Firms, Incentives, and the Supply of Food Safety: A Formal Model of Government Enforcement

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Introduction

Regulatory approaches to ensure food safety are challenged by the changes in the supply chain, rapidly advancing food technologies (Pritchard and Walker, 1998; Schofield and Shaol, 2000) and complexities of the institutional environments (Goldsmith, Turan and Gow, 2003; Roosen, Lusk and Fox, 2003; Goldsmith, Gow and Turan; 2003). Consumers do not have adequate information on the safety attributes of the food products that they purchase and concurrently food firms do not have direct incentives to reveal this information (Crutcfield et al., 1997; Segerson, 1999; Caswell, 2000; Böcker, 2002; Goldsmith, Gow and Turan, 2003; Ollinger and Ballenger, 2003; Ollinger and Mueller, 2003; Elbasha and Riggs, 2003; Christensen et al., 2003; Kola and Latvala, 2003). Moreover "without the ability to fully capture returns to costly control of product hazard, firms lack the incentive to implement controls for food safety" (Unnevehr and Jensen, 1999; p.626).

The market for safety attributes of food products is not fully developed (Caswell, 2000) and information asymmetries and incentive problems pose systemic risks in the food sector (Hennessy, Roosen and Jensen; 2003) where sub-optimal outcomes may occur. Some argue with this market failure at hand government intervention is justified in order to enhance social welfare (Elbasha and Riggs, 2003; Roosen, Lusk and Fox, 2003; Kola and Latvala, 2003; Unnevehr and Jensen, 1999; Segerson, 1999). Yet government's task is not simple. There are various policy options and alternative mechanisms, both public and private, available beyond traditional regulation to incentivize food firms to actively engage in food safety. Evaluating and comparing these alternative approaches would involve risk assessment and cost-benefit analysis (Henson and Heasman, 1998; Jouve, 1998; Caswell, 2000; Hobbs, Fearne and Spriggs, 2002). The overarching policy question is how to achieve a safe food supply given both the availability of alternative regulatory, institutional, and market-based strategies and the complexities of operating within a global business environment.

At the heart of this policy question is understanding the fundamental relationship between government (society) and the firm where the market for food safety is of concern. How does society elicit the level of safety it wants? Food firms do have incentives to deliver some safety along with their food products. Some firms have incentives to supply more safety than others. The departure in terms of the safety that any one firm bundles with its products is a function of the private-public goods nature of the safety. Supplying safety is costly. For example, greater levels of safety may need to be bundled with certain food products because of the significant investment, ex-ante, in a national brand and the extent of a financial loss if a breach were to occur (Sporleder and Goldsmith, 2001). In such a case much of the value of safety is a private good whose rents are internalized. Other firms may not have such private incentives and thus may deliver lesser levels of safety. And discussed in conclusion, there may be instances where firms are forced to deliver too much safety.

Correspondingly, there is a demand for safety. As discussed below, the assumption of a downward sloping demand curve for safety is not unrealistic. In such a case the marginal value for each unit of safety declines in quantity. Conceptually then, the problem can be modeled as a market efficiency question. What is the correct amount of safety? And how does government (society) elicit the proper amount of safety if private incentives are inadequate?

To better understand the underlying economics of the market for safety this research formalizes the analysis using agency theory. The framework of the model is the complex power relationship between the regulator and the firm and the efficient delivery of safety.

The salient features of this model are:

- The risk preferences of the agent;
- The mapping between effort and safety and the stochastic properties of food safety breaches;
- The quantity/quality of information and modern immeasurability issues.

The base case depicts the government as the risk neutral principal who needs to induce a risk averse agent, the food firm, to engage in active pursuit of food safety. After the base-case we then turn to the salient features and examine how they impact the delivery of safety. Finally the paper applies the model to analyze recent developments in the U.S. meat industry.

The Model: Food Safety Problem in a Principal-Agent Setting

The Base Case Scenario

In this model the government as the regulator wishes to achieve food safety for the public and the regulated firm produces both food and safety. The two are engaged in an agency relationship. The government can face certain informational, transactional, administrative and political constraints (Laffont, 1994), which create obstacles in the process of implementing preferred policies (Laffont and Tirole, 1993). This generates a moral hazard problem since delegation of a task, in this case providing safe food, is costly and involves information asymmetry between the principal and the agent (Laffont and Martimort 2002; Elbasha and Riggs, 2003). The answer to the moral hazard problem is rooted in the use of incentives (Kreps, 1990; Vetter and Karantininis, 2002). As the principal, government can "incentivize" the agent (Laffont and Martimort, 2002) via use of penalties or compensation schemes.

In order to ensure that the food firm is taking proper actions to provide safe food to the public and choosing the optimal level of effort (e^*), assume the government uses a compensation scheme, *CR (.)*. The compensation that the firm receives is not monetary but rather denominated in terms of "days of operation." The government will let the firm operate; in other words give days of operation as compensatory payment to the firm and send its inspectors to the plant as long as the firm complies with the regulations. If there is a violation then the firm will face the threat of government removing its inspectors. Without the necessary government "stamp," the firm's products would be virtually be unmarketable creating extreme financial distress and likely bankruptcy.[3] Furthermore in case of violations, the firm could face penalties in form of additional fees and further legal (civil or criminal) action. During the time that the firm stays in operation, the government continually sends its inspectors ensuring the plant is in compliance. Therefore *CR (.)* represents the regulatory costs to the government.

