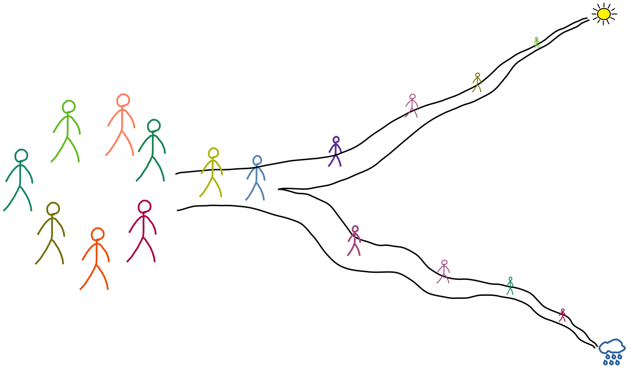
Public Projects with Preferences and Predictions[1]



Bo Waggoner
University of Colorado, Boulder

ESSET, Gerzensee
July 2024

[1] Based on joint work with Mary Monroe. Supported by the Ethereum Foundation.

Inspiration: blockchain governance

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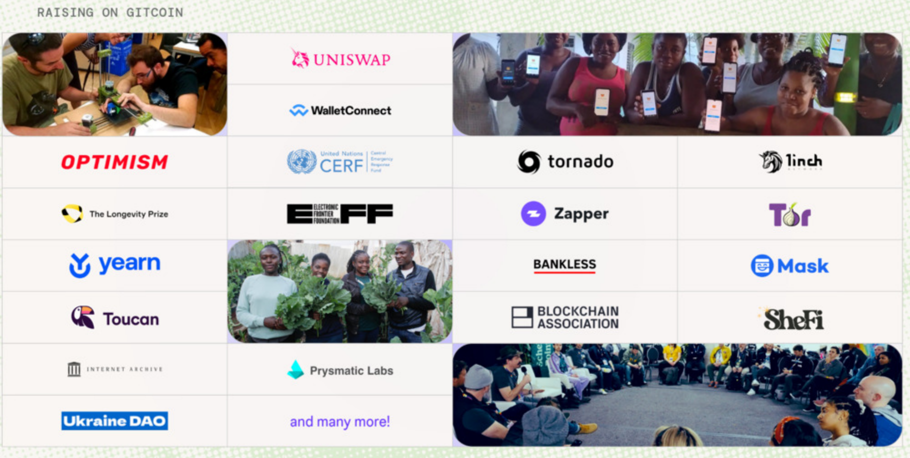
Gitcoin (2017-):

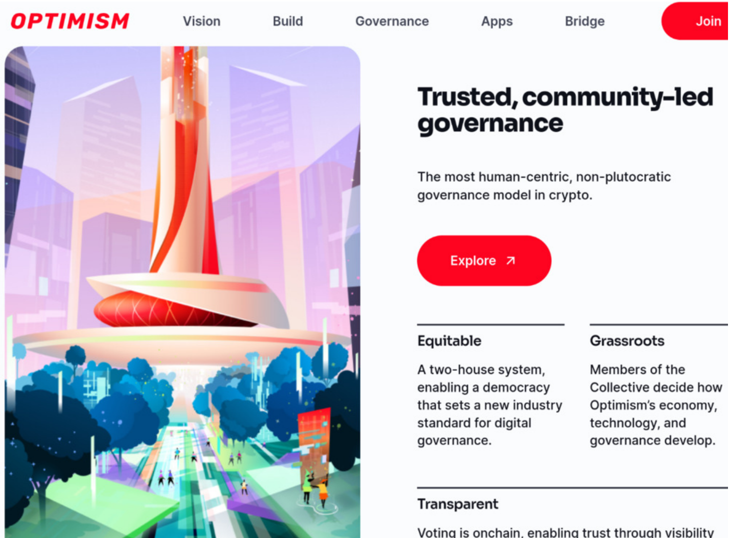
- $\$60$M distributed
- Uses "quadratic funding" donation-matching



