Mathematical Modeling and Experimental Economics in Studying Environmental Decisions.

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- Any policy adoption relies on specific quantitative goals it is trying to achieve and/or specific incentive structure of proposed mechanism (rebates, audit, loans, etc.)

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- Design of optimal mechanisms and policies aimed to promote pro-environmental decisions is more robust if it is supported by formal theoretical framework with quantitative predictions
- Mathematical modeling allows to determine the effect of such policies or incentive schemes

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- Complementary to field/survey studies that identify barriers, etc., and allow for more accurate assumptions
- Analysis of performance of specific programs (for example audit, rebate, loan) often reduced to monetary incentives alone
- how to isolate the effect of the mechanism/program itself from monetary insentives within the mechanism.

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- Adoption of pro-environmental technologies may be limited due to status quo bias
- Typically involves high upfront investment with the potential of better payoffs in the future (over the course of lifecycle), or/and more desirable properties.

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- Possible reasons for deviations: bounded rationality, comprehension of dynamic effects, risk aversion, inaccurate anticipated benefit like increased comfort.

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- Leading to more accurate and improved models that take into account behavioral component and provide accurate predictions

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- In Social Dillemas there is typically underprovision of a good that benefits everyone compared to efficient level (or overprovision of a bad, like pollution).
- Examples: unsufficient conservation (of energy or resources) based on private decisions; society benefits from more efficient building structure, longer life cycle, but private investor does not have incentives to adopt it.

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- Another example from the energy sector is the NIMBY (not-in-my-backyard) problem (siting of alternative energy facilities such as biomass, wind, solar, and geothermal power).
- We propose a Generalized Voluntary Contributions Mechanism (GVCM) to study the decisions and possibility of reaching efficient outcome in such cases.

Dynamic Public Bad (PB)
Model (Pevnitskaya and Ryvkin, 2011)
There are n risk neutral players.
In period t player i has endowment m
and chooses production allocation $\mathbf{x}_{it} \in [0, m]$,
which yields private revenue $a\mathbf{x}_{it}$, $a > 1$.

Production by i in period t generates emissions

$$e_{it} = q_i \mathbf{x}_{it}$$

with *technology* $q_i \geq 0$. If $q_i = 0 \Rightarrow$ clean technology.
Total level of *emissions* in period t,

$$E_t = \sum_{i=1}^{n} q_i x_{it}$$

which leads to accumulation of PB (pollution).

The level of PB (pollution) at the end of period t, Y_t, evolves as

$$Y_t = \gamma Y_{t-1} + E_t; \qquad Y_0 = 0.$$

where, $\gamma \in [0, 1]$ - retention rate of pollution.

Decision-maker's objective.
Player i's payoff in period t is

$$\pi_{it} = m - x_{it} + ax_{it} - b\gamma Y_{t-1}.$$

$b > 0$ is the cost of unit of public bad.

$$\pi_{it} = m + (a-1)x_{it} - b\gamma \sum_{k=1}^{t-1} \gamma^{t-1-k} E_k.$$

where $E_t = \sum_{i=1}^{n} q_i x_{it}$.

In each period there is a continuation probability $\beta \in (0, 1)$.
The **expected payoff of player** i in period t is

$$\Pi_{it} = \tilde{\Pi}_{i,t-1} + \sum_{k=t}^{\infty} \beta^{k-t} \pi_{ik}.$$

where, $\tilde{\Pi}_{i,t-1}$ is the payoff player i has accumulated by the beginning of period t.

Investment in clean technology (private access)
(Pevnitskaya and Ryvkin, 2015).

In addition to production allocation, x , each player i can invest amount, r_{it},
to reduce q_i to a new post-investment technology in period $t, \hat{q}_{it} \leq q_i$:

$$\hat{q}_{it} = \max\{0, q_i - \alpha r_{it}\}$$

. α is the effectiveness of private investment in clean technology (abatement).
The resulting payoff in period t is

$$\pi_{it} = m + (a-1)x_{it} - r_{it} - b\gamma \sum_{k=1}^{t-1} \gamma^{t-1-k} E_k.$$

where $E_k = \sum_{j=1}^{n} \hat{q}_{jk} x_{jk}$

Investment in clean technology (**public access**)
(Pevnitskaya and Ryvkin, 2015)

