Early identification of emerging food risks and prevention of white-collar food crime

A systems approach by game-theoretic analysts, criminologists, and food technologists

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Content

1. **The problem of "food risk analysis"**
   (wishful thinking and states of ignorance)

2. **The message from the strategic management literature**
   (weak signals, graduated response, early warning systems)

3. **The interdisciplinary approach**
   - **economics/game-theory and PA-approach**
   - **criminology/control theories and protective factor approach**

4. **The case study "Waiting Period after Fungicide Use"**

5. **Conclusions regarding practical tools (M-HACCP)**

The Problem of Food Risk

"a function of the **probability** of an adverse health **effect** and the **severity** of that effect, consequential to a **hazard** (178/2002)

→ positive probability of

harmful ⎤
undesired ⎦ product properties

- protection against health risks

- protection against quality risks
  (free and informed consumers' choice)

Wishful Thinking and States of Ignorance

Managing Surprise and Discontinuity – Strategic Response to Weak Signals (I.Ansoff, 1976)

available information **the firm context**	**States of ignorance**				
	5	**4**	**3**	**2**	**1**
Conviction that threats are existing	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Area is identified which is the source of threat	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Characteristics of threat, nature and gravity of impact are known	**No**	**No**	**Yes**	**Yes**	**Yes**
Response identified: action programs, timing, budgets	**No**	**No**	**No**	**Yes**	**Yes**
Impact and consequences of responses are computable	**No**	**No**	**No**	**No**	**Yes**

