

Latent fatalism on cyber risk: Interdependency, ambiguity-aversion and loss-aversion

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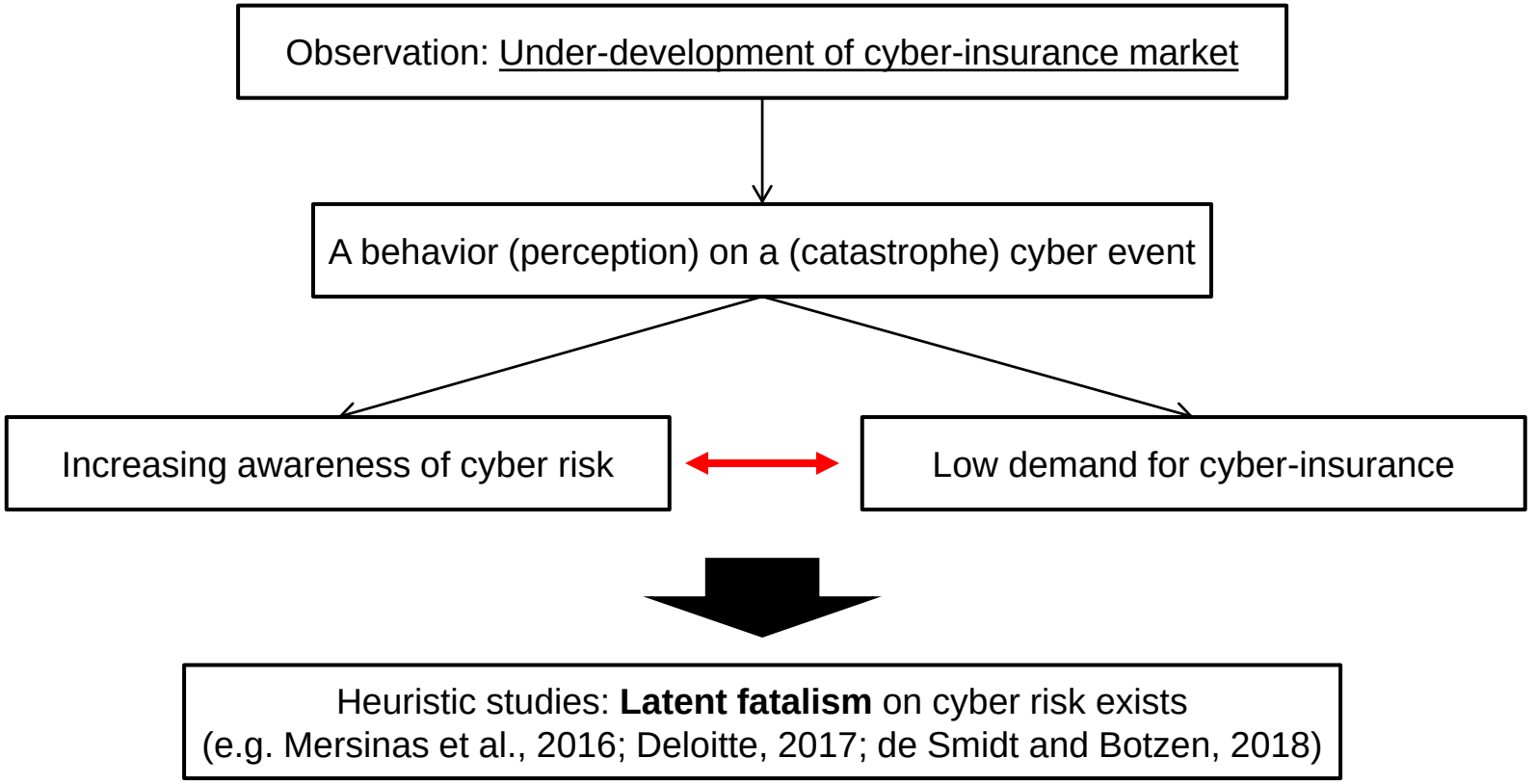
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Contents

- ❑ **Motivation / Objective**
- ❑ **Literature review – Positioning of the study**
- ❑ **Theoretical background**
- ❑ **Model framework**
- ❑ **Contribution**

Motivation of the study

Motivation

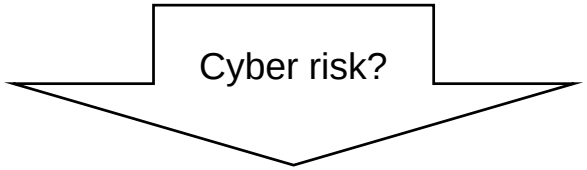


Motivation of the study

Motivation

- Latent Fatalism?