The government is a risk neutral regulator. The utility function of the principal is denoted as $U_p(.)$, with $U'_p>0$ and $U''_p=0$. On the other hand the risk averse agent has the utility function $U_a(.)$, which is twice continuously differentiable, strictly increasing and concave. Accordingly this is denoted as: $U'_a(.)>0$, $U_a(.)''\leq 0$.

The agent prefers to exert less effort to more effort and the cost of effort to the agent $C(e)$ is strictly increasing and convex with $C'(e)>0$, $C''(e)>0$ and $C(0)=0$. The compensation payment to the agent, *CR (.)* depends on a generalized food safety measure denoted by S (see Goldsmith and Basak, 2001). This measure can be used to represent various safety indicators such as $\frac{1}{\text{Number of Deaths}}$ or $\frac{1}{\text{Number of Illnesses}}$, some performance indicator of the firm's Hazard Analysis Critical Control Point (HACCP) program in use, or a consumer faith measure.

The principal's problem is to maximize $U_p(.)$ subject to the participation and the incentive constraints of the agent:

[3] See the case of Supreme Beef available at Lexis-Nexis 26205.

$$\max_{CR(S),e} \int U_p(S\text{-}CR(S))\, f(S;e)dS \qquad (1)$$

$$\text{st. (i)} \int U_a(CR(S))\, f(S;e)dS - C(e) \geq U_o$$

$$\text{(ii) } e^* \text{ solves } \max_{e} \int U_a(CR(S))\, f(S;e)dS - C(e)$$

The agent must receive at least its reservation utility U_o, in other words its next best opportunity, in order to accept the contract offered by the principal. This is shown by the participation constraint (i). The incentive compatibility constraint (ii) insures that under the compensation plan *CR(S)* the agent's optimal choice of effort is e^* (Mas-Colell, Whinston and Green,1995). It is possible to write this constraint using the first order approach, with the assumption that the expected utility of the agent is concave in effort (Jewitt, 1988). Then the first order incentive compatibility constraint becomes:

$$\text{(iii)} \quad \int U_a(CR(S))\, f_e(S;e)dS = C'(e)$$

The food safety measure shown as S is stochastically related to the effort level of the agent by the probability density function $f(S;e)$. $f_e(.)$ is the partial derivative with respect to effort. The Lagrangian of this problem can be written as:

$$L = U_p(S - CR(S))f(s;e) + \alpha(U_a(CR(S))f(s;e) - C(e)) + \beta(U_a(CR(S))f_e(s;e) - C'(e))$$

After solving the principal's problem with respect to the compensation payment scheme $CR(S)$ and rearranging the Kuhn-Tucker Conditions the "second-best"[4] risk-sharing rule (Holmström, 1979)[5] is:

$$\frac{U'_p(S\text{-}CR(S))}{U'_a(CR(S))} = \alpha + \beta\left[\frac{f_e(S;e)}{f(S;e)}\right] \qquad (2)$$

Furthermore with optimization of (1) with respect to e we get:

[4] If the principal had full information, in other words if the effort were fully observable then there would not be a moral hazard problem and the solution to the principal's problem could be characterized as the "first-best", with β =0 since the incentive compatibility constraint becomes irrelevant.
[5] See Sherstyuk (2000); Goldsmith and Basak (2001); Laffont and Martimort (2002).

$$\int U_p(S - CR(S)) f_e(S;e)dS = \beta\left(\int U_a(CR(S)) f_e(S;e)dS - C'(e)\right) \quad (3)$$

The safety measure S affects the principal's utility in two ways:

- Since the regulator prefers higher levels of food safety to lower levels of food safety, as S increases the utility of the principal directly increases.
- The compensation payments to the firm $CR(S)$ increase as S takes higher values. This becomes costly to the government and therefore reduces its utility.

$\frac{f_e(S;e)}{f(S;e)}$ is the likelihood ratio, which is monotone and non-decreasing in S. It calculates the ratio of the likelihood of observing a particular food safety indicator level $\tilde{S}$ when the agent chooses to exert the optimal effort level e^*, to the likelihood of achieving $\tilde{S}$ in the case that the agent has chosen to exert some other sub-optimal level of effort (Varian, 1992). The likelihood ratio therefore demonstrates the strength of the relationship between the agent's effort level e and the safety indicator S. In application this ratio describes the dual relationship between firm level safety efforts and society's perspective of the safety produced. So a firm may give high effort but have little impact on the likelihood of a breach. Or, where societal perceptions are involved, a firm may give high effort and society may perceive safety is enhanced because a breach has not occurred. The converse with respect to low effort holds as well.

α and β are the multipliers of the participation and the first order incentive compatibility constraints respectively. In other words these parameters represent the principal's shadow prices for the two constraints (i) and (iii). Higher α values are associated with higher reservation utilities of the agent whereas higher β values represent severe information problems due to government's inability to observe the firm's effort level (Ligon, 2001).

Three Salient Features of the Model

Risk Preferences of the Agent

Lundesgaard (2001) and Laffont and Martimort (2002) point out that with the risk averse agent, the principal faces the "insurance-efficiency trade-off." With a risk averse agent, efficiency requires some sharing of the risk between the principal and the agent (Sappington, 1991). Paying a fixed amount fully insures the risk averse agent however when the principal is not able to directly observe the agent's effort level, the principal needs to include in the payment schedule a motivational amount contingent on the effort level so that the agent applies high levels of effort (Mas-Colell, Whinston and Green, 1995). This means that there exists a welfare loss associated with the unobservability since some of the efficiency has to be given up to induce the agent exert high level of effort (Mas-Colell, Whinston and Green, 1995; Kreps, 1990).