Wishful Thinking and States of Ignorance

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available information **the food risk context**	**States of ignorance** **5** →	**4** →	**3** →	**2** →	**1**
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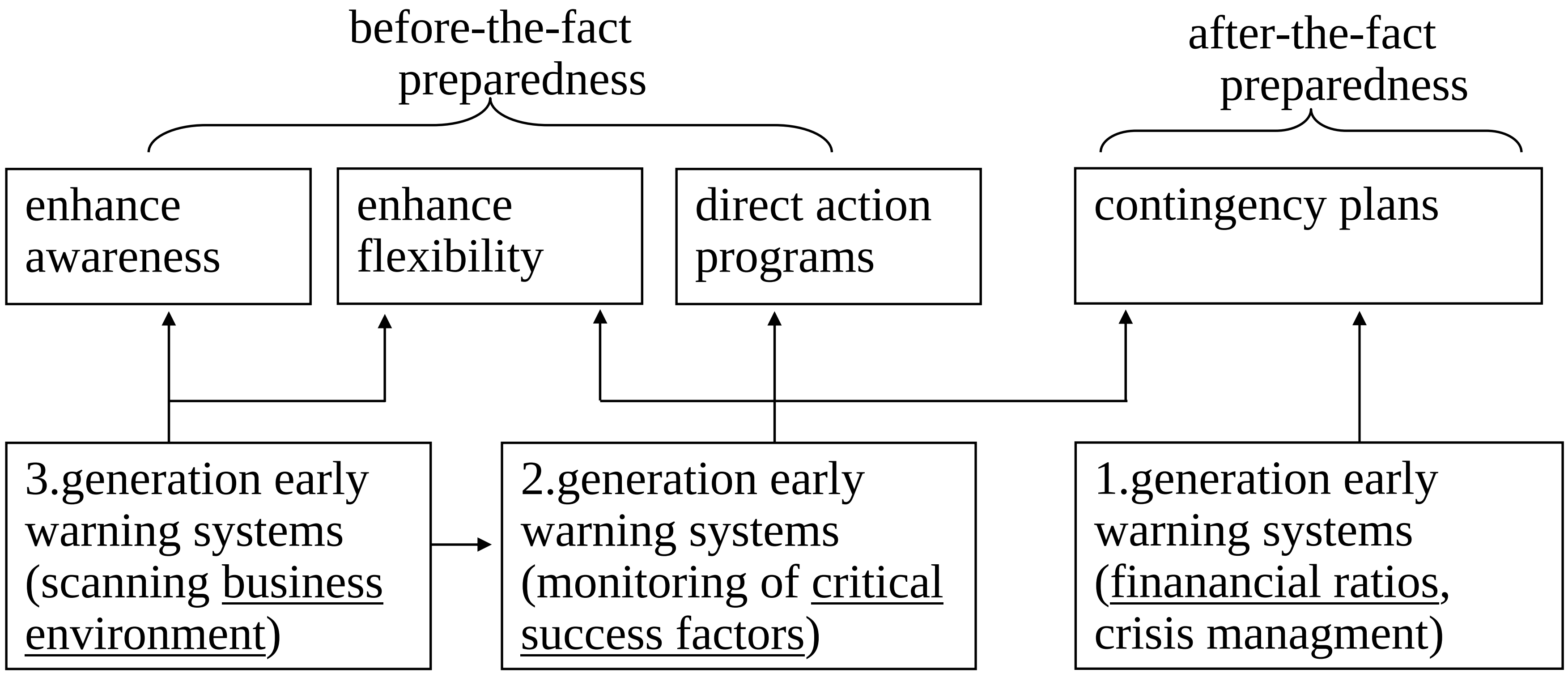
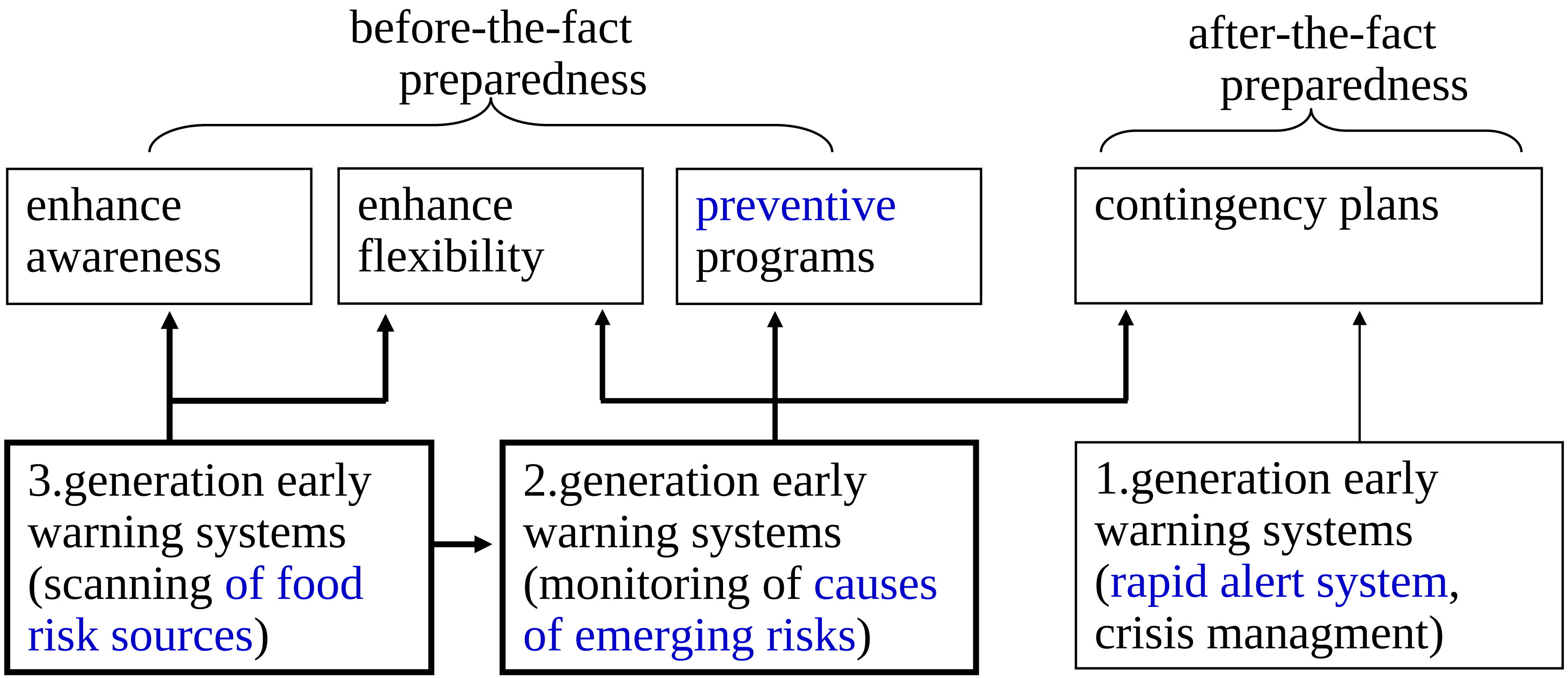
Weak Signals, Graduated Response, Early Warning
- the firm context -



