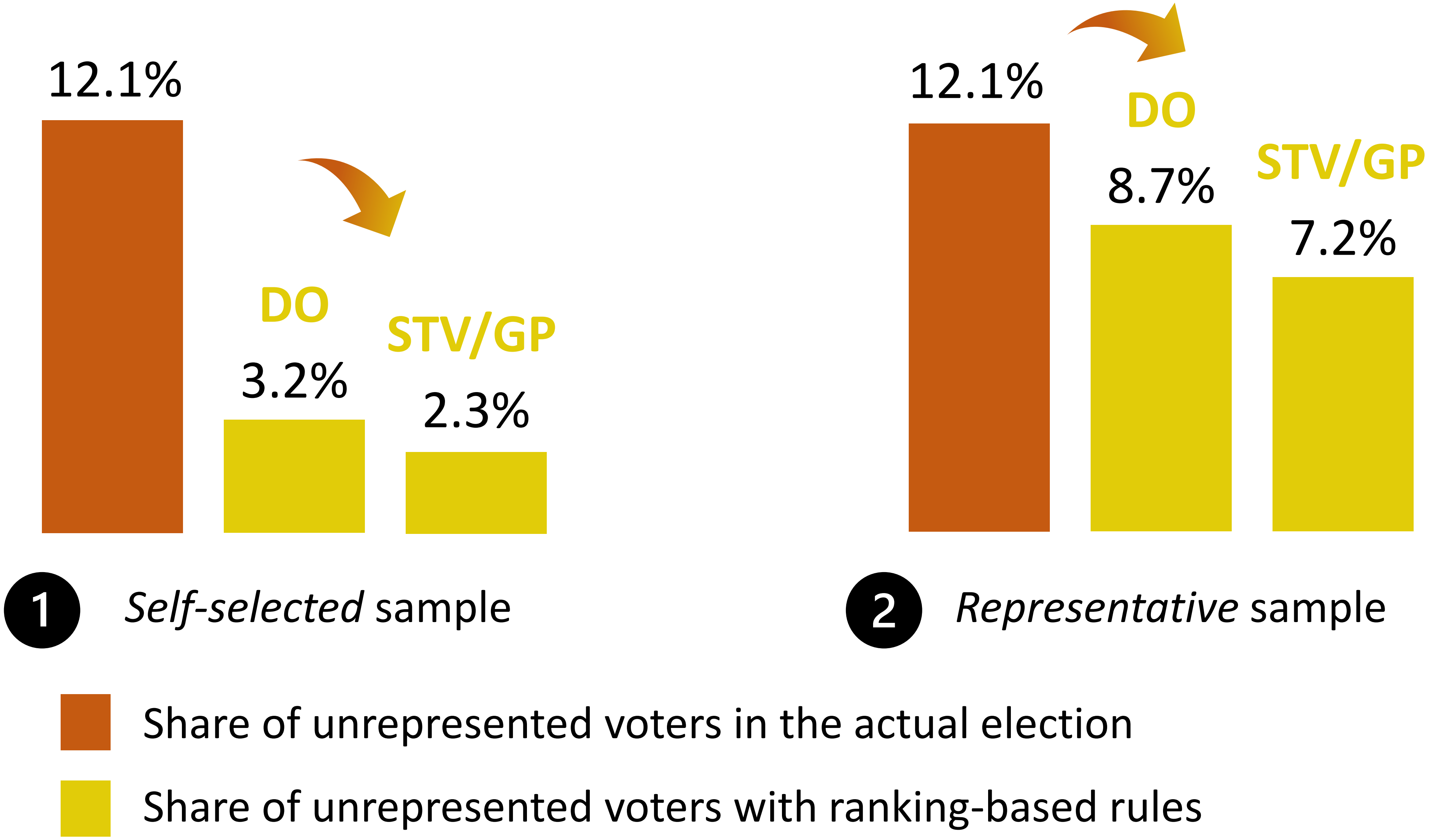


1 *Self-selected* sample

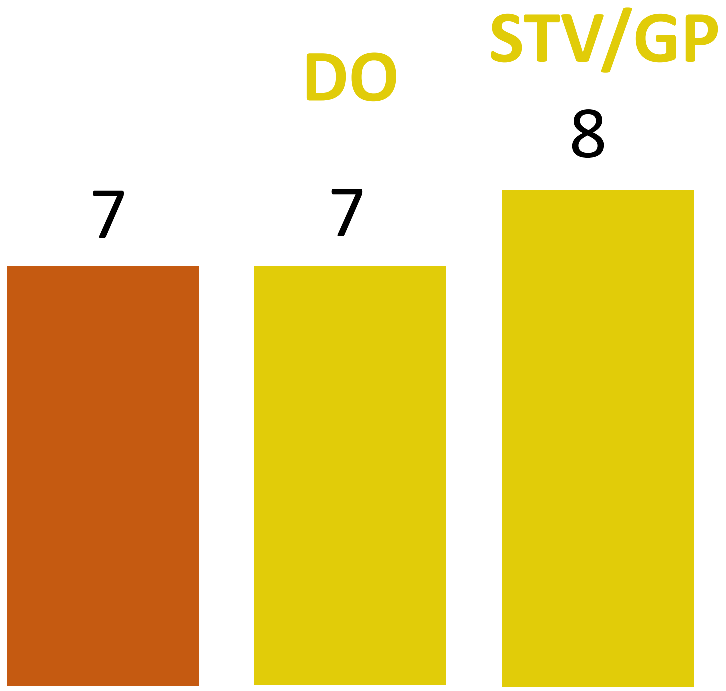
2 *Representative* sample

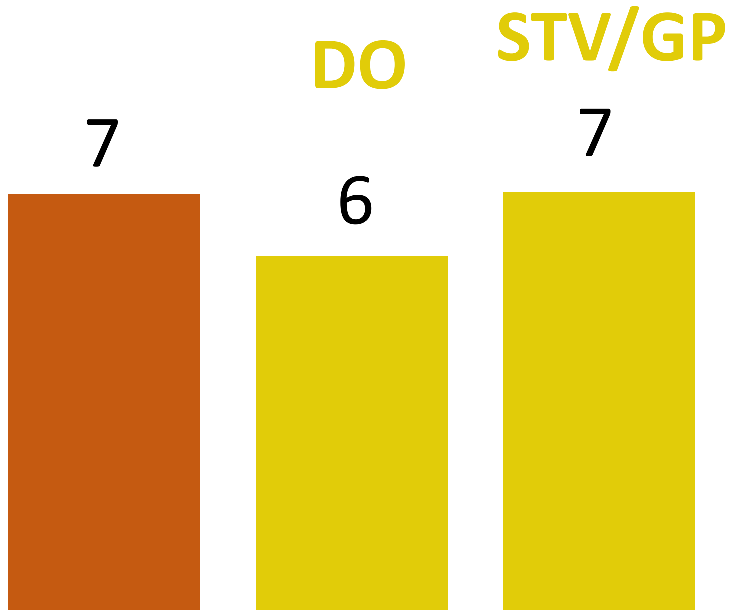
- Share of voters that vote for a “small” party in the actual election
- Share of voters that put a “small” party first in their ranking

