Karlsruhe Institute of Technology (KIT)

Resource Allocation via the Median Rule

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joint work with Klaus Nehring

Winter School IT12, Alba di Canazei

January 9, 2017

Agenda

Motivation

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- Moreover, in general, there is a large *multiplicity* of 'insincere' equilibria.
- **Question:** Does that mean that strategically robust implementation is impossible in economically relevant applications?

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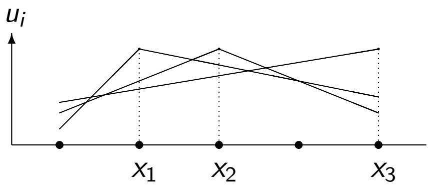
Median Voter Theorem: *Suppose that social alternatives can be ordered from left to right such that all preferences are* single-peaked, *then the choice of the median of the individual peaks defines a non-dictatorial and strategy-proof voting rule.*



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Question 1: Generalized Single-Peakedness

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Question 1: Generalized Single-Peakedness

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Question 2: The Median Rule in Public Goods Allocation Problems

This talk

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1. General Motivation
2. Generalized Single-Peakedness
3. Resource Allocation
   - Theory
   - Simulation

Strategy-Proofness

- A social choice function F maps profiles of individual preferences on a (finite) set of alternatives X to a collectively chosen alternative:

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- F is **strategy-proof** if it is a (weakly) dominant strategy to submit true preference ordering: for all $\succeq_1, \ldots, \succeq_n$ and $\succeq'_i$,

$$F(\succeq_1, \ldots, \succeq_i, \ldots, \succeq_n) \succeq_i F(\succeq_1, \ldots, \succeq'_i, \ldots, \succeq_n)$$

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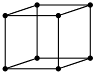

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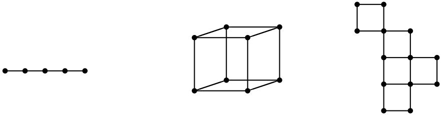

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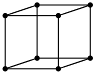

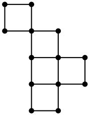

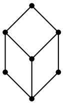

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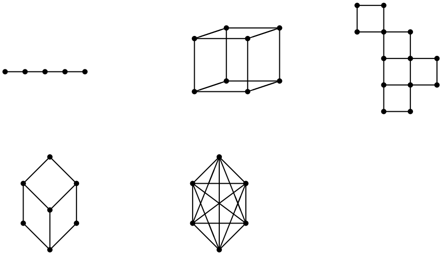

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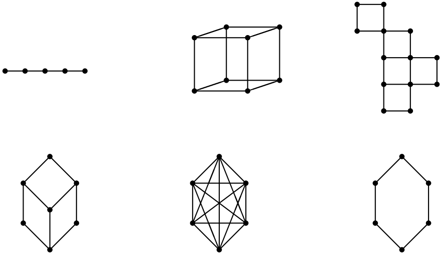

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Characterization of all strategy-proof voting rules on **all** generalized single-peaked domains:

- Betweenness-preserving embedding of graph in (high-dimensional) hypercube
- Simple game in each dimension ('voting by issues')
- Key steps:
    - 'peaks only' based on Barberá, Masso & Neme 1997
    - consistency of simple games across dimensions ('intersection property')

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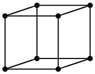

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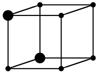

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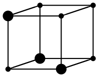

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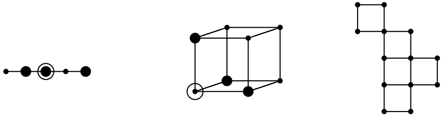

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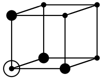

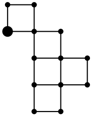

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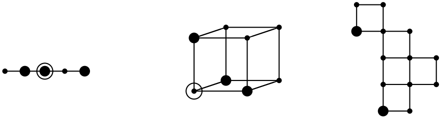

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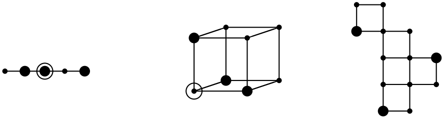

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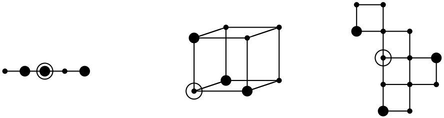

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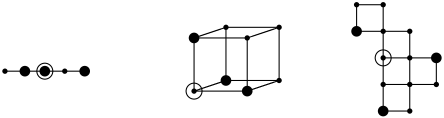

Special cases: Moulin 1980, Demange 1982, Barberá, Sonnenschein & Zhou 1991, Barberá, Gul & Stacchetti 1993

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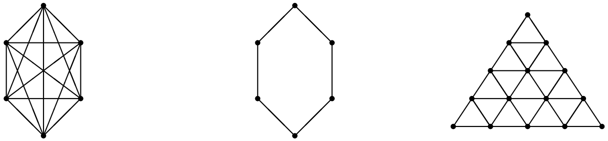

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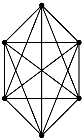

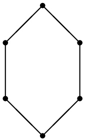

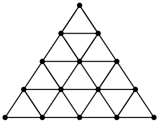

Special cases: Gibbard-Satterthwaite, Schummer & Vohra 2002

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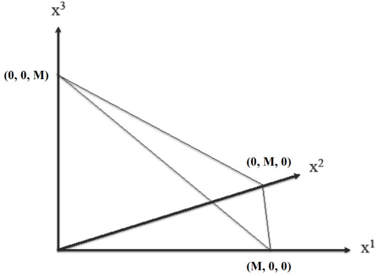

