A framework for the design and analysis of incentive systems for food safety control in supply chains

Coen P.A. van Wagenberg[1], Gé B.C. Backus[1], Jack G.A.J. van der Vorst[2], Bert A.P. Urlings[3]

[1] LEI Wageningen UR, Wageningen, the Netherlands
[2] Operations Research and Logistics Group, Wageningen University, Wageningen, the Netherlands
[3] Animal Sciences Group, Wageningen University, Wageningen, the Netherlands

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[1] LEI Wageningen UR, Wageningen, the Netherlands

[2] Operations Research and Logistics Group, Wageningen University, Wageningen, the Netherlands

[3] Animal Sciences Group, Wageningen University, Wageningen, the Netherlands

Abstract. *Since 2005 the EU food industry has primary legal responsibility for food safety control. This requires new responsibilities and relationships between government and industry, and between companies. This research presents a framework for incentive systems for food safety control in supply chains. It emphasizes key elements of food safety control from multiple perspectives and provides insights for the design and analysis of incentive systems for food safety control. An incentive system combines inter-company incentive mechanisms with intra-company decision making processes to control a hazard within the legal environment. Incentive mechanisms, which consist of a performance measure and a performance reward, induce companies to use control measures. The framework can be used to analyze the effectiveness and efficiency of alternative incentive systems in which companies have to cooperate with partners from other stages of the supply chain.*

Keywords: Incentive mechanism, food safety, supply chain control.

1. Introduction

Food safety is an important food attribute for consumers, governments and companies. Food safety is the "assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use"[12]. A food product is safe for human consumption if it has been produced by applying all food safety requirements appropriate to its intended use, meets risk-based performance and process criteria for specified hazards, and does not contain hazards at levels that are harmful to human health[13].

In 2006 the EU reported 353,000 cases of human zoonoses, of which 53,568 were caused by 5,710 food borne outbreaks resulting in 5,525 hospitalizations and 50 deaths[15]. Reported cases are only a fraction of all food borne illnesses. Societal costs of food borne illness are expected to be high, although accurate reports are lacking. The EU estimated the costs of food-borne Salmonella in 2003 at €2.8 billion (European Commission Press Release IP/03/1306, 29-09-2003). Mangen et el.[41] estimated the costs of campylobacteriosis in the Netherlands in 2000 at €21 million.

Demographic and public health developments in the EU will likely increase the susceptibility of the population for food borne hazards and the associated societal costs. In the EU-27 the number of people of 65 years or older with a higher than average susceptibility for food borne illnesses, is expected to grow from 16% of the population in 2004 to 30% in 2050. More people will be cured from diseases as cancer with chemotherapy and radiation treatment resulting in an affected immune system. And more people will longer survive chronic viral diseases as HIV, that affect the immune system. These developments show the need for increased demands to future food safety control.

EU food safety legislation at the end of the 20th century was insufficiently equipped to deal with the demands to future food safety control. It was fragmented, based on prescriptive laws, and used governmental inspection and testing for compliance[16]. With the General Food Law the EU adopted a new legislation to control food safety. Being based on integrated risk analysis throughout the food chain and primary legal responsibility for the food industry, it requires new responsibilities and relationships between the government and industry and between companies. Within this new institutional framework, EU food companies can design and implement effective and efficient solutions that deal with the demands to future food safety control.

As food safety, food quality is an important food attribute. In contrast to food safety, it has been important for decades. Food quality control can therefore be a good example for future food safety control. Food quality control combines managerial problem solving and technological solutions[40]. To control food quality companies have implemented control systems. A control system for food quality is the set of interdependent processes that function harmoniously, using various resources, to achieve the objectives related to food quality[33]. With a control system companies manage internal production processes. However, the quality of end products also depends on the quality of raw materials, as determined by suppliers. To improve raw material quality the food industry has implemented incentive mechanisms that induce quality control at suppliers[10,25]. Based on the example of quality control, we define an incentive system for food safety control as the combination of control systems for food safety within companies and incentive mechanisms for food safety control between companies in the supply chain. An incentive mechanism for food safety control is the set of performance measures and performance rewards between buyer and supplier, which induce the supplier to improve food safety.

Incentive systems specifically designed for food safety control are only just arising. The first incentive system for food safety control was introduced in Denmark in 1995 and aimed to reduce Salmonella prevalence in primary pig production[3]. Further reductions of Salmonella prevalence in pork products can only be realized by allocating combined control effort among producers and slaughter plants[2,5]. How to design an incentive system that optimally allocates control effort among all companies in the food supply chain is unknown.

This paper presents a framework for the design and analysis of incentive systems for food safety control in multi actor supply chains. The framework identifies key elements of incentive systems for food safety control in a supply chain and considers food safety performance measures and performance rewards. These elements are critical for designing cost-effective incentive systems that meet future EU-level targets for food safety.

