Trust and the Profitability of Rule-breaking in Grain Production

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Abstract

Malpractice in food production entails unacceptable procedures and undesirable product qualities and other negative material outcomes. Despite their physical implications, behavioural sources of risk have become known as moral hazards. The probability of malpractice increases with attached profits. It decreases with the probability of disclosure and resulting losses. It also decreases with social values, emotional bonds etc. which prevent food producers from yielding to economic temptations. Trust can be generated both by reducing the profitability of malpractice and by enhancing social trust factors. Referring to Hennessy et al. (2003), who conclude that misdirected incentives are a major source of food risk, we focus on the former and analyse the incentives related to various regulations in grain production.

Keywords: *behavioural risk, moral hazard, incentive-compatibility, trust*

1 Introduction: the Moral Hazard Problem in Food Production

Risks stemming from food production may be caused by technological hazards, i.e. by a genuine lack of knowledge about the stochastic effects of complex production processes, or by safety breakdowns caused by unintentional human or technical failures. They may, however, also be caused by food business operators who breach the rules that are aimed at protecting consumers' health, the environment etc. Suppliers of food products, e.g., might exploit the fact that - due to information asymmetries - their production activities as well as resulting product properties cannot be directly observed by buyers (be they downstream food business operators or consumers). From the buyers' point of view, the fact of asymmetric information is sometimes described with the term credence quality. Credence qualities involve both "simple" quality risks (i.e. the risk of being deceived with regard to a product's quality category) and "serious" health risks (i.e. the risk of using or consuming substances which are harmful). While being tantamount to technological practices and while leading to downstream diseconomies and unacceptable physical outcomes such as consumers' exposure to increased residue levels, the threat of opportunistic malpractice has been labelled moral hazard, emphasising both the underlying cause of risk and the direction of potential countermeasures.

Non-compliance with regulations and contractual agreements may often be more profitable than compliance. This is the reason why measures aimed at eliminating misdirected incentives are an important field of action for public authorities who act on behalf of consumers (citizens) as well as for downstream food business operators who are interested in the quality of purchased inputs. Interested parties need to assess behavioural risks in order to identify those food chain activities where deviance is a viable proposition for food business operators. They then need to manage behavioural risks by designing incentive-compatible contracts and by fostering trust factors. Incentive-compatible contracts (if available at reasonable costs) would work independent of moral attitudes since they eliminate the temptations to infringe upon rules and replace the need for character trust by situational trust (cf. Noorderhaven, 1996).

We attack the behavioural source of risks in grain production by analysing the monetary incentives from an operational-level moral hazard perspective. The context is that of a farmer (agent) and a corn dealer or public authority (principal). Procedural decisions made by the farmer affect the probability distributions of product properties and other outcomes. The principal, however, cannot contract contingent on actual actions because he cannot fully observe them (asymmetric information). Moreover, he cannot directly observe the outcome either.

Moral hazard models, also known as principal agent (PA-) models, have the capacity to provide structural insights into real-life problems such as behavioural food risks and other situations characterised by asymmetric information (cf. Akerlof, 1970; Stiglitz, 1987). However, sound empirical estimates of parameters such as prices, costs of compliance, frequency of control etc. are needed to facilitate practical conclusions. That is, we need suitable methods to obtain estimates for the parameters that define the players' payoffs. We also need to specify adequate models. Since expert opinion is the main source of information in most empirical contexts, suitable methods of empirical social research need to be found for the collection and systematisation of this information. Furthermore, general PA-models as found in the game-theoretic literature (cf. e.g. Fudenberg and Tirole, 1991; Grossmann and Hart, 1983; Kreps, 1990) need to be modified into "leaner" models (cf. Hirschauer, 2004) which account for the limited availability of data and facilitate an analysis with reasonable efforts and costs.

A significant knowledge gap exists with regard to the impact of product inspection and traceability. While a few authors consider partial inspection and multiple agents (c.f. e.g. Demski and Sappington, 1984; Fox and Hennessy, 1999; Starbird, 2005), the fact that quality can usually only be observed through random inspections and the fact that product irregularities cannot always be traced are still to be incorporated into applicable models in the food context.

2 Offence-prone Regulations in Grain Production

We tentatively assessed potential temptations to disregard rules in modern grain farming by interviewing an expert (insider), i.e. a large-scale farmer in Germany. Offence-prone regulations concern a wide diversity of production-related activities and refer, e.g., to food safety and environmental issues. Using the evidence that the farmer provided with regard to the imminence of various offences, we examine the incentive situation in the following situations.

