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Allocation policies, participation behavior and social welfare in Platform Economy

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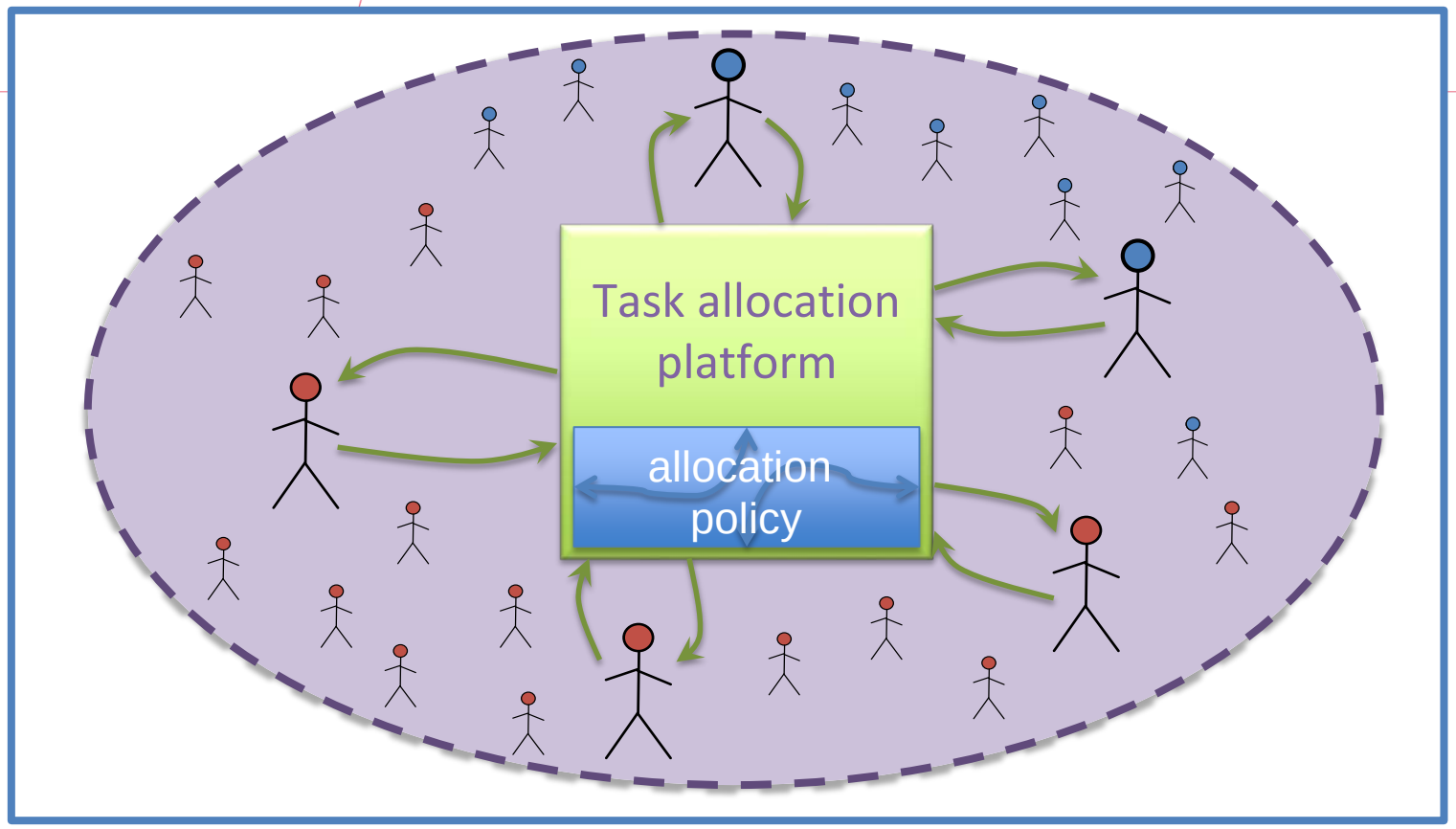
A research case study

- Expansion of the Port of Rotterdam with Maasvlakte 2 will increase inter terminal transport (ITT)
- Asset light: *Use existing trucks at the port to do ITT jobs*

A task allocation platform

Repeated task allocation in a round *r*:

- Auctioneer (platform owner) announces available tasks
- Agent (company) decides whether to participate
- If she participates, she submits bid based on availability and costs
- Auctioneer decides on task allocation and compensation

