CYBER-INSURANCE AND SECURITY INTERDEPENDENCE: FRIENDS OR FOES?

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Presentation outline

- Introduction
- Motivation and goals
- Main contribution
  - Analysis
  - Initial result
- Conclusion, Discussion and Future plans

Introduction

- Cyber insurance is more than just a financial instrument to smooth the losses
  - **Indicator** (premium) for quality of protection
  - Lead to new and more advanced **standards** in cyber security
  - An incentive to increase **self-protection** and **social welfare.**

- In fact, the real impact of cyber insurance on self-protection investments is unclear.
  - Correct security modelling is not straightforward.
  - Scarcity of data to validate the models.
  - Authors contradict each other ([1],[2] vs. [3],[4]).

- Cyber security is (highly) interdependent.
  - Security interdependency decreases self-investments.

1. H.Ogut, N.Menon, S.Raghunathan: ***Cyber insurance and it security investment: Impact of interdependent risk***.

2. G. Schwartz and S. Sastry: ***Cyber-insurance Framework for Large Scale Interdependent Networks***

3. PwC: ***Managing cyber risks in an interconnected world***

4. J.-C. Bolot and M. Lelarge: ***A New Perspective on Internet Security using Insurance***

Motivation and goal

- But, interdependency affect self-investments in both cases:
  - if insurance **is** available
  - If it is **not** available

	Insurance available		No-insurance available
No (low) security interdependence (*Π=1*)	x_{LI}^{IA}	$<$	x_{LI}^{NA}
	$\vee$		$\vee$
High security interdependence (*Π<1*)	x_{HI}^{IA}	?	x_{HI}^{NA}

Assume that

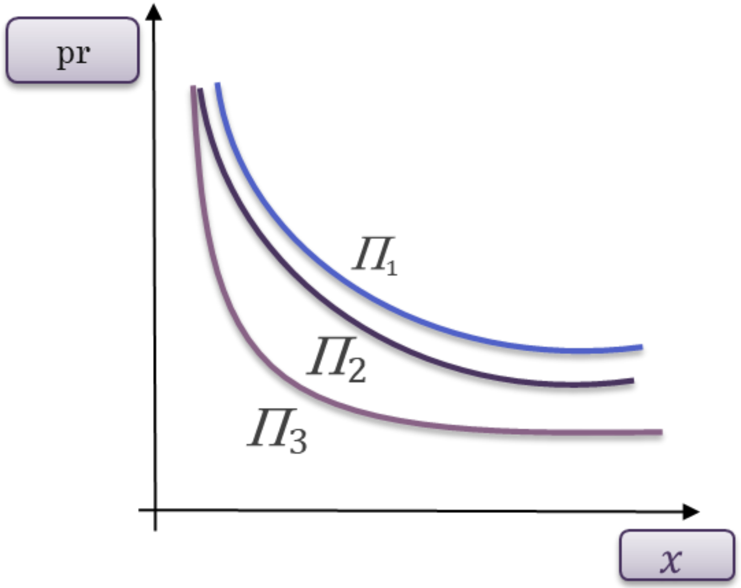
We know that

We would like to know

Security investments and interdependence

- x - Self-protection,
- π(x) Direct probability of attack ,
  - Direct attack – it affects to someone directly from attacker
  - Indirect attack – it affects to someone through someone
  - $\mathbf{0 < \pi(x^N) < 1}$
  - $\boldsymbol{\pi'(x^N) < 0}$
  - $\boldsymbol{\pi''(x^N) > 0}$
- *Π* - interdependency degree,
- Probability of an event to occur as pr(x; *Π*):

$$pr(x, \Pi) = 1 - (1 - \pi(x))\Pi.$$



Generic utility function for an agent

- Utility function – satisfaction experienced by the consumer of a good.
  - Risk averse - ($U' \geq 0$; $U'' \leq 0$) Von Neumann-Morgenstern utility function

- Initially company has W wealth.

