The Consequences of Heterogeneous Agents and Moral Hazard on Food Safety and Trade

by

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Abstract

The probability that buyers are being deceived with regard to the quality or safety of products increases with the profits that sellers can earn through opportunistic behaviour. It decreases with the probability and level of losses that result from disclosure of malpractice. A systematic prevention of malpractice in food chains needs to eliminate misdirected incentives along the whole chain through a suitable contract design. The scope of this paper is more limited. It demonstrates how moral hazard models can be used for behavioural risk assessment and exemplarily investigates the case of grain producers who might be tempted to breach the minimum waiting period after fungicide application.

Keywords: contract design, fungicides, incentives, moral hazard, risk management

1 Background and Objectives

Food quality and safety regulations as well as voluntarily contracted standards may have significant effect on trade. This is obvious for private contractual arrangements governing transactions in the food sector and defining the specific quality requirements of individual buyers. However, it also applies for regulatory measures implemented by public authorities. In international food trade, for instance, there have been many cases where countries have been denied market access due to their failure to meet standards and/or document their compliance with regulations which are in force in the relevant export markets.

While the WTO Sanitary and Phytosanitary (SPS) Agreement promotes harmonising national with international standards such as those set by the Codex Alimentarius Commission, countries are permitted to take measures which are more stringent than these international benchmarks. However, it requires **scientific justification** to do so (Wilson and Otsuki 2003). This formulation is a source of trade dispute, especially if national standards significantly exceed the international benchmarks. Hence, new regulatory measures must be based on risk assessment which provides scientific evidence of their benefits. Such evidence can refer to public health and technological aspects (which levels of hazardous agents can be tolerated? which technological procedures are acceptable? what kind of process controls are needed?), behavioural aspects (which incentive and control systems are needed to induce compliance?) and informational aspects (what labelling or other information should accompany products?).

Food quality measures are linked to these aspects through product, process, control and information standards. They may, for instance, require that tolerance standards are met with regard to pesticide or drug residues, pathogens, toxins etc. (product standards). They may also define the conditions of food production such as sanitary conditions, pest management procedures etc. (process standards). Although end-of-pipe controls are still important, the emphasis has shifted from product to process standards in recent years, enhancing the need for integrated systems and shared information. Instead of simply inspecting and controlling the physical or bio-chemical qualities of the end product, buyers require that compliance with prescribed production and control procedures, including the application of company-based safety assurance systems such as HACCP (Hazard Analysis and Critical Control Points system), is adequately documented and communicated to trading partners (control and information standards).

Three decisive reasons for this development can be distinguished: (1) consumers increasingly value credence qualities which do not represent physical attributes inherent to the product, but which are rooted in the very way of production (e.g. organically grown products, adherence to social standards, animal protection standards etc.). (2) End-of-pipe controls are incomplete and costly at the same time. It is not feasible, for instance, to test for all hazardous agents such as pesticide residues and the like out of the nearly unlimited number of harmful substances. However, it may be feasible to document a proper and professional use of pesticides in an integrated approach which shares procedural information between the different stages of production down to the retail market. (3) There is a growing scientific understanding that food-borne health problems cannot be excluded by simply guaranteeing tolerance standards with regard to hazardous agents. In most cases, even exposure to low levels of these substances is detrimental. Furthermore, these levels are always subject to stochastic influences. Hence, business operators must be made to choose the right procedures which 'move distributions of unwanted qualities (e.g. toxin levels) to the left', instead of simply 'truncating them at arbitrary tolerance levels' through end-of-pipe controls and a rejection of objectionable batches.

However, the specification of suitable technological procedures and quality management systems does not suffice to guarantee compliance because documents themselves may be subject to fraud by opportunistic economic agents. That is why it is essential to design incentive-compatible contracts which induce compliance with process standards as well as with quality assurance systems. Incentive compatible contracts work independent of the moral attitudes of economic agents because they eliminate economic temptations to infringe rules and thus replace the need for **character trust** by **situational trust** (cf. Noorderhaven 1996).

Utilising a case study from agriculture, this paper focuses on the behavioural aspect of risk assessment by demonstrating how food risk stemming from opportunistic behaviour of heterogeneous agents can be identified through systematic moral hazard analyses. We exemplarily investigate the incentive situation of grain farmers with regard to their compliance with the minimum waiting period after pre-harvest fungicide use. Specifically, our moral hazard investigation aims to **assess** the **behavioural risks** (positive analysis) by answering the following questions: (i) do misdirected economic incentives persist in the actual contractual arrangements in that it is more profitable to infringe the waiting period than to comply with it? (ii) Which consequences result from farmers being heterogeneous with regard to their individual perception of economic parameters, cost estimates and risk attitudes?

