

Modeling Cyber-Insurance

Towards a Unifying Framework

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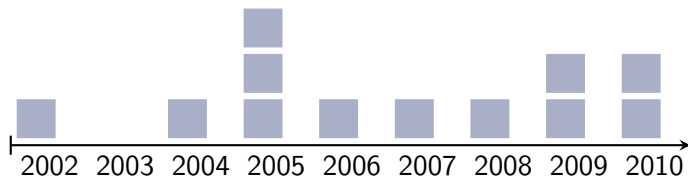
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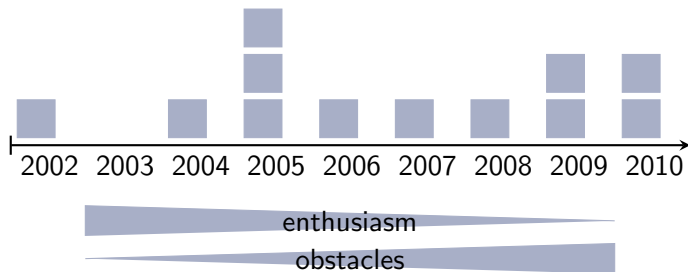
TRUST Workshop at Stanford University



Cyber-Insurance: Research Papers



Cyber-Insurance: Research Papers



Talk Outline

1. Characteristics of Cyber-Risk
2. Framework Overview
3. Selected Features
 - ▶ Network topology
 - ▶ Unified approach to interdependent security and correlated risk
4. Discussion and Conclusion

1

Characteristics of Cyber-Risk

What Is Specific to Cyber-Risks?

success factors of ICT

distribution & interconnection

universality & reuse

What Is Specific to Cyber-Risks ?

success factors of ICT

distribution & interconnection →

universality & reuse

Cyber-risks [focal features]

interdependent security

own security depends
on other parties' actions
(security)

What Is Specific to Cyber-Risks ?

success factors of ICT

distribution & interconnection

universality & reuse

Cyber-risks [focal features]

→ interdependent security

own security depends
on other parties' actions
(security)

→ correlated risks

incidents cause further
incidents

What Is Specific to Cyber-Risks ?

success factors of ICT

distribution & interconnection

universality & reuse

+

= complexity

Cyber-risks [focal features]

→ interdependent security

own security depends
on other parties' actions
(security)

→ correlated risks

incidents cause further
incidents

→ imperfect information

Textbook risks [economics & insurance literature]

neither interdependence nor correlation

Airline baggage security

interdependence, but no correlation

Kunreuther & Heal, 2003

Natural disasters in the actuarial literature

spatial correlation, but no interdependence

Embrechts et al., 1999

Cyber-insurance

BOTH interdependence and correlation

...

Textbook risks [economics & insurance literature]

neither interdependence nor correlation

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Natural disasters in the actuarial literature

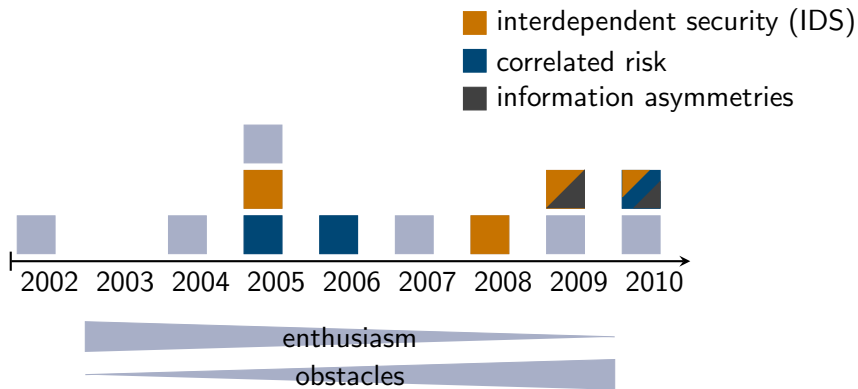
spatial correlation, but no interdependence