2nd Observation: less “lost” votes



3rd Observation: no political fragmation



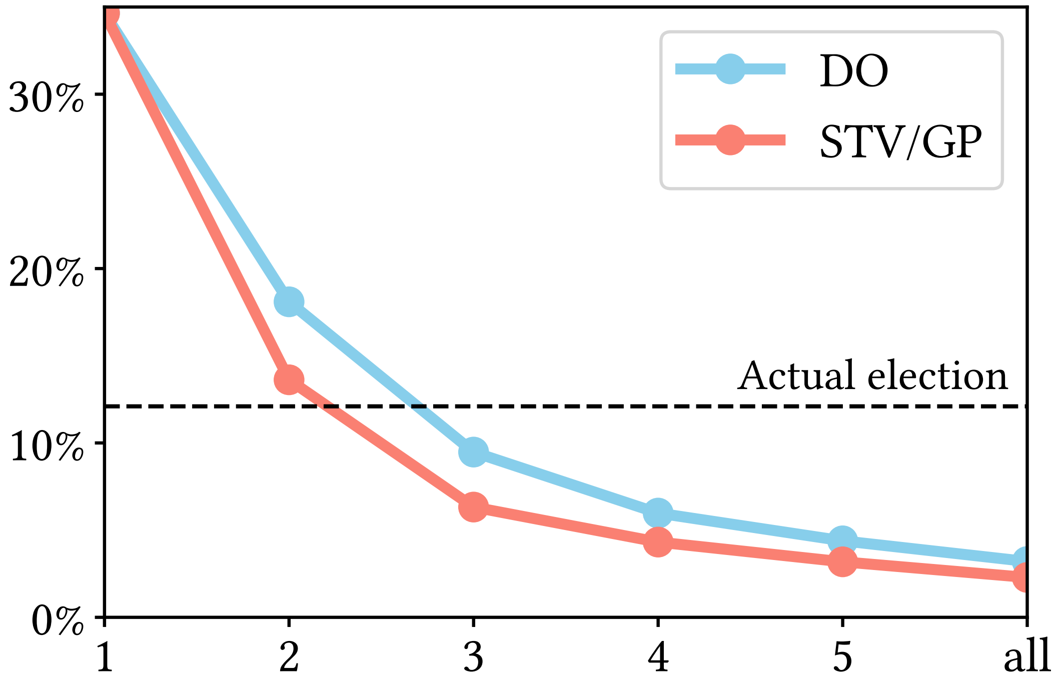


❶ *Self-selected* sample

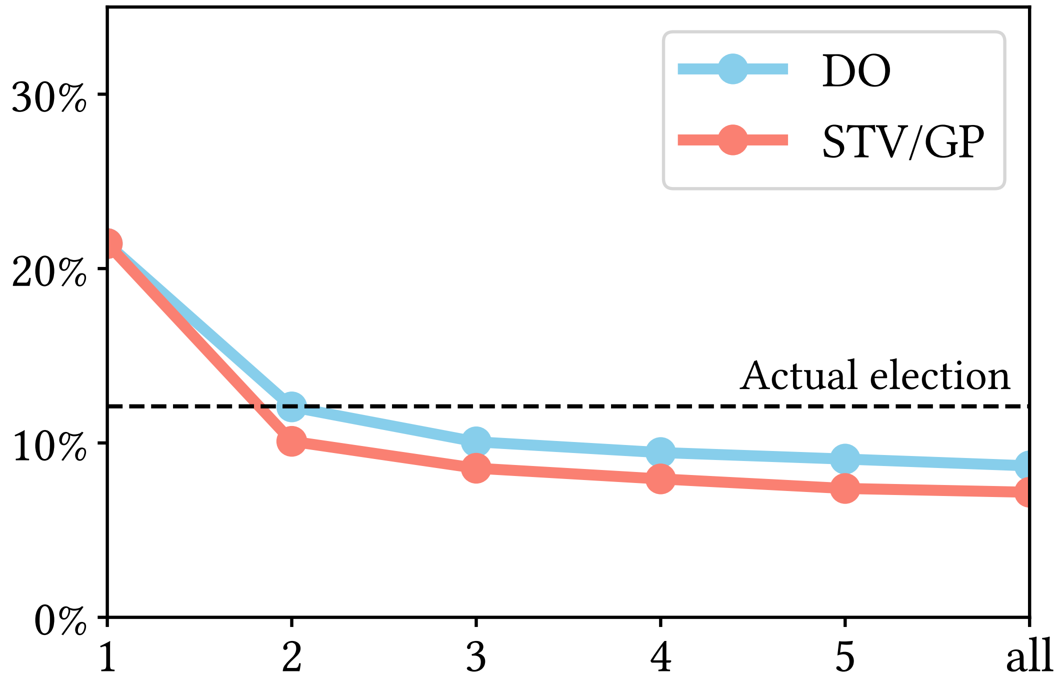
❷ *Representative* sample

- Number of parties receiving a seat in the actual election
- Number of parties receiving a sear with ranking-based rules

