2006

Traceability, Liability and Incentives for Food Safety and Quality

Daniel A. Sumner, *University of California, Davis*
Sebastien Pouliot, *University of California, Davis*

Traceability, Liability and Incentives for Food Safety and Quality

Daniel A. Sumner
University of California Agricultural Issues Center
and the Frank H. Buck, Jr., Chair Professor,
Department of Agricultural and Resource Economics,
University of California, Davis
Davis, CA 95616
Tel: (530)-752-1668
Fax: (530)-752-5451
Email: dan@primal.ucdavis.edu

Sébastien Pouliot
Department of Agricultural and Resource Economics,
University of California, Davis
Davis, CA 95616
Tel: (530)-752-6252
Fax: (530)-752-5614
Email: pouliot@primal.ucdavis.edu

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23-26, 2006

Traceability, Liability and Incentives for Food Safety and Quality

Recent food safety concerns and well-publicized food scares have heightened awareness of traceability in the food supply chain. When the first U.S. case of Bovine Spongiform Encephalopathy (BSE or "mad cow disease") was discovered in Washington State, federal authorities suggested that "it might take weeks, even months, to track the origins of the diseased cow" (Clemetson and Simon, p.1). With the cooperation of herd owners, livestock dealers and market operators as well as detailed record searches between United States and Canadian agencies, the authorities were able to trace the origin of the affected cow to Canada only after a week, but herd mates were never fully traced.

The December 2003 case of BSE in Washington State highlighted the demand for traceability to regain consumer confidence after the discovery of a first event. In addition, in the case of highly contagious disease or when multiple related dangers are suspected, traceability is important to reduce risk of further damage.

Traceability of food products back to the farm of origin may be motivated by many considerations in addition to consumer confidence and reducing effects of contagious disease. These include to : a) protect the general reputation of firms, an industry or a country; b) differentiate products by suppliers who provide traceability; c) guarantee product origin when origin is an attribute of interest to consumers or others; d) improve supply management by firms; e) monitor and assure production or processing methods; f) erect implicit international trade restrictions. Another motivation, the focus of this paper, is to provide information about suppliers that allows application of liability for food safety or other product quality problems.

Food traceability has received growing recognition in the economic literature. For example in their recent ERS report, Golan et al. (2004) discuss traceability as a solution to selected market failures. They describe the development of traceability systems in three food sectors: fresh produce, grains and oilseeds and cattle and beef. Dickinson and Bailey and Hobbs et al. estimated the willingness to pay for traceability using laboratory auction markets. They both find that consumers are willing to pay a small premium for traceability.

Hobbs, Golan et al.(2003) and Meuwissen et al. link food traceability to product liability. For Hobbs, one role of traceability systems is to provide ex post information that allows liability. She notes that traceability increases firms' incentives to provide safer food. Golan et al. (2003) also recognize that traceability can help to establish the extent of liability of a firm and potentially shift liability to others. Finally, liability is recognized as one item on the economic research agenda on traceability identified by Meuwissen et al.

In this paper we focus specifically on the implications for additional traceability in the context of liability for food safety problems. We model formally the linkage between traceability and food safety and establish the implications of an increase in traceability-liability for food safety and related economic outcomes. The capacity to trace the origin of food increases the possibility of legal remedy and compensation in case of food safety event. Traceability also allows parties to more easily document that they are not responsible for harm. Therefore, traceability systems create incentives for firms to supply safer food. Our formal model traces the linkage between traceability, liability and food safety incentives by farms and marketing firms.

A large body of literature compares the effectiveness of liability relative to regulation in maximizing social welfare (e.g. Shavell (1984); Kolstad, Ulen and Johnson; Hiriart, Martimort and Pouyet; Roe; and Boyer and Porrini). Companion work has begun to explore liability relative to regulation in the context of food safety and traceability using modeling approaches similar to those employed here. In this paper, we focus specifically on how private or market traceability enhancements affect food safety.

Cost of Foodborne Illness and Liability

Foodborne illnesses have important economics impacts. The ERS estimated that the annual medical cost, productivity losses, and costs of premature deaths due to seven major foodborne pathogens range between $6.6 and $37.1 billion in 1996 dollars (Buzby and Roberts). The total societal costs of foodborne illnesses are certainly higher as the ERS did not take into account the cost of pain and suffering and did not consider other type of pathogens. The implication is that there is considerable scope for potential liability if even a small share of those costs of foodborne illnesses could be traced back to their original and if those responsible could be held liable.