  → An anomaly showing opposite behaviors against modest risk and extreme risk. Individuals think of an unlikely event (e.g. an extreme case with less likelihood) as unrealistic to themselves so that they tend to stand without any protection, whereas they are willing to pay more against modest, but imminent risk than fair price.



1. Uncertainty from interdependent risk in the network environment (Contagion risk)
2. Uncertainty from dynamic nature of cyber risk – difficulty in modeling, risk of change

→ Unmeasurable risks from unidentifiable sources

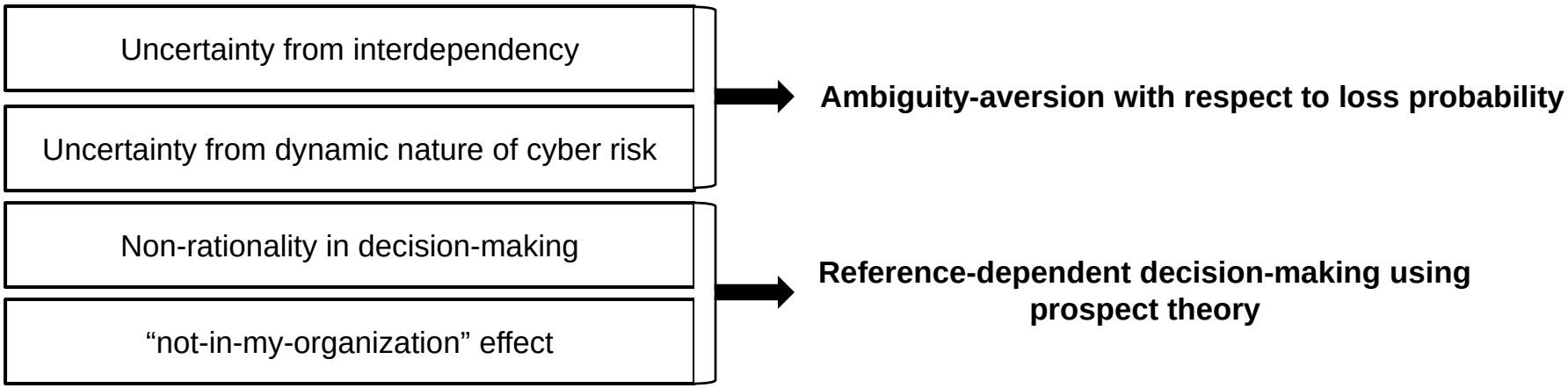
3. Observed non-rationality in decision-making (Mersinas et al., 2016)
4. “not-in-my-organization effect” (de Smidt and Botzen, 2018)