2. Key elements of incentive systems for food safety control

Food companies have adopted food safety control to comply with government regulation, to prevent market based threats, and to prevent liability[29,47]. An incentive system for food safety control induces companies in the various stages of the supply chain to implement control systems that ensure that food products meet specific food safety objectives. In designing such a system, we need to consider the supply chain organization. Critical dimensions of a supply chain are process activities, product flow, financial aspects, information, incentives, and governance[7]. Four institutional levels explain how companies function: social embeddedness, institutional environment, governance of relations, and incentive structures[63]. Based on the critical dimensions of supply chains and the institutional levels, we distinguish six key elements of an incentive system for food safety control (Figure 1):

1) Food safety hazards: The characteristics of the hazards determine how it can be controlled.

2) Legal environment: This provides the minimum requirements for the objectives of the incentive system and the companies involved in the system.

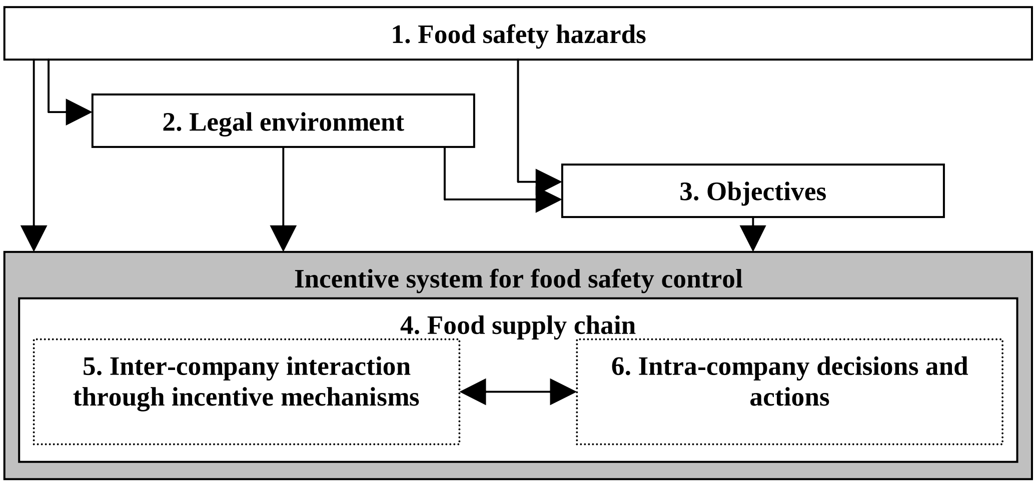

Figure 1. Key elements of incentive systems for food safety control

3) Objectives of the incentive system: This provides the performance objectives concerning the hazards that are to be managed by the incentive system.
4) Food supply chain: This concerns the stages and companies in the chain involved in controlling the hazards, product and process characteristics, and ownership patterns.
5) Interaction between companies through incentive mechanisms: This concerns the arrangements and mechanisms that induce a company to control food safety, and their institutional environment such as contracts and information sharing.
6) Intra-company decisions and actions: This concerns all drivers for and aspects of a company's decision to control the hazards such as the available control measures, their effectiveness and impact on process activities, product flow, and financial features.

In the next sections we discuss the key elements of incentive systems for food safety control.

2.1. Food safety hazards

The Codex Alimentarius[12] distinguishes microbiological, chemical and physical hazards. Microbiological hazards include bacteria, viruses, parasites, protozoa and fungi. Chemical hazards are caused by chemical substances and include residues of pesticides and medicines, and heavy metals and dioxins. Physical hazards include foreign bodies as glass, metal, wood and stone, and radiation. Food safety hazards can be characterized in how they enter and evolve in a product. A contaminant is "any biological or chemical agent, foreign matter, or other substance not intentionally added to food which may compromise food safety or suitability"[12]. Examples are microbiological hazards. In contrast, hazards exist that can only enter a product if specific operating procedures are used, as residues and needles. For microbiological hazards that can multiply as Salmonella and Listeria Monocytogenes, food safety risks can increase after entering the product. Conversely, some hazards, as chemical and physical hazards, do not multiply if present in a product. An incentive system for food safety control must consider the hazard's characteristics, because these provide restrictions on how to control it.

2.2. Legal environment

In 2000 in the White Paper on Food Safety the EU set out over 80 legal actions to improve food safety, that were adopted the following years with as basis Regulation (EC) No 178/2002 (General Food Law). Food safety control must be based on an integrated approach throughout the supply chain and on risk analysis of consumer health effects. The precautionary principle must be used in risk management decisions. Industry has the primary legal responsibility for producing safe food. Governments keep the final responsibility that marketed products are safe. EU food producing and processing companies have to work according to the principles of hazard analysis of critical control points (HACCP) (Regulation (EC) No 852/2004). Regulation (EC) No 882/2004 prescribes the EU member states how to perform official food safety controls. Governments can use tests, audits and inspections to verify if marketed products are safe. But, governments can also verify if a company's system to control food safety ensures this without using tests, audits and inspections. With this so called supervision of control principle, private control systems for food safety can be used in public food safety control. For exporting supply chains it is essential that companies and governments of the importing countries accept this principle.