In fact, liability has been difficult to establish for food products. First, it is hard to link foodborne illness to a specific product as there is rarely a sample of suspect food to test for contamination. Recently, an increase in the number of illnesses that require mandatory reporting to public health officials and an increase in the sophistication of public health investigators has reduced the magnitude of this obstacle (Clark). Second, even though the contaminated product is identified, it might be difficult to discover its origin. The lack of traceability is not a problem only for consumers, but also for food

marketers in the supply chain as they are not able to transfer liability to their supplier. Vertically integrated firms may not be able to use the proximate cause defence because they are responsible for more stages of the production process. [1]

The difficulty to link foodborne illness to a specific food product and to trace its origin leads to a very low number of cases being brought to court. A conservative estimate of the litigation rate for all food poisoning cases is 0.09 to 0.45 legal cases per 100,000 illnesses (Buzby and Frenzen). Viscusi calculates that 95% of the product liability claims (for all products not just food) that are not dropped before going to court are finally solved by an out-of-court settlement. He also estimates that When a case does go to court, the plaintiff success rate in court is 37%. Buzby, Frenzen and Rasco study the use of product liability law for injuries attributed to microbially contaminated foods. Using a sample of 175 foodborne illness lawsuits resolved in court from 1987-97, the authors examine the incentive to provide safe food under the threat of lawsuits by consumers in case of food safety problems.[2] They found that 31.4% of the cases resulted in some compensation paid by the firms to the consumers. When the plaintiff was favoured, the compensations awarded range from $2,256 to $2,368,858 with a median of $25,560 (1998 dollars). In 92 cases, no pathogen, toxins or illnesses were identified. Salmonella was the most commonly identified pathogen with 39 cases. When the plaintiffs identified a specific pathogen, she was favoured in almost 42% of the times.

[1] There are two types of causation in law: cause-in-fact and proximate cause. Cause-in-fact is determined using the "but-for" test. The plaintiff must prove that in the absence of an action by the injurer, there would have been no harm. In proximate cause, the foreseeability of an event determines the scope of liability. The court must determine if the harm resulting from an action was reasonably predictable (Golan et al. (2004)).
[2] The number of cases considered by Buzby, Frenzen and Rasco is small compared to the 200 cases that attorney Bruce Clark claimed that he has personally been involved over a six years period. The website of Marler Clark gives a list of legal cases related to foodborne illnesses that have been resolved.

The actual compensation allocated in food safety litigation is non-negligible. For example, Clark claims that he has been involved in claims that account for a total of 200 millions dollars in a period of six years. However, the importance of the cost of foodborne illness stresses how traceability, by making liability more feasible, could lead to large transfer of compensation to consumers and create significant incentives for firms and farms to supply safer food, thus reducing the societal costs of foodborne illnesses.

The model

In this section, we lay out definitions and specifications of our model. Results are derived in the following section.

Golan et al. (2003) define traceability as "*recordkeeping systems designed to track the flow of product or product attributes through the production process or supply chain*". For the purpose of this paper, this definition is sufficient. We simply define traceability as the ability to trace the history of a product along a supply chain.

Strict liability is the applicable legal rule in the food industry in the U.S. (Clark). Strict liability means that the seller of a product that causes injury to a consumer may be legally responsible even in the absence of ex ante knowledge by the seller of the product's hazard (Cooter).

Unlike earlier articles in the product liability literature, which assume only one step in the supply chain and costless traceability, we model a supply chain comprised of consumers, marketers (any firms provide services between farmers and consumers) and farmers (raw material producers).[3] Further, we allow for market power by marketers in

[3] For a review of the literature on economic theory of liability, see Cooter, Polinsky and Shavell or Shavell (2006).

buying from farmers and in selling to the consumers. For generality, we also allow for market power by farmers in selling raw material for consumer food products. Consumers have no market power. The source of food safety problems can be either the marketers or the farmers.

We assume that the level of contamination (which increases the probability of a food safety problem or negative event) is a decreasing function of the effort, or level of care, exerted by marketers and farmers. This allows us to write the probability of a negative food safety event as a function of the efforts to supply safe food by the marketers and the farmers. Let e_m and e_f be the efforts to provide safe food by the marketers and the farmers. Denote by $P = P\left(e_m, e_f\right)$ the probability of a food safety event.

For simplicity and ease of exposition, we assume that marketers' and producers' efforts to control contamination are independent, i.e. $\frac{\partial^2 P}{\partial e_m \partial e_f} = \frac{\partial^2 P}{\partial e_f \partial e_m} = 0$. We write the probability of a food safety event as $P = g_m\left(e_m\right) + g_f\left(e_f\right)$. This assumption contrasts with the seminal work of Brown and the recent elaborated version of Brown's model by Roe. These authors examine only one type of firm but assume that consumers and suppliers each are sources of product safety problems. They assume that there are no independent sources of liability so that any negative act by the supplier may be offset by a positive act by the consumer and vice versa.

We also assume that $\frac{\partial g_m(e_m)}{\partial e_m} < 0$, $\frac{\partial g_f(e_f)}{\partial e_f} < 0$, $\frac{\partial^2 g_m(e_m)}{\partial e_m^2} \geq 0$, $\frac{\partial^2 g_f(e_f)}{\partial e_f^2} \geq 0$.

That is, the probabilities of an event decrease at a decreasing rate with the level of care and the marginal effect of additional effort decreases with respect to effort.

The independence of the effect of efforts on the probability of an event simplifies the analysis but is a limitation. To see this, consider the following example. Imagine that a farmer applied pesticides late such that there is pesticide residue on fruit when harvested. The marketer is aware of this possibility and has the capacity to wash the fruit but neglects to do so. If a consumer is sick after eating some fruit, the marketer is liable for the event. In that case, traceability to the farm would imply no additional liability burden for the farmers for food safety events occurring at the consumer level. However, when the probabilities are independent, the marketer can transfer liability to the farm if it is possible to trace the food item to the farm and to link the specific source of contamination to the farmers rather than the marketer. If the probability were not independent, we would need to specify rules for sharing liability.