1. Conventional grain farmers regularly spray fungicides five to six weeks before harvesting. Applied products are labelled for control of fungal infections (*fusaria, erysiphe graminis*) which reduce the grain quality. Farmers might be tempted to breach the waiting period of 35 days if, a few days before its expiration, ripeness and weather are ideal for harvesting.

2. In humid years, farmers oftentimes apply pre-harvest herbicides (roundup) in order to kill all green plants, thus accelerating the necessary drying of plant material. The required waiting period between spraying and harvesting is 10 days. Again, farmers might be facing significant economic temptations to infringe upon the waiting period.
3. While being an effective and low-cost herbicide for control of *apera spica-venti* (Windhalm), the use of Isoproturon (IPU) is ruled out for a variety of soil types as well as for certain time periods. The use of alternative herbicides without restrictions increases costs by 20 €/ha. Thus, farmers may be tempted, e.g., to use IPU outside the authorised period.
4. Some farmers may have remaining stocks of pesticides the use of which has been ruled out (e.g. maize herbicide Simazin, DDT) and which are to be professionally decontaminated. Farmers may be tempted to illegally use old pesticide stocks both because they are highly effective and because they would be costly to dispose of legally.
5. Farmers are required to leave a minimum distance between spraying areas and neighbouring waters. Temptations to break these rules might result from the fact that spraying will increase the quantity and quality of grain produced from the concerned acreage.
6. Only trained personnel with an official licence is authorised to handle pesticides and operate dispersion appliances. Often, only one employee has gone through the required training. In case of sickness, the employer may face temptations to assign the urgent spraying tasks to non-trained personnel because they cannot be delayed without economic losses.

Using a straightforward principal agent model, we investigate grain farmers' incentives regarding compliance with these six regulations. That is, we identify critical situations according to the rationale that offences are most imminent if their technological viability coincides with a high level of misdirected economic incentives.

3 Economic Incentive Analysis

3.1 The Model

With a view to the empirical application, we resort to a general discrete PA-model as described, for instance, by Kreps (1990 p. 577). The model assumes that a risk-averse agent has opportunity costs (reservation utility) μ for accepting a contract. After accepting, he has the choice between discrete actions a_n ($n = 1,2,\ldots,N$) and corresponding deterministic efforts $k_n < k_{n+1}$. In a stochastic environment, these actions result – with given probabilities π_{nm} – in discrete outputs $y_m < y_{m+1}$ ($m = 1,2,\ldots,M$). For these outputs the principal defines output-dependent remunerations $w_m < w_{m+1}$. 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 risk-neutral, his design problem can be stated as follows:

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

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

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

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

Step 2: determine the maximum payoff over all actions a_n

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

Since expert opinion is *the* source of information for quantifying the model parameters in many food risk contexts, we adjust the general PA-model to the availability of data by making the following modifications: **(i)** We apply a binary perspective and consider only two possible actions (a_1 = non-compliance; a_2 = compliance), two corresponding effort levels ($k_1 < k_2$), two outcomes ($y_1 < y_2$), and two remunerations ($w_1 < w_2$). This enables us to use expert estimates in the form of binomial distributions for variables such as outcome and remuneration. **(ii)** 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. **(iii)** We assume a reservation utility $\mu = 0$. This reflects a situation with binding regulations where the agent has to refrain from production if he does not officially "participate". **(iv)** Assuming that the principal is pre-determined to induce compliance and only strives to do so at minimum (budgetary) costs, the second step of the optimization can be omitted and the problem is reduced to cost minimization. **(v)** We take into account that observation regularly takes the form of random inspections carried out with a control intensity $s \leq 100$ % which determines the disclosure probability if there are no other sources of detection. **(vi)** With a view to product inspection, we incorporate a tracing-probability coefficient $z \leq 100$ %, taking into account that identified irregularities are not (or cannot) always (be) retraced to single sellers.

Instead of simply reformulating the Kreps-model for the above-mentioned modifications we now use the handier notation from table 1. Both a control intensity $s < 100$ % and a traceability $z < 100$ % influence the expected remuneration for non-compliance $w(a_1)$ and for compliance $w(a_2)$. In the case of random product inspections, e.g., the buyer (principal) has to pay P whenever the quality is not ascertained or cannot be ascribed to a single agent. The agent can only be made to pay a sanction S if the undesired quality y_1 is evidently his making.