Product liability laws can be a powerful inducement to improve food safety, if contaminations can be traced to the source and the responsible party faces significant liability costs[9]. The difficulty in identifying the source of contamination and limits on punitive penalties in the EU restrict the potential of product liability laws to improve food safety on farms and processing plants. However, product liability laws can provide strong incentives to improve food safety control in consumer outlets[34].

In Regulations (EC) No 2073/2005, 2160/2003, 396/2005, 2377/90 and 1881/2006 the EU establishes process and product norms, which depend on the hazard. Process norms ensure that the hygiene of a process complies with food law. Product norms provide a maximum concentration or prevalence of hazards in an epidemiological unit. For microbiological hazards, the European Food Safety Authority defines Appropriate Level of Protection (ALOP), Food Safety Objective (FSO), Performance Objectives (PO), and Performance Criterion (PC) [16]. The legal environment must be considered in the design of an incentive system for food safety control, because it sets minimum requirements to the system.

2.3. Objectives

The objectives of an incentive system relate to the hazards and are set by its owner. The likely increase of susceptibility for food borne illnesses and deaths may influence future food safety objectives. A government system aims at compliance with the food safety legislation, for example in using FSO and PO as objectives. A private system aims at compliance with private norms. Private norms should include legal norms and can include additional norms of trading partners. Private systems can be used as marketing device and to exclude competitors. The objectives of an incentive system can focus on effectiveness, the extent to which an incentive system improves food safety. The objectives, especially of a private system, can also focus on efficiency, which relates the costs and benefits of food safety control to the effectiveness: Companies aim to control food safety with minimal costs. The effectiveness is often defined as the average performance change from the steady state before implementation of an incentive system related to the steady state after implementation. For example, the incentive system for Salmonella control in Danish pig production decreased the number of salmonellosis cases caused by pork from 1,100 in 1993 to 166 in 2000[3]. Practical objectives should be realistic, because zero-tolerance and 100% compliance do not exist in real life. The objectives of the system as determined by the owner must be considered in the design of an incentive system for food safety control.

2.4. Food supply chain

A supply chain is a network of physical and decision-making activities connected by material and informational flows that cross organizational boundaries[60]. A food supply chain produces and distributes agricultural and horticultural products. Food supply chains have a large number of spatially dispersed primary producers that deliver products to few wholesalers or processing companies. Most primary producers are small compared to the wholesalers and processing companies. The distribution of returns between companies depends on the ownership structure in the supply chain, such as a cooperative or an investor owned firm[34]. Products and production processes in food supply chains have specific characteristics[4,61]. Biological mechanisms and weather, pests and other biological hazards result in large variation in quantity and quality. Seasonality in production necessitates global sourcing to provide a year round supply. Quality decay, while products pass through the supply chain, limits the shelf life of products. To restrict decay conditioned processing, transportation and storage is essential. However, even provides this, turnaround time from harvest to consumption has to be short for certain products to prevent spoilage. In the design of an incentive system for food safety control, number and size of companies, ownership structure, and product and process characteristics in the food supply chain must be considered, because these influence the choice of incentive system parameters.

2.5. Inter-company interaction through incentive mechanisms

Interactions between firms can be characterized by frequency, uncertainty and asset specificity. The agreements, or contracts, companies use in interactions are analyzed in Contract Theory[8]. If a contract is court enforceable, a formal contract, the risk of reneging is lower than if it is not court enforceable, an informal contract, which is often based on trust. The transaction costs of contracting, monitoring, and enforcing formal contracts exceed those of informal contracts. Transaction costs increase with the completeness of a contract, the extent to which it provides security on all possible outcomes. Limitations to the cognitive abilities of people and high transaction costs make all real contracts incomplete[62]. This creates room for opportunistic behaviour. Inter-company incentive mechanisms can minimize opportunistic behaviour.