In the conventional principal-agent model with non-observable agent effort, if the agent were risk neutral then the socially optimal outcome would be achieved. The agent chooses the same level of effort as in the case of the first best situation, where the effort is observable (Kreps, 1990; Mas-Colell, Whinston and Green, 1995; Laffont and Martimort, 2002). Kreps (1990, p.593) explains the intuition behind this favorable outcome from the general case of a principal-agent model:

> If the agent is risk neutral, efficient risk sharing between the principal and agent is consistent with the agent bearing all the risk. And by having the agent bear all the risk, we have him bearing entirely the consequences of his action choice. It is as if the principal "sold the venture" to the agent, who is now sole proprietor and is working for himself, and who now chooses the optimal action in his own sole and best interests.

In the case of a risk neutral agent moral hazard does not impose transaction costs that cause inefficiencies since the principal has the ability to achieve the first-best utility level as in the case where the principal can directly control the agent's effort, (Laffont and Martimort, 2002). When the agent is risk neutral, the optimal risk sharing is determined with the first-best rule and consequently the agent can be offered a fixed compensatory payment.

At an initial level of analysis this would imply that the government would prefer, or food safety would be optimized, if the government dealt with a risk neutral firm as opposed to one that was risk averse. With such a contract, the risk neutral firm would be willing to bear all the risks associated with establishing a safe food system and making the key investments in order to comply with the standards. Therefore remaining consistent with the conventional theory the firm would choose to apply the socially optimal level of effort.

Correspondingly with a risk averse agent, the government would need to engage in risk sharing associated with the food safety investments so that the agent accepts the contract offered and participates in providing safe food to the public. Without risk sharing the risks of investing in the delivery of safety would be too great forcing non-participation by the agent. The government left with non-participation might think about full insurance to induce participation. However this is not plausible since the principal needs to also induce high level of effort with less than full information.

In this model the risk to the firm (agent) stems from investing in food safety. Whether driven by compliance with government regulations and/or responding to market incentives, food safety risk mitigation strategies can impose sizeable costs[i] on firms (Antle, 1999; Loader and Hobbs, 1999; Caswell, 2000; Siebert, Nayga Jr., and Hooker, 2000; Ollinger and Mueller, 2003). The assumption is that these costs are associated with the public goods aspects of food production and thus the benefits can not be internalized, and therefore the costs are burdensome.

Two key questions emerge with respect to the first salient feature, agent risk preferences:

- What are the risk preferences of the U.S. food firms?

- How does risk affect the efficient delivery of optimal levels of food safety by the firm?

The formal model will be used later to explore these questions with respect to the U.S. meat industry.

Mapping between Effort and Safety: the Likelihood Ratio

Assessing whether a firm is putting forth maximal effort is a significant element of the information asymmetry found in principal-agent relationships. High effort may be given with little to show the principal, or the stochastic properties of breach may be such that low levels of effort appear to the principal to result in positive outcomes. This is especially significant within the context of food safety. For example in the case of Supreme beef (see Lexis-Nexis 26205) a critical issue was the regulatory and legal implication of a (repeated) failed pathogen test(s). Did failure serve as a valid assessment of the firm's HACCP program and therefore serve as signal that the firm was out of regulatory compliance? The mapping between effort and safety is also of interest for firms utilizing a quasi-due diligence defense for safety breaches resulting in civil or criminal actions.

This relationship between effort and safety is captured by the likelihood ratio. The higher this ratio, the stronger is the relationship between e and S. The second best solution where the principal needs to compensate the agent to elicit optimal effort is vastly dependent on the distribution of S and the functional relationship between S and e determined by $f\ (.)$. Consequently the higher the likelihood ratio the more willing is the government to pay higher for higher levels of effort (Goldsmith and Basak, 2001).

Goldsmith and Basak (2001) indicate, if in the limit, the sub-optimal level of effort has a very small effect on achieving a given level of S, say $\tilde{S}$, the denominator of the likelihood ratio will approach zero and the likelihood ratio can take the maximum value of ∞. Accordingly in the case of optimal level of effort e^* leading to a high probability of obtaining $\tilde{S}$, the principal will be willing to increase the compensatory payment above the fixed portion and pay an additional motivational amount (premium). This is due to the fact that under these conditions the principal has a greater ability to influence S via the compensatory payment. Therefore when the relationship between S and e appears to be strong, indicated by a high likelihood ratio, the principal pays the agent the fixed amount plus a motivational amount (Goldsmith and Basak, 1999). On the other hand if S is not at all a function of the agent's effort then the optimal compensatory payment will consist of only the fixed payment (Holmström, 1979; Goldsmith and Basak, 2001; Laffont and Martimort, 2002).

Quantity/Quality of Information and Immeasurability Issues

If the principal has full information about the effort level the agent chooses to exert, then a moral hazard problem does not exist. With fully observable effort, the incentive compatibility issue would be resolved and the optimal contract from this "First-Best" solution would be to pay the agent a fixed amount (Holmström, 1979; Kreps, 1990).