Table 1. Notation for the binary food risk model

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

Additionally considering the control costs depending on the intensity $c(s)$ and the costs of imposing sanction $c(S)$, the principal's design problem can be restated as follows:

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

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

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

$$0 < sz \leq 1$$

While there are only few parameters to be considered in the model, their empirical estimation still represents a formidable task. It is not trivial, for instance, to define different control alternatives and to provide their cost estimates (let alone intensity-dependent control cost functions $c(s)$ for different control systems and technologies). In our case study, we therefore solely assess the current incentive situation and tentatively investigate incentive-compatible alternatives through variant calculations. That is, we determine the parameters *K, q, r, s, z, P,* and *S,* and then use Eq.(3') to quantify resulting incentives.

3.2 Farmers' Economic Decision Parameters

Table 2 summarises the parameter values that are attached to the offence prone regulations listed in section 2 according to the perception of the interviewed farmer. Due to the related interpretation of most parameters, as well as due to the limits regarding the length of this paper, we hereafter only comment on the parameters of the first regulation in detail.

Table 2. Economic decision parameters for offence-prone activities in grain production*

	1. Minimum waiting period after fungi-cide use	2. Minimum waiting period after use of roundup	3. Restricted applica-tion of IPU	4. Ruled-out use of Simazin	5. Minimum spray-ing distance to waters	6. Training required for personnel using spraying appliances
Type of control						
analytical control of product	X	X				
analytical control of soil			X	X	X	
observation of activity					X	X
Relevant parameters						
(a) probability of desired outcome in case of compliance (*q*)	100 %	100 %	100 %	100 %	100 %	100 %
(b) probability of undesired outcome in case of non-compliance (*r*)	**5 %	***10 %	100 %	100 %	100 %	100 %
(c) probability that an irregularity is detected (*s*)	5 %	5 %	5 %	5 %	25 %	10 %
(d) costs (€/ha) arising from compli-ance with the rules (*K*)	100	90	20	50	250	120
(e) "price" (€/ha) paid for desired outcome (*P*)	984	984	984	984	984	984
(f) "sanctions" (€/ha) if non-compli-ance is proven (*S*)	1 100	1 100	50	75	2 000	10
(g) probability that the farmer can be traced (*z*)	100 %	100 %	100 %	100 %	100 %	100 %

* All monetary values are indicated per hectare. If the interviewee provided absolute figures per farming enterprise, they were transformed in a per hectare basis according to the size of the farm the interviewee had in mind.
** if the farmer harvests 6 days prematurely; *** if the farmer harvests 3 days prematurely

After the last pre-harvest application of fungicides, farmers might, under certain weather conditions, be tempted to breach the minimum waiting period of 35 days. In the interview, we focused, amongst others, on weather conditions which make it "technologically optimal" to harvest 6 days prematurely. Using the interviewee's situation, we assume a transaction context where farmers sell their wheat to a 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. According to interview evidence, corn dealers usually blend the individual "loads" into "batches" before testing for pesticide residues. Thus, infringements are only detected if the blended batch exceeds the tolerance limits. This happens only if a critical number of farmers simultaneously break the rule. Otherwise, residues are "sufficiently" diluted and free-riders stay undetected because they run virtually no other risk of being found out.

(a) The interviewed farmer thinks that, in case of compliance with the waiting period, one runs no risk at all to exceed the residue limit in his grain ($1\text{-}q = 0$). **(b)** If weather conditions favour harvesting 6 days early, the farmer estimates that non-compliance with the remaining waiting period increases the probability of exceeding the residue limit to $r = 5$ %. **(c)** In the considered case, the detection probability s does not only reflect the control intensity, but also a dilution effect. The latter is caused by the fact that individual loads are blended into batches before being tested for residues. While ignoring the actual percentage of batches that are controlled as well as the determinants of the dilution effect (such as one's own share in a batch and the behaviour of other farmers), the farmer provided an ad hoc estimate of s = 5% regarding the joint effect of both factors (i.e. the probability that an irregularity is detected if one's individual load exceeds the limit). **(d)** The compliance costs K = 100 €/ha also arise from two sources: if it is technologically optimal to harvest 6 days early the farmer expects a 50%-threat that the grain degrades from food to feed grain quality, resulting in an expected loss of 87.5 €/ha. He also expects an increase of machinery costs by 12.5 €/ha due to rougher harvesting conditions. **(e)** The farmer is convinced that, due to cross-compliance regulations, income from wheat sales and EU-subsidies - adding up to P = 984 €/ha - would be lost if an offence was detected. **(f)** The farmer estimates that one would have to pay an equivalent of 350 €/ha in direct sanction payments such as fines, damage compensations etc. in case of detection. Furthermore, he estimates that capitalized future losses on the market would amount to a net present value of 750 €/ha, adding up to a sanction S = 1 100 €/ha. **(g)** The farmer is convinced that individual loads are traced if irregularities are found in the blended batch (z = 100%). He thinks that the samples that were stored from individual loads according to EU-regulations will all be tested despite the costs of chemical analysis if problems are found.