Table 1. Elements of incentive mechanisms for food quality control

Report	Characteristics of incentive mechanism							Main findings
	Objective	Performance measurement					Perfor-mance reward	
		Performance indicator	I/O/P[a]	Absolute / relative	Who measures	Accuracy		
Chalfant et al.[10]	Quality	Prune quantity, size	O	Absolute	Dried Fruit Association	Sample; testing error	Variable piece rate	To maximize profit processors use errors in grading process that reduce farmer incentives to produce high quality products.
Curtis and McClusky[14]	Quality	Potato quantity, tuber weight, tare, various damages	O,P	Absolute	Washington State Department of Agriculture	Sample	Variable piece rate	Incentive contracts are effective at increasing potato load quality over a spot market.
Hueth, Ligon, Wolf and Wu[26]	Quality, efficient use inputs	Fruit and vegetable quality, not further specified	I,O,P	-	-	-	Variable piece rate	Input control, field visits, quality measurement and residual price risk are instruments to reduce information asymmetry and align incentives between growers and first handlers.
Hueth et al.[25]	Quality	Tomato quantity, colour, 'limited use', soluble solids, various damages	O	Absolute	Processing Tomato Advisory Board	Sample	Variable piece rate	Growers facing high-powered incentives produce higher quality at higher cost. Quality measurement improves efficiency. Information constraints decrease efficiency.
Hueth and Melkonyan[28]	Quality	Sugar beet quantity, purity	O	Absolute, relative	-	-	Variable piece rate	Regional variation in growers' ability to control measures of sugar beet quality causes variations in the set of performance indicators.
Knoeber and Thurman[35]	Quality, efficient use inputs	Broiler meat quantity, feed conversion	I,O	Relative	-	-	Fixed, variable piece rate	In mixed tournaments: price changes that do not change price differences, do not affect performance; more able players will choose less risky strategies; handicap players of unequal ability and reduce mixing can prevent disincentive effects.

Levy and Vukina[39]	Quality, efficient use inputs	Broiler meat quantity, settlement costs	I,O	Relative	-	-	Fixed, variable piece rate	Tournaments mixing players of unequal abilities create a group composition effect. With fixed groups and a sufficiently long time horizon, piece rates improve welfare over tournaments.
Martin[42]	Quality, efficient use inputs	Pig meat quantity, weight gain	I,O	Absolute, relative	-	-	Fixed, variable piece rate	Contracts with absolute performance measures reduce risks of income variability compared to a spot market. Relative performance measures can further reduce income variability.
Martinez and Zering[43]	Quality, efficient use inputs	Pig meat quantity, leanness, PSE, safety	I,O,P	Absolute	-	-	Fixed, variable piece rate	'Smart' contracts induce industry efforts to improve quality, reduce measuring costs, control quality attributes that are difficult to measure, facilitate adaptations to changing quality standards, and reduce transaction costs of relationship-specific investments.
McDonald and Schroeder[44]	Quality	Beef quantity, yield grade, quality grade	O	Absolute	-	All items tested	Fixed, variable piece rate	Grid base price, feeder price, and cumulative quality in a pen are main determinants of profit for cattle farmers.

[a] I/O/P = Performance indicator based on Input product / Output product / Process

Table 2. Elements of incentive mechanisms for food safety control

Report	**Characteristics of incentive mechanism**						**Main findings**
	Objective	**Performance measurement**[a]				**Performance reward**	
		Performance indicator	**Who measures**	**Accuracy**	**Number of deliveries**		
Alban et al.[3]	Minimize *Salmonella* prevalence in pork	Serological *Salmonella* prevalence	Principal	Sample size, test accuracy, cut-off value	Current and past deliveries	Penalty, mandated actions	Danish program for *Salmonella* control in pigs was revised on: sampling procedure; exclusion of small herds; cut-off value of the test; use of results of previous months in performance; and monthly assignment of a herd to one of three levels.

Backus et al.[5]	Minimize costs and *Salmonella* prevalence in supply chain	Serological and bacteriological *Salmonella* prevalence	Principal	Sample, testing probability	Current and past deliveries	Participation premium, penalty	Dynamic principal-agent model of controlling *Salmonella* in the pork supply chain combines dynamic producer incentive systems on farm level with slaughter plant investments in control measures. Allocation of control effort among both farmers and slaughter plant results in lowest costs.
Hirschauer et al.[23]	Minimize fungicide levels	Fungicide residue level, type-II-error	Principal	Random control intensity	Current delivery	Bonus, penalty	Moral hazard model accounting for incomplete inspection and tracing, and for costs of monitoring, tracing and sanctioning analyzes behavioural food risks. High penalties can be necessary to provide sufficient incentives to farmers to keep the minimum waiting period after fungicide use.
King et al. [34]	Minimize costs and *Salmonella* prevalence	Serological *Salmonella* prevalence	Principal	Sample, testing probability	Current and past deliveries	Participation premium, penalty	Dynamic principal-agent model analyzes two incentive systems for *Salmonella* control that use producer performance history, testing frequencies, and charge testing costs and penalties to the producer. Relating the testing probability to a favorable production history reduces testing costs.
Pouliot and Sumner[49]	Minimize food safety failures	Safe product not specified, type-II-error	Third-party, government	-	Current delivery	Piece rate, liability costs	In a farm-marketer-consumer-chain, traceability creates incentives for farms and marketers to supply safer food through liability. Imperfect consumer-marketer traceability dampens liability and farm incentives. Food safety declines with the number of farms and marketers.
Starbird[53]	Minimize unsafe lots	Safe batch not specified	Principal	Sample size, acceptance number	Current delivery	Piece rate, penalty, internal failure costs	A principal-agent model shows that regulation of sampling inspection procedures is an effective tool for policy makers to improve food safety.
Starbird[54]	Select safe suppliers	Contaminated lot not specified	Third-party, government	Sample size, testing accuracy	Current delivery	Revenue loss, destruction	Test accuracy and sampling error can be used to segregate safe and unsafe suppliers.