In addition to production allocation, each player can invest some amount, r_{it}, to reduce $q_{jt} = q_t$, in period t to

$$\tilde{q}_t = \max\{0, q - \rho \sum_{k=1}^{t-1} r_{it}\}$$

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Solution concepts: NE, SO

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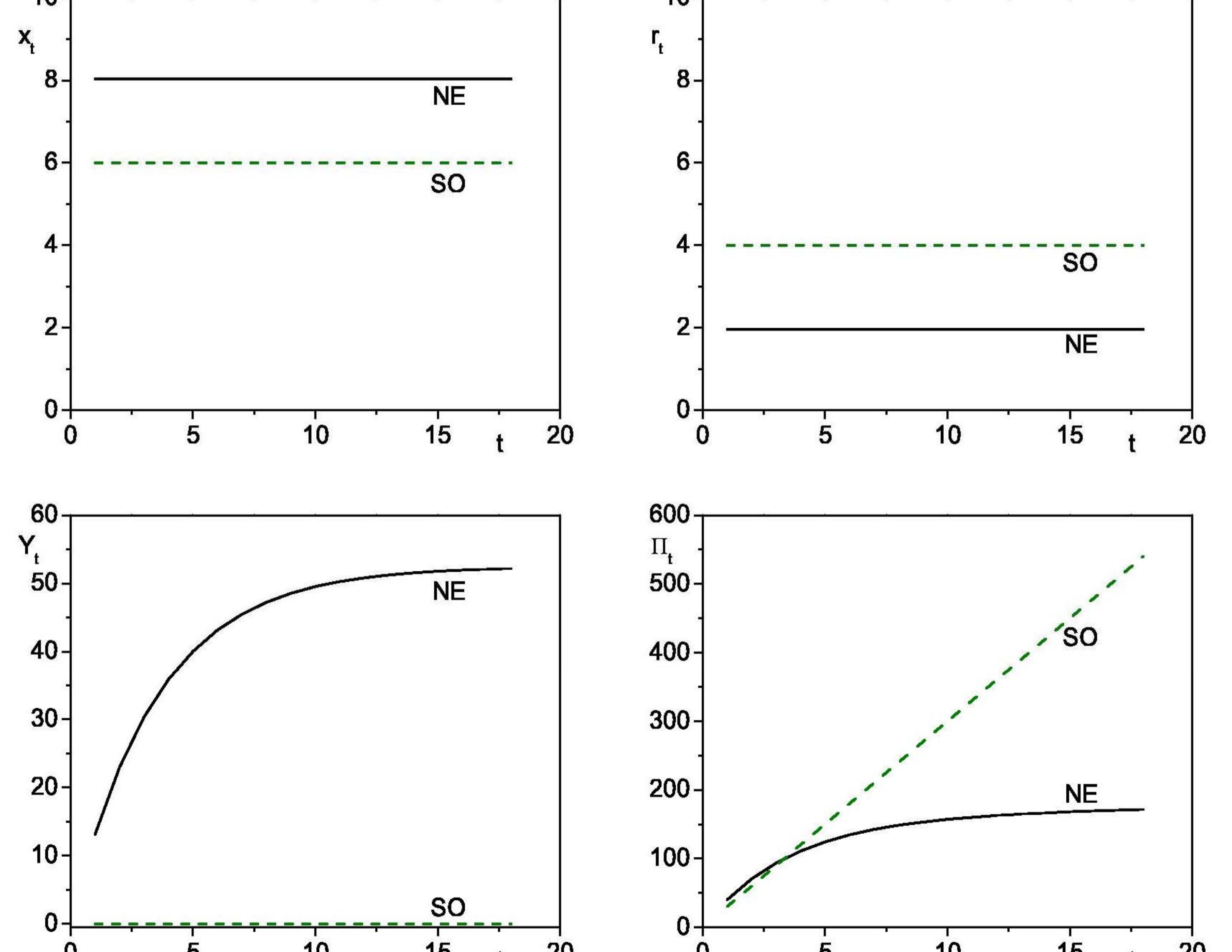
Nash equilibrium
Socially optimal outcome
Sustainable outcome
Target pollution rate


x_t
NE
SO
t
r_t
SO
NE
t
Y_t
NE
SO
Π_t
SO
NE

Experiment Design

- $\mathbf{n} = \mathbf{4}$, $m = 10$, $a = 5$, $b = 1$, $\gamma = 0.75$, $\beta = 0.95$