For the sake of a straightforward interpretation of table 2 we will also briefly comment on the relevant aspects of the other five regulations: **(a)** the perception of a probability q = 100 % (i.e. there is no risk of producing the undesired outcome in case of compliance) applies to all cases. **(b)** In the case of offences with regard to regulation 1 and 2, the farmer expects a beneficial stochastic effect from the environment, resulting in low probabilities r = 5 % and 10 %, respectively, despite non-compliance. In contrast, in cases 3 to 6 he is convinced that an offence produces a deterministic result regarding the observable negative outcome (r = 100 %). He believes, for instance, that a chemical analysis of the soil would provide unambiguous evidence if rule 3, 4 or 5 had been broken. **(c)** While dilution in blended batches plays a similar role for offences 1 and 2, the detection probability s of all other offences simply reflects the inspection intensity. **(d)** Compliance costs K comprise several components that differ from regulation to regulation. In the case of an illegal use of Simazin remainders, for instance, they arise from reducing expenses for new pesticides as well as from saving the costs of legal disposal. **(e)** While not being well informed concerning the new cross-compliance regulations, the farmer's perception is that – for all offences considered - market income as well as EU transfer payments would be completely lost for the concerned acreage if an offence was proven. **(f)** While not being well informed either with regard to the sanctions, the farmer "has heard stories". This results in a differentiated subjective perception of imminent sanctioning for the various offences under investigation. **(g)** Despite the fact that, in cases 1 and 2, controls are only made at the downstream control point "blended batch", the traceability amounts to z = 100 % because samples are taken from individual loads. In all other cases, the traceability coefficient z can be equated with unity because we observe informational signals which are unambiguously attached to the agent (e.g. residues in the farmer's soil).

3.3 The Resulting Incentive Situation

Part A of table 3 indicates the incentive situation resulting from the parameter values indicated in table 2. There is a significant temptation to break the regulations 1, 2 and 6 according to the farmer's perception of relevant parameters. It would be unprofitable, in contrast, to infringe upon the regulations 3 to 5. The perception of a comparably high deterrent regarding offence 5 is due to the farmer's understanding that disregarding the minimum spraying distance to waters would be visible to the naked eye (s = 25 %) and that the sanction – at a per hectare rate – would be very high (S = 2000 €/ha).

Table 3. The incentive situation for various parameter constellations

	1. Minimum waiting period after fungicide use	2. Minimum waiting period after use of roundup	3. Restricted application of IPU	4. Ruled-out use of Simazin	5. Minimum spraying distance to waters	6. Training required for personnel using spraying appliances
A: economic inferiority (-) / superiority (+) of compliance (€/ha)	-95	-80	32	3	496	-21
B: ceteris paribus critical sanction level S (€/ha)	39 016	17 016	-	16	16	216
ceteris paribus critical detection probability s	96.0%	43.2%	1.9%	4.7%	8.4%	12.1%
critical sanction level S for s = 25 % (€/ha)	7 016	2 616	-	-	16	-

Resorting to Eq.(3') a critical value analysis (see part B of table 3) reveals which change of sanction and controls would ensure/maintain incentive-compatible contracts. In all cases under consideration, the participation constraint (Eq.2') does not need to be accounted for in such an 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 is q = 100 % for complying farmers. Thus, they can be assumed to be neither affected by increased sanctions nor by intensified controls. If present prices and controls are maintained, the perceived sanctions in case 1 (2, 6) need to be increased from their present level of 1100 €/ha (1100, 10) to 39016 €/ha (17016, 216) in order to eliminate the temptation to break the rule. In all other cases, sanctions could be reduced to the indicated levels without jeopardising the incentive-compatibility. Increasing the probability of being detected to s = 25 % in all considered cases, allows for a general decrease of sanctions. In cases 3, 4 and 6 no sanctions would be needed at all.