Besides risk assessment, moral hazard models have also the potential to support the **management of behavioural risks** in that they can be used for weighing and selecting appropriate prevention measures. In other words: if misdirected economic incentives are found to exist, the question which contractual arrangement should be designed by the downstream buyer could be answered through a model-based moral hazard analysis (normative analysis). However, this requires that the costs of measures that aim to change incentives (e.g. paying premiums, increasing control intensities, rising information standards and increasing traceability, imposing sanctions etc.) are estimated as well. The necessary cost estimates, however, exceed the scope and the aim of this paper whose objective is limited to the assessment of the existing behavioural risks. For further use, we will nonetheless present the complete moral hazard model which is suited for positive as well as for normative analysis.

While not trying to determine the optimal design of the contract between grain dealer (buyer, principal) and grain producer (seller, agent) in this paper, we use the grain producer example to discuss which kind of rule is needed in the first place to turn buyers on all chain levels into 'responsible principals'. Responsible principals would indeed act on behalf of the entire downstream chain and introduce behavioural risk management systems in order to design incentive-compatible contracts for their purchasing transactions. The 'making of responsible principals' requires that they are forced, in turn, to internalise societal costs resulting from downstream diseconomies and finally from consumers' exposure to increased residue levels. In this context, we comment on trade implications resulting from an introduction of behavioural risk management standards, especially in the light of international trading agreements.

2 The Moral Hazard Model for Behavioural Food Risks

Principal-agent models (also referred to as PA- or moral hazard models) tackle the problem of information asymmetries arising in transaction. They assume that a less well informed principal and a better informed agent have conflicting interests. While both maximise their respective objective functions, the principal has the power to design the contract and to take account of the expected actions of the agent within the limits of his informational constraints.

With a view to empirical application, we develop an adequate approach for the analysis of moral hazards in food chain transactions by using a general PA-model (as found, for instance, in Kreps 1990, pp. 577) as a starting point (cf. Hirschauer 2004). The model assumes that an agent has the choice between discrete actions $a_1, a_2, \ldots, a_N$ and corresponding efforts $k_1 < k_2 < \ldots < k_N$. In a stochastic environment, these actions result - with given probabilities π_{nm} - in discrete outputs $y_1 < y_2 < \ldots < y_M$ and output-dependent remunerations $w_1 < w_2 < \ldots < w_M$. The agent's utility depends on his remuneration and effort ($u(w_m) - k_n$), where $u(w_m)$ represents a von Neumann-Morgenstern utility function. If the principal is presumed to be risk-neutral, his design problem can be stated as the following constraint optimisation problem:

Step 1: determine the minimum wage costs $w_{min}(a_n)$ for each possible action

$$\underset{w}{Min} \sum_{m=1}^{M} \pi_{nm} w_m = w_{min}(a_n) \tag{1}$$

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

$$\sum_{m=1}^{M} \pi_{nm} u(w_m) - k_n \geq \sum_{m=1}^{M} \pi_{n'm} u(w_m) - k_{n'}, \quad n' = 1,\ldots,N \quad \text{(incentive compatibility constraint)} \tag{3}$$

Step 2: determine the maximum payoff over all actions a_n

$$\underset{a_n}{Max} \left(\sum_{m=1}^{M} \pi_{nm} y_m - w_{min}(a_n) \right) \tag{4}$$

The specific structure of PA-problems which is caused by information asymmetries and a stochastic environment is illustrated by the fairly general problem formulation used above. While the meaning of model parameters varies with investigated contexts, PA-models have the capacity to provide valuable insights into the structure of many real-life problems that involve transactions under information asymmetries, including behavioural food risks. In the food risk problem, the principal is to be considered the buyer of a product whose uncertain qualities depend on the actions of the seller (i.e. the agent) and a stochastic influence.

However, empirical estimations of parameters such as prices, costs of compliance, frequency of control, traceability, level of sanctions etc. are needed to provide intelligence for specific action situations (i.e. specific food chain activities and transactions). That is, if model calculations are to facilitate practical conclusions, they must be simple enough to be 'filled with empirical data' from the chain activity under investigation. Bearing the applicability of the model in mind, a number of modifications are made to model (1) to (4):

