Teaming and Competition for Demand-Side Management in Office Buildings

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The Problem

- Significant fraction of electricity consumed by the services sector (29.8%) (source European Environment Agency (2017))
  - Key part comprises office buildings
- User consumption behavior is key factor to be addressed, yet a tricky one
- Multiple factors that influence energy-consumption behavior, and decisions in general – Behavioral Economics try to explain people's behaviors

Our Objectives

1) Change "bad" energy-consumption behaviors at work context
   We employ a **serious-game approach** to maximize user engagement

2) Maximize game potential effectiveness in a sustainable way
   Optimize game parameters
   Maximize energy conservation at the lowest cost for achieving it

3) Investigate potential effectiveness of our game in real settings

The approach

We employed Behavioral Economics (BE), specifically:

- Sensitivity to loss of personal comfort
- Normative social influence
- Desire for teaming
- Mobilization by means of rewards

The Game Setup

- Team competition based on energy-saving performance
- Team scores build on individual performance
- Teams receive a reward that depends on their rank
- Individual performance Δpi for employee i

User's Problem: How should I play?

User utility maximization based on four components:

- Personal discomfort $d_i(\Delta p_i)$
- Societal advantages from conforming to social norms $s_i(\Delta p_i, \Delta p_{-i})$
- Desire for teaming $t(|G_j|)$, $|G_j|$ is size of team j
- Mobilization through rewards $r_i(\Delta p_i, \Delta p_{-i})$

Game Designer's Problem

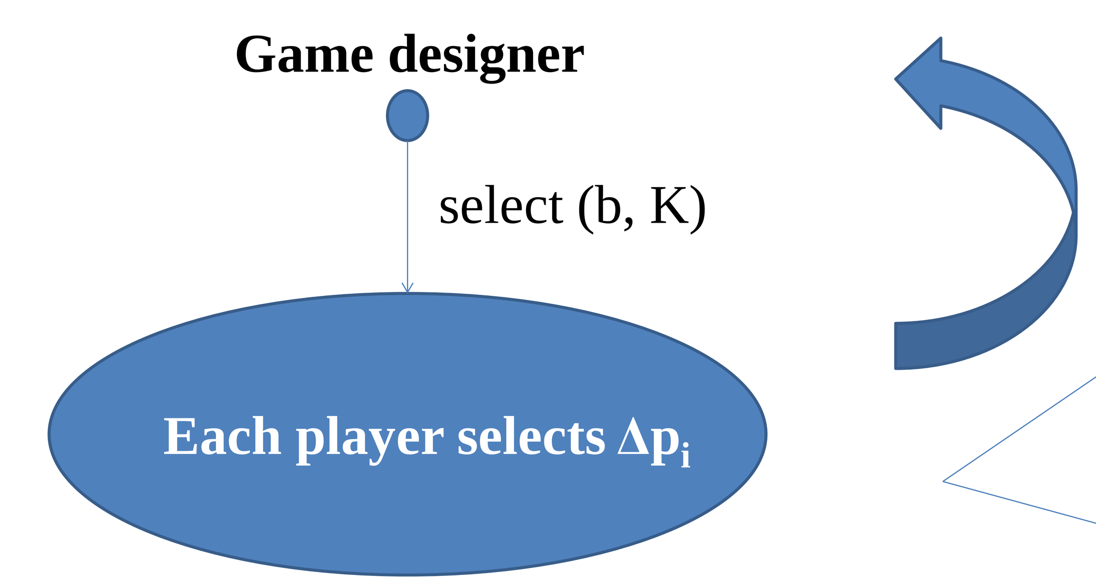
How to split teams and what rewards to give?