Operating with full information is an unlikely case because of various monitoring and information costs in food safety. The post-modern agri-food system contains additional factors that contribute to the measurability problems such as dynamic process innovation and advances in biotechnology (Crutcfield et al., 1997; Fearne, 1999; Caswell, 2000; Sporleder and Goldsmith, 2001; Cho and Hooker, 2002; Ollinger and Mueller, 2003; Elbasha and Riggs, 2003; Hennessy, Roosen and Jensen, 2003; Roosen, Lusk and Fox, 2003). The high speed and internal nature of current innovation creates significant challenges keeping regulatory metrics up to date and well-placed. Many impacts of agricultural biotechnology are unknown at the present time because; the technology is so novel, there are intergenerational uncertainties, and isolating individual effects from system effects is difficult. Additionally, Christensen et al. (2003) and McCluskey (2000) mention that information provided by the firms regarding the food safety attributes might in fact be inaccurate and misleading because of economic incentives that spring from profit maximizing behavior.

Therefore the principal's (government) ability to measure is challenged by both quantitative and qualitative issues associated with food safety information. This dynamic and novel context, where incentives for full disclosure do not exist, creates significant levels and types of information asymmetry. The principal is then challenged not only by the measurability problem, but also at a practical level determining whether or not the firm has exerted socially optimal level of effort to provide the socially optimal level of safety to the public.

System Failure and the Weibull Distribution

In order to explore these three salient features a model that specifies *f(s; e)*, U_p and U_a is used. Let the utility functions of the risk neutral regulator and the risk averse firm be

U_p= S-CR (S) and U_a=2$\sqrt{CR(S)}$ respectively. The stochastic relationship between the effort and safety is characterized by the Weibull Distribution, with the probability density function (pdf) written as:

$$f(S;e) = \frac{\gamma}{e}\left(\frac{S}{e}\right)^{\gamma-1} \exp^{-\left(\frac{S}{e}\right)^{\gamma}}$$ where e is the scale parameter and γ is the shape parameter (or slope). Three general cases, γ=1, γ>1 and γ<1 can be analyzed. These values represent constant, increasing and decreasing failure rates respectively.

Constant Failure Rate: γ =1

When γ=1, the Weibull probability density function is the same as an exponential pdf. This traditional approach has the properties of analytical tractability and the system under study would have a constant failure rate (see Holmström, 1979; Laffont and Martimort, 2002). The time interval between failures of the system in place is a random variable that is exponentially distributed. The firm's effort determines the expected time before there is a (safety) failure and the safety indicator S is proportional to the length of time that the firm operates without a failure of this kind (Holmström, 1979)[6]. The pdf is written as: $f(s;e) = e^{-1}\exp^{-e^{-1}S}$

The general formula for the failure rate function for the Weibull Distribution is as follows:

$$\frac{f}{1-F} = \phi(S) = \frac{\gamma}{e}\left(\frac{S}{e}\right)^{\gamma-1} \tag{4}$$

where F denotes the cumulative density function (cdf). Therefore for γ=1, the exponential distribution case, the failure rate function, in failures per unit of measurement (failures per week, month or per cycle etc) is a constant that is equal to $\frac{1}{e}$.

The exponential distribution possesses a "Memoryless Property." The fact that a safety failure has not occurred says nothing about the length of time before the next breach. In terms of food safety, the time length for the second food safety breach does not depend on the length of time for the first. Consequently the statistical characteristics of the second arrival will not be influenced by the length of time for the first occurrence of the food safety breach in the system[7]. Thus γ=1 has a property of randomness with respect to system failure. The failures originate due to factors outside the system and are unknown, not from components inherent to the system (i.e. effort (e)).

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[6] The proportionality factor=1.
[7] See http://www.weibull.com/AccelTestWeb/acceltestweb.htm

The likelihood ratio for γ=1 becomes:

$$\frac{f_e(s;e)}{f(s;e)} = \frac{S-e}{e^2} \tag{5}$$

and the optimal risk-sharing rule from equation (2) can be written as:

$$\frac{1}{U'_a} = \alpha + \beta\left(\frac{S-e}{e^2}\right) \tag{6}$$

this determines the optimal compensatory payment schedule:

$$CR(S) = \left[\alpha + \beta\left(\frac{S-e}{e^2}\right)\right]^2 \tag{7}$$

This example demonstrates the key role of $f(s;e)$ and the likelihood ratio in determining the second best risk sharing arrangement and consequently the compensatory payment. As noted previously, if the effort is fully observable or if the likelihood ratio is zero then the regulator offers the firm a fixed (first best) compensatory payment schedule $CR^{fb}=\alpha^2$. Without full information the agent is offered an extra motivational amount, $2\alpha\beta\left(\frac{f_e(s;e)}{f(s;e)}\right)+\left(\beta\left(\frac{f_e(s;e)}{f(s;e)}\right)\right)^2$ that reflects the willingness to pay more for higher levels of the likelihood ratio, when the principal cannot fully observe the effort. Therefore from Equation (7) the second best compensatory payment schedule is:

$$CR^{sb}=\alpha^2 + 2\alpha\beta\left(\frac{f_e(S;e)}{f(S;e)}\right)+\left(\beta\left(\frac{f_e(S;e)}{f(S;e)}\right)\right)^2 = \alpha^2 + 2\alpha\beta\left(\frac{S-e}{e^2}\right)+\left(\beta\left(\frac{S-e}{e^2}\right)\right)^2 \tag{8}$$

Parameterizing the Weibull then with γ = 1 seems unrealistic. The assumption of a constant failure rate provides mathematical models that can be easily implemented and explained, yet leads us away from the benefits that can be gained from adopting models that more accurately represent real world conditions (ReliaSoft, 2001). For example, such a depiction may not be appropriate for the context of food firms where failure may in fact be a function of effort; certainly a supposition behind the USDA's HACCP policy. Therefore we will focus on the increasing and decreasing failure rate cases to analyze the contract space, and the relationship between the payment schedule and effort.