1. Instead of using a generally discrete formulation, we reduce the model to a binary perspective. That is, we consider only two possible actions (a_1 = non-compliance; a_2 = compliance), two effort levels ($k_1 < k_2$), two outcomes ($y_1 < y_2$), and two remunerations ($w_1 < w_2$). The binary perspective allows us to estimate and use simple binomial distributions for stochastic variables such as outcome and remuneration.
2. Instead of accounting for risk aversion endogenously, we assume risk neutral principals and agents in model calculations. Therefore, optimal risk sharing will not be our concern here. However, due to a costly and incomplete output observation (see 5.) we still have the non-trivial problem of how to design an optimal control and remuneration scheme.
3. Instead of accounting for a positive reservation utility μ, we assume a reservation utility of zero. This matches a situation where there are binding rules on how food processing activities have to be carried out: if the agent does not officially 'participate', he does not have the choice to produce a lower quality category and to sell it at a lower price, but has to refrain from production altogether.
4. Instead of accounting for a principal who maximises his utility by selecting the agent's optimal effort level, we assume that the principal knows a priori that his maximum utility results from the higher effort level (i.e. from compliance on the part of the agent). Therefore, he is determined to induce compliance and only strives to do so at minimum costs. Hence, the second step of the optimisation can be omitted and the principal's problem is reduced to cost minimisation for action a_2.
5. Instead of assuming that the output can be verified without costs, we take the characteristics of the food risk problem (credence qualities) into account and consider that observation is costly and that it can only take the form of random sampling inspections carried out with a control intensity $s \leq 100$ %. This results in incomplete output information.
6. The standard PA-model does not account for multiple agent settings. Incentive problems resulting from incomplete output information will be aggravated if identified properties cannot be retraced to a single upstream seller. We consider such situations which are frequently found in food chains by accounting for a limited traceability $z \leq 100$ %.

Instead of simply reformulating the model for these modifications, we turn to its explicit food risk interpretation and a handier notation for the binary incentive problem (see table 1).

Table 1: Notation for the binary food risk model

w_1	=	$-S$	: sanction (loss) inflicted on the agent if the undesired/hazardous quality y_1 is detected
w_2	=	P	: price paid for a product of the desired quality y_2
k_2-k_1=k_2	=	K	: agent's cost of compliance with regulations*
π_{11}	=	r	: probability of undesired product quality y_1 in case of action a_1 (i.e. non-compliance)
π_{12}	=	1-r	: probability of desired product quality y_2 in case of action a_1 (i.e. non-compliance)
π_{22}	=	q	: probability of desired product quality y_2 in case of action a_2 (i.e. compliance): $q >$ 1-r
π_{21}	=	1-q	: probability of undesired product quality y_1 in case of action a_2 (i.e. compliance)
		s	: intensity (frequency) of random controls ($0 < s \leq 100$ %)
		z	: probability that responsible sellers are traced ($0 < z \leq 100$ %)

*We replace k_2-k_1 by the costs K of compliance. It is unrealistic to assume that food business operators produce the unauthorised quality at cost $k_1 = 0$. For the sake of simplicity we normalise k_1 to zero and thereby avoid having to carry an extra variable through the analysis without impeding the general insights into the structure of the problem. A consideration of $k_1 \neq 0$ in applications will be easy. It is only necessary in normative analysis.

Abstracting at first from incomplete inspection and traceability and following the notation of table 1 the principal's minimisation problem may be restated as follows:

$$Min\, w(a_2) = Min\big(-(1-q)S + qP\big) = Min\big(P-(1-q)(P+S)\big) \qquad (1')$$

$$s.t.\; w(a_2)-k_2 = -(1-q)S + qP - K = P-(1-q)(P+S)-K \geq 0 \qquad (2')$$

$$w(a_2)-k_2-w(a_1) = -(1-q)S + qP - K + rS - (1-r)P = (q+r-1)(P+S)-K \geq 0 \qquad (3')$$

In the next step we need to account for incomplete inspection and traceability: prohibitively high costs of complete inspection (e.g. because the product is destroyed by testing) force the principal to resort to partial and random controls. Control intensities $s < 100\ \%$ result in incomplete information about the relevant output (product quality). The limited traceability problem arises whenever an undesired product quality cannot be traced back to a single seller out of the many in a supply chain. This is regularly the case if the principal is dealing with multiple agents without having established an absolutely reliable traceability system.