Embrechts et al., 1999

Cyber-insurance

BOTH interdependence and correlation
[never modeled together so far]

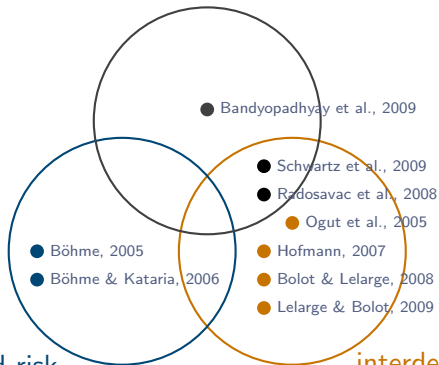
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Focus

of the Cyber-Insurance Models

information asymmetries



correlated risk

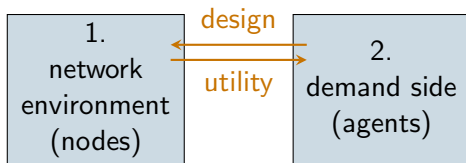
interdependent security (IDS)

2

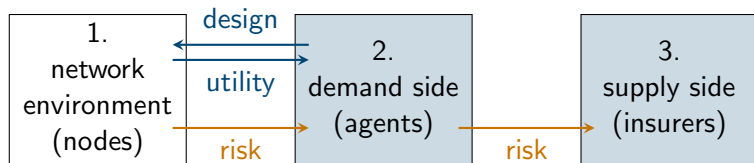
Framework Overview

1.
network
environment
(nodes)

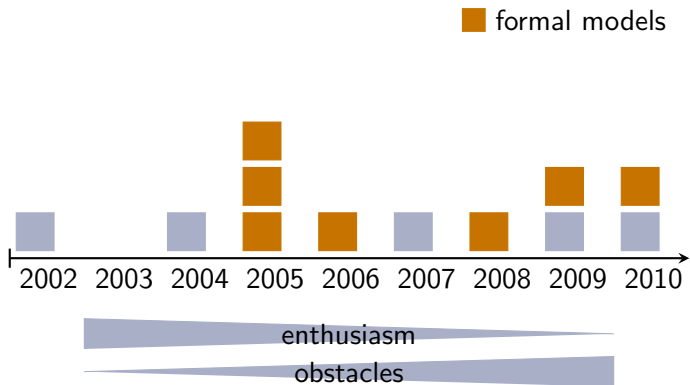
Framework



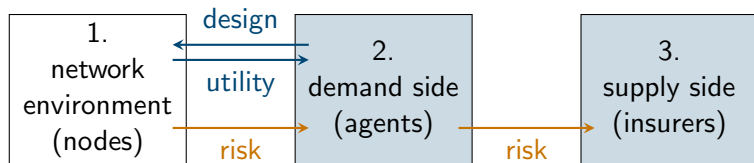
Framework



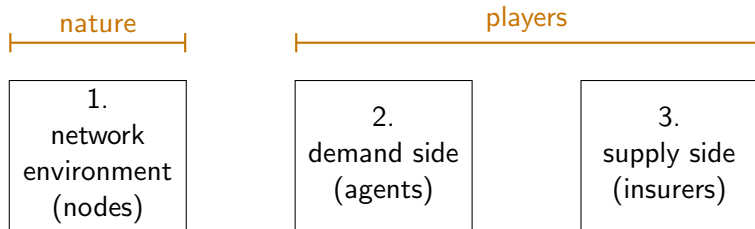
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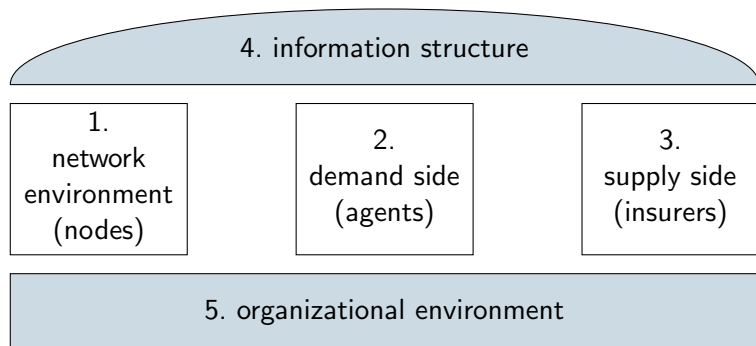