Increasing Failure Rate: γ >1

Alternatively, when γ >1, the food safety system operates with an increasing failure rate which means system wears out and probability of a breach increases with time. This formulation captures the notion of system fatigue[ii]. Assume for tractability γ =5. Then the Weibull pdf becomes:

$$f(S;e) = \frac{5}{e}\left(\frac{S}{e}\right)^4 \exp^{-\left(\frac{S}{e}\right)^5} = f(S;e) = \frac{5S^4}{e^5}\exp^{-\frac{S^5}{e^5}} = 5S^4e^{-5}\exp^{-S^5e^{-5}} \quad (9)$$

Using equation (4) the failure rate for this case is:

$$\phi(S) = \frac{5}{e}\left(\frac{S}{e}\right)^4 \quad (10)$$

the likelihood ratio is:

$$\frac{f_e}{f} = 5e^{-1}(S^5e^{-5} - 1) = 5(S^5e^{-6} - e^{-1}) \quad (11)$$

and the payment schedule is:

$$CR(S) = \left[\alpha + \beta\left\{5(S^5e^{-6} - e^{-1})\right\}\right]^2 \quad (12)$$

In order to incentivize the agent to exert higher levels of effort, the principal pays increasing amounts for each marginal unit of effort (Equation 13). Society's demand for safety is assumed to be downward sloping indicating negative marginal benefits from food safety. Therefore the optimal payment schedule consistent with these preferences increases at a decreasing rate (Equation 14).

$$\frac{\partial CR(S)}{\partial e} = \beta e^{-2}\left\{\alpha\left[1 - 6S^5e^{-5}\right] + \beta e^{-1}\left[S^5e^{-5}(35 - 30S^5e^{-5}) - 5\right]\right\} \geq 0 \quad (13)$$

$$\frac{\partial^2 CR(S)}{\partial e^2} = \beta e^{-3}\left\{\alpha\left[42S^5e^{-5} - 2\right] + \beta e^{-1}\left[S^5e^{-5}(390S^5e^{-5} - 280) + 15\right]\right\} \leq 0 \tag{14}$$

System fatigue (gamma >1) may swamp the effect of increasing effort and underlie a weak likelihood relationship. Under such conditions with either fixed or human asset fatigue principals may find it necessary to redirect a firm's effort and rebuild the system. This "pump priming" strategy can occur by channeling investments to different food safety protocols, re-training employees, or bringing in new technology. Redirection and rebuilding may then help avoid the asymptotic problem of increasing effort, flat payment schedules, and little impact on safety.

Decreasing Failure Rate: γ <1

In this case food safety system operates with a decreasing failure rate where γ <1. Decreasing failure rate is systems occur when there is learning by doing. It certainly can be imagined that a food company that engages in new programs, protocols, and investments in food safety would find decreasing failure rates over a relevant range. (Then system fatigue may arise switching the appropriate gamma parameter to greater than 1.)

Assume γ=0.5. For this particular level of gamma the Weibull pdf is:

$$f(S;e) = 0.5e^{-0.5}S^{-0.5}\exp^{-S^{0.5}e^{-0.5}} \tag{15}$$

Using equation (4) the failure rate is

$$\phi(S) = \frac{0.5}{e}\left(\frac{S}{e}\right)^{-0.5} \tag{16}$$

Then the likelihood ratio becomes:

$$\frac{f_e(S;e)}{f(S;e)} = 0.5e^{-1}(S^{0.5}e^{-0.5} - 1) \tag{17}$$

and through the risk-sharing rule, the compensatory payment schedule is:

$$CR(S) = \left[\alpha + \beta\left\{0.5S^{0.5}e^{-1.5} - 0.5e^{-1}\right\}\right]^2 \tag{18}$$

Similar to the γ>1 case the effort-payment relationship is concave (Equation 19), increasing at a decreasing rate (Equation 20), and asymptotic reflecting the decreasing marginal value of effort on the delivery of safety.

$$\frac{\partial CR(S)}{\partial e} = \beta e^{-2}\left\{\alpha\left[0.5 - 1.5S^{0.5}e^{-0.5}\right] + \beta e^{-1}\left[S^{0.5}e^{-0.5}(1.25 - 0.75S^{0.5}e^{-0.5}) - 0.5\right]\right\} \geq 0 \qquad (19)$$

$$\frac{\partial^2 CR(S)}{\partial e^2} = \beta e^{-3}\left\{\alpha\left[3.75S^{0.5}e^{-0.5} - 1\right] + \beta e^{-1}\left[S^{0.5}e^{-0.5}(3S^{0.5}e^{-0.5} - 4.375) + 1.5\right]\right\} \leq 0 \qquad (20)$$

This is consistent with an assumption that the indifference curves that represent the preferences of the society/government for safety are convex and therefore the demand for safety is downward sloping. So for the principal, the last unit of safety is less valuable than the first unit.