[a] All use absolute product related performance indicators based on output.

2.5.1. Information asymmetry

Information asymmetry about food safety exists between companies in a supply chain and the other stakeholders, because 1) real contracts are incomplete[62], so not all food safety related aspects are formalized in contracts; 2) it is often difficult or impossible to observe for other stakeholders as consumers, other companies or governments if a company uses control measures[23]; and 3) conflicting interests obstruct companies to share information about food safety control[11].

Transactions in the presence of information asymmetry are addressed in Agency Theory or the Theory of Incentives[38]. A principal delegates a service to an agent. This shifts part of the risk of reaching the desired outcome to the agent. The principal compensates the agent for the risk based on the performance of the service. Two agency problems can arise. The first is the adverse selection or hidden information problem. Prior to contracting the principal does not have full information about which agents use control measures. The principal only offers low compensation to avoid paying a high compensation to agents that do not use control measures. The low compensation is sufficient for agents that do not use control measures, but not for agents that do, because they have higher costs. So, agents that use control measures will not be contracted and the safer food is driven out of the market. The second is the moral hazard or hidden action problem. After delegation of the service, a principal can not observe the effort of agents to fulfill the service. This might tempt the agents to perform less effort, resulting in a lower performance than the principal desires. In food safety control agency problems can arise on three levels. First, the consumer is the principal and food companies are agents who have to use control measures to control food safety. Second, the government is the principal and companies are agents. Third, a buying company is the principal and its suppliers are agents.

By sharing information companies can create value in a supply chain[17]. Companies refrain from sharing information out of fear for trading partners misusing it[46]. They fear that information sharing will diminish their bargaining power and precluding their sharing in the economic benefits[11]. Bigger companies are more willing to share information, because they receive a larger share of the total gains[45].

The presence of information asymmetry between organizations in and around the food supply chain must be considered in designing an incentive system for food safety control, to prevent adverse selection and moral hazard problems.

2.5.2. Incentive mechanisms

We defined incentive mechanisms as the set of performance measures and performance rewards between a buyer and supplier, which induce the supplier to improve food safety. The reward induces the supplier to control food safety and is based on the supplier's performance. To determine the key elements of incentive mechanisms for food safety control we first analyze incentive mechanisms for food quality control. A non-exhaustive literature review revealed a number of incentive mechanisms for food quality control in animal and plant production (Table 1). The objectives of the incentive mechanisms are high product quality and efficient use of inputs. The performance indicators are product related, based on input or output, and process related. Process related indicators focus on a holistic view of agent effort, which prevents the sole allocation towards tasks that are rewarded, the dysfunctional behavioural response[6]. Audits and inspections are used to assess process related performance. These rely on personal judgment of the auditor or inspector unaided by information feed back, which can result in a possible inaccurate measurement of performance. Indeed, Hueth et al.[27] show evidence of grader bias in Iowa cattle markets. Harmonization and information feed back can be used to minimize the probability of an inaccurate measurement.

Incentive mechanisms may use absolute and relative performance indicators. Absolute performance indicators assess an agent's performance independent of the performance of other agents. Relative performance indicators or tournaments assess an agent's performance relative to the performance of other agents in a reference group. Relative performance indicators filter out common risks on performance and structural errors in the performance indicator, and reduce income variability of the agent[42,50]. The organization that measures performance can be the principal or a third party. The assessment can be biased in favor of the assessor. Several reports consider samples and errors in performance measurement. Samples are used to measure performance, because testing all food products and auditing and inspection of all processes every day can be costly and time consuming. The characteristics of a sample can differ from those of the batch, the sampling error. The sampling error can be partially controlled by random sampling. The characteristics of the processes during an audit or inspection can differ from the processes on other days, for example due to prior announcement of the visit. Random audits and inspections without prior announcement can partly overcome this problem. The quality performance is rewarded financially with a fixed or variable piece rate. Each quality attribute has its own performance measure and performance reward.