Weak Signals, Graduated Response, Early Warning
- the food risk context -



Sources of Food Risk

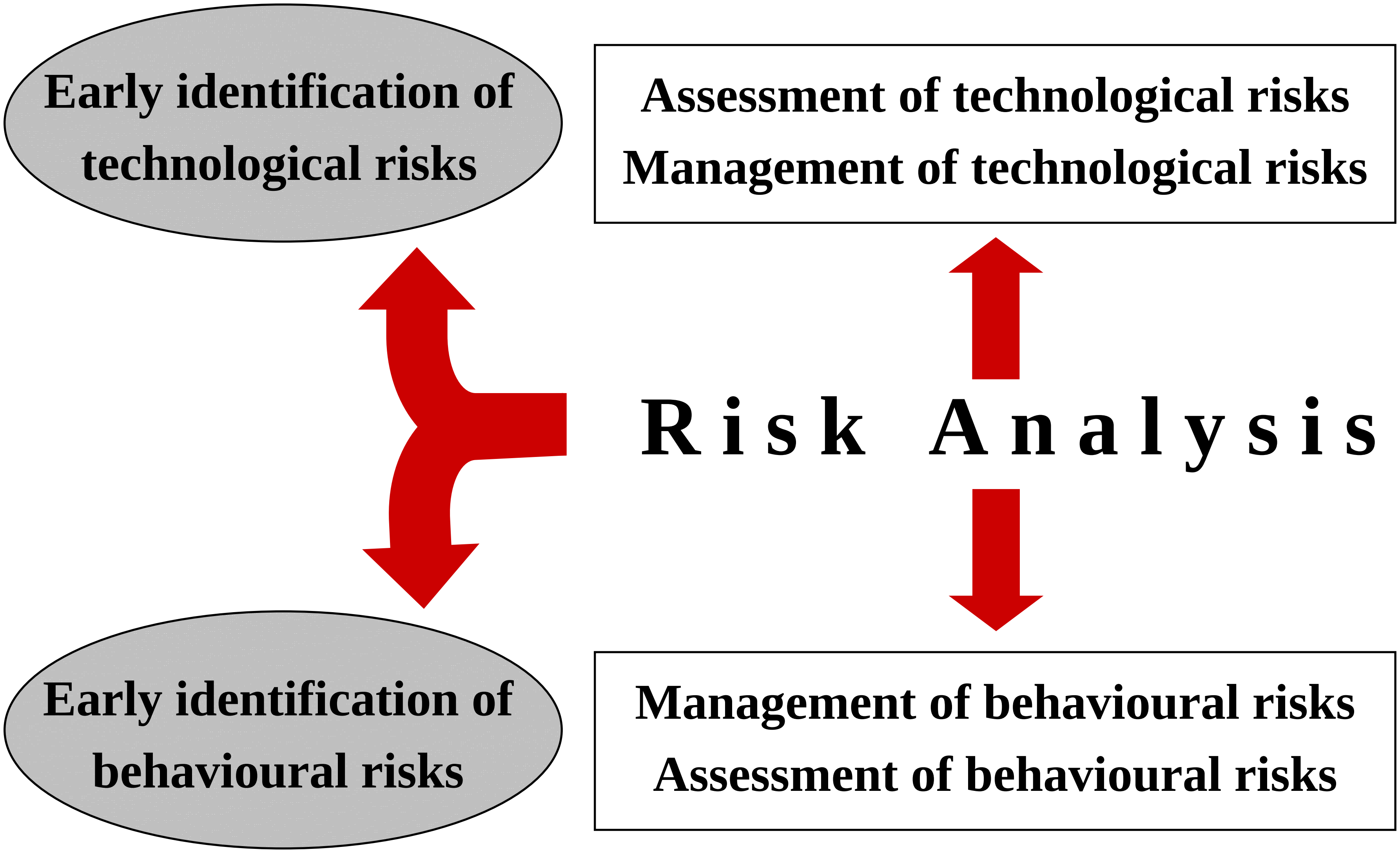
Technological Hazard

- genuine lack of scientific knowledge concerning stochastic influences and the outcome of current production processes