Table 2: Output and remuneration probabilities

	output probabilities for ...		remuneration probabilities for …	
	y_1	y_2	$w_1 = -S$	$w_2 = P$
a_1 = non-compliance (low effort)	r	$1-r$	szr	$1-szr$
a_2 = compliance (high effort)	$1-q$	q	$sz(1-q)$	$1-sz(1-q)$

Both a control intensity $s < 1$ and a traceability coefficient $z < 1$ change the expected remuneration for non-compliance $w(a_1)$ as well as for compliance $w(a_2)$. Independent of the agent's action or the product quality, the principal has to pay P whenever the quality is not ascertained or cannot be ascribed to a single agent. The agent can at best be made to pay a sanction S if the undesired quality y_1 is evident and clearly due to his making. Contrary to complete inspection and traceability where output probabilities coincide with remuneration probabilities, partial (sampling) inspection and limited traceability entail remuneration probabilities according to table 2. If we additionally consider the control costs depending on the intensity $c(s)$, the costs for achieving different levels of traceability $c(z)$, and the costs for imposing different sanctions $c(S)$, the principal's incentive problem needs to be restated as follows:

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

$$s.t.\;\; w(a_2)-k_2 = P - sz\cdot(1-q)\cdot(P+S)-K \geq 0 \qquad (2'')$$

$$w(a_2)-k_2-w(a_1) = sz\cdot(q+r-1)\cdot(P+S)-K \geq 0 \qquad (3'')$$

$$0 < sz \leq 1$$

3 Perspectives and Scope of Behavioural Risk Investigations

Any investigation into behavioural risks can be related to the definition of the risk analysis process according to regulation EC 178/2002 which defines that "risk analysis means a process of three interconnected components: risk assessment, risk management and risk communication." Furthermore, analogous to the business analysis and planning process, the time horizon determines which parameters are 'givens', and which are 'decision variables' that can be influenced by the decision-maker (i.e. the designing principal). Table 3 visualises how the time horizon and the three components of the risk analysis process are interconnected with the parameters of the moral hazard model. In the overview, the technological parameters of the production process (costs of compliance K; stochastic linkage between the agents' action and the outcome, represented by q and r) are assumed to be constant over all perspectives.

Table 3: Time horizon and the components of the risk analysis process

	(i) short-term perspective	(ii) medium-term perspective	(iii) long-term perspective
risk assessment	all parameters that are in force in the present situation are considered in the analysis of the existing incentive situation		
risk management	givens: K, q, r, s, z, $[c(S)]$ decision variables: P, $[S]$	givens: $K, q, r, c(s), z$, $[c(S)]$ decision variables: P, s, $[S]$	givens: $K, q, r, c(s), c(z)$, $[c(S)]$ decision variables: P, s, z, $[S]$
risk communication	all risk assessment and risk management findings are interactively exchanged among stakeholders		

In **behavioural risk assessment**, the stochastic links between behaviour and technological outcomes as well as the economic parameters (compliance costs, control intensities etc.) need to be assessed for each activity and for each group of actors in the present situation. Using the binary model, there are only few parameters to be considered. In **behavioural risk management**, the decision variables which are under the control of the principal vary with the perspective: (i) a short term given state of a control system can be seen, for instance, as being equivalent to a given control intensity and a given traceability. (ii) In a medium-term perspective, it may be possible to change the control intensity by stocking up on control personnel and equipment. Solving the principal's constraint minimisation problem consequently implies that control costs $c(s)$ are considered. (iii) In a long-term perspective, the traceability that results from the structure of transactions along the chain may be changed by restructuring and documentation efforts. This implies that traceability costs $c(z)$ for achieving different traceability levels are taken into account. Furthermore, it is necessary to consider the costs for imposing sanctions $c(S)$ whenever the sanction is treated as a decision variable. The brackets in table 3 indicate that the sanction is only partially under the control of the principal. Due to legal constraints, its range is usually limited by an upper level. In **behavioural risk communication**, a clear conceptualisation of the problem provides a 'language' for its perception, description and exchange of information, thus improving the interactive communication of behavioural food risk findings among all actors along the food chain.

While there are only few parameters to be considered in the model, their estimation still represents a formidable task. It is not trivial, for instance, to define different control alternatives and provide their cost estimates (let alone intensity-dependent control cost functions $c(s)$ for different control systems and technologies). It is even more daunting to provide reliable estimates for the costs of increasing traceability or for imposing increased sanctions. As has been mentioned before, we therefore limit our investigation to the assessment of behavioural risk in the present system. While using critical value analyses to find out which changes of contract would get incentives 'right', we do not try to optimise the system as a whole. Technically speaking, we estimate the parameters K, q, r, s, z, P, and S from within the food chain and then use equation (3'') to quantify the incentives in force.

4 The Situational Incentives of Farmers after Fungicide Use

4.1 The Situational Background

Grain farmers regularly apply a last dose of fungicides approximately five to six weeks before harvesting. Applied products are labelled for control of fungal infections which could otherwise significantly reduce the quality and quantity of harvested grain. Under certain weather conditions, profit maximising farmers might be tempted to breach the minimum waiting period of 35 days. This is particularly tempting if, a few days before the end of the waiting period, the weather is ideal for harvesting, whereas a long period of rain is expected afterwards.