- Expected utility without insurance:
  - **No incident:** lose investments *(x)* only
  - **Incident:** lose investments *(x)* and suffer from loss *(L)*

$$E[U(W)] = U_{NN} * (1 - pr(x, \Pi)) + U_{NL} * pr(x, \Pi), \;\; where$$
$$U_{NN} = U(W - x) \text{ if no incident occurs;}$$
$$U_{NL} = U(W - L - x) \text{ if an incident occurs.}$$

- Expected utility with insurance:
  - **No incident:** lose investments *(x)* and premium *(pr(x; Π)*I)*
  - **Incident:** lose investments *(x)*, premium and suffer from loss *(L)*, but get indemnity *I*

$$E[U(W)] = U_{IN} * (1 - pr(x, \Pi)) + U_{IL} * pr(x, \Pi); \;\; where$$
$$U_{IN} = U(W - pr(x, \Pi) * I - x) \text{ if no incident occurs;}$$
$$U_{IL} = U(W - L - pr(x, \Pi) * I + I - x) \text{ if an incident occurs.}$$

Finding optimal investment

- No-insurance is available:
  - First order condition (FOC) from Expected Utility by self-protection (x)
  - Find optimal investment (x^N)

$$\pi'(x^N)\Pi = \frac{(1-(1-\pi(x^N))\Pi)U'_{NL} + (1-\pi(x^N))\Pi * U'_{NN}}{(U_{NL} - U_{NN})}$$

- Insurance is available for an agent:
  - FOC for *I* as well as for x.
  - The optimal value *I** = *L* → optimal investment level (x^I):

$$\pi'(x^I)\Pi = -\frac{1}{L}.$$

Comparing the investments

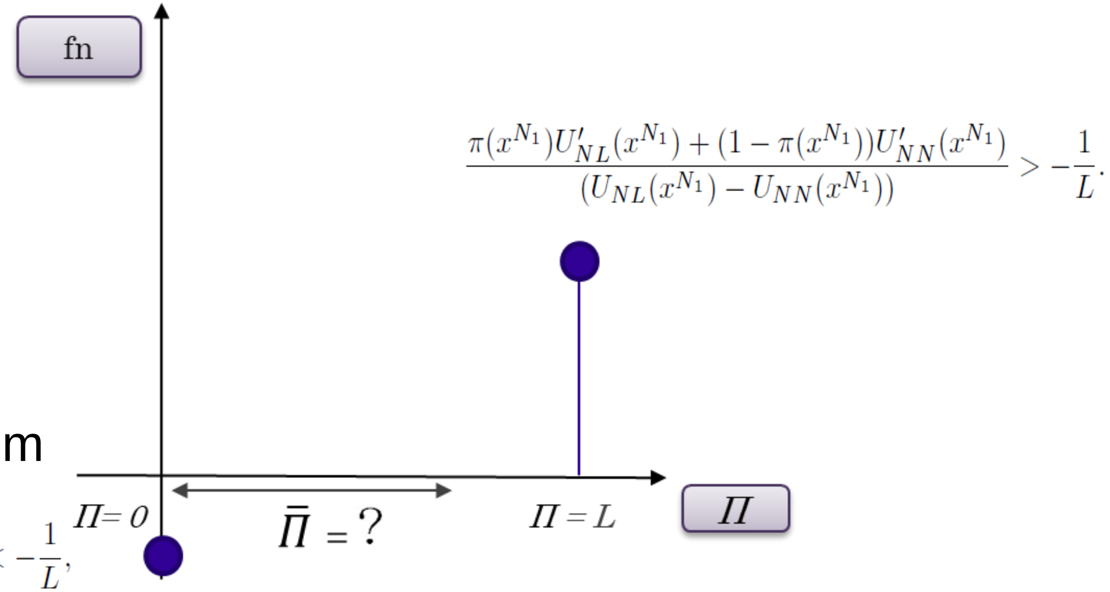
- We are interested in comparing the investments with the degree of interdependence increases.
  - Without solving complicated equations, we can reason on values of x^N and x^I
  - If $\pi'(x^I) > \pi'(x^N)$ investments in case of insurance are higher than in case of no insurance.
- We would like to know if there is such *Π*, which makes $\boldsymbol{\pi}'(\boldsymbol{x}^N) = \boldsymbol{\pi}'(\boldsymbol{x}^I)$.
  - Outcome of “FOC” in both cases.

$$\pi'(x^N)\Pi = \frac{(1-(1-\pi(x^N))\Pi)U'_{NL} + (1-\pi(x^N))\Pi * U'_{NN}}{(U_{NL} - U_{NN})} = -\frac{1}{L}. \quad = \pi'(x^I)\Pi.$$

  - x^N depends on *Π*
  - U_{NN} and U_{NL} depend on x^N.
- Lets investigate a function *fn(*$\boldsymbol{x}^N$), defined by the left hand of equation above.