Inspiration: blockchain governance

Layer 2's and platforms:

- e.g. Uniswap (2018-), Arbitrum (2018/2021-), Optimism (2019-)



Inspiration: blockchain governance

Layer 2's and platforms:

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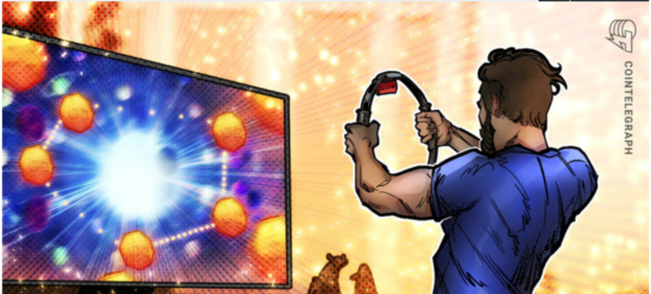
AMAKA NWAOKOCHA JUN 09, 2024

Arbitrum to distribute $215M in ARB tokens for gaming innovation

Initially introduced in March, the proposal was approved on June 7, with over 75% of votes in favor.

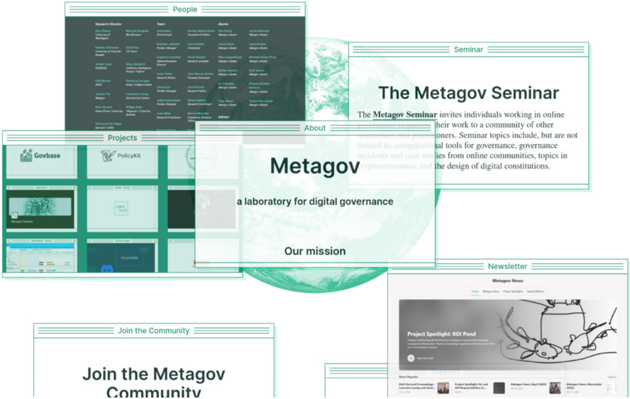
8092 Total views 10 Total shares Listen to article 0:00



Inspiration: blockchain governance

Non-mechanism design governance research, e.g. at CU Boulder:

- Nathan Schneider: co-ops perspective, e.g. Metagov
- Eric Alston: government & corporation perspective, e.g. constitutions



Paradigms for group decisionmaking

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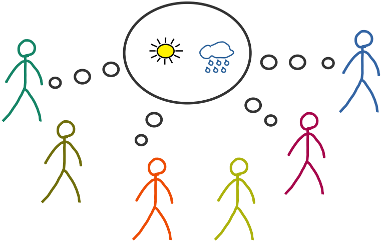
aggregate
preferences

Paradigms for group decisionmaking

aggregate preferences

aggregate information



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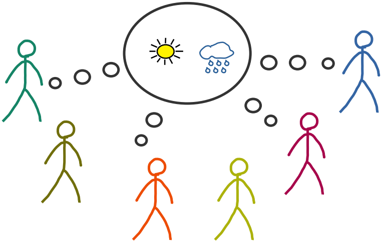

Can a formal mechanism **do both**?

Paradigms for group decisionmaking

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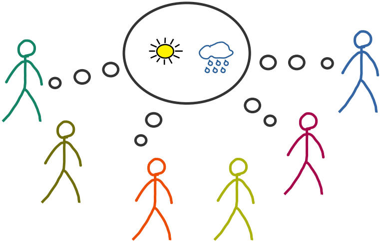
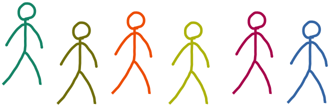


Can a formal mechanism **do both**?