In our model as in reality, traceability is imperfect such that it is not always possible to identify the source of the contamination. We measure the level of traceability as the probability to trace back the source of contamination. Let $T_m \in (0,1)$ be the level of traceability at the marketer level and let $T_f \in (0,1)$ be the level of traceability from the marketers to the farms.[4] Thus, the probability that a product is traceable to the farm is $T_m T_f$.

[4] In practice, even if no traceability technology is in place, minimum positive levels of traceability may exist. We simplify by normalizing this minimum level of traceability to zero.

We assume that full compensation is available when the source of contamination is identified. We do not consider cases where the firms are not able to compensate the consumers in case of an event.[5] We may consider that, as in reality, marketers and farmers contract liability insurance. The insurer provides legal defence and pays for the damages. We suppose that insurance is provided at a fair price and that the insurer knows the risk from marketers and farmers activities.

Let M be the number of marketers, A be the size of the damage and denote by $\bar{P} = \frac{\sum_{i=1}^{M} P_i\left(e_m, e_f\right)}{M}$ the average probability of a food safety event at the consumer level. We assume that the consumers observe only the average level of safety supplied by the marketers, that is consumers are not able to differentiate the food safety attributes of different firms. Therefore, we define $E = \left(1 - T_m\right)\bar{P}A$ as the expected consumer loss in welfare from the consumption of a unit of food. Only traceability to the marketers matters to consumer because any possible compensation would be paid to consumers by the marketers. We suppose a linear demand function in which the expected consumer loss in welfare decreases the consumer willingness to pay for food. The inverse demand function is denoted by $\theta\left(q, E\right) = \Omega - q - E$, where θ is the price and q is the consumption quantity and Ω scales the intercept.[6]

[5] Shavell (1984) studies the effect of inefficiencies such as the possibility that parties would not be able to pay fully for harm done or the event does not result in a legal judgement.

[6] In an earlier version of this paper we derive this linear demand assuming that safety is a vertically differentiated characteristic using a model similar as Tirole p. 96. These details do not add to the results and complicate the notation.

We suppose Cournot conjectures in the marketing sector. Each of the identical M marketers have an output x such that $M\,x = q$. The expected profit function of each marketer is

$$\Pi_m = \theta\left(q, E\right)x - \varphi\delta\, x - c_m\left(x, e_m\right) - xT_m g_m\left(e_m\right)A - xT_m\left(1 - T_f\right)\bar{g}_f\left(e_f\right)A;$$

where φ is the price paid to farmers in terms of marketers' output and δ is a parameter converting the marketers' units of input in terms of output. For simplicity we assume that $\delta = 1$. We denote production cost by $c_m\left(x, e_m\right)$. To obtain analytical results and focus on traceability instead of technology, we assume that the marginal cost of production is constant with respect to the output but increases with the level of effort exerted to producer safer food, $c_m\left(x, e_m\right) = x\gamma\left(e_m\right)$, where $\gamma\left(e_m\right)$ is an increasing function. For simplicity, we assume that traceability itself is costless and we shift the quantity of traceability rather than the cost of traceability. This assumption does not have any consequence on the effort exerted by marketers and farmers.

The total cost of insurance at a fair price for marketers to cover potential liability costs is $xT_m g_m\left(e_m\right)A + xT_m\left(1 - T_f\right)\bar{g}_f\left(e_f\right)A$. The first term in this expression, $xT_m g_m\left(e_m\right)A$, is the expected liability cost for damages that are due to marketer practices. The second term in the expression, $xT_m\left(1 - T_f\right)\bar{g}_f\left(e_f\right)A$, is the expected liability cost due to farmers activities. Because the marketers cannot use the proximate cause defense, they are liable for any damages due either to their own activities or the activities of the farmers from whom they buy raw materials. When an event can be traced to the farm, the marketers can transfer the liability cost to the farmers. As with

consumers, the marketers observe the average safety of raw material supplied in the farm industry and not the level of safety supplied by each farmer.

The farm sector is characterized by N farmers competing in output y. Again, for notation simplicity we suppose that the farms are identical. For each farmer the expected profit function is

$$\Pi_f = \varphi\left(N\,y, e_f\right)y - c_f\left(y, e_f\right) - yT_m T_f g_f\left(e_f\right)A;$$

where $\varphi\left(N\,y, e_f\right)$ is the marketers' inverse demand function. We assume that the farmers use a production technology similar to the marketers

$$c_f\left(y, e_f\right) = y\xi\left(e_f\right);$$

where $\xi\left(e_f\right)$ is an increasing function. The expected liability costs of a farmer is $yT_m T_f g_f\left(e_f\right)A$, the total liability costs that are transfer from the marketers.