The literature review revealed that actual incentive mechanisms in food safety control are scarce (Table 2). Only Alban et al.[3] describe an actual incentive mechanism, the others theoretical mechanisms. Despite this, we can use these reports to derive specific characteristics of incentive mechanisms for food safety control not found in food quality control. The performance indicators include the prevalence of certain hazards, the level of residues, and the probability that unsafe products remain undetected within an epidemiological unit, the type-II-error. The type-II-error can only be measured if traceability exists. Alban et al.[3], Backus et al.[5] and King et al.[34] include performance of multiple deliveries in a mechanism to average out the variance in performance over deliveries. Backus et al.[5] show the value of including multiple stages of a supply chain to control Salmonella. Most reports consider the accuracy of the test through the rate of false positives and false negatives. The long time required before the test results are available[58], can collide with the turnaround time from harvest to consumption for certain products. The performance rewards include penalties for high risk products, additional internal costs, liability costs and scrapping costs.

To our knowledge no empirical literature about the effectiveness of non-financial rewards in food production is available and literature about non-financial preferences is scarce. For dairy farmers non-financial rewards as internal esteem and having healthy animals were equally motivating as monetary rewards[59]. Information sharing in relationships leads to favorable behavioural intentions and delivers value to the chain[17]. Publicizing information about an agent’s performance to a peer group results in peer pressure effects and improved performance[18]. Displaying hygiene grade cards in restaurant windows caused inspection scores of the restaurants to increase, consumers to be sensitive to a restaurant’s hygiene quality, and the number of food borne hospitalizations to drop[31]. Non-material extrinsic awards as orders, medals, decorations and prizes are widely used in monarchies, republics, non-profit organizations and companies[21]. Awards in Dutch agriculture include the “Hillenraad 100” for companies in horticulture and the “Dutch Flower Awards” for suppliers in the flower sector. So, non-financial rewards as information provision, peer pressure, and non-financial awards used in incentive mechanisms might induce company effort.

From Table 1 and Table 2 we derive the key elements of performance measurement and performance reward in incentive mechanisms for food safety control (Figure 2). Performance measurement includes the performance indicator used to assess food safety performance, measurement accuracy, who measures performance, costs and time. Performance reward, which induce companies to use control measures, can be financial and non-financial.

2.6. Intra-company decision making and actions

The decision of an agent to use actions to control food safety is a key factor for his food safety performance. In food supply chains agents are companies. A company’s strategy is an important driver for its decisions. Main drivers for a company to adopt food safety control are expected sales and reputation [30]. Attuning an incentive mechanism to a company’s strategy helps it to optimally induce food safety control.

Decisions in companies are made by people, implying that the drivers of their decisions also drive company decisions. Rational individuals maximize expected utility knowing all options, probabilities and effects. However, bounded rationality makes human behaviour deviate from rational behaviour[52]. The heuristics people use in assessing probabilities and predicting values under uncertainty result in systematic errors[56]. Furthermore, individuals are not only triggered by absolute gains and losses, but also by the relative height of these gains and losses compared to a reference value[32]. People value losses twice as heavy as gains[57]. Financial incentives might induce an agent to decrease effort if his income is above a certain reference income[48]. People relate their gains and losses to those of others. They prefer fair outcomes that are based on equality[51]. If people judge an outcome to be unfair, they are willing to reciprocate even if this is disadvantageous for them[19]. Non-linear discounting makes people overvalue direct consumption and short term gains compared to future consumption and long term gains[20,22]. An all inclusive theory is not yet available.

Companies often have conflicting interests[11]. The interaction of companies with conflicting interests is addressed in non-cooperative Game Theory[37]. A company decides on his actions, given the expected actions of the other company that again depend on his own actions. When neither company can improve its performance by one-sidedly deviating from a decision, both companies will stick to their decision, and a Nash equilibrium exists. In designing an incentive mechanism, a company's rational drivers for decisions and its structural deviations should be considered.

Incentive mechanism for food safety control

Performance measurement

- Food safety performance indicator
  - Process variable: temperature, humidity, CCP
  - Product variable: prevalence, quantity, type-II-error, public health
  - Input / output, absolute / relative, simple / holistic
  - Current / past deliveries
- Accuracy
  - Sampling strategy: size, acceptance number
  - audit/inspection: number of visits, days per visit
  - Testing technology: sensitivity, specificity, cut-off value
  - Harmonization auditors/inspectors
- Who measures performance
  - Principal, third party, agent
- Costs and time

Performance reward

- Financial:
  - Fixed
  - Fixed piece rate
  - Variable piece rate
  - Bonus / penalty, recall
- Non-financial
  - Information provision
  - Peer pressure
  - Awards, medals

Figure 2. Key elements of an incentive mechanism for food safety control

2.6.1. Control measures

To control food safety companies use control measures. A control measure is "any action and activity that can be used to prevent or eliminate a food safety hazard or reduce it to an acceptable level"[12]. A control measure can reduce the risks of multiple hazards or a combination of multiple control measures can be necessary to reduce the risk of a hazard. Preventive measures ensure a hazard does not enter a product. Curative measures eliminate or reduce the hazard in a product. Curative measures located at the end of the production process, are called end-of-pipe measures. The hazard characteristics determine which combination of preventive and curative measures effectively controls it. Hazards for which no curative measures exist must be controlled by preventive measures, or products contaminated with such hazards can be processed separately for markets for which these hazards pose no risk. Hazards that can only enter a product with specific operating procedures, can be precluded by not using the operating procedure. For contaminations, a combination of preventive and curative control measures can be necessary. The stages of the food supply chain for which control measures for a hazard exist should be included in the incentive system. The characteristics of the control measures for a hazard and the effectiveness for each company should be considered in the design of an incentive system.