Hanson ("futarchy", 2000; 2007); Schoenebeck and Tao (2021); Amanatidis, Birmpas, Lazos, and Marmolejo-Cossío (2022)

Setting: public projects with organizational mission

voters



mission

e.g. minimize
carbon footprint

Setting: public projects with organizational mission

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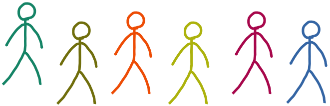
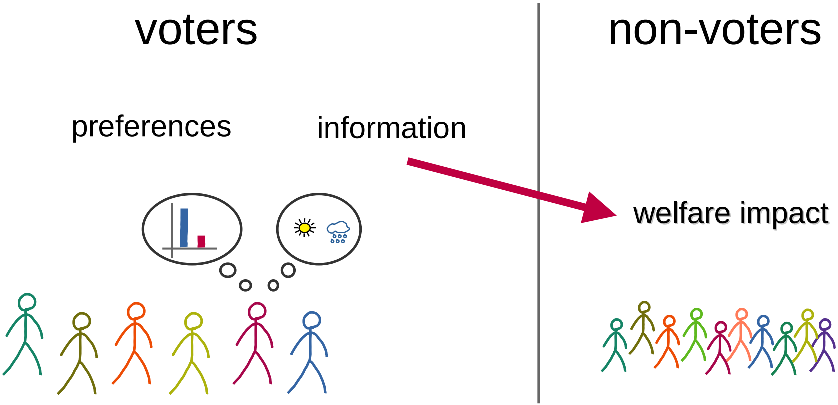


non-voters

welfare impact

Setting: public projects with organizational mission



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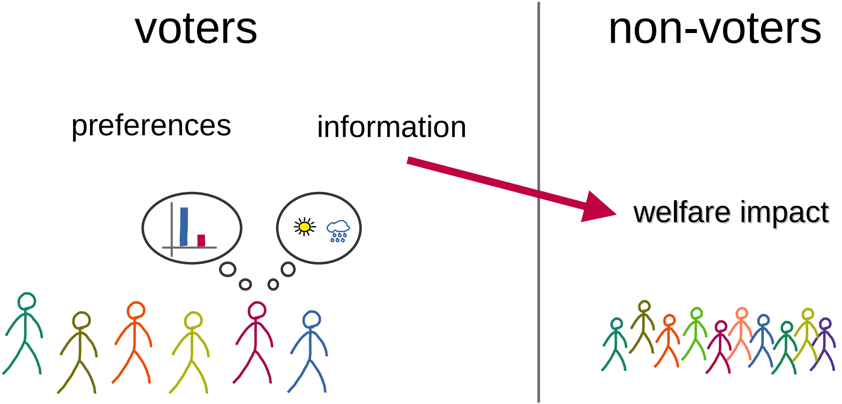

Goal: welfare guarantees ("Price of Anarchy")

Outline:

1. Public Projects from preferences
2. Public Projects from predictions
3. Public Projects with preferences and predictions

Outline:

1. **Public Projects from preferences**
   - Model, definitions
   - Related work: VCG, QTM
   - Our results: QTM
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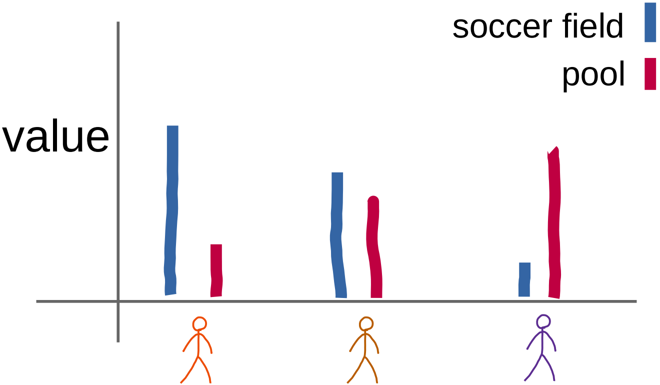
3. Public Projects with preferences and predictions

