Designing Frugal Best-Response Mechanisms for Social Network Coordination Games

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joint work with
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# The Paris university jungle

## Within Paris
1. Pantheon-Sorbonne  
2. Pantheon-Assas  
3. Sorbonne Nouvelle  
4. Paris-Sorbonne  
5. Paris Descartes  
6. UPMC  
7. Paris Diderot  
8. Paris Dauphine

## In the surroundings
9. Vincennes  
10. Nanterre  
11. Paris-Sud  
12. Val de Marne  
13. Paris Nord  
14. Versailles  
15. Evry

## Grand Ecoles
16. ENS Paris  
17. ParisTech  
18. ECP  
19. Sciences Po  
20. HEC Paris  
21. ESCP Europe  
22. ESSEC  
23. ISC Paris

and many others...
Do not fear!

Geographically Coherent Pools

- Paris Sciences-Lettres (PSL)
- University Paris-Saclay (UPSa)
Joining a pool: PROS and CONS

**PROS**

- Improving international valuation
- Fixing organizational deficiencies
Joining a pool: PROS and CONS

**PROS**

- Improving international valuation
- Fixing organizational deficiencies

**CONS**

- Changing location
Which pool? PSL or UPSa?

An university social network

The role of scientific relationship

- Better scientific cooperation
- Possible joint research project
- Common teaching programs
The goal

To maximize the welfare of Paris university system
The goal

To maximizes the welfare of Paris university system

How?
Force the universities to join a specified pool
The goal

To maximizes the welfare of Paris university system

How?
Force the universities to join a specified pool  NO COST!
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But...
Universities join a pool only sequentially and after long bargaining
The goal

To maximize the welfare of Paris university system

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But...
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Can we use this intrinsically dynamical process to induce the optimal pools?
Social network games

- players as nodes of a social network
Social network games

- players as nodes of a social network
- to each edge $e = (i, j) \in E$ is linked a two-player game $G_e$
Social network games

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- each strategy $s_i$ has a preference cost $p_i(s_i)$ for player $i$
Social network games

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  - costs arising from $G_e$ are called communication costs
- each strategy $s_i$ has a preference cost $p_i(s_i)$ for player $i$
- total cost $= \text{communication cost} + \text{preference cost}$
Two-strategy social coordination games

A social network game with...

- only two strategies, 0 and 1, for player
- $G_e$ is a coordination game

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$\beta_k^e(b) \geq \alpha_k^e(b') \geq 0$
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Properties

- computing social optimum is easy
- an equilibrium always exists
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- unbounded PoA and $PoS > 1$
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Properties

- computing social optimum is easy
- an equilibrium always exists
- unbounded PoA and PoS $> 1$
  - We need a mechanism for inducing optimum
Mechanism + Dynamism = Best-response mechanism

Best-response mechanism [Nisan et al., ICS 2011]

- Starting from an arbitrarily given profile...
- At each time step $t$
  - a subset of players is selected
  - each selected player announces her best-response strategy
- The process ends when a Nash equilibrium has been reached
- Players’ payoffs are evaluated only after the process ends
Mechanism + Dynamism = Best-response mechanism

Best-response mechanism [Nisan et al., ICS 2011]

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Examples

- Ascending-price auctions
- Border Gateway Protocol (BGP)
Best-response mechanism & NBR-solvable games

It models dynamical bargaining among agents but...
Best-response mechanism & NBR-solvable games

It models dynamical bargaining among agents but...

- Why should players play best-response?
Best-response mechanism & NBR-solvable games

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NBR-solvable games with clear outcome

Games for which a Nash equilibrium is

- computable by iterated elimination of never best-response
- the best profile for a player when she eliminate her strategies
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A best-response mechanism for an NBR-solvable game with clear outcomes terminates and is incentive compatible
The mechanism for social network games

- Social network games are not NBR solvable
The mechanism for social network games

- Social network games are not NBR solvable

Use monetary incentive or tolls for transforming the game in an NBR-solvable game with clear outcomes
The mechanism for social network games

- Social network games are not NBR-solvable
- If the player plays the desired strategy
  - Pay the communication costs in her place
  - Assigns a (possible negative) fee

Use monetary incentive or tolls for transforming the game in an NBR-solvable game with clear outcomes
The mechanism for social network games

- Social network games are not NBR-solvable
- If the player plays the desired strategy
  - Pay the communication costs in her place
  - Assigns a (possible negative) fee
- total cost(desired strategy) = fee + preference cost
- total cost(otherwise) = communication + preference costs

Use monetary incentive or tolls for transforming the game in an NBR-solvable game with clear outcomes
Example

Preference costs

- For players $i_0$ and $i_2$ strategy 1 costs 3
- For players $i_1$ and $i_3$ strategy 0 costs 3

Game $G$

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A best-response mechanism

- Optimum is $(0, 0, 0, 0)$ and costs $10 + 6$
#### Example

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**A best-response mechanism**

- Optimum is $(0, 0, 0, 0)$ and costs $10 + 6$
- $t = 1$: selected $i_1$. Fee $\gamma_{i_1} = -2$. 
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- $t = 3$: selected $i_2$. Fee $\gamma_{i_2} = 0$
Cost of mechanism

Cost of mechanism $C = \text{Communication costs} - \text{fees}$

- $C > 0$: implementing mechanism is expensive
- $C < 0$: players pay more than in the optimum
- $C = 0$: OK
Authority with a limited budget