Analyzing

- Consider two border cases: $\Pi = 1$ and $\Pi = 0$.



- concave function $U'_{NL} * L > U_{NN} - U_{NL}$.
- function fn(Π) is continuous
- according to the Intermediate Value Theorem

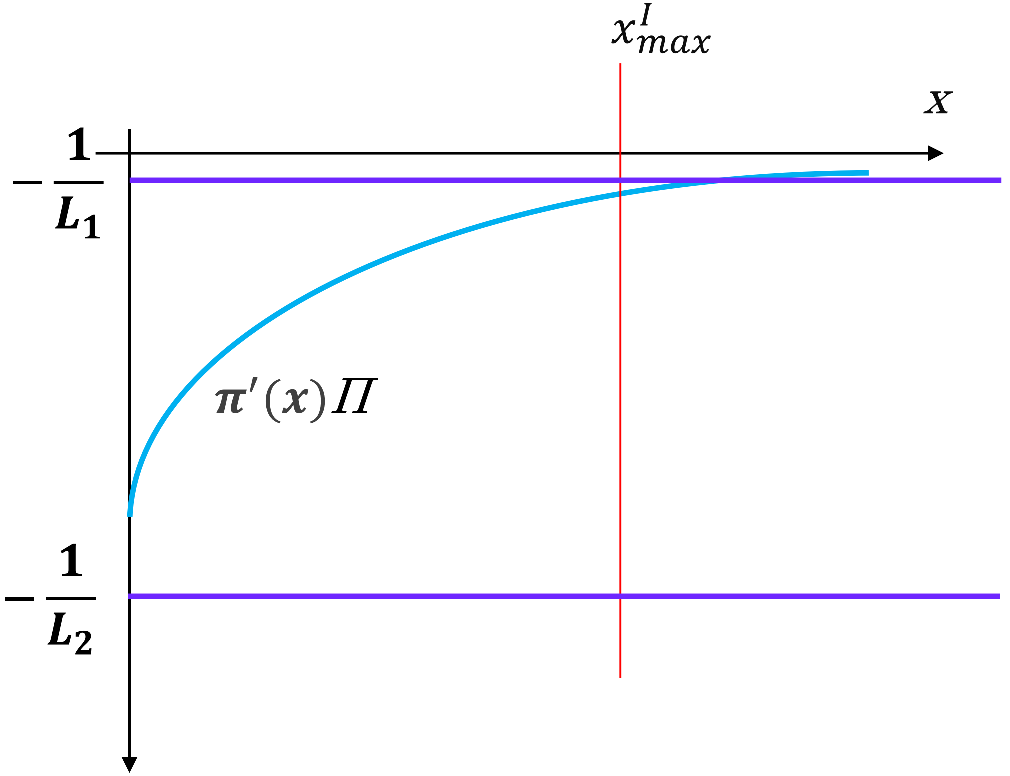
$$\frac{U'_{NL}(x^{N_2})}{(U_{NL}(x^{N_2}) - U_{NN}(x^{N_2}))} < -\frac{1}{L},$$

- There is such 1 > $\bar{\Pi}$ > 0 which makes $fn(\bar{\Pi}) = -\frac{1}{L}$:

$$\frac{(1-(1-\pi(x^N))\bar{\Pi})U'_{NL} + (1-\pi(x^N))\bar{\Pi} * U'_{NN}}{(U_{NL} - U_{NN})} = -\frac{1}{L}.$$

Beware of border cases

- **Pay everything or avoid**:
  - $W - L - x^N > 0$ **or**
  - $W - pr(x^I, \Pi) * L - x^I > 0$
- **Pay nothing**:
  - $fn(x^N) = \pi'(x^N)\Pi$
  - $-\frac{1}{L_1} = \pi'(x^I)\Pi$



Conclusion, Discussion, Future work

- Interdependent cyber security world has a greater chance to benefit from applying cyber insurance
- Beware of border cases
- Limitation of this work: what if insurance is incentive for *Π=1* $(\pi'(x^I) > \pi'(x^N))$?
- Future work:
  - Find a rigorous answer to the case if insurance is incentive for *Π=1* $(\pi'(x^I) > \pi'(x^N))$
  - Extend the model for several actors (i.e., expand *Π and consider the game of agents*)
  - Assess effects of information asymmetry, non-competitive market and various regulation mechanisms.

Thanks for the attention.

Questions

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