Effects of traceability on food safety

In this section we analyze how degree or level of traceability and the number of marketing firms and farms influence the supply food safety. Our model recognizes that consumers are willing to pay for traceability for two liability-related reasons. Recall that the expected consumer loss in welfare from the consumption of one unit of food is given by $E \equiv \left(1 - T_m\right)\bar{P}A$. Take the first derivative with respect to traceability to the marketers

$$\frac{\partial E}{\partial T_m} = -\bar{P}A + \left(1 - T_m\right)\left(\frac{\partial \bar{P}}{\partial e_m}\frac{\partial e_m}{\partial T_m} + \frac{\partial \bar{P}}{\partial e_f}\frac{\partial e_f}{\partial T_m}\right)A.$$

We refer to the first term, $-\bar{P}A$, as the consumer willingness to pay for traceability as a specific attribute as it provides better chances of compensation in the case of a food

safety event. We refer to the second term, $\left(1-T_m\right)\left(\frac{\partial \overline{P}}{\partial e_m}\frac{\partial e_m}{\partial T_m}+\frac{\partial \overline{P}}{\partial e_f}\frac{\partial e_f}{\partial T_m}\right)A$, as the additional consumer willingness to pay for traceability because they know that with more traceability firms and farms are likely to supply safer food. Because the supply of safer food has public good characteristics with in the industry, we will see that the free-rider problem is imbedded in this second term.[7] Therefore, when the number of firms tends to infinity this term collapse to zero. We can derive similar effects for the price paid to farmers by marketers.

As shown in the previous section, the level of food safety supplied by the marketers and the farmers is determined by their liability burden and the premium they receive from the consumers to supply safer food. From the first order condition for profit maximization, we find that the effort by the marketers is implicitly given by

$$\frac{\partial \gamma\left(e_m\right)}{\partial e_m}+T_m\frac{\partial g_m\left(e_m\right)}{\partial e_m}A=-\frac{1}{M}\left(1-T_m\right)\frac{\partial g_m\left(e_m\right)}{\partial e_m}A. \tag{1}$$

To find the effort of the farmers, we begin with the aggregate demand function of the marketing firms. Taking the first order condition with respect to the output and rearranging, we find that the inverse demand function for one representative marketer,

$$\varphi=\Omega-\left(M+1\right)x-\left[g_m\left(e_m\right)+\left(1-T_mT_f\right)g_f\left(e_f\right)\right]A-\gamma\left(e_m\right).$$

Solving for the price paid to the farmers, the aggregated inverse demand for the marketers may be written in terms of farmers output

$$\varphi=\Omega-\frac{\left(M+1\right)}{M}Y-\left[g_m\left(e_m\right)+\left(1-T_mT_f\right)g_f\left(e_f\right)\right]A-\gamma\left(e_m\right).$$

[7] Some industries solve the free-rider problem by regulating the supply of safe food. For example, Alston et al. analyse the collective action in the marketing order in the California pistachio industry.

Taking the derivatives of the inverse demand function with respect to farmers' effort, we obtain,

$$\frac{\partial \varphi}{\partial e_f} = -\left(1 - T_m T_f\right)\frac{1}{N}\frac{\partial g_f\left(e_f\right)}{\partial e_f}A.$$

The farmers' first order condition with respect to the effort is

$$\frac{\partial \varphi}{\partial e_f} - \frac{\partial \xi\left(e_f\right)}{\partial e_f} - T_m T_f \frac{\partial g_f\left(e_f\right)}{\partial e_f}A = 0.$$

Substituting for $\frac{\partial \varphi}{\partial e_f}$ and rearranging we obtain that the effort by the farmers is implicitly given by

$$\frac{\partial \xi\left(e_f\right)}{\partial e_f} + T_f T_m \frac{\partial g_f\left(e_f\right)}{\partial e_f}A = -\frac{1}{N}\left(1 - T_f T_m\right)\frac{\partial g_f\left(e_f\right)}{\partial e_f}A. \qquad (2)$$

In equations (1) and (2), the term on the left-hand-side is the due to the consumers and marketers willingness to pay for traceability because it increase their likely compensation. The term on the right-hand-side is the effect of the willingness to pay by consumers and marketers for traceability because it creates higher incentives to supply safe food. Clearly, when the number of marketers in (1) and the number of farmers in (2) tend to infinity, the free-rider problem make the effect of the premium for safer food tend to zero.

When the number of marketer and farmer is 1, the effect of added traceability disappears because traceability is guaranteed. The same is true when the levels of traceability are already equal to 1. In those two cases the first order condition are

$$\frac{\partial \gamma\left(e_m\right)}{\partial e_m} + \frac{\partial g_m\left(e_m\right)}{\partial e_m}A = 0; \qquad (1')$$

$$\frac{\partial \xi\left(e_f\right)}{\partial e_f}+\frac{\partial g_f\left(e_f\right)}{\partial e_f}A=0\,. \tag{2'}$$

This is the Pareto optimal solution where the marginal costs of supplying food safety is equal to the marginal benefit.