The problem

If the authority has no budget, then she cannot pay the fees
Authority with a limited budget

The problem
If the authority has no budget, then she cannot pay the fees

How to solve?
- Compute a specific order $\pi$ in which fees should be assigned
- Assign a fee to player $i$ only if fees has been assigned to each player $j$ preceding $i$ in $\pi$

Compute fees and order such that the mechanism has a non-positive cost at each time step (and null cost at the end)
Authority with a limited budget

Example

Game $G^*$

\[
\begin{array}{ccc}
0 & 1 \\
\hline
0 & 1,1 & 11,11 \\
1 & 11,11 & 1,1 \\
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Preference costs
- $p_{i_0}(1) = p_{i_2}(1) = 3$
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- Consider fees $(2, -1, 10, -1)$ and order $(i_0, i_1, i_3, i_2)$
Authority with a limited budget

Example

Game $G^*$

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0 & 1,1 & 11,11 \\
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Game $G$

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Preferences costs

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- $t = 1$: selected $i_1$. Do nothing.
Authority with a limited budget

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- Consider fees $(2, -1, 10, -1)$ and order $(i_0, i_1, i_3, i_2)$
- $t = 1$: selected $i_1$. Do nothing.
- $t = 2$: selected $i_0$ and $i_3$. Fees $\gamma_{i_0} = 2$. 
Authority with a limited budget

Example

Game $G^*$

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Preference costs

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Authority with a limited budget

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- $t = 3$: selected $i_2$. Do nothing.
- $t = 4$: selected $i_i$. Fees $\gamma_{i_1} = -1$
Order-Freeness

The problem

- Players $i_0$ and $i_2$ are symmetric
- $i_0$ pays 2 and $i_2$ plays 10
- Players envy each other
Order-Freeness

The problem

- Players $i_0$ and $i_2$ are symmetric
- $i_0$ pays 2 and $i_2$ plays 10
- Players envy each other

The fees should not depend on the order
Collusion-resistant mechanism

No subset of players has incentive to jointly deviate even if side payments are allowed
Summarizing

Desiderata

- Given a two-strategy social coordination game...
- We want to compute fees and an order so that...
Summarizing

Desiderata

- Given a two-strategy social coordination game...
- We want to compute fees and an order so that...
  - the resulting game is NBR solvable
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  - at each time step the cost of the mechanism is non-positive
Summarizing

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  - the final cost of the mechanism is null
  - at each time step the cost of the mechanism is non-positive
  - the fees do not depend on the order
  - no subset of players jointly deviate (even with side payments)
Does this mechanism always exist?

Base value

Maximum fee that makes dominant the optimum
Does this mechanism always exist?

Base value

Maximum fee that makes dominant the optimum

- Sum of base values ≥ Sum of original communication costs
Does this mechanism always exist?

Base value
Maximun fee that makes dominant the optimum
- Sum of base values $\geq$ Sum of original communication costs
- Base values can be easily computed
Does this mechanism always exist?

**Base value**
Maximum fee that makes dominant the optimum

- Sum of base values $\geq$ Sum of original communication costs
- Base values can be easily computed

**Fees:** Assigns the base values

**Order:** Schedule the players with a positive base value at beginning
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- Base values: $(6, -1, 6, -1)$
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1,1</td>
<td>11,11</td>
</tr>
<tr>
<td>1</td>
<td>11,11</td>
<td>1,1</td>
</tr>
</tbody>
</table>

Game $G$

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1,1</td>
<td>2,2</td>
</tr>
<tr>
<td>1</td>
<td>2,2</td>
<td>1,1</td>
</tr>
</tbody>
</table>

Preference costs

- $p_{i_0}(1) = p_{i_2}(1) = 3$
- $p_{i_1}(0) = p_{i_3}(0) = 3$

- Base values: $(6, -1, 6, -1)$
- To any order corresponds a mechanism (order-freeness)
Example

Game $G^*$

\[
\begin{array}{ccc}
0 & 1 \\
0 & 1,1 & 11,11 \\
1 & 11,11 & 1,1 \\
\end{array}
\]

Game $G$

\[
\begin{array}{ccc}
0 & 1 \\
0 & 1,1 & 2,2 \\
1 & 2,2 & 1,1 \\
\end{array}
\]

Preference costs

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- To any order corresponds a mechanism (order-freeness)
- The order $(i_0, i_2, i_1, i_3)$ gives non-positive cost at each step
Example

Game \( G^* \)

\[
\begin{array}{c|cc}
0 & 1,1 & 11,11 \\
1 & 11,11 & 1,1 \\
\end{array}
\]

Game \( G \)

\[
\begin{array}{c|cc}
0 & 1,1 & 2,2 \\
1 & 2,2 & 1,1 \\
\end{array}
\]

Preference costs

- \( p_{i_0}(1) = p_{i_2}(1) = 3 \)
- \( p_{i_1}(0) = p_{i_3}(0) = 3 \)

- Base values: \((6, -1, 6, -1)\)
- To any order corresponds a mechanism (order-freeness)
- The order \((i_0, i_2, i_1, i_3)\) gives non-positive cost at each step
- No coalition can jointly deviate
Other results

Fairness

▷ Several and different fairness goals
▷ Hardness results in general cases
▷ Polynomial algorithm for special cases
Other results

Fairness

- Several and different fairness goals
- Hardness results in general cases
- Polynomial algorithm for special cases

Failed extensions

- To non-coordination games
- To more than two strategies
- To non-optimal profiles
Thank you!