Public projects: model

Each agent i has a value v_k^i for each option k *nonnegative*



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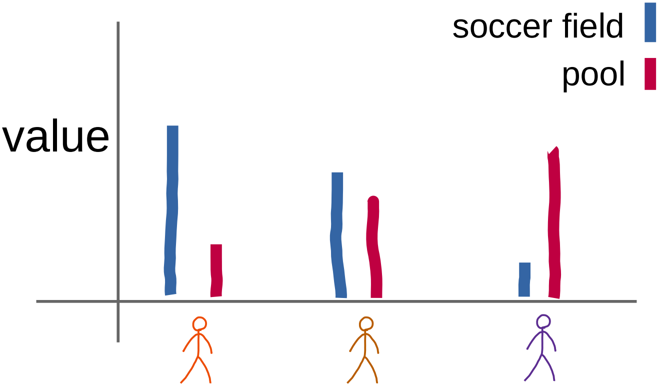

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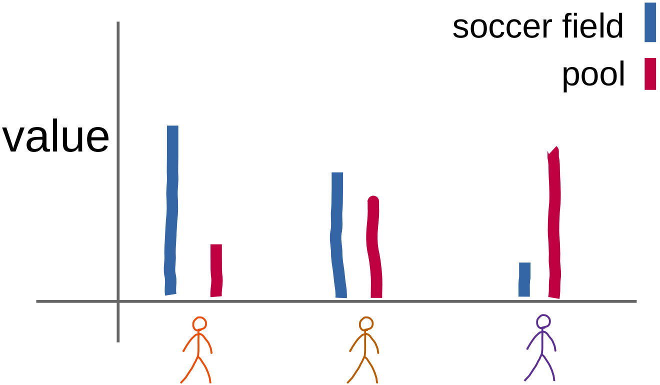
- Mechanism: collect reports, pick an alternative k, assign payments



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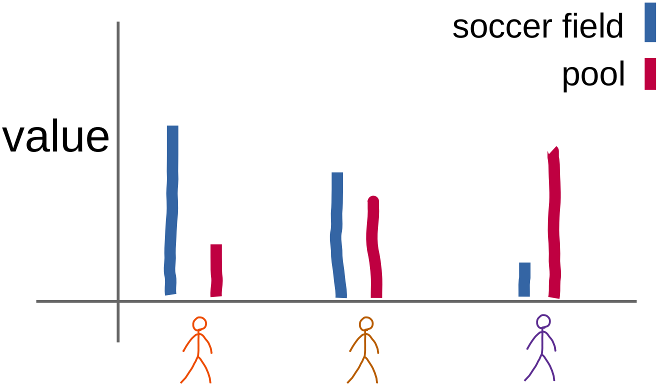
- Net utility of agent i: $v_k^i -$ payment *quasilinear*



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Price of Anarchy

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$$\frac{\mathbb{E}[V_k]}{\max_{k'} V_{k'}}$$

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$$\textbf{Price of Anarchy} = \min_{\text{equilibria}} \frac{\mathbb{E}[V_k]}{\max_{k'} V_{k'}}$$

our mechanisms: pure-strategy Nash equilibria
(convex strategy space, strictly concave utilities)

Related work

- **VCG mechanism:** Price of Anarchy $= 0$ *efficient equil. exists*
  Not budget-balanced, revenue unstable

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- **"First-price":**[2] Price of Anarchy $\to 0$ *but sequential model:* $= 1$

- **Quadratic Transfers Mechanism:**[3]
  In an i.i.d. model, Price of Anarchy $\to 1$
  as population grows large

[2] Lucier, Singer, Syrgkanis, Tardos (2013)
[3] Eguia, Immorlica, Ligett, Weyl, Xefteris (2019; 2023).

Quadratic Transfers Mechanism (QTM)[4]

Agent i submits votes $\{a_k^i\}$

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Agent i submits votes $\{a_k^i\}$ and pays $c\sum_k (a_k^i)^2$ *$c =$ a parameter*

can redistribute payment to all others $\implies$ budget-balanced

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Pick $k = \arg\max A_k$ (?)