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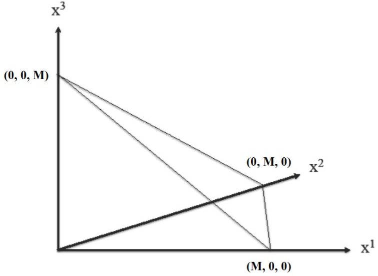

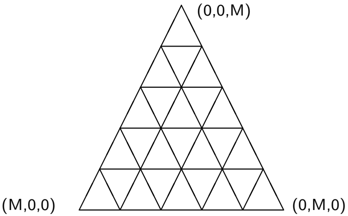

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Corollary (from Impossibility Theorem)

If $L \geq 3$, then all strategy-proof allocation mechanisms are dictatorial, **even if** *one restricts the domain to sufficiently rich sets of 'generalized single-peaked' preferences (e.g. Euclidean, Cobb-Douglas, etc.).*

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Observation

The one-dimensional median minimizes the **sum of the distances** *to the individual peaks.*

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where $||\cdot||_1$ is the l_1-distance, i.e.

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- By observation above, median rule chooses usual median if $L = 2$.
- Chooses the coordinate-wise median whenever that is feasible.
- Preference aggregation: 'Kemeny-Young rule' (Young & Levenglick 1978)
- In the general judgement aggregation model: Nehring & Pivato (2014a-c)

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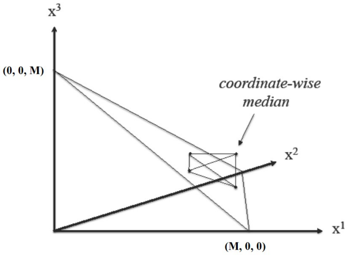

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Single-valued selections: Take any fixed allocation $\tilde{x} \in X$, and choose median allocation with minimal *Euclidean* distance to $\tilde{x}$.

Strategy-Proof?

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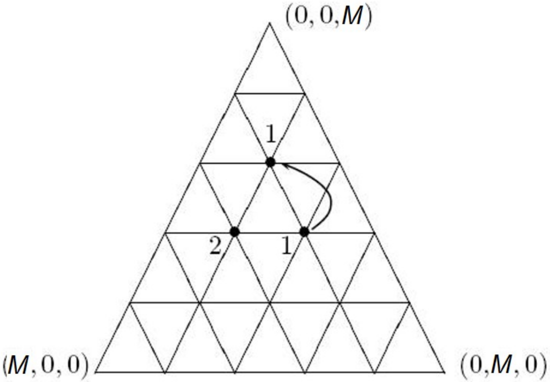

Theorem

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The (single-valued) median rule is strategy-proof *on the domain of all preferences admitting a utility representation of the form $u(x) = -||x - x^*||_1$, for some $x^* \in X$ (the peak).*

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Agenda

1. General Motivation
2. Generalized Single-Peakedness
3. Resource Allocation
   - Theory
   - Simulation

Simulation Study (with Tobias Lindner)

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- Peaks randomly drawn from Dirichlet distribution.
- Voters play myopic best response in random sequence ...
- ... under Cobb-Douglas preferences.
- Maximal 15 iterations with ...
- ... sample size 10.000.
- **Parameters:**
  - rule (mean vs. median),
  - number of voters,
  - number of goods,
  - budget size.

Simulation Study: Results

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Extent of Manipulation:

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Table: Number of agents = 5

	No. of Revisions	Max. Utility Gain	Manipulating Agents
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Table: Number of agents = 45

	No. of Revisions	Max. Utility Gain	Manipulating Agents
Mean	53.09	1.87%	100.00%
Med	58.09	0.78%	39.05%

Simulation Study: Results

Effect of Manipulation

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Effect of Manipulation

Table: Number of agents = 5

	Deviation	Distance of Outcome	Welfare Loss
Mean	39.28%	7.38%	1.60%
Med	4.86%	4.51%	1.05%

Simulation Study: Results

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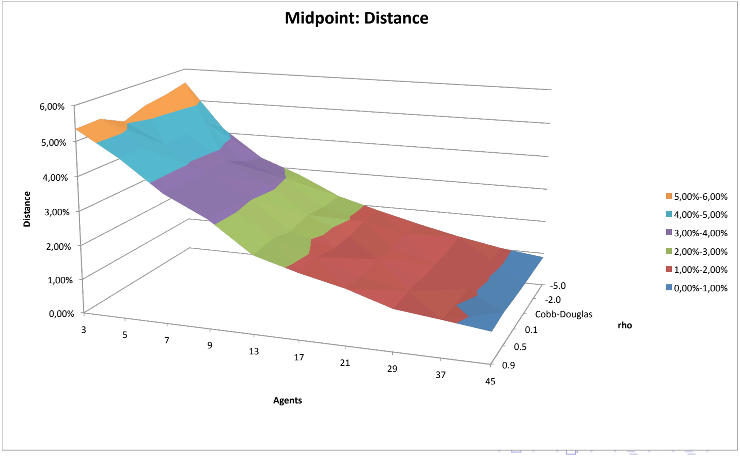
Table: Number of agents = 45

	Deviation	Distance of Outcome	Welfare Loss
Mean	43.09%	5.73%	1.02%
Med	2.96%	0.88%	0.20%

Simulation Study: Effect of Manipulation with CES



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Thanks for your attention!!