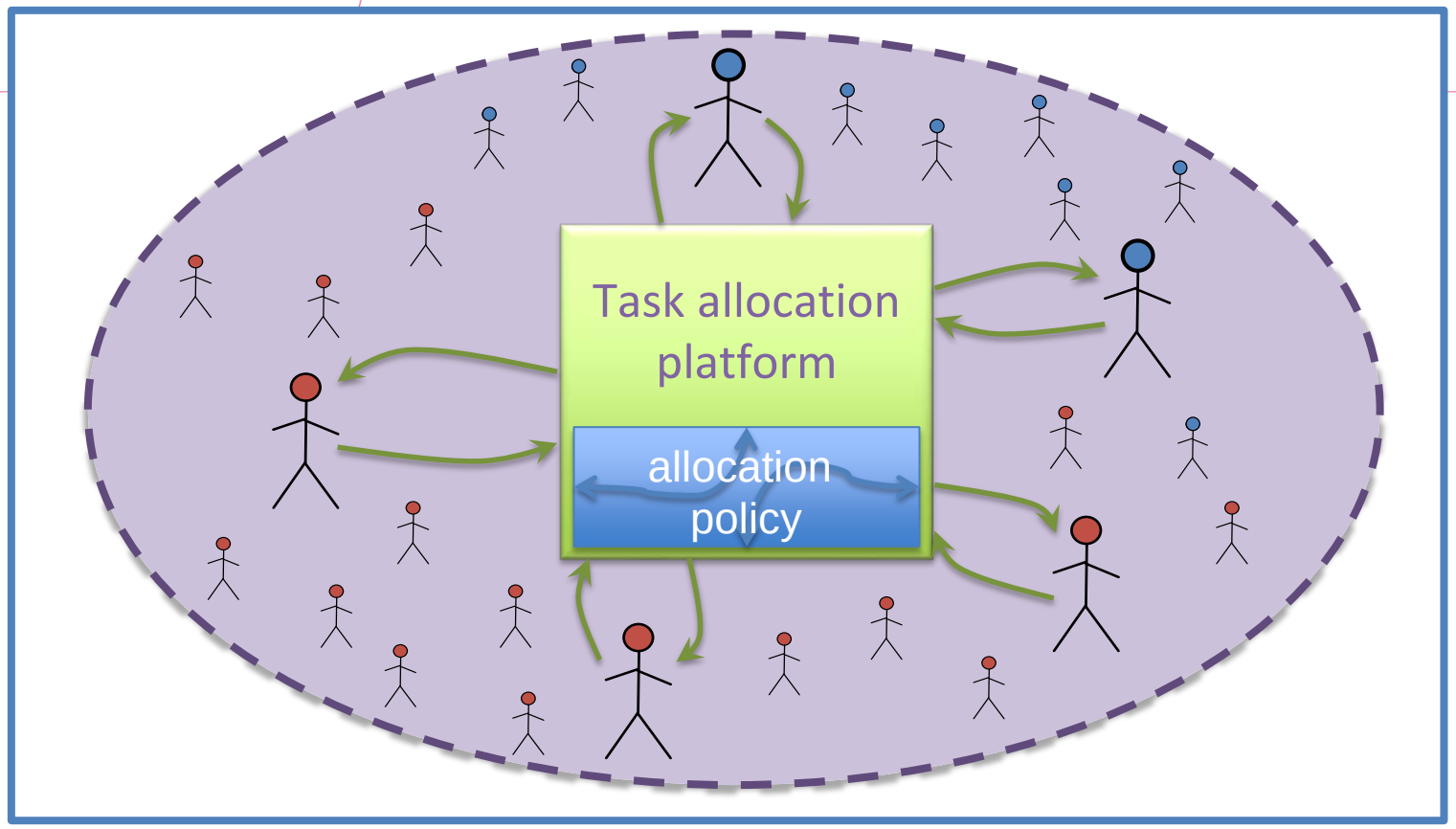


Policy 1: Cost minimization allocation

– Optimize for platform; widely used in “traditional” markets

Policy 2: Fair, cost minimization allocation

- Take into account incentive of participation
- Optimize for all parties



Two steps:

1. *Allocation policy: algorithm design*
2. *Evaluating policies: agent based modelling and simulation*