2.6.2. Product flow

Sampling, testing and control measures as decontamination procedures can increase the turnaround time of products within a company and negatively impact shelf life. If two companies have different levels for a hazard in a product to accept it, for example due to private standards or different local legislation, this can endanger the supply assurance of the company with the tightest level. When suppliers can regularly shift deliveries from one buyer to another, the additional effort for compliance with the tighter level can result in them to cease delivering to that company. The impact of sampling, testing, control measures and norms on product flow and supply assurance must be considered in the design of an incentive system for food safety control.

2.6.3. Financial features

Products with increased food safety risk can result in additional internal and external failure costs. Internal failure costs are additional processing and production costs within the company. External failure costs are financial consequences for society due to consumer illness and death and for the following stages of the supply chain. The financial consequences for society can be calculated with the human capital or the friction cost method[36] using Quality Of Life, Quality Adjusted Life-Year or Disability Adjusted Life-Year[1,41]. The financial consequences for the supply chain are additional processing and production costs. A company faces the external failure costs through product recalls[55], damaged relationships with suppliers with subsequent trade implications, and liability for damages including human health problems[9]. External failure costs are only attributable to a company, when traceability shows that it is involved[24]. Companies can insure themselves against the external failure costs.

Control measures increase costs through labor, investment in equipment, or redesign of the production process. The preparation, execution, and finalization of audits and inspections require labor of the auditor or inspector and company personnel. Testing and sampling require investment in testing and sampling technologies and labor of company and laboratory personnel. But, control measures also decrease internal and external failure costs. So, control measures can be seen as an insurance against these costs with the control measure costs as the insurance premium. Control measures can also result in positive externalities as lower production and processing costs, increased sales, higher sales prices, and market access.

It depends on the owner of and the individual actor in the incentive system how to weigh each of the costs and gains in their decision to control food safety. A company, in general, will focus more on the costs it faces and less on external failure costs that are not attributable to it. In contrast, a government owned system will generally focus more on societal costs and less on company costs.

The costs and positive externalities of control measures, audits, inspections, testing, sampling procedures, and internal and external food safety failures, and how each actor weighs these should be considered in the design of a control system for food safety.

3. Framework for the design and analysis of incentive systems for food safety control in supply chains

In the previous sections we have elaborated upon the key elements of incentive systems for food safety control. Figure 3 provides the extended framework for the design and analysis of incentive systems for food safety control in supply chains. The characteristics of the hazard determine where and how it can be controlled. Food safety and liability legislation provides minimum requirements for the system on controlling the hazard. The owner of the incentive system determines the objectives of the system concerning the hazard. The system considers the number of companies and ownership structure in all supply chain stages in which the hazard can be controlled. Between each two stages an incentive mechanism, embedded in the contract between the companies, induces the supplying company to implement the necessary control measures. Each incentive mechanism considers the presence of information asymmetry. In its decision to control food safety, each company considers the available control measures, their effectiveness and financial consequences, the impact on the internal product flow and supply assurance, internal and external failure costs, and the incentive mechanism it faces. The extent to which external failure costs are attributable to the company depends on the presence of traceability at the following supply chain stages and within the company itself. The incentive system for food safety control can be optimized by considering the cost of all companies and the timeliness of all processes.