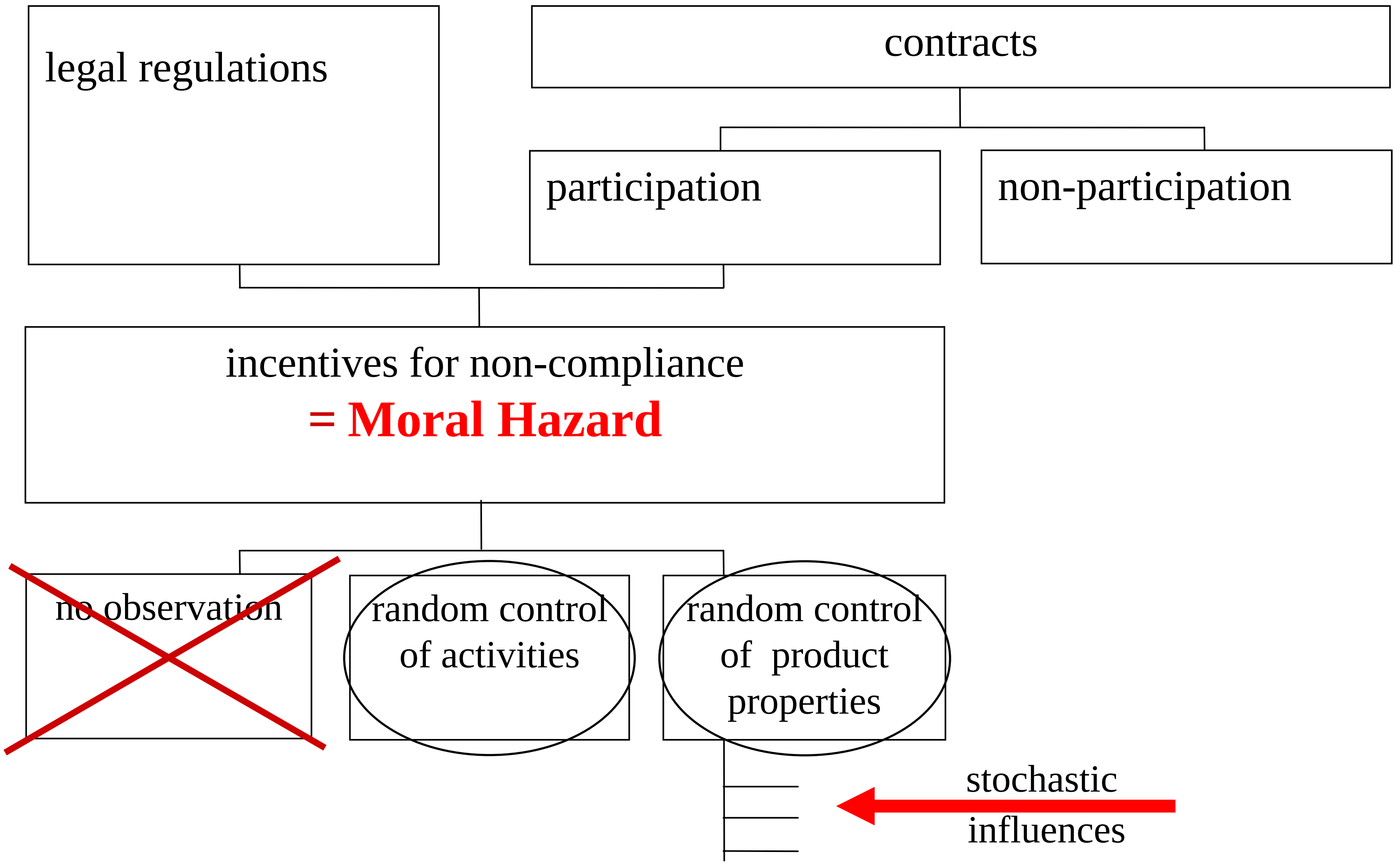
- unintended food incidents and food safety breakdowns

Moral Hazard

- opportunistic malpractice of upstream sellers who exploit information asymmetries in the case of credence qualities (behavioural risk)
- negligence and lack of information on the part of food business operators