Define $S_m=1-g_m\left(e_m\right)$ the level of safety supplied by the marketers and by $S_f=1-g_f\left(e_f\right)$ the level of safety supplied by the farmers. To see the impact of additional traceability on the supply of food safety, we can take the total derivatives of (1) and (2). Holding the level of traceability to the farm and the size of the damage and the number of firms constant, we obtain

$$\begin{aligned}&\frac{\partial^2\gamma\left(e_m\right)}{\partial e_m^2}de_m+dT_m\frac{\partial g_m\left(e_m\right)}{\partial e_m}A+T_m\frac{\partial^2 g_m\left(e_m\right)}{\partial e_m^2}de_m A\\&=\frac{1}{M}dT_m\frac{\partial g_m\left(e_m\right)}{\partial e_m}A-\frac{1}{M}\left(1-T_m\right)\frac{\partial^2 g_m\left(e_m\right)}{\partial e_m^2}de_m A;\end{aligned}$$

and

$$\begin{aligned}&\frac{\partial^2\xi\left(e_f\right)}{\partial e_f^2}+T_f dT_m\frac{\partial g_f\left(e_f\right)}{\partial e_f}A+T_f T_m\frac{\partial^2 g_f\left(e_f\right)}{\partial e_f^2}de_f A\\&=\frac{1}{N}T_f dT_m\frac{\partial g_f\left(e_f\right)}{\partial e_f}A-\frac{1}{N}\left(1-T_f T_m\right)\frac{\partial^2 g_f\left(e_f\right)}{\partial e_f^2}de_f A.\end{aligned}$$

We can solve these two equations for $\frac{de_m}{dT_m}$ and $\frac{de_f}{dT_m}$. Using the fact that

$\frac{dg_m\left(e_m\right)}{dT_m}=\frac{dg_m\left(e_m\right)}{de_m}\frac{de_m}{dT_m}$ and $\frac{dg_f\left(e_f\right)}{dT_m}=\frac{dg_f\left(e_f\right)}{de_f}\frac{de_f}{dT_m}$, after some manipulation, we have,

$$\frac{dS_m\left(e_m\right)}{dT_m}=\frac{\left(\frac{\partial g_m\left(e_m\right)}{\partial e_m}\right)^2\left(M-1\right)A}{\left(1+T_m\left(M-1\right)\right)\frac{\partial^2 g_m\left(e_m\right)}{\partial e_m^2}A+M\frac{\partial^2\gamma\left(e_m\right)}{\partial e_m^2}}>0; \tag{3}$$

and

$$\frac{dS_f\left(e_f\right)}{dT_m}=\frac{\left(\frac{\partial g_f\left(e_f\right)}{\partial e_f}\right)^2 T_f\left(N-1\right)A}{\left(1+T_fT_m\left(N-1\right)\right)\frac{\partial^2 g_f\left(e_f\right)}{\partial e_f^2}A+N\frac{\partial^2\xi\left(e_f\right)}{\partial e_f^2}}>0\,. \tag{4}$$

Traceability to the marketers increases the supply of safer food. We can proceed in the same way to find the effect increasing traceability to the farm. We find that

$$\frac{dS_m\left(e_m\right)}{dT_f}=0\,; \tag{5}$$

$$\frac{dS_f\left(e_f\right)}{dT_f}=\frac{\left(\frac{\partial g_f\left(e_f\right)}{\partial e_f}\right)^2 T_m\left(N-1\right)A}{\left(1+T_fT_m\left(N-1\right)\right)\frac{\partial^2 g_f\left(e_f\right)}{\partial e_f^2}A+N\frac{\partial^2\xi\left(e_f\right)}{\partial e_f^2}}>0 \tag{6}$$

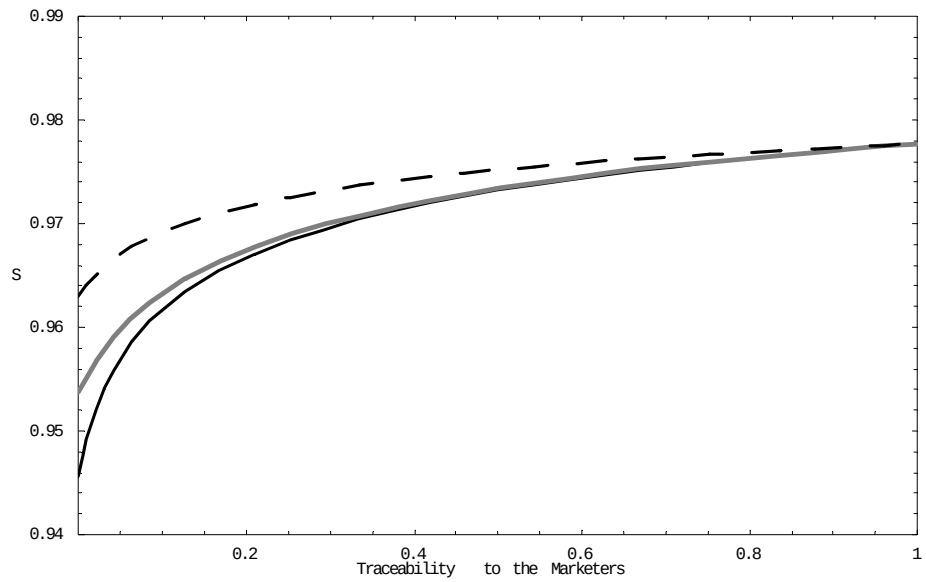
Comparing (3) to (5) and (4) to (6), we see that additional traceability to the marketers or to the farms have different impacts on the supply of food safety by the farmers. More traceability to each type of suppliers increases the incentives for farmers to supply food safety as both (4) and (6) decrease with respect to traceability. However, increasing traceability to the farm *decreases* the liability burden of marketers for contamination originating from the farms, whereas increasing traceability to the marketers *increases* both marketers and farmers liability. An increase in the level of traceability to the farm has no effect on the supply of food safety by the marketers because it does not create incentives for the marketers to expend additional effort on safer food. This is due to the assumption of independence of the effort of marketers and

farmers. That is, the fact that the farmers does not change the supply of safe food by the marketers.