Framework



Framework





Overview of Model Attributes

1. network environment

defense function
network topology
risks features
attacker model

2. demand side

node control
heterogeneity
agent risk aversion
action space &
timing

3. supply side

market structure
insurer risk aversion
insurer markup
contract design

4. information structure

Information asymmetries
Their timing:
ex ante (adverse selection)
ex post (moral hazard)

5. organizational environment

regulator(s)
ICT manufacturers
network intermediaries
security service providers

Cyber-insurance market

Under which conditions will cyber-insurance thrive?

Network security

Can we expect fewer attacks if cyber-insurance is broadly adopted?

Social welfare

Will the world be a better place with cyber-risk reallocation?

3

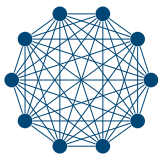
Selected Features

Network Topology

Examples



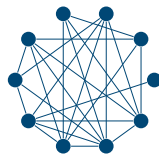
ideosyncratic



fully connected



single-factor model



Erdős-Rényi graph

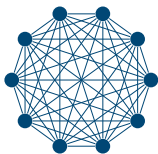
Network Topology

Examples



ideosyncratic

hardware failure



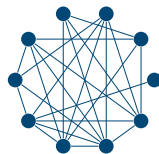
fully connected

email spam



single-factor model

OS vulnerability



Erdős-Rényi graph

inter-organizational
dependence

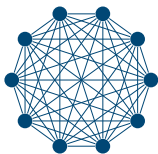
Network Topology

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ideosyncratic

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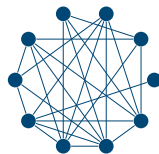
fully connected

email spam



single-factor model

OS vulnerability



Erdős-Rényi graph

inter-organizational
dependence

→ Comprehensive insurance policies are **bundles of contracts**.

Unifying “Interdependence” and “Correlation”

Defense function D for node i (security interdependence only):

$$P_i = D(l_i, w_i, \mathbf{s}, G, \dots)$$

l_i – size of loss

w_i – initial wealth

\mathbf{s} – vector of security investments: $\mathbf{s} = s_i \cup \mathbf{s}_{j \neq i}$

G – network topology

Defense function D for node i (simplified):

$$p_i = D(s_i, \mathbf{s}, G, \dots)$$

Illustration

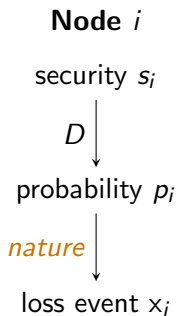
Node i

security s_i



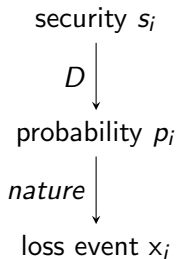
probability p_i

Illustration

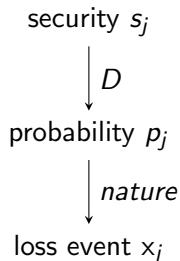


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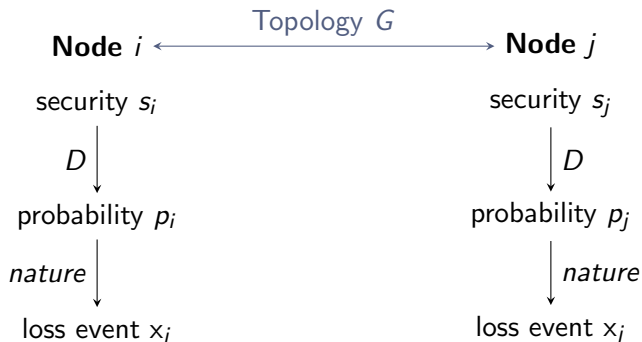
Node i