Early identification of technological risks
Assessment of technological risks
Management of technological risks
Risk Analysis
Early identification of behavioural risks
Management of behavioural risks
Assessment of behavioural risks

Struktur of Moral Hazard/Food Risks



Necessary Scientific Tools/Approach

- methods of systematically obtaining expert and lay knowledge regarding moral hazards (early warning systems 1-3)
- systematic analysis of food chains at large
- economic/game theoretic modell to process this type of information (incentive analysis)
- criminological/social psychological reconstruction of non-economic social factors that shield actors from deviant behaviour in spite of contrary incentives

The Economic/Game-theoretic Approach

Enforceable contracts are often not available !!!

Positive Analysis (PA-model)

→ **reconstruction of the economic incentive situation in food supply chains**
identification of misdirected economic incentives
(levels, actors, activities and transactions of the food chain)

Normative Analysis

→ **design of adequate control and incentive systems**
= getting the incentives 'right'

Missing: Practical Moral Hazard Models (data !!!)

The Criminological/Control Theories-Approach

Complete contracts are often not available !!!

Positive Analysis

→ **systematic reconstruction of social context factors in food supply chains**
identification of protective factors
(levels, actors, activities and transactions of the food chain)

Normative Analysis

→ **design of measures to enhance protective factors**
= relative merits of differential control styles (smart/soft controls)

Missing: Practical application to white collar crime in the food context

The interdisciplinary approach

Common conception of human behaviour

purposive action, i.e. economic motives
in conjunction with the individual‘s social
context factors determine his behaviour

Cooperation across the disciplines

Economics:	quantification of economic incentives identification of misdirected incentives optimal contract design = getting the incentives right
Criminology:	qualitative reconstruction of social behavioural determinants identification of existing protective factors possibilities of their enhancement

→ joint deduction of c*onsistent* recommendations (adequate preventive measures; social engineering) which account for the complexity of human decision-making.

What is a PA-Model ?

A principal who cannot observe the

agent's action and effort wants to

design a remuneration scheme contingent on a stochastic output which

induces the agent to act in a way that maximises the principal's utility

The Standard PA-Model

Step 1:

$$\min_{w(\cdot)} \sum_{m=1}^{M} \pi_{nm} w_m = w_{\min}(a_n) \qquad \textbf{(1)}$$

$$s.t. \quad \sum_{m=1}^{M} \pi_{nm}(u(w_m)) - k_n \geq \mu \qquad \textbf{(2)}$$

$$\sum_{m=1}^{M} \pi_{nm}(u(w_m)) - k_n \geq \sum_{m=1}^{M} \pi_{n'm}(u(w_m)) - k_{n'}, \quad n' = 1, \ldots, N \qquad \textbf{(3)}$$

Step 2:

$$\max_{a_n} \left(\sum_{m=1}^{M} \pi_{nm} y_m - w_{\min}(a_n) \right) \qquad \textbf{(4)}$$

The Binary Food Risk-Model (I)

- **Legal regulations or private contracts define required behaviour conforming to specified standards.**
- **Two actions are available to the agent/seller: compliance and non-compliance**
- **Non-compliance increases the probability of the undesired product quality**
- **Non-compliance of an agent/seller cannot be observed directly by the principal/buyer (information asymmetry).**
- **The better informed agents maximise profits. According to their individual utility function they break rules if there are economic incentives for doing so (opportunistic behaviour).**
- **Prices for desired and sanctions for non-desired qualities as well as (costly) controls and traceability measures can be defined by the principal who wants to induce compliance by changing the agent's incentive situation**

The Binary Food Risk-Model (II)

- **Agent = upstream seller**
- **Principal = downstream buyer**
- a_1 **= action 1 = non-compliance**
- a_2 **= action 2 = compliance**
- y_1 **= output 1 = undesired quality**
- y_2 **= output 2 = desired credence quality**
- r **= probability of "undesired" product quality for non-compliance**
- q **= probability of "desired" product quality for compliance;** $q > 1-r$
- K **= effort = costs of compliance**
- P **= price = remuneration for desired quality**
- S **= sanction = remuneration for undesired quality**
- s **= control intensity** $(0 < s \leq 1)$
- z **= traceability** $(0 < z \leq 1)$

