Voluntary Participation in Cyber-insurance Markets

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The cyber-insurance market [1]

- Over 30 companies offering insurance in the US.
- Growth of 10-25% in premiums reported.
- Total amount of premiums estimated between \$500M and \$1bn.
- Premiums \$10k - \$50M, coverage limits \$16M - \$300M.
- Cyber-insurance proposed for both risk transfer and shaping incentives.

[1] Romanosky, *Comments to the Department of Commerce on Incentives to Adopt Improved Cybersecurity Practices*, 2013.
The Betterley Report: Cyber/Privacy Insurance Market Survey, 2012.

Interdependent security risks

- Security investments of a user have *positive externalities* on other users.
- Users' preferences are in general heterogeneous:
  - Heterogeneous costs.
  - Different valuations of security risks.
- Heterogeneity leads to under-investment.

Cyber-insurance literature

Competitive markets
[Shetty 10, Pal 13]

- Perfect competition with free entry.
- Insurance contracts optimized from *individual* users' viewpoint.
- Decreases incentive to invest in security, but individually rational.

Monopolistic markets
[Hoffman 07, Lelarge 09]

- A single profit neutral insurer (social planner).
- Socially optimal investments in model with binary decisions.
- Assumes compulsory insurance, participation incentives not studied.

Outline

Interdependent security (IDS) investment game

- A set of N users.
- User i's action: invest $x_i \geq 0$ in security.
- User i chooses x_i to maximize its utility:

$$u_i(x) := -L_i f_i(\mathbf{x}) - h_i(x_i) \ .$$

L_i: assets subject to loss

$f_i(\mathbf{x})$: security risk of i, $\mathbf{x}$ vector of investments

$h_i(\cdot)$: cost of investment

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Cyber-insurance implementation

- A monopolist profit-neutral insurer, determines $\{(\rho_i, I_i)\}_{i=1}^N$: premium and indemnification payment (coverage).
- Utility of user i when purchasing insurance:

$$u_i(\mathbf{x}, \rho_i, I_i) = -(L_i - I_i)f_i(\mathbf{x}) - h_i(x_i) - \rho_i \ .$$

- The positive externality investment mechanism [Hurwicz 79]
Each participant i inputs message $m_i := (\chi_i, \pi_i)$, consisting of an investment profile and a price profile.

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On incentives to participate

- User participation depends on:
  1. game form
  2. options when staying out
- Most public good problems assume a **zero share** of resources for those staying out.
- Security is a **non-excludable** public good: users can stay out and still free-ride on (possibly lower) levels of security.
- **Loner**: stays out and best responds to the remaining $N-1$ users.

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Reasons for opting out (I)

Free riders paying for security; can enjoy spill-overs without paying.
Free-rider 4 is happy; free-rider 1 would rather stay out.

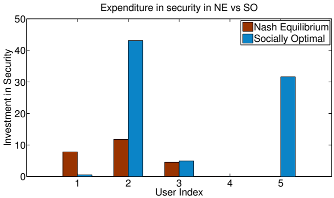


Figure : Expenditure in security

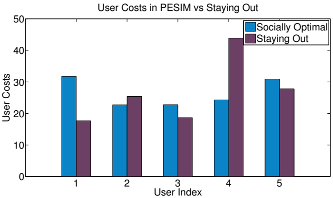
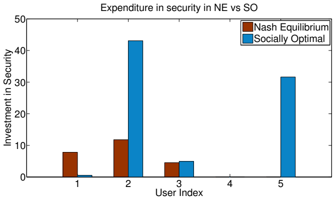


Figure : Participation Incentive

Reasons for opting out (II)

Main investor not receiving high enough compensation.
Investor 2 is happy; investors 3 and 5 would rather stay out.



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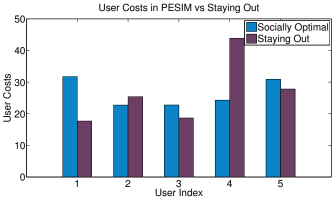

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An impossibility result

There are instances in which **no mechanism** can satisfy both types.

- Free-riders are only willing to pay so much (esp. given spillovers).
- Main investors demand compensation.
- Mechanism designer does not inject resources into the system.

Positive examples

Problem families in which users voluntarily participate in the positive externality mechanism.

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Discussion

Tradeoffs

- Profit-neutrality, socially optimal outcome, participation

Alternative mechanisms?

- Capital injection, e.g., cyber-insurance with catastrophe coverage
- ϵ-optimal solution
- Partial coverage

Combined with secondary incentives?

- Business opportunities

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Conclusion

- Sub-optimality of an unregulated interdependent security games
- A positive externality mechanism to induce socially optimal security investment
- The challenge of ensuring voluntary participation