A realistic model which tries to reconstruct the decision situation needs to incorporate the relevant factors *as perceived by decision-makers*. The actual behaviour of farmers in the light of temptations to break rules is not known. It seems reasonable to picture farmers through a typology consisting of two extreme- and one mixed-type decision-maker: (i) the one extreme is the farmer whose character is utterly trustworthy. Because of his personal set of preferences he resists every perceived economic temptation to break the rules. (ii) The other extreme is the farmer who is only trustworthy if, given his exclusive objective of maximising profits, the perceived situational incentives of the contract are "right". (iii) Between these two is the mixed-type who accepts a profit trade-off in exchange for a personal feeling of moral integrity resulting from his rule-abiding behaviour. He might yield to rule-breaking behaviour, however, if the additional profits to be earned exceed his personal resistance.

4 Outlook

Designing effective measures against behavioural risks requires systems analysis approaches which consider all relevant factors that motivate human behaviour. Game-theoretic PA-models are efficient means to process quantifiable information regarding payoff relevant economic factors, even though this information will often need to be based on expert opinion. Going beyond the critical value analyses of this paper, identifying optimal incentive-compatible contracts would require that, besides remuneration costs, we consider the costs of different control and sanction regimes. Estimates are needed, e.g., for the costs of control depending on the intensity, for the costs of imposing sanctions, and, in the long run, even for the costs of changing the overall chain structures. Furthermore, the problem needs to be attacked of how to deal with agents that are heterogeneous, e.g., with regard to their type or their compliance costs. That is, the adverse selection aspect of the incentive problem needs to be considered.

Despite efforts aimed at designing optimal contracts, misdirected economic incentives may persist because they cannot be reduced to zero with reasonable costs. The search for optimal trust systems requires, on the one hand, the consideration of the marginal returns of measures that reduce misdirected incentives and, on the other hand, of activities that enhance trust factors in the social context. It also requires that we account for the interdependence of both types of measures such as dysfunctional effects of increased controls which might arise in situations with heterogeneous agents where the trustworthy ones are control-averse. Trust factors in social contexts, even though they may represent crucial determinants of behaviour, are intrinsically hard to quantify and usually resist their representation in formal models. Future research aiming to improve our understanding of what it is that makes food producers choose certain actions should therefore integrate economic and non-economic social science disciplines and combine the relative merits of their respective approaches and toolboxes. We apply, for instance, an economic-criminological approach in a project that examines moral hazard in the poultry industries. This project looks at the economic temptations to disregard rules as well as at the so called “protective factors” (bonds to norms) that reduce the actors’ freedom to do so (Braithwaite, 2003; Tittle, 2000). It seems sensible to exclude social factors from formal models even though they are payoff (utility) relevant. A criminological analysis, e.g., guarantees that – instead of being merely considered as constraints or subordinate objectives in a formal economic model – social factors are considered in their own right by using an adequate toolbox and a complementary social-psychological perspective.

While the tentative investigation of this paper has illustrated the capacity of moral hazard approaches to behavioural risks, revealing relevant regularities and providing decision support also requires that we enlarge the data base: first, with regard to grain production, the information resulting from interviews with one randomly selected farmer should be complemented by a broad investigation of representative samples of farmers in different regions, with different farm sizes, with different socio-economic characteristics etc. Second, a nearly endless number of activities on all levels of the grain chain and other food chains may represent sources of behavioural risks. They all lend themselves to the above-described incentive analysis. However, given budgetary constraints and the costs of investigations, one will first need to scan the food chains and to gather expert knowledge in order to narrow down the number of in-depth investigations to the most imminent threats.

Future work should also focus on the development of easy-to-apply tools that can be used, e.g. by public authorities, for a systematic analysis and prevention of behavioural risks on all levels of food chains. Extending efforts to a systematic analysis of behavioural risks in the food sector at large may require that the structure of the above-described PA-model is developed further and extended with regard to its restrictive assumptions. It may also require that we develop and use approaches from the social sciences that are apt to dig deeply into the social determinants of trust, for instance, by including ethnographic perspectives and concepts of comparative deviance and cultural criminology (Presdee, 2004). With a view to a realistic assessment of the possibilities of asserting the necessary changes, this should be accompanied by an institutional analysis of relevant societal subsystems. While the particular contributions of various groups of actors are crucial for implementing change, different actors may follow their own rationalities and thus oppose changes whenever central control/enforcement is lacking.

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We replaced k_2-k_1 by the costs K of compliance. It is unrealistic to assume that food business operators produce the unauthorized quality at cost $k_1 = 0$. For the sake of simplicity we normalise k_1 to zero and avoid having an extra variable without impeding the insights of the analysis.