The individual farmer's incentives depend on the contract, i.e. the overall conditions of the transaction including control and tracing activities on the part of the buyer. The contract details reflect the quality requirements of the grain buyer as well as the degree of trust he puts on the farmer. Since contracts are never completely enforceable (e.g. due to costly controls), farmers are left with opportunities to hide rule-breaking behaviour.

Aiming to assess the rough dimension of the incentives in force, we use stylised facts from a case study instead of collecting data in an extensive survey. The farmers who participated in the case study sell their wheat to a local corn dealer who takes and stores samples from all individual trailer loads, tests them for their technological qualities (humidity, protein content etc.) and differentiates prices for different quality categories. However, before testing for pesticide residues, the corn dealer blends the ‘loads’ from different farmers into ‘lots’ according to the specific quality requirements of his downstream trading partners. Because residues are monitored at downstream control points only, farmers might be tempted to infringe the waiting period. Infringements are only detected if blended lots exceed the tolerance standards. This is only the case if a critical number of farmers break the rule. Otherwise, free-riding farmers stay undetected since residues resulting from their premature harvest are ‘sufficiently’ diluted. That is, **actual tracing** does not take place although complete **ability to trace** is assured through stored individual samples. In other words: the free-riding opportunity arises precisely because the confided group appears trustworthy on the whole, but is in fact (morally) heterogeneous. Despite a complete ability to trace, and even if 100 % of blended lots are monitored, there is only a small probability that the harmful behaviour of a minority of shirking farmers triggers the testing of stored individual samples. Technically speaking we might say that the free-riding problem ‘moves the distribution of the unwanted quality to the right’.

4.2 Assessing Farmers’ Situational Decision Parameters

The economic parameters determining the farmers’ incentive situations were assessed in oral interviews with three farmers in a grain producing area in the federal state of Brandenburg, Germany (see table 4). Additionally, the local corn dealer was asked to appraise the situation. Information is uncertain, and resulting data give evidence of the individual perception of the parameters. Since only discrete data can be gained in a survey, the interviewees were asked to assess the economic parameters for four discrete types of weather, implying, in turn, four different ‘technologically optimal’ harvest dates: 10 days, 6 days and 2 days prematurely (i.e. before the end of the waiting period) as well as an optimal harvest date after the expiration of the waiting period. The term ‘technologically optimal’ implies that, in the absence of a prescribed waiting period, a farmer would harvest because he expects economic losses due to a reduced quality, and/or quantity, and/or increased costs for any posterior date.

Table 4: Parameters determining the profitability of shirking as perceived by interviewed farmers

	x-days	parameter	Farmer A	Farmer B	Farmer C
1) probability that the farmer exceeds the residue	10	*r*	15 %	95 %	33 %
limit in his individual load if he harvests	6	*r*	5 %	50 %	20 %
x-days before the end of the waiting period	2	*r*	0 %	0 %	0 %
	0	*1-q*	0 %	0 %	0 %
2) the farmer’s probability of being detected if his individual load exceeds the residue limit		*s*	5 %	50 %	5 %
3) losses in sales and additional costs (€/ha) if the	10	*K*	200	260	200
waiting period is met in spite of weather conditions making it optimal to harvest x-days prematurely	6	*K*	100	130	100
4) losses in sales (€/ha) if non-compliance is proven		*P*	984	984	984
5) ‘sanctions’ (€/ha) if non-compliance is proven		*S*	1 100	20 750	13 375
thereof: - short-term sanctions (fines, damages, …)			350	20 000	13 000
- capitalised long-term losses in the market			750	750	375
6) probability that the farmer can be traced		*z*	100 %	100 %	100 %

Ad 1): although none of the farmers had access to results of scientific tests concerning the decomposition of fungicides, they all agreed that there is no risk of exceeding the tolerance standard if they comply with the waiting period of 35 days. Trusting that a safety margin had been built into the prescribed waiting period, they also agreed that harvesting two days early would still involve a zero probability of exceeding the limit. According to this perception, a 2days-infringement of the waiting period has the same results as compliance ($r = 1\text{-}q = 0$ %). The farmers' assessments of the decomposition process before that date differed widely, however. Farmer A, for instance, estimated that the probability of exceeding the limit would rise to 5 % (15 %) in the case of a 6days- (10days-) infringement. In wide contrast to that, farmer B, for instance, believed this probability to rise to 50 % (95 %).