Define $S = 1 - P = 1 - g_m(e_m) - g_f(e_f)$ the total level of food safety, which is the probability that food is safe. We illustrate the total level of food safety using three figures. In Figure 1, we keep the number of farmers constant and look at how the level of safety changes with traceability for different number of marketers. The intercept of every curve gives the level of safety when traceability to the marketers is equal to zero. Analytically, we can fin this level of safety by setting $T_m = 0$ in (1) and (2). The level of safety is strictly higher with low number of farmers for every level of traceability. Larger is the number of marketers, more important is the free-rider problem and lower is the level of safety. However, as the level of traceability approaches one, the free-rider problem disappears and the levels of safety are the same almost. Although this not obvious in the figure, the level of safety when $T_m = 1$ differ slightly because the level of traceability to the farms is not 1.

In figure 2 we do a similar exercise by keeping the number of marketers is constant and looking at how traceability to the farmers influences the level of safety for different number of farmers. The shape of Figure 2 is essentially the same as Figure 1. However, the lines are closer as the number of firms is larger and because the level of traceability to the farm is relatively high at $T_m = 0.90$. Figure 3 offers an alternative 3D representation of the level of safety in function of traceability to the marketers and to the farms.

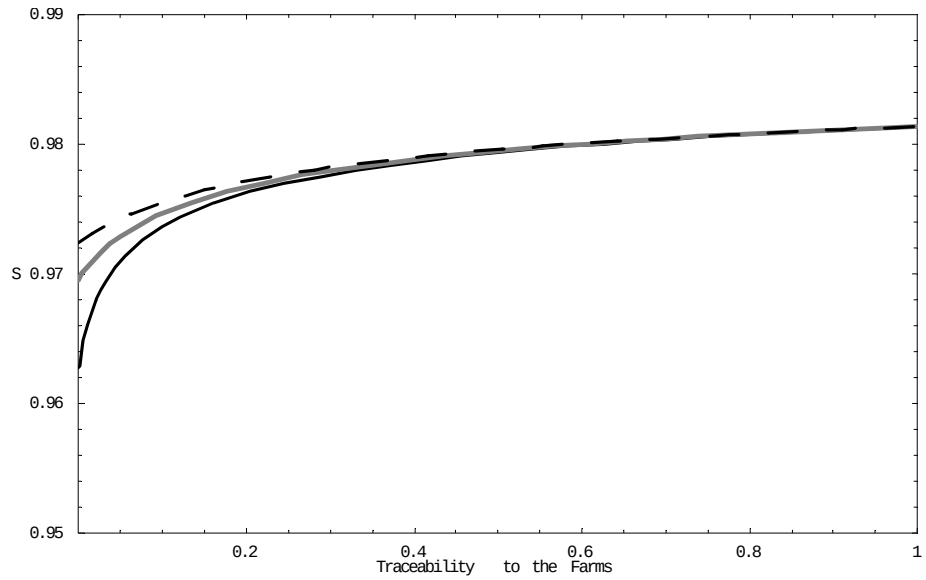
Figure 1: Food Safety in Function of the Level of Traceability to the Marketers.



The dashed line represents the probability of a food safety event when there is only one marketer. Similarly, the gray line represents a case where the number of marketers is equal to 15 and the black line a case where the number of marketers is equal to 150. The number of farmers is constant and equal to 300. The level of traceability to the farm is equal to 20%. The other specifications are $A = 425$; $\Omega = 20$; $g_m\left(e_m\right) = \frac{3}{100\left(1+e_m\right)}$;

$g_f\left(e_f\right) = \frac{3}{100\left(1+e_f\right)}$; $\gamma\left(e_m\right) = \frac{\left(e_m\right)^2}{4}$; and $\xi\left(e_f\right) = \frac{\left(e_f\right)^2}{4}$.