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~~*Pick* $k = \arg\max A_k$ *(?)*~~

Pick $k \sim \mathbf{p}$ randomly where *"soft max"*

$$p_k = \frac{e^{A_k}}{e^{A_1} + \cdots + e^{A_m}}.$$

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Our results on QTM for public projects

Theorem (Monroe and Waggoner (2024))

Let $v^* = \max_{i,k} v_k^i$ *and* $\epsilon = \frac{v^*}{\max_k V_k}$. $\epsilon =$ "influence"

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For two alternatives, choosing $c = \frac{1}{2} v^*$*, the QTM has*

$$\textit{Price of Anarchy} \geq \max \left\{ \frac{1}{2} \, , \; 1 - (2\epsilon)^{2/5} \right\} .$$

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Notes:

- builds on tools of analogous asymptotic result of Eguia et. al
- 3+ alternatives: PoA $\geq \frac{1}{\#\ \text{alternatives}}$; better is open nonasymptotically.

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   - Prediction markets
   - Decision markets
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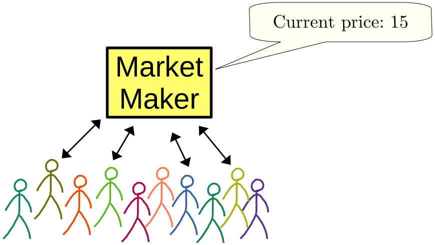
Background: prediction markets

Prediction markets: *all we need today*



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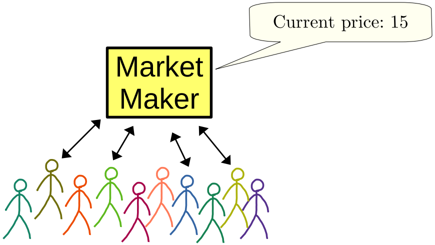

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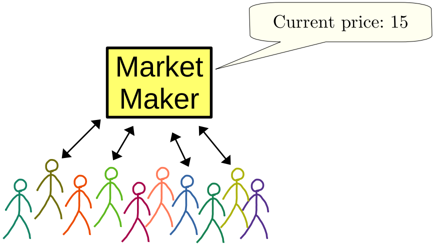

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Ostrovsky (2012): In any equilibrium, all* information is aggregated:

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Alternative: wagering mechanisms

can average the predictions, but aggregation is not guaranteed

Decision markets[5]

Mechanism (pick among m alternatives):

1. Suppose B_k = welfare impact of k *nonnegative, higher is better*

[5] Hanson (1999); Othman and Sandholm (2010)

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Chen et al. (2010): **randomization** + importance weighting $\implies$ truthful

Combine with Ostrovsky (2012): approximately efficient

[5] Hanson (1999); Othman and Sandholm (2010)

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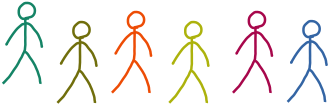
2. Public Projects from predictions
3. **Public Projects with preferences and predictions**
    - Model
    - Mechanism: SQUAP
    - Results
    - Caveats

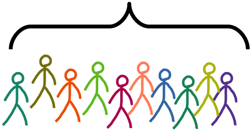
Model

voters



non-voters

total welfare if k: B_k



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private signal about $\{B_k\}$

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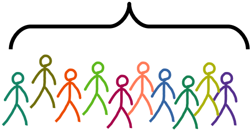

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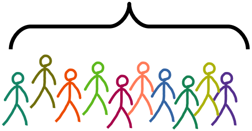

$$W_k := V_k + \mathbb{E}[B_k \mid \text{signals}]$$

total welfare of option k

Related work

VCG+scoring rules mechanism of Cai, Mahdian, Mehta, Waggoner (2013)

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VCG+scoring rules mechanism of Cai, Mahdian, Mehta, Waggoner (2013)

- Each i submits valuation $\{v_k^i\}$ and conditional predictions $\{p_k^i\}$
- Compute $\hat{B}_k = g(\{p_k^i\})$ *assume g component-wise convex*
- Select $k = \arg\max_k \left(V_k + \hat{B}_k\right)$
- Use VCG payments combined with scoring rules *constructed from g*