Select rewards $\vec{b}$ and number of teams K, so as to maximize total net savings of the building:

$$\max_{\vec{b},K} \sum_{i\in N} p_i^0 \Delta p_i(\vec{b}, K) - B$$

where $B=\Sigma_k b_k$

Stackelberg Game Setting



Competitive GamePlay

Employee *i* chooses Δp_i so as to: $\max_{\Delta p_i} u_i(\Delta p_i, \Delta p_{-i})$

where: $$u_i(\Delta p_i, \Delta p_{-i}) = \frac{1}{3}\left(s_i(\Delta p_i, \Delta p_{-i}) + t_i(|\mathcal{G}_j|) + r_i(\Delta p_i, \Delta p_{-i})\right) - d_i(\Delta p_i)$$

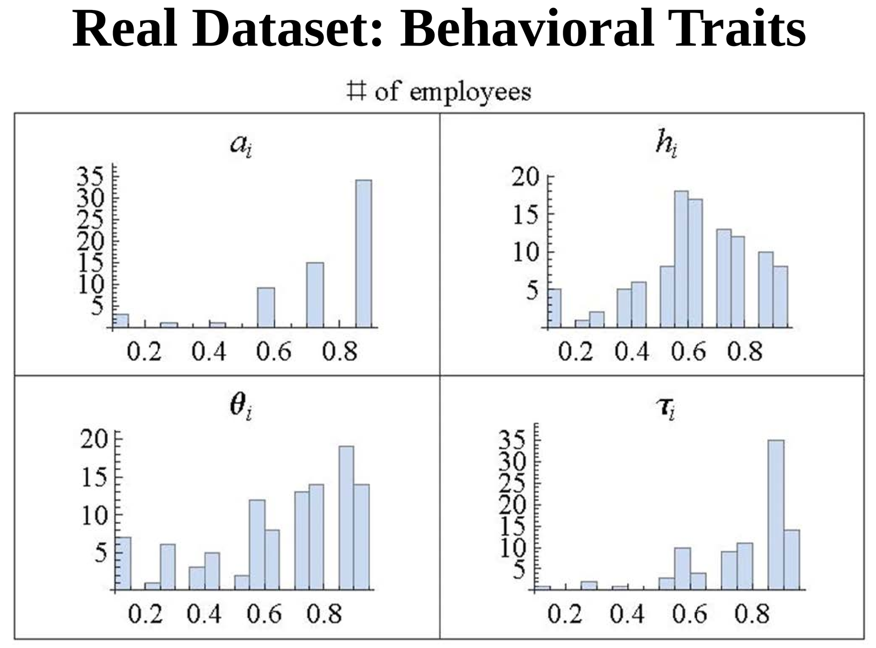
Any competitive equilibrium leads to Pareto-efficient allocation point

Results

Evaluation Setup

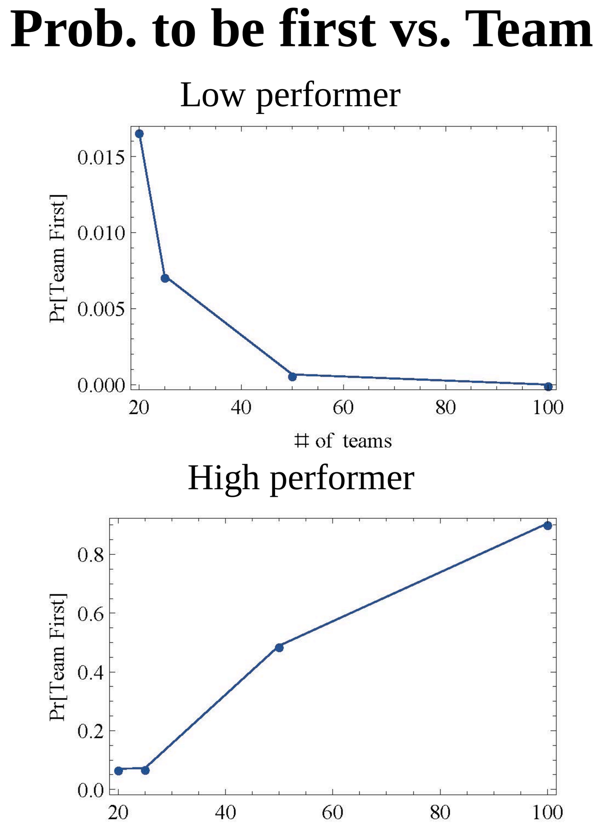
- Real dataset: N=100 random out of 115 employees at 3 pilot sites
- Reward b is given to each member of the first team only
- Normal-like prior distribution of individual performance
- Δp_i in {0, 0.2, 0.4, 0.6, 0.8, 1}
- p_i^0=1 for all employees