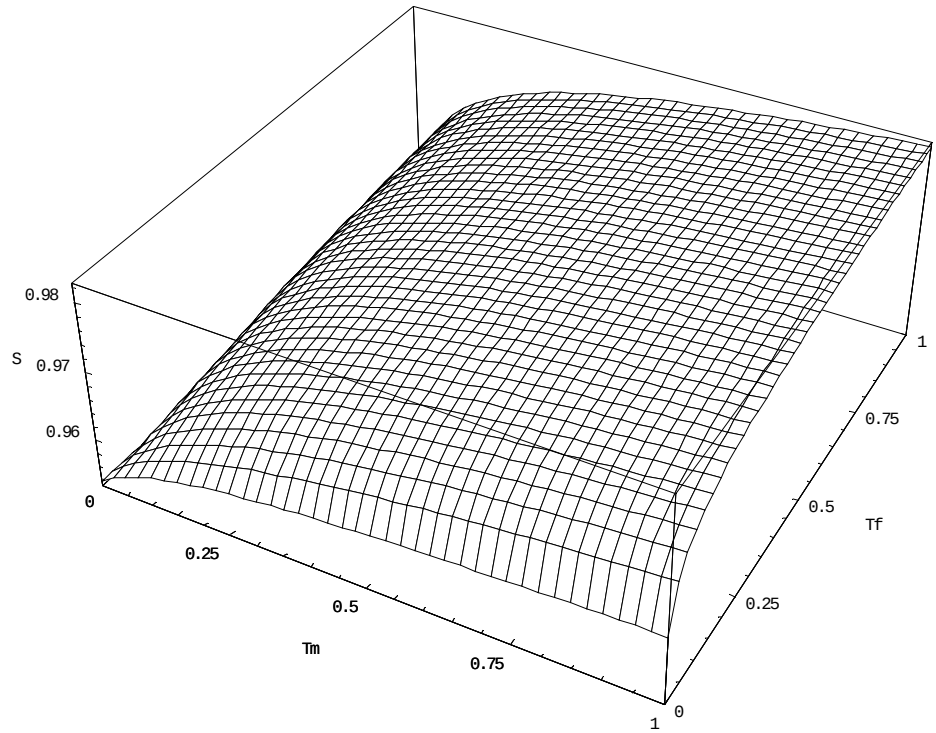
Figure 2: Safety in Function of the Level of Traceability to the Farms.



The dashed line represents the probability of a food safety event when there are 15 farmers; the gray line represents a case where the number of farmers is equal to 30; and the black line a case where the number of marketers is equal to 300. The number of marketers is constant and equal to 300. The level of traceability to the marketers is equal to 90%. The other specifications are $A = 425$; $\Omega = 20$; $g_m\left(e_m\right) = \frac{3}{100\left(1+e_m\right)}$;

$g_f\left(e_f\right) = \frac{3}{100\left(1+e_f\right)}$; $\gamma\left(e_m\right) = \frac{\left(e_m\right)^2}{4}$; and $\xi\left(e_f\right) = \frac{\left(e_f\right)^2}{4}$.

Figure 3: 3D Representation of Food Safety.



The number of marketers and farmers are constant and respectively equal to 15 and 300. The other specifications are $A = 425$; $\Omega = 20$; $g_m\left(e_m\right) = \dfrac{3}{100\left(1+e_m\right)}$;

$g_f\left(e_f\right) = \dfrac{3}{100\left(1+e_f\right)}$; $\gamma\left(e_m\right) = \dfrac{\left(e_m\right)^2}{4}$; and $\xi\left(e_f\right) = \dfrac{\left(e_f\right)^2}{4}$.

Conclusions

Many issues surround traceability of food products from the consumer through the marketing and processing firm and back to the farm of origin. Traceability may be a product attribute demanded by consumers or traceability may be required to document some other attribute that consumers value, such as a certain production method. Sometimes governments may impose mandatory traceability in order to enhance protection from invasive diseases or to facilitate regulation.

This paper is the first to explore in detail the relationships between traceability and the provision of food safety when traceability facilitates attributing liability for lapses in food safety to individual firms. The paper develops a formal model of how, by facilitating liability, traceability causes the degree of food safety to increase. We show that an increase in the likelihood that a marketing firm or farm will be held liable for losses suffered from a food safety event causes them to increase their effort to improve the food safety. We also show that when there is a finite number of firms and farms, the improved food safety caused by traceability also increases consumers' willingness to pay for the (safer) product and this creates an additional incentive to improve the food safety reputation of the industry. We show that incentives of this industry reputation effect for individual firms and farms declines as the number of firms and farms rises.

Overall, we show that traceability enhances the market-based incentives of private firms to provide safer food. Furthermore we demonstrate the incentives for marketing firms to encourage more traceability on the part of their raw material suppliers. This result is consistent with reports from farmers that some marketing firms are encouraging or demanding enhanced traceability as a precondition for a supply relationship. Our

results also suggest that, other thing constant, food safety will be higher with fewer firms in an industry because the firms internalize more of the costs imposed by food contamination problems. These results also document a rational for collective action in industries with many firms to facilitate firms taking account of the benefits having a safer product has for the industry as a whole.

Our general modeling approach is rich enough to accommodate investigation of several related topics that are not discussed thoroughly here. Results concerning effects of enhanced traceability on industry output, market price and profit have been developed and are available in an appendix. In addition, with some relaxation of assumptions made to simplify the exposition, we can explore how changes in the shape of cost function for traceability affect food safety. By relaxing our assumption of identical firms, we can explore how differences in costs of providing traceability may provide strategic advantages for some firms as the demand for traceability changes. For example, increases in perception of widespread food safety problems may benefit firms that can provide traceability more cheaply. By indicating their willingness to accept liability for their products these firms may receive higher prices and enhance profits while supplying additional traceability and perhaps food safety.