The Binary Food Risk Model (III)

Behavioural Risk Assessment

$$Min\, w(a_2) = Min\left(P - sz \cdot (1-q) \cdot (P+S) \quad + \quad c(s) + c(z) + c(S)\right)$$

s.t.

$$w(a_2) - k_2 = P - sz \cdot (1-q) \cdot (P+S) - K \geq 0$$

(participation constraint)

$$w(a_2) - K - w(a_1) = sz \cdot (q + r - 1) \cdot (P+S) - K \geq 0 \text{ ,} \textit{with } K = k_2 - k_1$$

(incentive compatibility constraint)

The Binary Food Risk Model (IV)

Behavioural Risk Assessment

$w(a_2) - K - w(a_1) = sz \cdot (q + r - 1) \cdot (P + S) - K \geq 0$ *,with* $K = k_2 - k_1$

(incentive compatibility constraint)

for $q = 1$:

$$w(a_2) - K - w(a_1) = szr \cdot (P + S) \geq K$$

The Game-theoretic Food Risk-Model

Are there misdirected economic incentives?
(Is it more profitable to comply or not to comply?)

Which activities are most offence-prone?

What can we do to get the incentives “right”?

The Fungicide Residue Example (I)

A: conventional application of fungicides prior to harvesting

- labelled to control of fusaria, erysiphe graminis etc.
- prescribed waiting period: 35 days

B: profit maximising farmer might be tempted to breach the waiting period

- ***if*** the weather is optimal for harvesting prior to the expiration
- ***if*** the situational incentives are not "right"

C: breaching the waiting period increases the probability

- of harvesting higher technological qualities and quantities of wheat
- of exceeding the tolerance standards for fungicide residues

D: controls/tests are made at different control points

- technological qualities are tested for individual trailer "loads"
- pesticide residue controls are made in blended "batches" only
- reset sampling (traceability vs. actual tracing)

The Fungicide Residue Example (II)