Step 1: task allocation

- Inputs:
  - Tasks with finite time windows
  - Companies that own trucks
    - agents with available resources during given time periods, incurring costs for doing tasks
- Output: an allocation of tasks among companies with optimization objectives

- Policy 1: *Minimizing cost with maximized number of allocated tasks -> using existing (max-flow min-cost) algorithms*

Policy 2: Fair, cost minimization allocation

- Additional desired property: fairness
- Optimization objectives:
  - number of allocated jobs is maximized
  - allocation is fair (max-lexmin fair) to the participating companies
  - total cost is minimized

Example: 5 time periods (t1-t5), 5 jobs (J1-J5), 3 companies (k1,k2,k3), 1 truck per time period per company

	k1	k2	k3
J1	t1 : 20	t1 : 30	t1 : 10
J2		t2 : 40	t2 : 20; t4 : 30
J3		t2 : 25	t2 : 20; t3 : 25
J4			t3 : 25; t4 : 20
J5			t5 : 20

- Cost minimization solution: J3 → **k2**, {J1, J2, J4, J5} → **k3**
  - cost: 25+10+20+20+20=95, *Job distribution: (0, 1, 4)*
- Fair solution: J1 → **k1**, J2 → **k2**, {J3, J4, J5} → **k3**
  - cost: 20+40+25+20+20=125, *Job distribution: (1, 1, 3)*
- Best fair (fair and min-cost) solution:
  J1 → **k1**, J3 → **k2**, {J2, J4, J5} → **k3**
  - cost: 20+25+20+20+20=105, *Job distribution: (1, 1, 3)*

Example: 5 time periods (t1-t5), 5 jobs (J1-J5), 3 companies (k1,k2,k3), 1 truck per time period per company

- **No existing algorithms for policy 2**
- **Our key result:**

  Exponential many allocations,
  but polynomially solvable
  using our proposed algorithm!

Fair task allocation in transportation, by Ye, Zhang, and Dekker, Omega. Volume 68, Pages 1-16. 2017
(Best paper award for 2017)

- Best fair (fair and min-cost) solution:
  J1 → **k1**, J3 → **k2**, {J2, J4, J5} → **k3**
  - cost: 20+25+20+20+20=105, *Job distribution: (1, 1, 3)*

Step 2: evaluate allocation policies

1. *Allocation policy: algorithm design for task allocation*
2. Evaluating policies

    1. How two policies perform in terms of total cost (i.e., social welfare), assuming all companies are participating?

    2. How two policies perform in terms of (long term) social welfare, if companies have different participation behaviours?