Real Dataset: Behavioral Traits



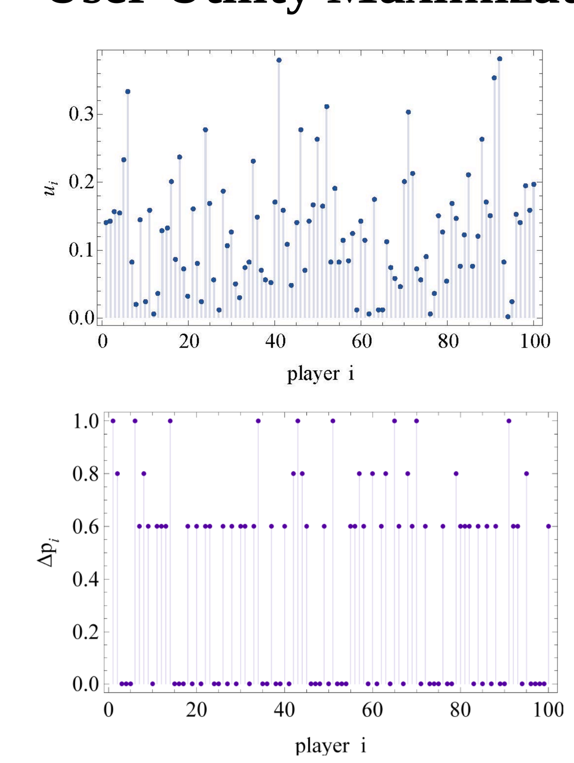
Based on an online survey at 3 office sites

Prob. to be first vs. Team size



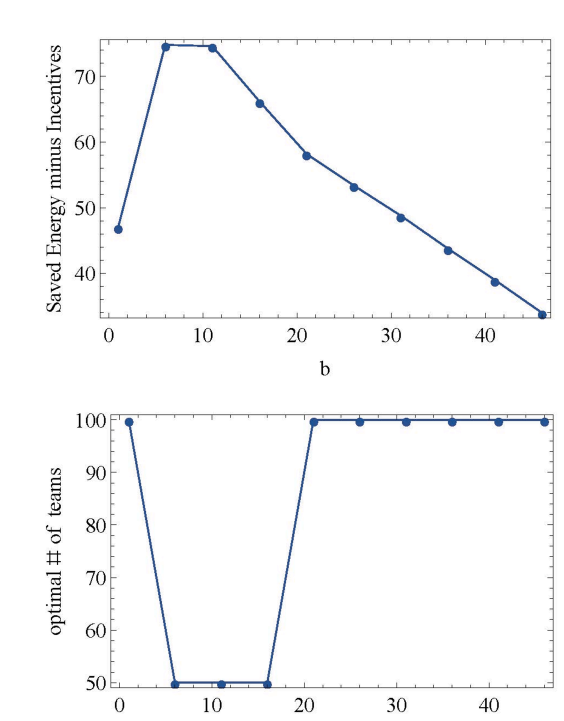
Low performers prefer big teams, high performers prefer playing alone

User Utility Maximization



38 KWh saved out of 100 at equilibrium for K=50, b=1

Game Parameters Optimization



Optimal K=50, b = 6

Conclusions

- We showed that the number of teams and the amount of rewards play significant role on the effectiveness of this game setting for energy conservation
- As a future work, we intend to investigate bounded demand elasticity, optimal reward allocation and a more detailed user-utility model

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