Ad 2): in the considered situation, the parameter s represents the aggregate 'probability of being detected' if the individual load exceeds the residue limit. This probability results from the joint effect of two components: (i) the control intensity (i.e. percentage of blended lots which are controlled), and (ii) the dilution effect caused by the fact that loads from different farmers are blended before being tested for residues. All farmers ignored the actual control intensity. They had no information as to whether all blended lots are inspected, or whether only random controls are being made. They likewise ignored the details responsible for the physical dilution effect.[1] However, their ad hoc estimations differed widely with regard to the overall effect of these two factors, i.e. the probability that an infringement would be detected if their individual load exceeded the limit.

Ad 3): reduced sales resulting from suboptimal harvest dates are treated as opportunity costs forming the major part of the compliance costs K: expected losses resulting from technologically suboptimal harvest dates are mainly due to a threatening decline of quality which could force farmers to sell their wheat as animal feed grain at 80 - 90 € per metric ton, instead of food grain at 110 - 120 € per ton. If it is technologically optimal to harvest 10 days before the end of the waiting period, the three farmers expected an almost certain loss of sales of 175 - 210 € per hectare (or 25 - 30 € per ton) due to the degradation of grain to feed quality. If it is technologically optimal to harvest 6 days prematurely, they commonly expected the loss to occur with a 50 % probability only. Besides these opportunity costs, farmers estimated machinery costs to increase by 25 - 50 € per hectare if they were to harvest 10 days later than optimal, and by 12.5 - 25 € per hectare if they were to harvest 6 days later than optimal.

Ad 4): all three farmers are convinced that they would completely loose their income from the wheat sales (including EU-subsidies) of $P = 984$ €/ha if non-compliance was detected. The farmers' perception that – besides sales - transfer payments would be lost can be seen as a positive result of the EU joint compliance approach that enhances incentive compatibility.

Ad 5): farmers estimated that they would have to pay an equivalent of 350 - 20000 € per hectare in direct sanction payments such as fines, damage compensations etc. Farmer B's and farmer C's perception of comparably very high sanctions is mainly due to their understanding that they could be forced to pay damage compensations for large amounts of grain if these were contaminated by their individual load. In addition to these short-term sanctions, farmers assumed that their capitalised future disadvantage on the market (loss of negotiating power) would amount to 375-750 € per hectare of wheat.

Ad 6): farmers agreed that the traceability z amounts to 100 % due to the fact that samples are taken and stored from the individual farmers' loads.

[1] Explicitly determining the 'physical dilution effect' requires expectations concerning one's own share in a blended lot, the residue levels in individual loads depending on the harvesting decision, and the behaviour of other farmers whose loads are part of a blended lot.

4.3 *Investigating Farmers' Incentive Situations*

Table 5 demonstrates the incentive situation which - according to (3'') - results from the farmers' perception of the relevant parameters in force. Results are indicated for the two weather types that favour most premature harvest. We did not endogenously account for risk aversion. Besides avoiding the problem of having to empirically estimate risk utility functions, this is the due approach since risk attitudes are considered exogenously by the very way data were obtained: risk-averse farmers implicitly increased cost-benefit ratios when answering questions with regard to decision parameters (i.e. risk premiums are deducted already).

Table 5: Economic Inferiority (–) / Superiority (+) of Complying with the Waiting Period According to the Perception of the Present Decision Parameters by Interviewed Farmers (€/ha)

weather type	technologically optimal harvest date	Farmer A	Farmer B	Farmer C
I	10 days premature	– 184	+ 10 064	+ 39
II	6 days premature	– 95	+ 5 304	+ 44

Only farmer A perceives an economic reason to infringe upon the waiting period. His actual behaviour in the light of such a temptation is not known. Using the parameters for weather type I as they had been assessed by the farmers, we identify - by means of simple critical value analyses - which change of contract conditions (sanction, control intensity) would c.p. ensure/maintain incentive-compatible contracts. It should be noted that, in the example under consideration, the participation constraint (2'') does not need to be accounted for in the critical value analysis. In contrast, it is possible to design 'boiling-in-oil-contracts' (cf. Rasmusen 1994, p. 180) since the probability of the desired product quality for complying farmers is $q = 1$. Thus, they are neither affected by increased sanctions nor by intensified controls. Increasing the price would nonetheless be a way to reduce the temptation to break the rule. Paying a higher price, however, directly increases the costs of the buyer. This makes only sense if it is not viable or very costly to increase sanctions and/or control intensities.

Examples of contracts which get the incentives 'right' and thus replace the need for 'character trust' by 'situational trust' are given in table 6 for each of the three farmers.