Parameters determining the profitability of shirking as perceived by the farmer

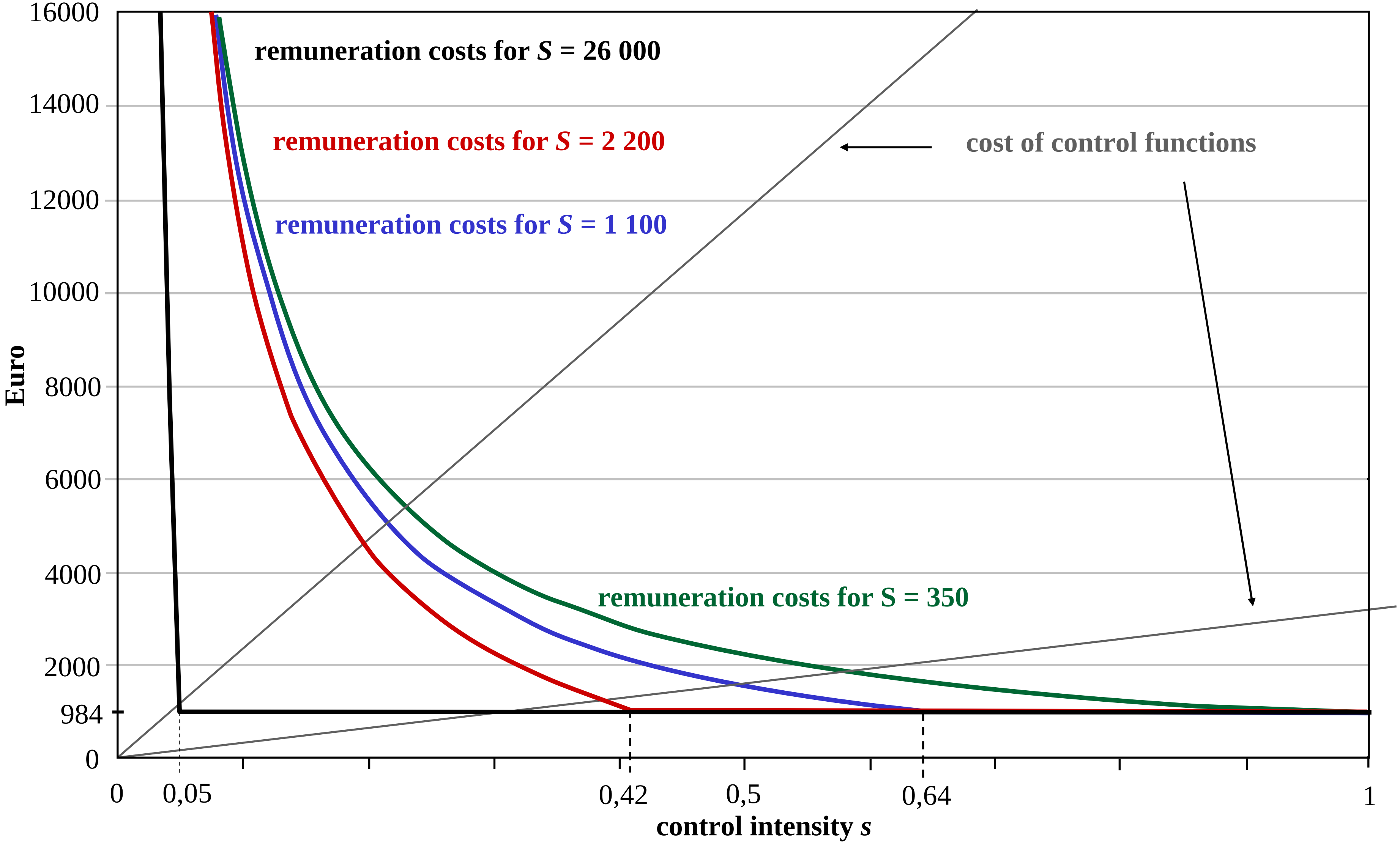
	x-days	parameter	Farmer A
1) probability that the farmer exceeds the residue limit in his individual load if he harvests x-days before the end of the waiting period	10	*r*	**15 %**
	6	*r*	5 %
	2	*r*	0 %
	0	*1-q*	0 %
2) the farmer's probability of being detected if he exceeds the residue limit in his individual load		*s*	**5 %**
3) losses in sales and additional costs (€/ha) if the waiting period is met in spite of weather conditions making it optimal to harvest x-days prematurely	10	*K*	**200**
	6	*K*	100
4) losses in sales (€/ha) if non-compliance is proven		*P*	**984**
5) 'sanctions' (€/ha) if non-compliance is proven		*S*	**1 100**
thereof: - short-term sanctions (fines, damages, …)			350
- capitalised long-term losses in the market			750
6) probability that the farmer can be traced		*z*	**100 %**

The Fungicide Residue Example (III)

The incentive situation

superiority of non-compliance (€/ha)	184
critical sanction in the present system of downstream controls (*s* = 5 %)	26 000
critical sanction after introduction of complete upstream controls (*s* = 100 %)	350
critical control intensity of individual loads with present sanction *S* = 1 100)	64 %
critical control intensity of individual loads with assumed sanction *S* = 2 200	42%

The Fungicide Residue Example (IV)



Lessons to be learnt

- ***making of responsible principals***
  responsible principals internalise external (downstream) diseconomies including consumer health problems and do their best to design incentive-compatible contracts and control schemes
- **systematic information gathering activities**
- **analytic support from game-theory**

The seven principles of HACCP

1. **Analyse food operations and prepare a list of potential hazards.**
2. **Determine critical control points.**
3. **Define adequate tolerance limits.**
4. **Establish adequate monitoring procedures.**
5. **Define corrective measures and contingency plans that are to be used if deviations are found.**
6. **Document all HACCP steps.**
7. **Verify that the system is working correctly and update it, if appropriate.**

The seven principles of M-HACCP

1. Analyse food supply transactions and prepare a list of potential moral hazards.
2. Determine critical control points, including activity controls.
3. Define adequate tolerance limits.
4. Establish adequate monitoring procedures.
5. Define corrective measures and contingency plans that are to be used if deviations are found.
6. Document all M-HACCP steps
7. Verify that the system is working correctly and update it, if appropriate.