→ Violation of classical decision theory

Objective of the study

Objective

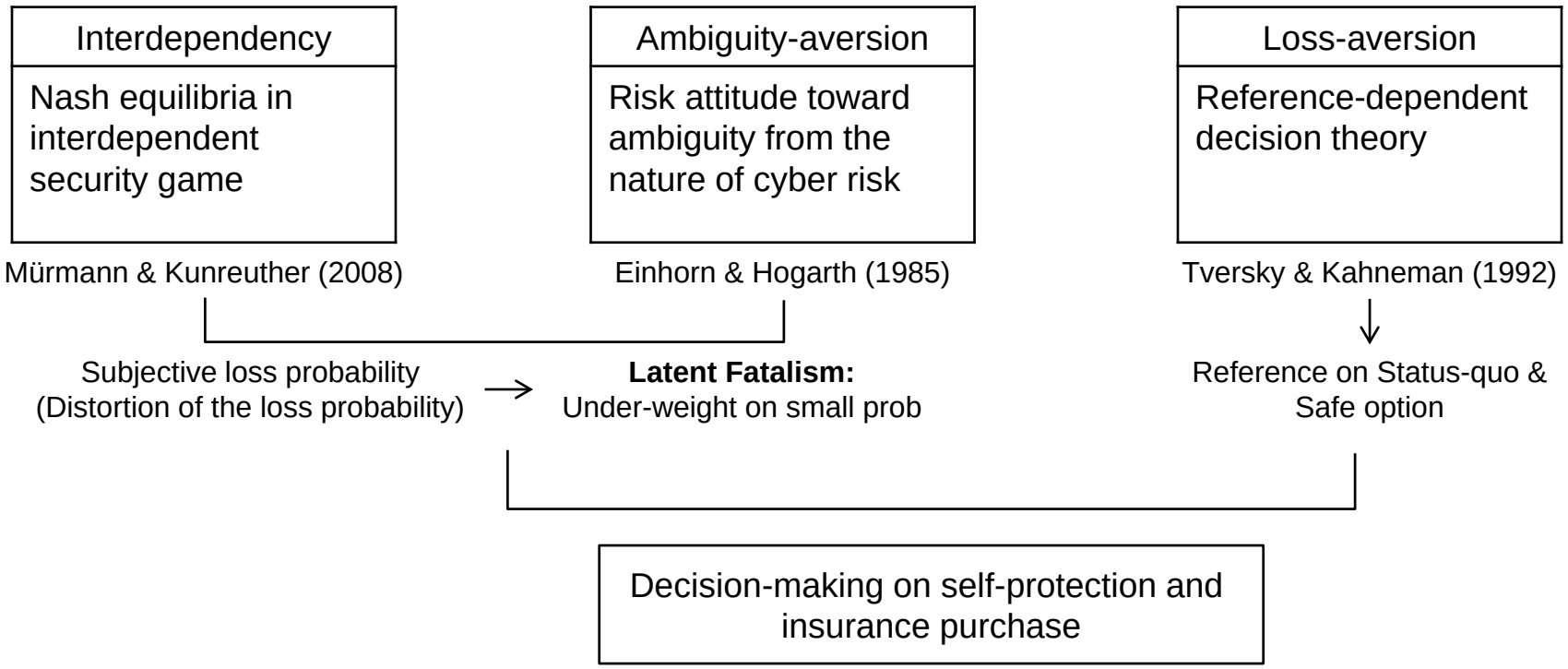
- We attempt to explain the market behavior against cyber risk by considering observed factors
- Modeling such factors in the decision-making framework:



- The aim of the study is to investigate
  (1) the effect of the loss-aversion assumption on demand for cyber-insurance (depending on reference points)
  (2) the effect of ambiguity-aversion on the insurance decision and the security investment

Objective of the study

Overview of modeling



Literature review

Positioning of the study

		No interdependent risk		Interdependent risk	
		No ambiguity	**Ambiguity**	**No ambiguity**	**Ambiguity**
Risk-aversion (EU)	**Non-cyber**	· EB72 (SP) · LRS12 (SP)	· EH85 · HK89 · KMM05 · S11 (SP) · AGT13 (SP)	· H07 (SP) · MK08 (SP)	-
	Cyber-related	· BK06	-	· ORM11 (SP) · LB09 (SP) · SSFW10 (SP)	-
Loss-aversion (PT)	**Non-cyber**	· EW11 · S16	· RHM06	-	-
	Cyber-related	· PC12	-	· V08 (SP)	-

Present paper

Note: "SP" in the parentheses indicates that the paper considers self-protection measure in the decision-making model. The literature categorized above is listed in the following; EB72: Ehrlich and Becker (1972); EH85: Einhorn and Hogarth (1985); HK89: Hogarth and Kunreuther (1989); KMM05: Klibanoff, Marinacci and Mukerji (2005); BK06: Böhme and Kataria (2006); RHM06: Roca, Hogarth and Maule (2006); H07: Hofmann (2007); MK08: Mürmann and Kunreuther (2008); V08: Verendel, 2008; LB09: Lelarge and Bolot (2009); SSFW10: Shetty et al. (2010); EW11: Eckles and Wise (2011); ORM11: Ogut, Raghunathan and Menon (2011); S11: Snow (2011); LRS12: Lohse, Robledo and Schmidt (2012); PC12: Pfleeger and Caputo (2012); AGT13: Alary, Gollier and Treich (2013); S16: Schmidt (2016).