Our model can also be adapted to explore the linkages between food safety regulation, mandatory traceability and enhanced demand for voluntary traceability and thus additional liability. An important literature explores related topics in terms of product liability where there is a single step in the supply chain and traceability is not an issue. Our ongoing work extends this literature to study the linkages from consumer tm marketer to raw material supplier when traceability is costly.

References

Alston, J.M., Brunke H., Gray R.S. and Sumner D.A. "Demand Enhancement Through Food-Safety Regulation: a Case Study of the Marketing Order for California Pistachios" Chapter 16 in: *The economics of commodity promotion programs : lessons from California* / H. M. Kaiser, J. M. Alston, J. M. Crespi and R. J. Sexton, editors. New York : Peter Lang, 2005, p. 361-384.

Boyer M. and Porrini D. "Modelling the Choice Between Regulation and Liability in Terms of Social Welfare", *Canadian Journal of Economics*, 37(2004): 590-612.

Brown, J.P. "Toward an Economic Theory of Liability." *The Journal of Legal Studies* 2(1973): 323-349.

Buzby, J.C. and, T. Roberts. "Guillain-Barré Syndrome Increases Foodborne Disease Costs." *Food Review* 20(1997):36-42.

Buzby, J.C., P. D. Frenzen. "Food Safety and Product Liability." *Food Policy*, 24(1999): 637-651.

Buzby, J.C., P. D. Frenzen and, B. Rasco, "Product Liability and Microbial Foodborne Illness." *Agricultural Economic Report No. 799*, USDA/ERS, 2001. Available at: http://www.ers.usda.gov/publications/aer799/.

Clark B., Communication to Buzby and Frenzen concerning their paper published in Food Policy, available at http://lists.foodsafetyweb.info/SCRIPTS/WA-FOODSWS.EXE?A2=ind0002&L=foodsafe&P=39412

Clemetson L., B. Simon, "U.S. Officials Say Ill Cow Is Linked to Alberta Herd." *The New York Times* December 28th (2003): 1.1.

Cruchtfield, S., T. Roberts. "Food Safety Efforts Accelerate in the 1990's." U.S. Dept. of Agr., ERS. *FoodReview*. 23,3(Sept.-Dec. 2000): 44-49. Available at: http://www.ers.usda.gov/publications/foodreview/septdec00/FRsept00h.pdf.

Cooter R. D. "Economic Theories of Legal Liability", *The Journal of Economic Perspectives*, 5(1991): 11-30.

Golan, E., B. Krissof, F. Kuchler, K. Nelson, G. Price, and L. Calvin. "Traceability in the U.S. Food Supply: Dead End or Superhighway." *Choices* 18(2003). Available at: http://www.choicesmagazine.org/2003-2/2003-2-04.htm.

Golan, E., B. Krissof, F. Kuchler, L. Calvin, K. Nelson, and G. Price. "Traceability in the U.S. Food Supply: Economic Theory and Industries Studies." *Agricultural Economic Report No. 830*, USDA/ERS 2004. Available at: http://www.ers.usda.gov/publications/aer830/.

Hiriart Y., Martimort D. and Pouyet J. "On the Optimal Use of Ex Ante Regulation and Ex Post Liability", *Economics Letters*, 84(2004): 231-235

Hobbs, J. E. "Information Asymmetry and the Role of Traceability Systems." *Agribusiness* 20(2004): 397-415.

Hobbs, J. E., D. Bailey, D.L. Dickinson, and M. Haghiri. "Traceability in the Canadian Red Meat Market Sector: Do Consumers Care?" *Canadian Journal of Agricultural Economics* 53(2005): 47-65.

Kolstad C.D., Ulen T.S. Johnson G.V. "Ex Post Liability for Harm vs. Ex Ante Regulation: Substitutes or Complement?", American Economic Review, 80(1990): 888-901.

Marler and Clark website: http://www.marlerclark.com/.

Meuwissen, M. P. M., A. G. J. Velthuis, H. Hogeveen, and R. B. M. Huirne. "Traceability and Certification in Meat Supply Chains." *Journal of Agribusiness*, 21(2003): 167-181.

Polinsky, A. M and S. Shavell. "The Economic Theory of Public Enforcement of Law" . *Journal of Economic Literature*, 38 (2000), 45-76.

Roe, B. "Optimal Sharing of Foodborne Illness Prevention Between Consumers and Industry: The Effect of Regulation and Liability." *American Journal of Agricultural Economic* 86(2004): 359-374.

Shavell, S. "A Model of the Optimal Use of Liability and Safety Regulation." *The Rand Journal of Economics* 15(1984): 271-280.

Shavell, S., "Liability for Accidents", *Handbook of Law and Economics*, A. Mitchell Polinsky, Steven Shavell, eds., Vol 1, 2006. Available at SSRN: http://ssrn.com/abstract=849285.

Tirole, J. 1988. *The Theory of Industrial Organization*. Cambridge, Massachussetts: The MIT Press.

Viscusi W. K. "Product and Occupational Liability", *The Journal of Economic Perspectives*, 5(1991): 71-91.