Exists **fully efficient** equilibrium
assuming you know how to aggregate

but **PoA** $= 0$
inherits VCG weaknesses

Mechanism

Synthetic-Players Quadratic Transfer Mechanism with Predictions (SQUAP):

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- Cancel all conditional markets but k
- Later, observe B_k and pay out k market
  use importance-weighted payment of Chen et. al (2011)

Main result

Theorem (Monroe and Waggoner (2024))

Let $v^* = \max_{i,k} v_k^i$ *and* $\epsilon = \frac{v^*}{\max_k W_k}$.

$\epsilon =$ "influence"

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Assume "markets aggregate information" (A1).

For two alternatives, there is a choice of SQUAP parameters s.t.

$$\textit{Price of Anarchy} \geq 1 - 2\boldsymbol{\epsilon} - (2\boldsymbol{\epsilon})^{2/5}\,.$$

Assumption *(A1)*:

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Assumption *(A1)*:
market converges to $\mathbb{E}[B_k \mid \text{signals}]$, then manipulation occurs
or: markets aggregate information off the equilibrium path
or: nobody has **exclusive** *private information*

Main result

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Assume "markets aggregate information" (A1).

For two alternatives, there is a choice of SQUAP parameters s.t.

$$\textit{Price of Anarchy} \geq 1 - 2\epsilon - (2\epsilon)^{2/5}.$$

Key intuitions (manipulation doesn't hurt much):

- Manipulating predictions is more costly than manipulating votes
- Importance weights: manipulation does not improve market payouts

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Notes:

- Can use revenue of QTM to subsidize prediction market, sometimes
  result: QTM revenue $= \Theta($ *"disagreement"* $)$
- Can use wagering instead of prediction markets
  strategically easier, but assume aggregation is possible

The giant caveat

Unfortunately: you can't run SQUAP.

synthetic player needs knowledge of values to find equilibrium

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- For that matter, can agents play QTM?
  just need to respond to vote totals $\{A_k\}$, *mean-field style*
- Possible solution: run process over time with aim of convergence

Proposed variant: given $\hat{B}_1, \hat{B}_2$, collect votes and pick using

$$p_1 = \frac{e^{A_1 + \frac{p_1 p_2}{v^*}(\hat{B}_1 - \hat{B}_2)}}{e^{A_1 + \frac{p_1 p_2}{v^*}(\hat{B}_1 - \hat{B}_2)} + e^{A_2 + \frac{p_1 p_2}{v^*}(\hat{B}_1 - \hat{B}_2)}}.$$

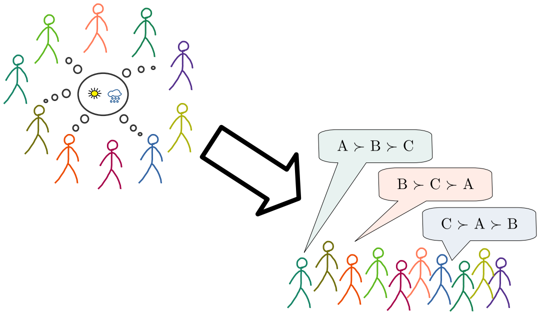
difficult to analyze, involves fixed-point computation

Future work: voters learn their preferences

In our model: Voters had *fixed* preferences.

Ideally: voters adjust preferences in response to aggregated information.[6]

Issue: market manipulation $\implies$ misled voters $\implies$ changed outcome.



[6] See Schoenebeck and Tao (2021)

End

Summary:

- Decisions should aggregate both preferences and information
- Proposed SQUAP, combining prediction markets and quadratic voting
- Proved Price of Anarchy bounds (under impractical assumptions)

Open:

- Analysis of “practical SQUAP”
- Better synthesis of information and preference aggregation
- Role of such mechanisms in a governance structure
- Can organizations avoid capture?

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Thanks!