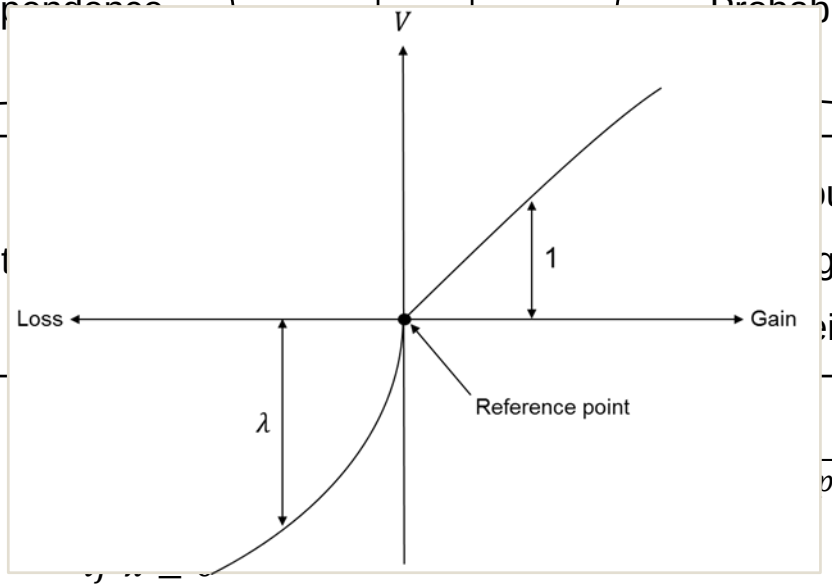
Theoretical background

Prospect Theory (Tversky and Kahneman, 1992)

Reference-dep… | …bility weighting

- Reference points
- Diminishing sensit…
- Loss-aversion

…us decision weights
…ghts on small probs
…ights on large probs



Value function:

$$v(x) = \begin{cases} x^{\alpha} & if\ x \geq 0 \\ -\lambda(-x)^{\alpha} & if\ x < 0 \end{cases}$$

where α is a parameter to determine the diminishing sensitivity, λ is a loss aversion parameter.

$$\theta^{+}(p) = \frac{p^{\gamma}}{(p^{\gamma} + (1-p)^{\gamma})^{1/\gamma}}$$

$$\theta^{-}(p) = \frac{p^{\xi}}{(p^{\xi} + (1-p)^{\xi})^{1/\xi}}$$

where γ and ξ are probability weighting parameters that are differentiated depending on gain or loss state.

Theoretical background

Modeling Ambiguity

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(Einhor
Hogartl

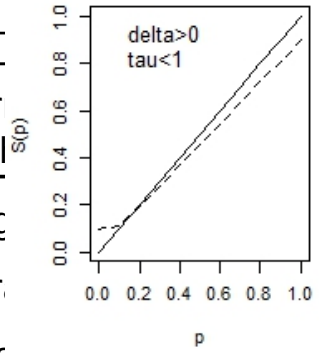
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- The non-a
probabiliti

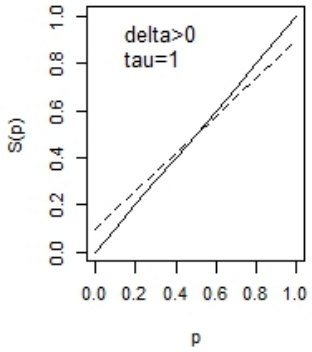
model
al., 2005)

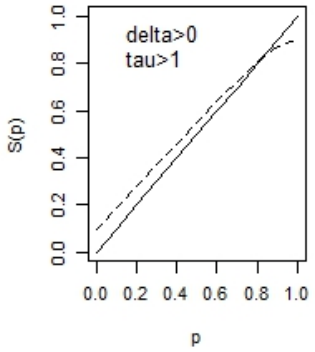
en ambiguity and

model

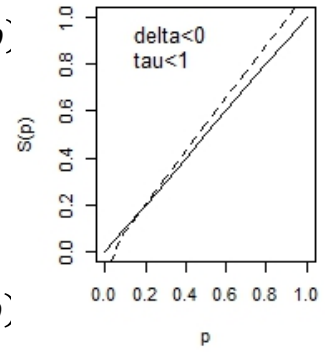
n indifference curve

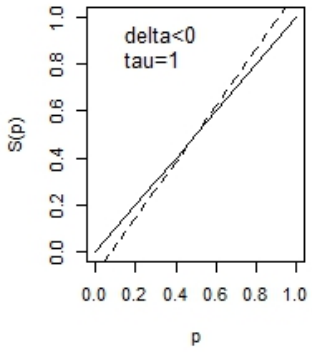


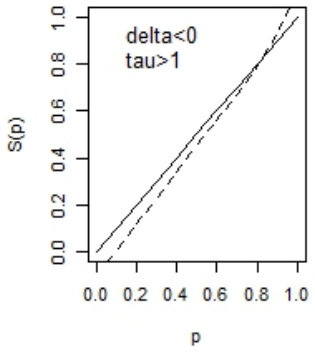




$S(p)$







$\tau\Big)\, d\mu \equiv \mathbb{E}_\mu \phi(\mathbb{E}_\pi u \circ f)$

$\alpha = \delta(1-p)$

on a real state space S (“act”)