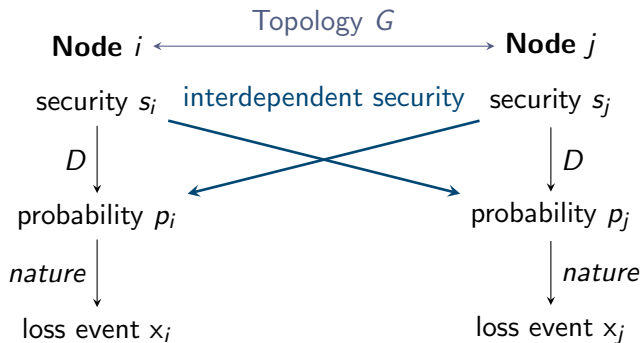
Node j



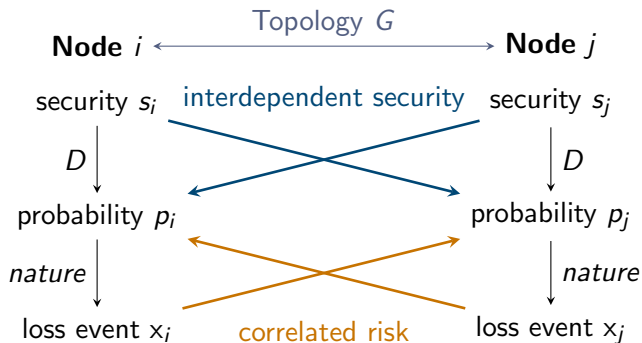
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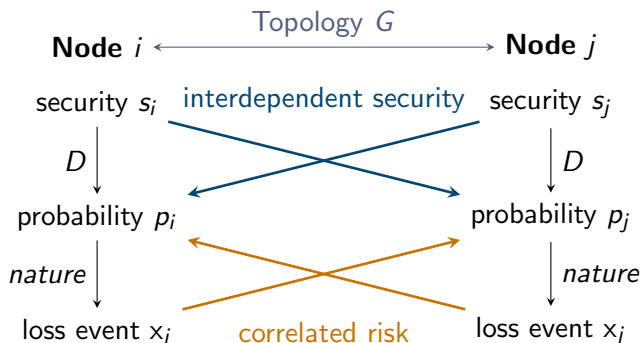
Illustration



Illustration



Illustration



Modeling interdependence AND information asymmetries is hard; modeling correlated risks is hard. requires recursive methods; may lead to complex equilibrium configurations (& dynamics).

“Interdependence” and “Correlation” together

Security interdependence and correlated risk can be modeled jointly [D dependent on both security choices \mathbf{s} and realizations \mathbf{x} .]

Defense function D for node i

$$p_i = D(s_i, \mathbf{s}, G, \mathbf{x}, \dots)$$

\mathbf{s} – vector of security investments: $\mathbf{s} = s_i \cup \mathbf{s}_{j \neq i}$

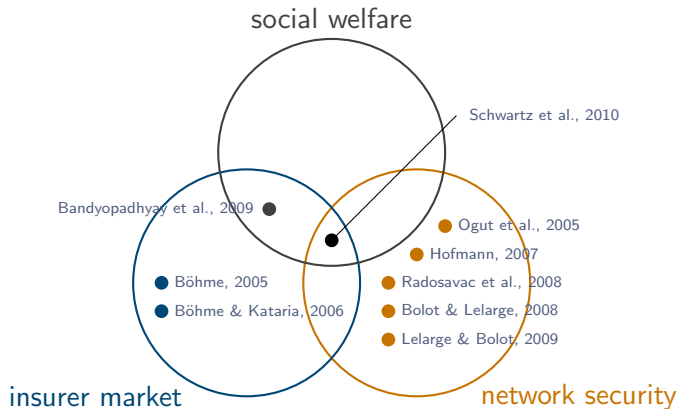
G – network topology

p_i – probability of loss for node i

4

Discussion and Conclusion

Dependent Variables in the Cyber-Insurance Literature



Discrepancies

between Statements and Models

Cyber-insurers will improve information about security

... but relevant parameters are not included in models.