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Treatments	n=4	n=4 Chat
T1: $q = 0.8$	2 (44)	
T2: $(q = 0.8)$ Private, $\alpha = 0.2$	3 (52)	2 (36)
T3: $(q = 0.8)$ Public access, $\rho = 0.05$	3 (48)	2 (40)

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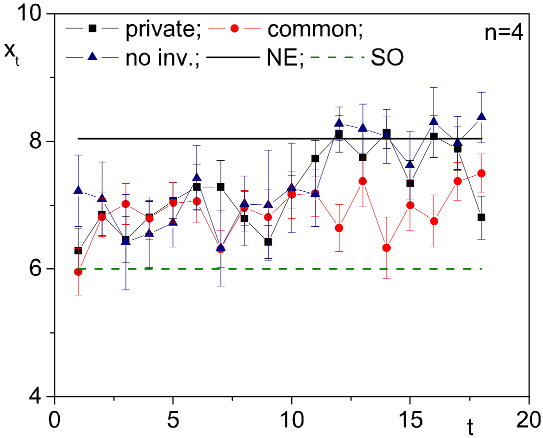
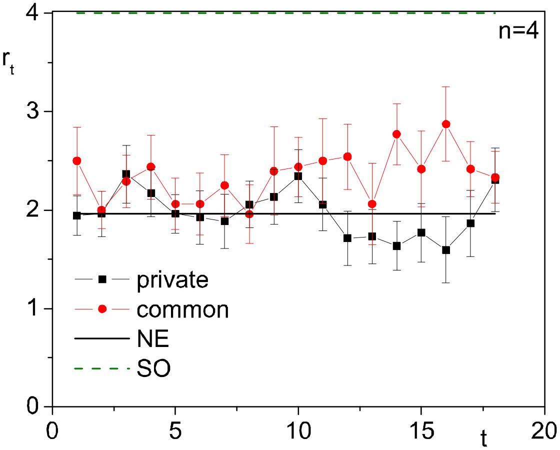
- Look at:
  Production decision, x_t Investment in clean technology, r_{it}
  Pollution, Y_t Payoffs, $\tilde{\Pi}_t$

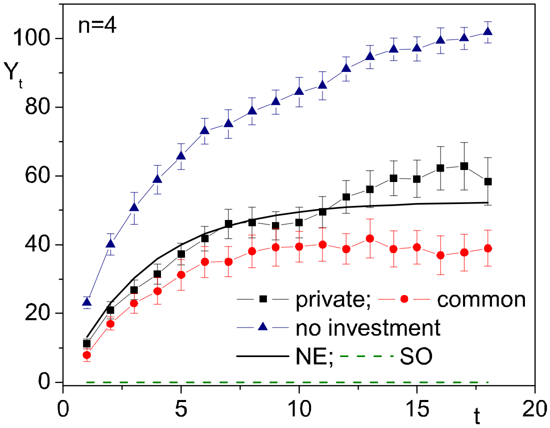
Production allocation, n=4



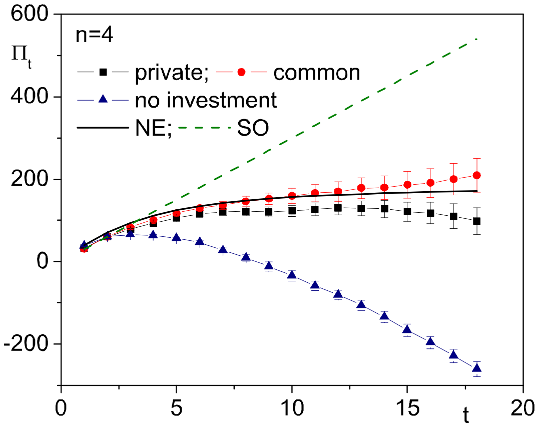
Investment in clean technology, n=4



Public Bad, n=4



Payoffs, n=4


600
400
200
0
-200
Π_t
n=4
private;
common
no investment
NE;
SO
0
5
10
15
20
t

New Directions

We assumed that a building is a consumer of energy, buying energy on the market
The government can create policies aimed at more efficient consumption

New technologies allow the building to also produce energy and be completely off the grid, or have periods when the building can transmit (supply) energy into the grid.
This makes it important to consider new energy pricing schemes to integrate decentralized power generation into the grid and energy market.

Now policies can involve real time pricing that allows more efficienct houses to generate income based on new green technologies.