Operationalizing the Model

The objective of this section is to integrate the three salient features with the various distribution parameterizations (gamma values) in order to analyze the construction of an optimal contract between the principal and the agent (Figure 2). Since the constant failure rate case (γ=1) involves applicability problems to the real world, only increasing failure rate (γ>1) and decreasing failure rate (γ<1) cases will be considered.

Risk Preferences of the Agent

Risk preferences of the agent changes the problem considerably for the government as a regulator. As in the full information case with a risk neutral agent (even with less than full information), the theory suggests that the incentive compatibility is automatically resolved and the first best outcome will be achieved through a fixed payment to the agent[8]. On the other hand with a risk adverse agent the government's task gets more complicated due to the incentive-insurance trade off that emerges in an environment of information asymmetry and moral hazard (Bontems and Thomas, 2003).

Mapping between Effort and Safety: the Likelihood Ratio

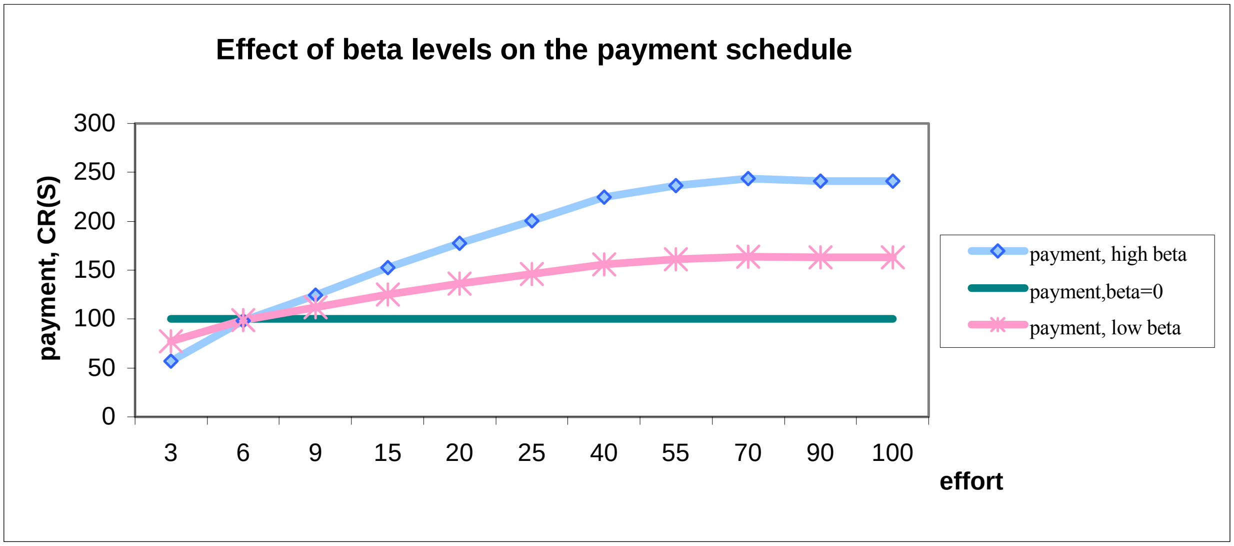
Effort-Safety mapping, linked to the likelihood ratio f_e/f, determines whether the payment schedule will include a motivational amount that rewards (punishes) high levels (low levels) of effort or not. If the safety outcome is considered to be unrelated to agent choosing high levels of effort (in other words if obtaining the desired level of safety is coincidental) the likelihood ratio approaches to zero. As the possibility of achieving the socially optimal outcome with a sub-optimal level of effort is high compared to obtaining the same result with the high (optimal) level of effort, then the payment schedule excludes the motivational amount[9].

Quantity/Quality of Information and Immeasurability Issues

Different levels of β represent various degrees of information asymmetry between the government and the food firm regarding the effort level. Higher levels of β represent more severe information problems and also increasing regulatory costs to the government. In order to demonstrate the effect of beta on the compensatory payment schedule, Figure 1 depicts the case of three different beta values: high, low and zero. $\beta=0$ corresponds to the full information state where the incentive compatibility constraint becomes irrelevant and the government as the principal offers a fixed payment to the firm.