4th Observation: we can ask for short rankings



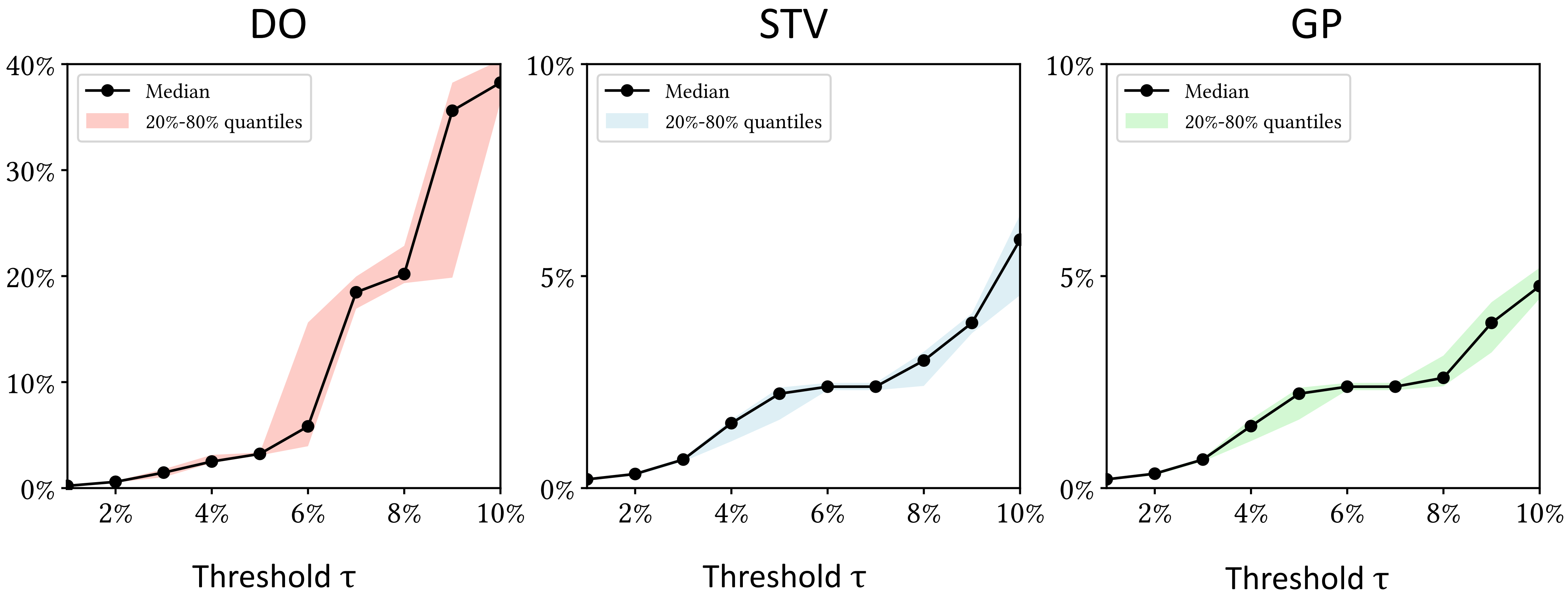
1 *Self-selected* sample



2 *Representative* sample

> Share of unrepresented voters if all rankings are truncated to rank k (x-axis).

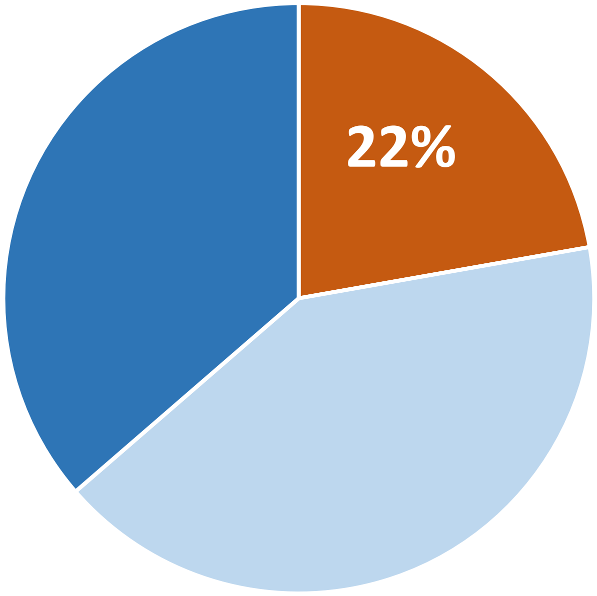
Robustness test



Share of unrepresented voters with different threshold values and with random noise added to the preferences *(self-selected sample).*

Opinion of the participants on the different systems

Which system do you think is better suited for the election of your representatives to the EU parliament?



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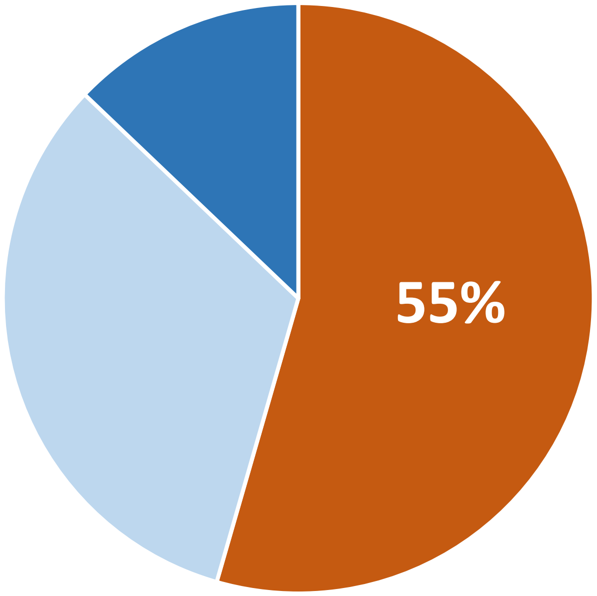

2 *Representative* sample

Uninominal (current system) **Two choices** **Truncated rankings**

Conclusion

Conclusion

We axiomatically and empirically studied rules for electing parliaments with electoral thresholds.

Main takeaway: We can significantly increase representativeness by allowing voters to **rank** parties.

- STV and GP leave *fewer voters unrepresented* than DO.
- DO and GP have *stronger strategyproofness guarantees* than STV.
- STV satisfies *independence of clones* and *represents solid coalitions.*

Thanks for your attention!

Questions?