Cyber-insurers will positively affect (i) agents' security decisions (ii) the network environment

... but existing models of contracts do not reflect that;
... real cyber-insurers do not condition premiums on security.

Broad adoption of cyber-insurance will change (i) insurer market structure(s) and (ii) behavior of ICT manufacturers

... but never modeled parametrically.

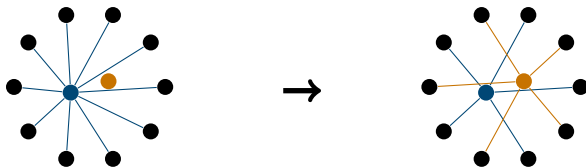
To Do

Future papers should model (i.e., endogenize) key parameters of: network environment, etc.

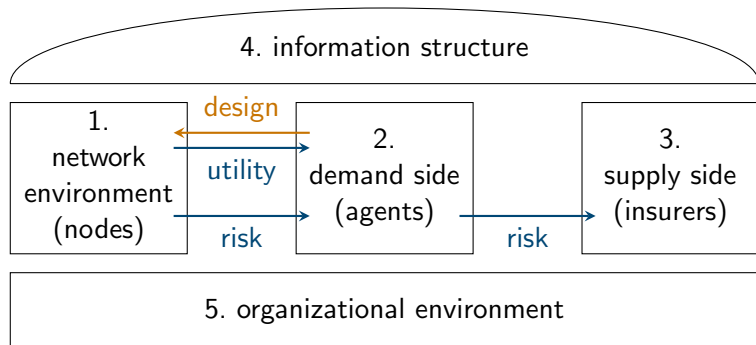
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Example:

endogenous network formation [model of platform switching]



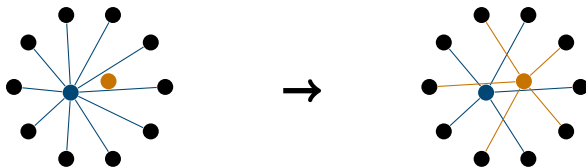
Framework



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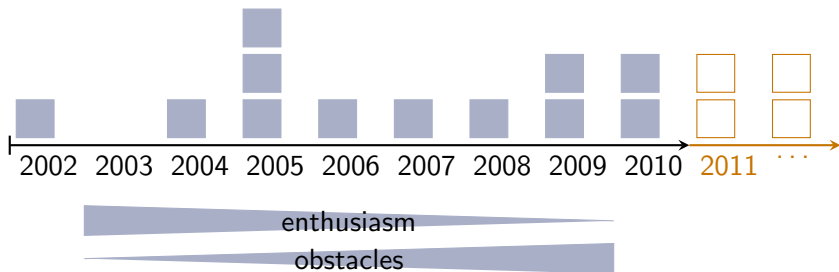
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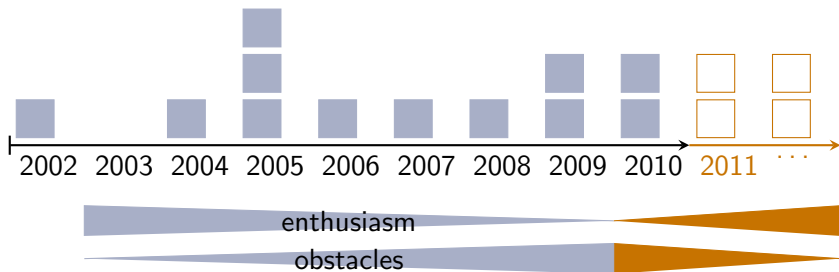


Policy recommendations should be justified by formal (game theory) models.

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Q & A

Thank you for your attention.

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