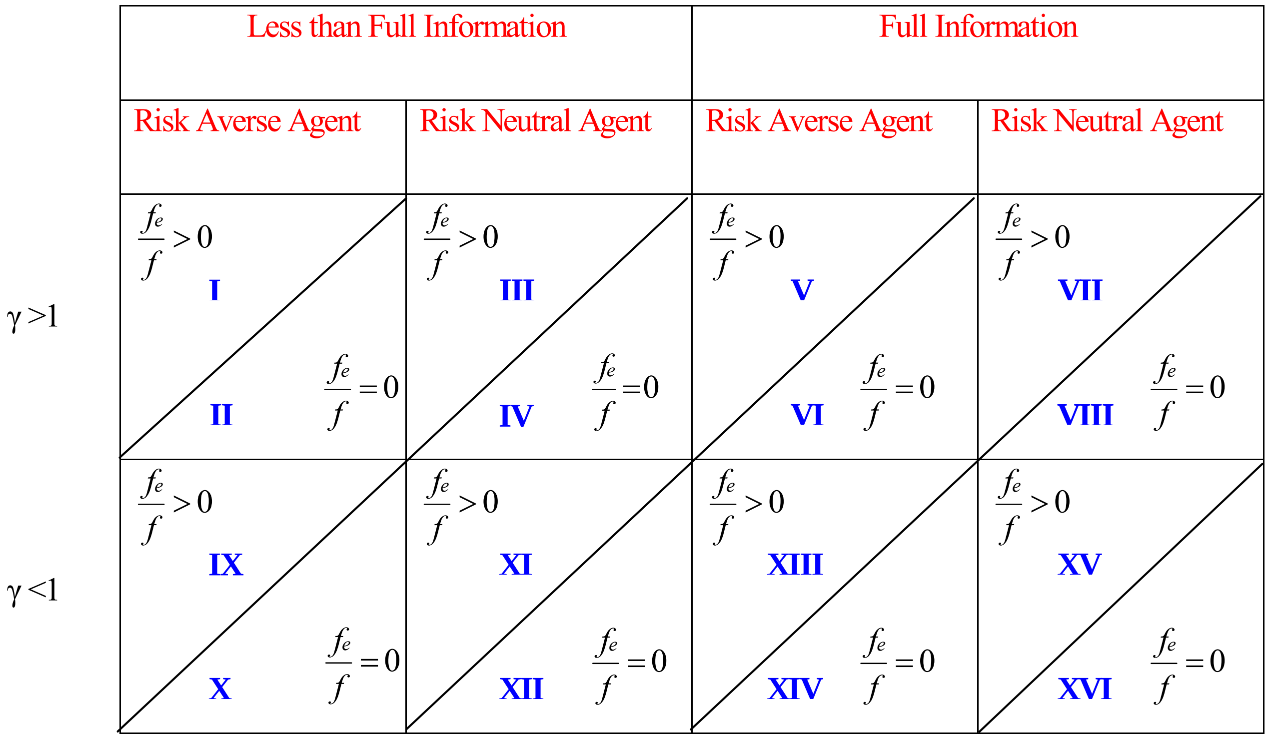
[8] The validity of this assumption in real world and the implications regarding all the three salient features will be explored in the next section through a study of the US meat sector.
[9] See the argument by the Supreme Beef related to the effort-safety mapping in the next section on the meat sector.

Figure 1. Effect of Information Problems on the Payment Schedule



Integrating the three salient features and the underlying failure structure creates a finite contract space (Figure 2). Sixteen different scenarios can be analyzed and, depending on the parameterization, contract performance differences can between evaluated. The ability to generate an efficient contract eliciting the correct amount of safety would then depend on the salient features of the cell in question. As a preliminary exercise of the model we analyze the U.S. meat industry to better understand the quality of the principal-agent relationship between the government and industry.

Figure 2. Food Safety Contract Space: Salient Features, Failure Rates and Optimal Contracting



Applications of the model to the U.S. Meat Industry

Pathogen related foodborne illnesses have been a continuous problem in the U.S. meat industry for more than a decade (Ollinger and Mueller, 2003; Christensen et al., 2003; Tauxe, 2002; Tucker Foreman, 2002; Crutchfield and Roberts, 2000; Crutcfield, 1999). Foodborne pathogens are estimated to result in 76 million illnesses and 5000 deaths in the United States each year (Mead et al., 1999). Foodborne illnesses outpace product liability cases from any other sector (Buzby, Frenzen and Rasco, 2001). Yet meat consumption continues to rise, consumer outcry is muted, and industry seems little affected (Goldsmith et al. 2002).

Considering the shift to larger firms and market concentration (Macdonald et al., 1996; Ollinger et al., 1997; Macdonald et al., 2000; Morrison Paul, 2001) U.S. meat industry firms then would be expected to be risk neutral agents. Hence it is normally anticipated that these larger firms as risk neutral agents would engage in proactive food safety activities and their rate of compliance would be much higher compared to the smaller ones (Caswell, 2000; Holleran, Bredahl and Zaibet, 1999; Loader and Hobbs, 1999). There are three factors that can distort the incentive structure of the risk neutral firms:

1. *Public Good Nature of Food Safety*

As discussed previously, food safety investments impose sizeable costs on the firms. Therefore in the process of supplying both meat and safety to the market the firms may not fully internalize the benefits from costly food safety activities due to the public good characteristics of safety. Without proper incentive mechanisms this would lead to under-provision of the public good (safety) in other words market failure. This internalization problem underlies a departure from common interests between the principal and the risk-neutral agent.

2. *Transaction Costs*

In their study of the U.S. meat industry using a cost function based on Antle's model (2000), Ollinger and Mueller (2003) have pointed out a consistent negative relationship between output and the percent of deficient sanitation and process control practices (SPCPs). Their data corroborates the presence of diseconomies of scale in sanitation and process control efforts, in other words costs associated with these practices went up as the plant size increased. Moreover they suggest that

> "…large plants and those plants with a high percent- deficient SPCPs will be more likely to be in non-compliance with necessary HACCP tasks. Conversely, small plans with a low percent-deficient SPCPs will be less likely to be in noncompliance with HACCP-like or HACCP tasks" (p.51).[10]

[10] Ollinger and Mueller (2003) also indicate that these results were statistically weak.