Experiments

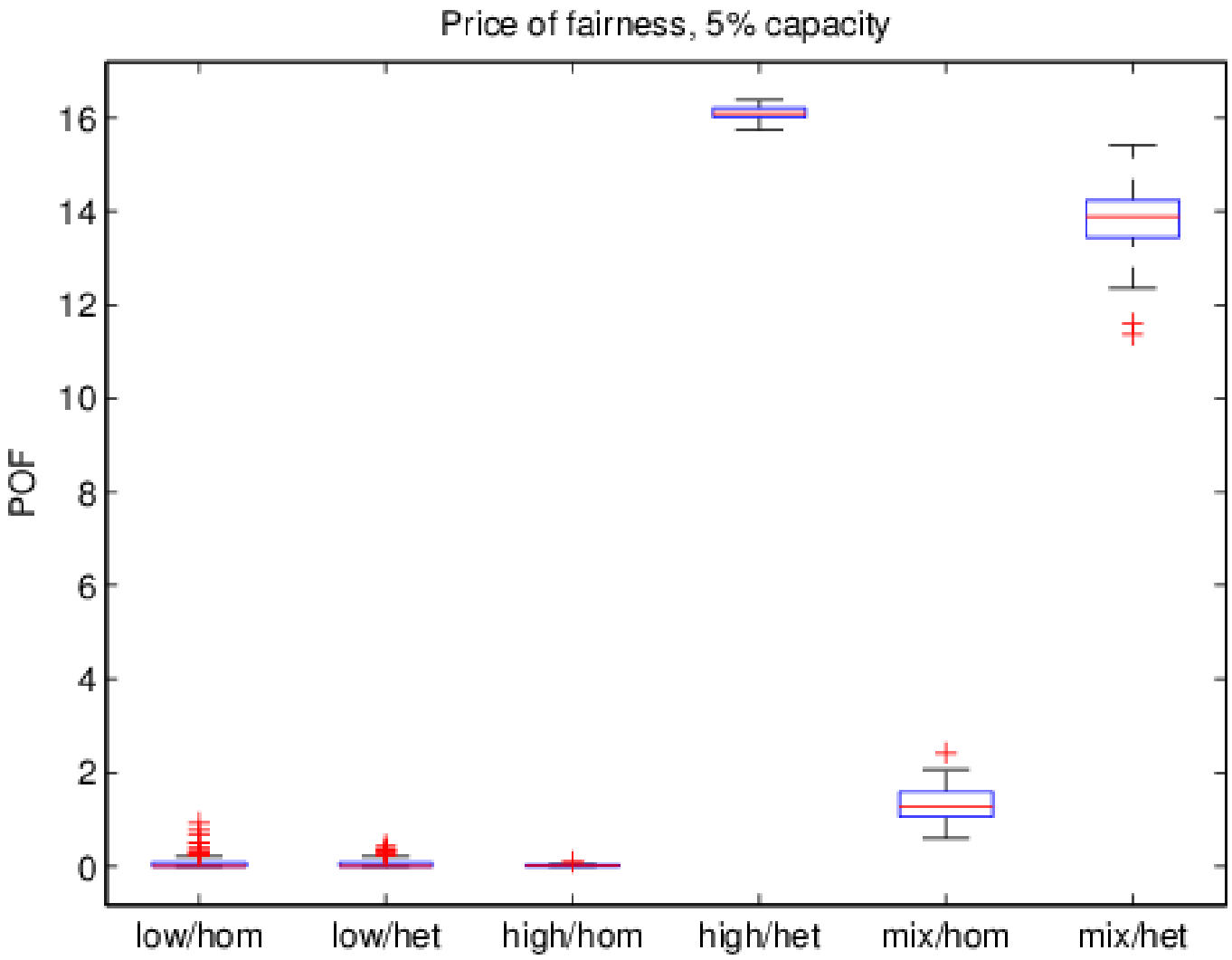
- Market: 50 companies, 250 jobs
- Various market conditions:
  - different scenarios (high, low competition) on available resources (trucks)
  - different scenarios (homogeneous, heterogeneous) on their costs
- What is the extra cost (of the platform owner) by using allocation policy 2, instead of policy 1?

  Price of fairness: $POF = \frac{TC(\text{MFMCA}) - TC(\text{MC})}{TC(\text{MC})}$