Practical conclusion from the analogy

- **the chain (regulator) could introduce a "moral hazard analysis and critical control point system" (M-HACCP)**
- **regulatory measures need to be based on the justification of eventual trade losses by gains in public health and consumer protection**

Some additional comments

- **The scope of HACCP is limited to the prevention of unintentional technological and human failures within one's own production process.**
- **Behavioural risks could be managed using similar principles and systematically aim to manage behavioural risks on the part of one's suppliers.**
- **This requires the definition of critical control points and adequate monitoring procedures with regard to risks that may arise from opportunistic malpractice of upstream trading partners.**

"…some control points (i.e. monitoring fungicide residues in blended lots) are less suited to manage behavioural risks than others (i.e. monitoring fungicide residues in individual loads). Controlling individual loads increases the probability that non-compliance is prevented"

- **A system of behavioural risk management could also be seen as an extension of traceability requirements in that a minimum standard of behavioural risk control is asked for in purchasing transactions in addition to simply documenting where inputs came from.**
- **The introduction of M-HACCP is in line with the principles of subsidiarity.**

Some additional comments (cont.)

- **challenging data requirements of standard PA-models often prevent practical applications**

  reduction of complexity is possible and adequate: we can derive models which can be filled with empirical data
- **PA-models are a powerful tool to analyse behavioural food risks (assessment, management, and communication)**
- **"the incentives in force are in the eyes of the beholder because agents are heterogeneous with regard to their perception of parameters"**
- **"…free riding opportunities in groups may arise *precisely because* the group is trustworthy on the whole, but is in fact (morally) heterogeneous"**
- **behavioural risks from heterogeneous agents are difficult to manage**
- **behavioural risk analysis can indicate the direction of change**
- **Joint compliance is in line with incentive compatibility requirements (adequate direction of change !) *if* the threat to loose subsidy payments is real.**

Some additional comments (cont.)

- **Subjectively perceived economic parameters may differ from objective parameter values; this needs to be accounted for when communicating that parameters have been changed in "the right direction" (beware of adverse effects from simplistic conclusions !**
- **Using parameter estimates from the actors under investigation prohibits an endogenous consideration of risk utility functions (avoid double counting !).**
- **Real-life behavioural risk management will involve the definition and check of discrete alternatives with regard to costs and incentive compatibility rather than solving a formal constraint optimisation problem.**
- **Real-life behavioural risk management will also involve attempts to enhance protective factors which make people obey the law in spite of economic temptations to the contrary.**

Summary:
conceptual insights for emerging food risks

Strategic management literature / corporate early warning systems experience

→

General conceptual framework for the early identification of emerging risks	
behavioural sources	technological sources

Interdisciplinary approach: game theory + criminology

→

Scientific models and tools for the early identification / analysis of re-emerging risks	
behavioural sources	**-**

Learning from analogies

HACCP → M-HACCP

„making of responsible principals“

→

Introduction of “emerging risk management systems“	
behavioural sources	**-**

Variants of the Food Risk Model

		$q < 1$		$q = 1$	
		$sz < 1$	$sz = 1$	$sz < 1$	$sz = 1$
wage costs of principal	$r < 1$	**1a** $P - sz(1-q)(P+S)$	**1b** $P - (1-q)(P+S)$	**3a** P	**3b** P
***participation* ≥ 0**		$P - sz(1-q)(P+S) - K$	$P - (1-q)(P+S) - K$	$P - K$	$P - K$
***incentive* ≥ 0**		$sz(q+r-1)(P+S) - K$	$(q+r-1)(P+S) - K$	$szr(P+S) - K$	$r(P+S) - K$
wage costs of principal	$r = 1$	**2a** $P - sz(1-q)(P+S)$	**2b** $P - (1-q)(P+S)$	**4a** P	**4b** P
***participation* ≥ 0**		$P - sz(1-q)(P+S) - K$	$P - (1-q)(P+S) - K$	$P - K$	$P - K$
***incentive* ≥ 0**		$zq(P+S) - K$	$q(P+S) - K$	$sz(P+S) - K$	$(P+S) - K$

Practical Examples

	$q < 1$	$q = 1$
r <1	hygienic regulations	time limits after antibiotic-treatment
r =1	genetically modified inputs	deceptive labelling; non compliance with productions standards

Legal Consequences

	$0 < q < 1$	$q = 1$
r <1	**behaviour ambiguous**	positive conclusion in case of undesired product quality
r =1	**behaviour ambiguous**	positive conclusion