Table 6: Incentive-Compatible Contracts for Weather Type I

	Farmer A	Farmer B	Farmer C
critical sanction with retention of the present system of downstream controls (blended lots)	25683 €/ha	no sanction needed	11016 €/ha
critical sanction after introduction of complete upstream controls (individual loads)	349 €/ha	no sanction needed	no sanction needed
critical control intensity of individual loads with present sanctions: A: 1100 €/ha, B: 20750 €/ha, C: 13375 €/ha	64 %	1.3 %	4.2 %
critical control intensity of individual loads with assumed sanctions: A: 2200 €/ha, B: 41500 €/ha, C: 26750 €/ha	42 %	0.6 %	2.2 %

If the system of downstream controls is maintained and if weather type I occurs, the sanction as perceived by **farmer A** would need to be increased from its present level of 1100 € to over 25000 € per hectare in order to eliminate his 184 €-per-hectare temptation to break the rule. Since it does not seem to be realistic to assume that the principal succeeds in making the farmer perceive the sanction to be at this level, we consider the effects of applying controls to the individual loads. To do so is equivalent to replacing downstream control points (blended lots of grain) by upstream control points (individual loads of grain), thus eliminating the dilution effect and raising the probability that an objectionable load is detected from the perceived level of $s = 5$ % to 100 %. With complete controls of individual loads, a sanction of approximately 350 € per hectare would suffice to eliminate misdirected economic incentives for farmer A. Alternatively, in accordance with the presently perceived sanction level of 1 100 € per hectare, a control intensity of 64 % would suffice if individual loads were being analysed.

Considering **farmer B and C** reveals that, due to information uncertainties, the incentives 'in force' are in the eyes of the beholder. Farmer B, for instance, in contrast to farmer A, clearly perceives no economic temptation whatsoever to break the rule, mainly because he believes economic losses resulting from detection to be very high. Thus, after applying controls to individual loads, a control intensity of roughly 1 % would suffice to generate incentive compatibility in the case of farmer B.

The **corn dealer's** view of the farmers' incentive situation is not depicted in table 3. It is summarised briefly: he believes that, in the present system of downstream controls, a shirking farmer's risk of being detected is almost zero due to the dilution effect. Knowing the approximate level of the other relevant parameters (sanctions, costs of compliance etc.), the corn dealer is convinced that situational incentives are indeed not 'right'. However, according to his interview statement, he relies on character trust with regard to his farmers. This statement triggers the question whether he is really motivated enough to act as a responsible principal.

Abstracting from individual particularities, we can finally generalise from the last row of table 6 that increasing the sanction level allows for a decrease of the control intensity without compromising the incentive compatibility. There is an optimal combination to be found which obviously depends on the costs of analytical controls on the one hand, and the costs of increasing effective sanctions (lawyers, lobbying for sanctions etc.) on the other hand.

The essence of this case study can be pictured through a typology consisting of two extreme- and one mixed-type decision-maker. We arrive at these three types by distinguishing between 'character trust' and 'situational trust': (1) on the one extreme is the farmer who is utterly trustworthy. Because of his personal set of preferences he resists every economic temptation to break the rules. (2) On the other extreme is the farmer who is only trustworthy if, given his exclusive objective of profit-maximising, the perceived situational incentives of the contract are 'right'. (3) Between these two extremes falls the mixed-type farmer who accepts a certain profit trade-off in exchange for a personal feeling of moral integrity resulting from his decision to abide by the rules. He might yield to rule-breaking behaviour, however, if the additional profits to be gained exceed his personal resistance.

It is common sense to assume that real decision-makers are of mixed-type. They might differ, however, with regard to their personal resistance to economic temptations. Taking into consideration that economic parameters may differ from one agent to the other and that they are seen through the eyes of the beholder, some farmers may perceive economic temptations to break the rules; others may not. Amongst the former some may indeed break the rules; others may not. Only these rule-breakers cause a problem from an incentive and food risk point of view. Finding an incentive-compatible solution is not easy: every buyer (principal) will have great difficulties to gain information about how heterogeneous sellers (agents) assess the relevant parameters. An even greater obstacle will be to gain knowledge about their individual characters. Hence, the only practical way to decrease the probability of shirking is to increase situational trust by "marching in the right direction" and increasing the levels of those parameters (as perceived by the agents) that promote compliance. Besides objective changes to the economic environment, this involves considerable communication efforts.

5 Moral Hazard Analysis Systems and Implications for Trade

Lessons with regard to the prevention of moral hazards may be learned from the widely established HACCP-approach which is basically a technological safety assurance system. According to its seven principles, its users are (1) to analyse their food operations and to prepare a list of potential hazards, (2) to determine 'critical control points' where these hazards can be controlled, (3) to define adequate tolerance limits, (4) to establish adequate monitoring procedures, (5) to define corrective measures and contingency plans in case deviations are being identified, (6) to document all HACCP steps, and (7) to verify that the system is working correctly and to update it, if appropriate. Because it consists of general principles, HACCP can be adapted to any production process. While representing the international Codex Alimentarius standard, HACCP has an impact on trade because compliance is costly and may even overstrain the capacities of individual food business operators in many countries. Nonetheless, regulatory measures and private contracts in (international) food trade increasingly involve requirements for HACCP process controls.