TC(MFMCA): total cost of policy 2

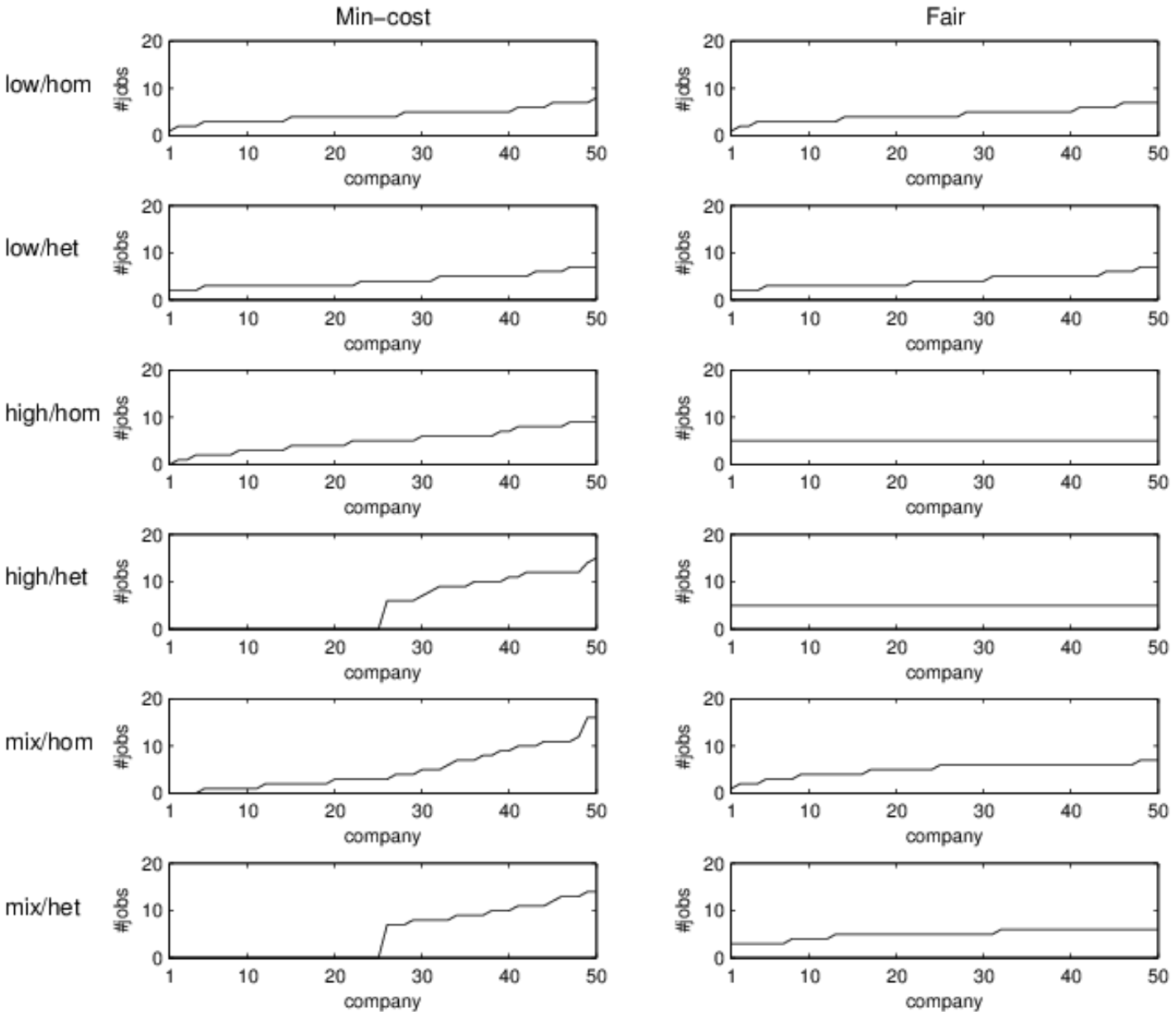
TC(MC): total cost of policy 1

Price of fairness



POF:
0-20%

Task distribution among companies



Evaluate two policies, with participation behaivor

1. *Allocation policy: algorithm design for task allocation*
2. *Evaluating policies*
   - *How two policies perform in terms of total cost, assuming all companies are participating?*
   - How two policies perform in terms of (long term) total cost, if companies have different participation behaviours?

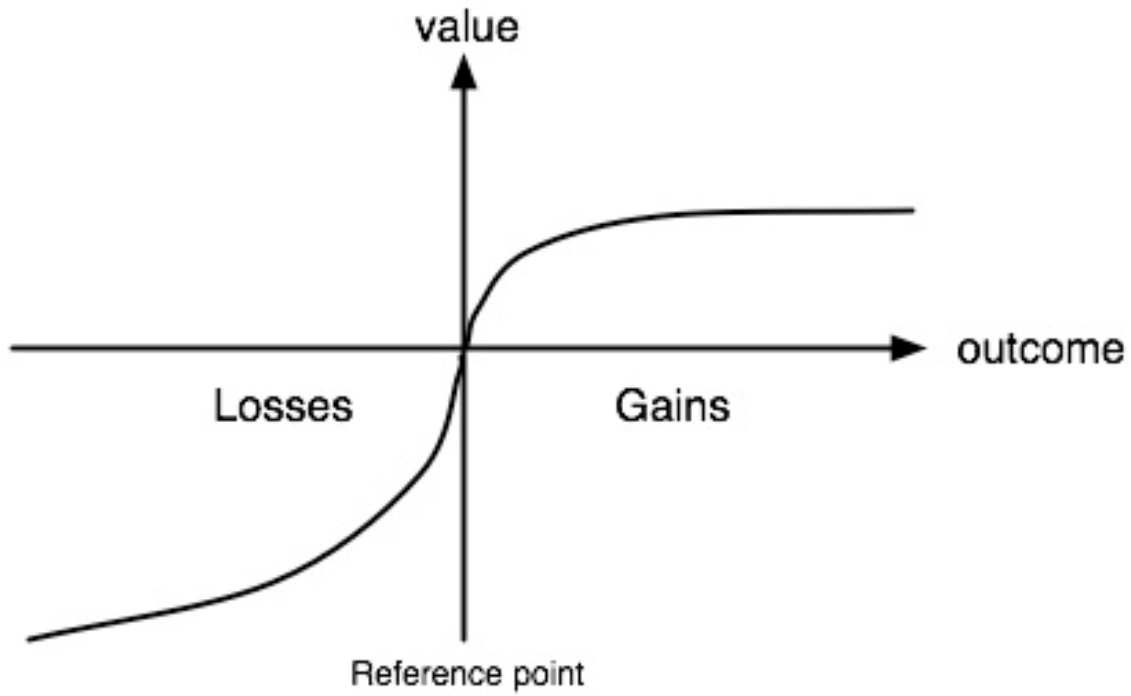
Evaluate two policies, with participation behaivor