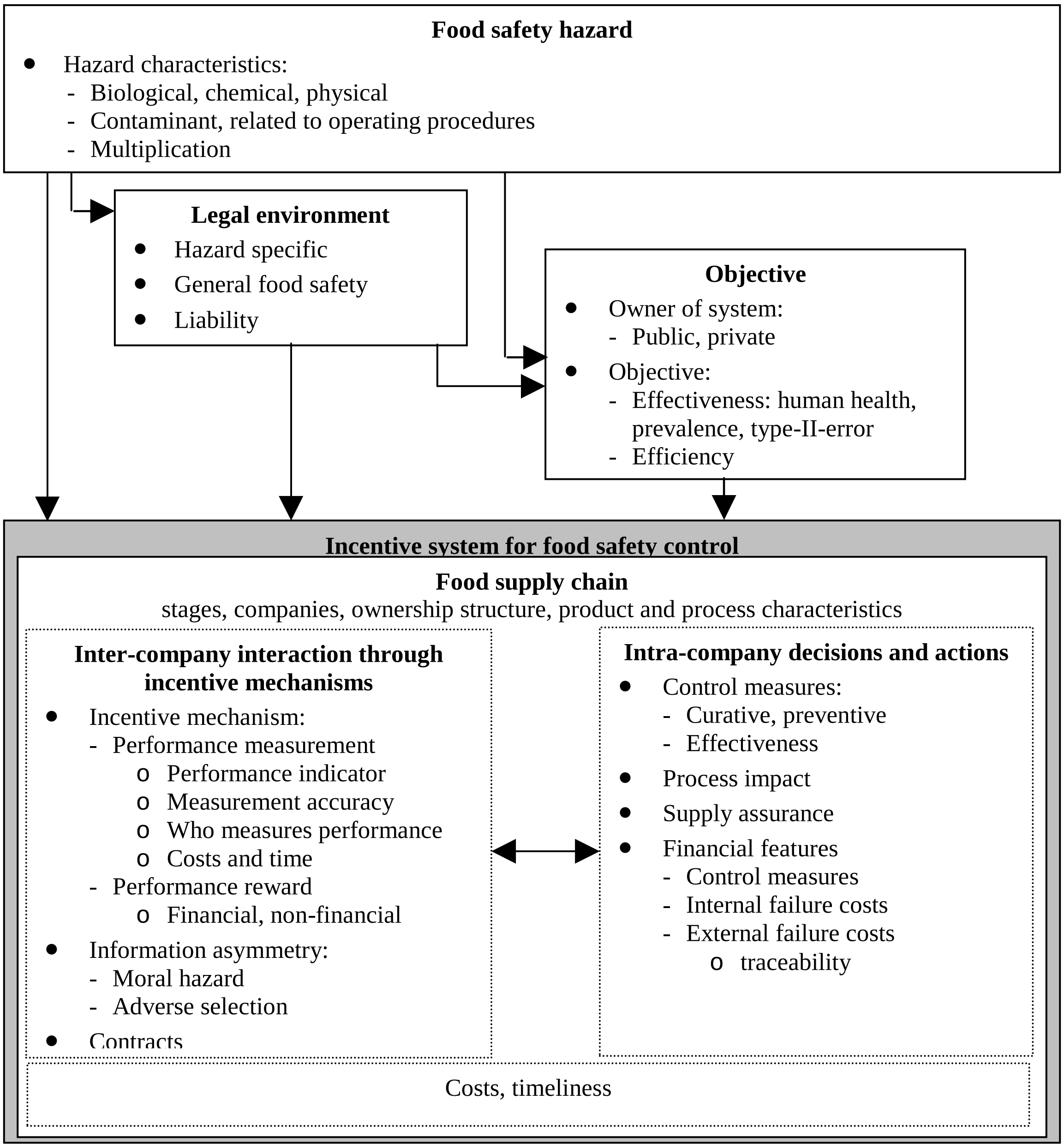

Figure 3. Framework for design and analysis of incentive systems for food safety control in supply chains

4. Conclusion and outlook

This paper presents a framework for incentive systems for food safety control in supply chains. The framework supports the analysis of food safety control issues, emphasizes key elements of food safety control from multiple perspectives, and provides insights for the design and analysis of incentive systems for food safety control. An incentive system aims to control a hazard in a supply chain by combining inter-company incentive mechanisms with intra-company decisions within the legal environment. Incentive mechanisms, which consist of a performance measure and a performance reward, induce companies to use the necessary control measures. The framework can be used for setting achievable targets for food safety hazards and for optimization of food safety control in supply chains.

It is important to recognize that the knowledge of how to apply incentive systems for food safety control in practice is still limited. Insight into the variation in effectiveness or efficiency of incentive mechanisms between companies is needed to improve the design of new incentive mechanisms. The elements of an incentive system for food safety control as control measures, supply chain structure, performance reward, and performance measurement should be geared to reach effective and efficient food safety control. Although the impact of some elements on company decisions has received attention [5,23,34,53,54], more insight is needed into the impact of these and other elements to design effective and efficient incentive systems for food safety control. Also, knowledge is lacking on the use of non-financial factors as information, internal esteem and producing animals according to societal accepted health and welfare standards in inducing agents to use control measures. Finally, knowledge about performance measurement and provision by an agent himself is lacking.

The framework presented in this paper was developed specifically for the case of food safety control, but it can be adapted for other settings with coordinated actions of multiple companies. For example, it can be used to determine the key elements of certification systems like those used for green label producers. As such, the framework can be a valuable tool for analyzing the effectiveness and efficiency of alternative incentive systems in settings where companies have to cooperate with trading partners from other stages of the food supply chain.

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