Based on an ERS (2002) study on costs of food safety regulation, Ollinger and Ballinger (2003) report "Large plants had no special economic advantage in food safety process control" (p.5). Using transaction cost logic (see Williamson, 1985) the advantages from scale economies might be cancelled out by bureaucracy costs due to trying to manage complex and dynamic tasks within large and complex organizations. Therefore, whereas larger firms can leverage economies for the supply of meat, an economic "good;" agency relationships may not exist to efficiently incentivize a firm to reduce its supply of economic "bads; " e.g poor safety.

3. *Institutional Setting in the U.S.*

Larger firms are in a better position taking advantage of economies of scale to invest in food safety innovations (Golan et al., 2004a). However the main problem that impedes optimal food safety behavior in the U.S. meat firms is not the technological but the "institutional and philosophical" barriers (Golan et al., 2004b).

The U.S. institutional setting is predisposed to protect the fundamental rights of the individuals at the constitutional level (Lord Irvine of Lairg, 2000, 2001; Goldsmith, Gow and Turan, 2003; Turan, Goldsmith and Gow, 2004). Within this of constitutional setting the judicial branch is to guard these fundamental rights and courts are assigned a massive amount of power to regulate crucial societal matters (Aldisert, 1977; Priest, 1991; Rustad and Koenig, 2002). Meat safety can turn into a futile game for the regulatory system when food safety matters keep on reverting back to the courts. For example, a particular challenge is establishing cause, effect, responsibility, and punishment under the U.S. regulatory regime (Turan, Goldsmith and Gow, 2004). As a result firms may take advantage of the U.S. constitutional setting to constrain the agency relationship with the government as the principal by means of using the legal system to thwart the efforts of regulators.

For example, in the Supreme Beef case, after repeated violations of the salmonella standard the USDA threatened to effectively shutdown the plant by removing inspectors. The Supreme Beef argued that the USDA violated the firm's rights to conduct business (Maixner, 2000). In December 2001, the Fifth Circuit Court of Appeals decided to uphold a lower court ruling that the salmonella performance standard exceeded USDA's statutory authority (Lexis Nexis 26205; Law.com, The 5th Circuit Court Opinion; Feedstuffs Washington Bureau, 2001). This was considered "a serious blow" to USDA's regulatory authority (Glickman, 2002; Tucker Foremen, 2002).

Conclusion

Returning to Figure 2 and the model's contract space, contracts involving risk neutral agents appear to be very problematic. In the context of the U.S. meat system risk neutrality on the part of agents theoretically would assume that a fixed payment is efficient and that incentives are aligned between the principal and the agent. But in application an efficient outcome will not occur because of the incentive distortions described above. Therefore contrary to the traditional agency framework, the principal is challenged to incentivize a risk neutral agent. This is difficult in both theory and practice and may explain in part why the U.S. regulatory system is not as effective as critics would like. Analysis with our model would indicate that the underlying agency relationship is flawed and the government as principal is fundamentally challenged to incentivize the industry.

An obvious question would arise then, if the underlying agency relationship is flawed and the impact of government as a principal is weak at best, how then is safety supplied? Many, especially those in the industry, would suggest that the meat system is very safe. If there is an abundant supply of safety, how then is that safety elicited if not from the government? Though beyond the scope of this paper, but the subject of subsequent work by this research team, is research that explores the agency relationships between the legal system as principal and the industry as agent. Also related is the study of private incentives such as insurance or brands as "principals." Either of them may be more effective explaining the source of safety in the US economy.

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Endnotes

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[i] These costs can originate from different sources such as purchases and maintenance of new equipment, expanding facilities, changes in organizational structures or hiring and training employees (Siebert, Nayga Jr., and Hooker, 2000; Unnevehr and Jensen, 2001). Investments in food safety improvement therefore can influence profitability and competitive advantage in the market (Unnevehr and Jensen, 2001).

Compliance and investments in food safety improvements can impose a heavier burden on smaller firms in the industry (MacDonald et al., 1996; Ollinger et al., 1997; Loader and Hobbs, 1999). For example there have been continuing concerns about the impacts of HACCP plan development and implementations on the smaller firms (Unnevehr and Jensen, 2001; Nganje and Mazzocco, 2000). After pointing out to the “large up-front investments” to build and implement a HACCP plan Unnevehr and Jensen (2001) explain the other reasons behind these concerns:

> [S]mall firms’ costs rise proportionally more than large firms’ with the implementation of HACCP, which may put them at a competitive disadvantage in the market. Furthermore, large firms frequently have more in-house resources at their disposal for design and implementation (e.g., meat scientists on staff, diagnostic labs) and therefore have lower transaction costs in implementing a HACCP plan. Some small firms might be expected to go out of business as a result of higher relative costs” (p.14).

Economies of scale enables large firms not only to meet more complex market demands for products (Ollinger et al., 1997; MacDonald et al., 1996) but can also have a positive impact on the compliance rates (Loader and Hobbs, 1999; Siebert, Nayga Jr., and Hooker, 2000).

> Indeed, firms with an established position, and economies of scale in production, testing and marketing often see regulation as something that they are able to respond to with a greater degree of speed and precision than other firms. Small firms may often finds it difficult to respond quickly to complex and specific legislation (Loader and Hobbs, 1999, p.701).

[ii] Fatigue may be thought of as either the natural depreciation of fixed assets or the natural decreasing sensitivity to stimuli by human assets, e.g. boredom, myopia, or repetitiveness. A common example of fatigue in human systems is the decline in performance over time of baggage inspectors at airports. Both have significant implications for principals and their elicitation of safety.