- Agent based modelling and simulation (ABMS)
  - agents: different parties/players, possibly with different interests and behaviors

- In ABMS, we model agents' participation behavior
  - Their behaviors are influenced by the allocation outcomes
  - Their behaviors also influence the allocation outcome of future rounds

Agent behavioral model

- Agent's behavior (i.e., participation probability) is dependent on experiences in previous rounds.
- Model agent's participation decision using ***prospect theory (or "loss-aversion" theory)***



Agent based simulation

- Simulate 50 rounds of the allocation game
- Measurements:
  - *participation* of agents over time
  - *social welfare* (i.e., total cost) over time
- Compare two policies

  cost-minimization vs. *fairness*

Participation behavior and social welfare in repeated task allocations, by Ye and Zhang. IEEE International Conference on Agents. pp 94-97, 2016

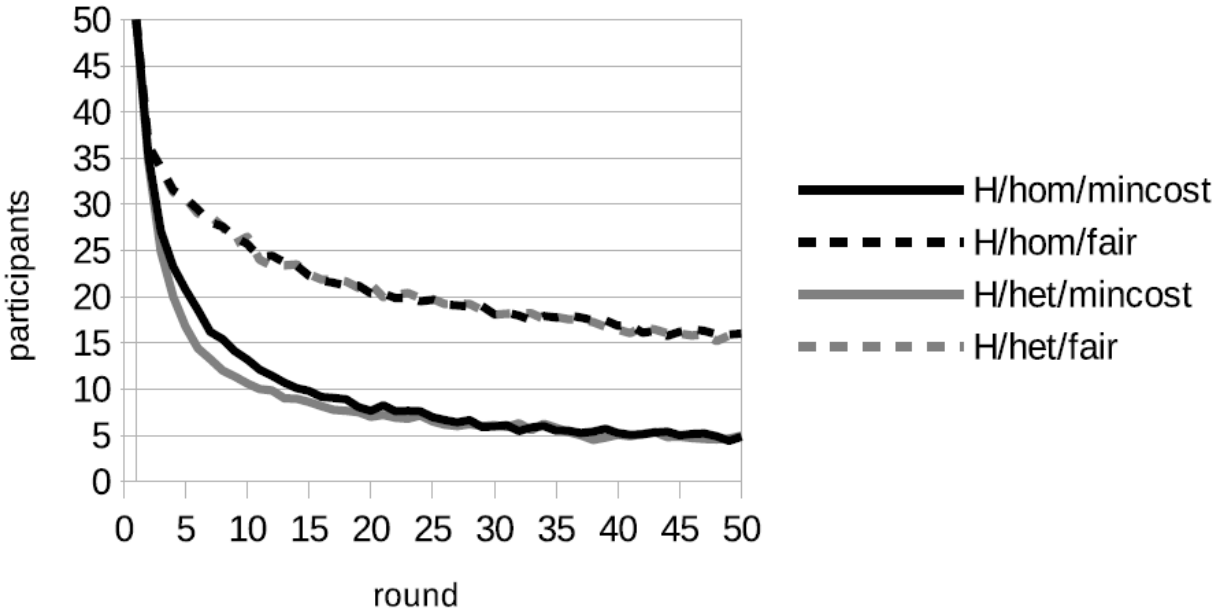
Modeling participation behavior in repeated task allocations with fuzzy connectives, by Ye, Zhang and Kaymak. IEEE International Conference on Systems, Man, and Cybernetics, pages 3219-3224, 2017

Fairness may suppress social welfare in a single round, but in long run:

- more allocated jobs
- more participants
- increased social welfare

Both platform and participants benefit!

Average number of participants per round with high competition



Average social welfare per round with high competition