The scope of HACCP is limited to the prevention of unintentional technological and human failures. Behavioural risks could be managed using similar principles: in addition to managing the risk of unintentional failures within one's own food production process, one could systematically aim to manage behavioural risks that result from information asymmetries in transactions with 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. Our case of grain producers has demonstrated, for instance, that some control points (i.e. monitoring fungicide residues in blended lots of grain) are less suited to manage behavioural risks than others (i.e. monitoring fungicide residues in individual loads of grain). Controlling individual loads clearly increases the probability that non-compliance is being 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.

A mandatory implementation of a 'moral hazard analysis and critical control points system' (M-HACCP) within a chain would force buyers on all levels to act as a 'responsible principals' when purchasing goods. Scientific evidence must be provided with regard to the benefits (prevention potential) of such a system before food businesses operators can be made to adopt it. If considered useful by some food chain actors for competitive reasons, its implementation could be achieved through private contracts. With a view to (international) trade, regulatory measures aiming at setting behavioural risk management standards would require evidence that justifies imminent trade losses by gains in public health and consumer protection.

6 Concluding Comments

Moral hazard (or: principal agent) models which are derived from the broader branch of game theory explicitly account for stochastic environments and information asymmetries. They consider economic actors as opportunistic (rational) 'players' and offer the opportunity to model situations of conflicting interests, including those of sellers (agents) and buyers (principals) of products with credence qualities. The probability of malpractice on the part of upstream sellers is conceptualised as varying with its expected economic benefits. Thus, moral hazard models enable interested parties to analyse economic incentives on different levels of food chains and to localise hot spots where profit maximising actors are most tempted to break rules (positive analysis). This facilitates conclusions on where and how to change contract and control designs in order to eliminate misdirected economic incentives and to induce compliance at minimum costs (normative analysis). In real-life, rather than solving formal constraint optimisation problems, this will involve to define discrete and feasible alternatives and to check them with regard to their costs and their incentive compatibility.

This article presents a principal agent model that has been adjusted to the characteristics of the behavioural food risk problem. The adjusted model has the capacity to account for incomplete (sample) inspection of the product quality as well as for limited possibilities to trace a product or ingredient to its origins. Its manageable data requirements qualify it as a starting point for the development of operational models which are tailored to particular activities in food chains. The general outline of the moral hazard approach has been demonstrated through a case study from primary grain production. Future research aiming to enable interested parties to reduce behavioural risks in food chains in general needs to extend such analyses to other activities of the considered chain level, other levels of the food chain, and other food chains.

While not representing a systematic analysis and listing of potential moral hazards, exploratory expert interviews revealed some interesting exemplary activities on the level of primary production which might be worth while examining with regard to misdirected economic incentives: (i) weed control directed at eliminating coach grass in barley is the more successful the later the herbicide is applied. The suitable time of application is close to the usual harvest date. But again, there is a prescribed minimum waiting period (10 to 14 days) that farmers might be tempted to disregard due to economic considerations. (ii) Considerable price premiums are paid for organically produced food. At the same time, organic farming must do without chemical pesticides, fertilisers etc. Thus temptations might arise to breach some of the rules of organic farming that either cause considerable additional costs or reduce the yields compared to conventional farming. Examples would be the use of conventional seeds instead of certified organic seeds, a (partial) use of conventional animal feed etc.

The extension of behavioural risk management to a wider variety of activities and, even more so, to other chain levels and other food chains will require that the structure of the food risk model (1'') to (3'') is developed further and extended with regard to its restrictive assumptions. Depending on the situation, the following extensions might be promising:

- Instead of a binary perspective, finer partitions of the agents' scope of action such as different degrees of compliance could be accounted for in a generally discrete model.
- Instead of considering a common set of outputs for compliance and for non-compliance, different sets or probability distributions for continuous output values could be considered.
- Instead of minimising costs, the value (damage) of the desired (undesired) product quality for the principal could be considered explicitly in utility maximising models.
- Instead of assuming a non-ambiguous observation of the output, a statistic measurement error rate could be estimated allowing for an appraisal of first and second degree errors resulting from random sampling inspections.

Before increasing the complexity of applied models, however, it should always be considered whether the informational gains justify the additional costs.

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