ion

sure on S

ective belief on the loss prob

δ determines the absolute size of the adjustment

τ indicates the individual’s attitude toward ambiguity

ϕ is an increasing and concave function indicating ambiguity-aversion

Model Framework

Model Framework

- Model parameters

Notation	Explanation
$v(\cdot)$	KT (Kahneman & Tversky) Value function
W	Initial wealth
L	Loss amount
s_i	The security investment level by a firm *i* ($s_i \in [0, W]$)
s_{-i}	The security investment level by firms interconnected to the firm *i*
$p(s_i, s_{-i})$	The anchor probability of loss depending on the investment level from all interconnected parties including the firm *i*
D	Deductible level ($0 \leq D$)
$I(L)$	Insurance coverage
$\pi(L)$	Cyber-insurance premium
δ	The amount of perceived ambiguity ($-1 \leq \delta \leq 0$)
τ	Agent's attitude toward ambiguity ($\tau \geq 0$)

where $I(L) = \max(L - D, 0)$,

$\pi(L) = p(s_i, s_{-i}) \cdot I(L)$.

Model Framework

Model Framework

- Subjective loss probability in the presence of interdependency: Two Nash Equilibria

  1. All agents invest in the security: $S_L\big(p(s_i, s_{-i})\big) = p(s_i, s_{-i}) + \delta(1 - p(s_i, s_{-i}) - p(s_i, s_{-i})^\tau)$
  2. None of them invest: $S_L(\bar{p}) = \bar{p} + \delta(1 - \bar{p} - \bar{p}^\tau), \quad where\ \bar{p} = p(0,0)$

- Assumptions on interdependency

  i. The loss probability decreases with increasing level of the security investment

$$\frac{\partial p(s_i, s_{-i})}{\partial s_i} < 0$$

  i. The absolute value of the marginal decrease in the loss probability slows down over increasing investment level.

$$\frac{\partial^2 p(s_i, s_{-i})}{\partial s_i^2} > 0$$

  ii. The loss probability cannot reach at zero in spite of substantial capacity of the agent to invest in the security.

$$\lim_{s_i, s_{-i} \to \infty} p(s_i, s_{-i}) \neq 0$$

Model Framework

Model Framework

- Scenarios:

	Case 1 (Reference point: Status-quo without self-protection)	
State	No-loss	Loss
Probability	$S_L(1-\bar{p})$	$S_L(\bar{p})$
Reference point	W	$W-L$
Final wealth	$W-s_i$	$W-s_i-L$
Gain / Loss	$\boldsymbol{-s_i}$	$\boldsymbol{-s_i}$
	Case 2 (Reference point: Status-quo with self-protection)	
State	No-loss	Loss
Probability	$S_L\big(1-p(s_i,s_{-i})\big)$	$S_L\big(p(s_i,s_{-i})\big)$
Reference point	W	$W-L$
Final wealth	$W-\bar{\pi}(L)$	$W-\bar{\pi}(L)+I(L)-L$
Gain / Loss	$\boldsymbol{-\bar{\pi}(L)}$	$\boldsymbol{I(L)-\bar{\pi}(L)}$
	Case 3 (Reference point: Full insurance)	
State	No-loss	Loss
Probability	$S_L\big(1-p(s_i,s_{-i})\big)$	$S_L\big(p(s_i,s_{-i})\big)$
Reference point	$W-s_i$	$W-s_i-L$
Final wealth	$W-s_i-\pi(L)$	$W-s_i-\pi(L)$
Gain / Loss	$\boldsymbol{-\pi(L)}$	$\boldsymbol{L-\pi(L)}$

Contribution

What could be the next?

- Set up the benchmark case: Risk-aversion model? Or no-ambiguity case?
- Loading factor needs to be included to reflect the realistic contract.
- What reference points can be further considered? (e.g. the initial wealth in Sydnor (2010))
- Public goods for cyber-security?

Contribution

- It posits two assumptions to explain the latent fatalism of agents observed in reality against cyber risk: Loss-aversion and ambiguity-aversion
- The utilization of prospect theory and ambiguity modeling will enable us to identify the optimal investment in the security system and the demand level for cyber-insurance over the level of ambiguity aversion and the reference point.

Thank you for your attention!