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Supply Chain Contracts and Food Safety

By S. Andrew Starbird

As this issue of *Choices* attests, food safety has become one of the most important issues facing the food industry. Unnevehr (2003) gives four reasons why food safety is more important than ever to consumers: Improved diagnostic techniques make it easier to trace illnesses to food-borne pathogens; increasing consumer affluence has led to increased demand for safer, higher quality foods; new sources of food and new production practices have introduced new risks into the food supply chain; and consumers are purchasing more prepared food and food away from home than ever before. The food industry is well aware of the market's demand for food safety, and it continues to develop methods and adapt operations to meet this demand (Golan et al., 2004).

In this issue of *Choices*, Roberts defines seven generic strategies employed by food companies to reduce the contamination that leads to food safety failures. Her second strategy, pathogen prevention, includes efforts to keep pathogens out of a processing facility, destroying pathogens or limiting their growth if they are already in a facility, and minimizing cross-contamination. The best way for a consumer or processor to prevent food safety failures is to make sure that inputs, ingredients, and raw materials are safe when they are purchased.

In this article, I examine how supply chain contracts can be designed to improve the safety of purchased inputs. Contracts are frequently used to govern the exchange of goods, services, information, and money between supply chain participants. Even when sellers have more information about the product safety than buyers do, contracts can be used to enhance food safety.

Safe or Unsafe?

Two critical problems associated with ensuring food safety is defining *safe* and figuring out how to measure it. Although advances in public health have made it possible to link illness to specific pathogens, the definition of a safe level of pathogen contamination remains imprecise. The involvement of the government in establishing food safety standards has not resolved the issue. The lack of resolution is due in part to the incompatible interests of producers, processors, and consumers, and in part to the shortage of scientific evidence relating contamination rates to illness.

When the definition of safety is imprecise, firms participating in the supply chain face uncertainty with respect to the economic consequences of their actions. A firm may be able to calculate the cost of a lot failing a safety inspection or the cost of a lot being recalled because it is unsafe; however, without a precise definition of safety, the firm cannot compute the probability of these events. Without knowing the probability of these events, managers cannot measure the return on investments that improve safety, the value of food safety insurance (if it is available), or the value of testing the safety of raw materials and ingredients.

Even if the definition of safe is unambiguous, measuring safety is subject to significant error. Two sources of measurement error are *diagnostic error* and *sampling error*. Diagnostic error is the error associated with false positive and false negative test results. A *false positive* is a test that indicates that a pathogen is present when it is not; a *false negative* is a test that indicates that a pathogen is not present when it is. Recent developments in diagnostic technology have reduced the false positive and false negative rates to less than 1% (Qualicon, 2005). In economic jargon, the rate of false positives is the producer's (or in our case supplier's) risk—the risk that an uncontaminated lot will be classified as contaminated. The rate of false negatives is the consumer's (or in our case buyer's) risk—the risk that a contaminated lot will be classified as uncontaminated.

Some food safety inspection procedures include a sequence of tests in order to reduce the rate of false positives. A positive first test is called a *presumptive positive* until it is confirmed with a second test. This practice is common in drug screening of employees and athletes. In the case of drug screening, the double sampling procedure is designed to protect the person being tested from false accusations of drug use. In food safety, the double sampling procedure is designed to protect companies from false accusations of contaminated food. Unfortunately, double sampling does not reduce the buyer's risk associated with contaminated food passing inspection (false negatives). The rate of false negatives is influenced by the accuracy of the test for pathogens, the frequency of sampling, and by sampling at multiple places in the production process.

The other source of error in food safety testing is sampling error. The enormous volumes of food that move through the supply chain on a daily basis make it impossible to test every gram, square centimeter, or milliliter of food for the presence of pathogens. Buyers are forced to take samples in order to test the safety of purchased lots. Sampling error occurs when the characteristics of the sample are different from the characteristics of the lot from which the sample is drawn. Random sampling is a means of controlling this error, but establishing random sampling techniques and making sure they are followed everywhere in the supply chain is a daunting task.

The existence of diagnostic and sampling error means that buyers know less than suppliers about the safety of the product they are buying. It also means that unsafe product will sometimes pass inspection and that safe product will sometimes fail inspection. The risk associated with these events influences the behavior of both suppliers and buyers, because it influences supplier and buyer profitability.

Measurement Error and Imperfect Information About Safety

Measurement error leads to what economists call *imperfect* or *asymmetric* information about food safety. One of the assumptions behind neoclassical economic analysis is that market participants have perfect information about quality and price. Safety is an attribute of food that is not immediately observable, also called a *credence attribute*, so information about safety is imperfectly distributed among supply chain participants.

When suppliers have better information about quality than buyers do, the market is subject to two rather unpleasant economic phenomena: *moral hazard* and *adverse selection*. Moral hazard occurs when a supplier promises to exert effort to enhance safety but does not do so. Because safety measurement is subject to significant diagnostic and sampling error, a buyer cannot be sure that a supplier has fulfilled its promise to deliver safe food ingredients. Adverse selection occurs when suppliers can be divided into different categories or types based on the safety of their product. The supplier's type is imperfectly observable when safety is imperfectly observable. If the supplier's type is unobservable, buyers offer a price that reflects the "average" quality or safety they get from suppliers. The average price is too low for the highest quality suppliers to make money, so they leave the market. Of course, this outcome is undesirable from the point of view of policy makers and consumers.

Under certain conditions, however, we can use the uncertainty associated with food safety to motivate suppliers to deliver safer food. We are assuming, of course, that the buyer wants safer inputs because the profitability of safer food is higher. This assumption implies that the buyer faces high safety failure costs or high inspection failure costs that can be partially allocated to the supplier responsible for the unsafe food. The objectionable effects of an imperfect allocation of information can be partially corrected by an equitable allocation of cost.

Correcting Problems Associated with Imperfect Information

Several strategies exist for correcting the problems associated with imperfect safety information. The most obvious strategy is to get more information about the supplier and the quality of the supplier's product. This strategy will correct some of the asymmetry in the distribution of information, but acquiring accurate information is expensive and may be infeasible. Another strategy is vertical integration. If the buyer cannot segregate safe and unsafe suppliers, the buyer can acquire or merge with a supplier and make it safe. A third strategy is to make revealing information valuable, thereby encouraging the supplier to "signal" its safety level in some fashion. Safety and quality signals include the adoption of process standards (ISO 9000 or HACCP compliance, for example), guarantees, warranties, and third-party certifications. A fourth strategy is to design contracts that appeal to safe suppliers but not to unsafe suppliers. A contract, consisting of a bid price, specifications, and inspection protocols, may exist that segregates safe and unsafe suppliers.

A Safe Contract

A safe contract is a contract that will be accepted by safe suppliers and rejected by unsafe suppliers. To

Table 1. The influence of contamination rate on the supplier's return per lot and buyer's cost per lot.

Contamination rate	Probability that a lot passes inspection	Probability that a contaminated lot passes inspection	Production cost per lot ($)	Supplier's return per lot ($)[a]	Buyer's cost per lot ($)[b]
0.00	0.99	0.000000	1.000	0.0046	1.0300
0.02	0.97	0.000206	0.942	0.0043	1.0403
0.04	0.95	0.000421	0.887	0.0020	1.0510
0.06	0.93	0.000644	0.835	-0.0024	1.0622
0.08	0.91	0.000878	0.787	-0.0090	1.0739
0.10	0.89	0.001121	0.741	-0.0177	1.0861

[a] Supplier's return per lot is net of inspection failure costs and the allocated portion of safety failure costs.
[b] Buyer's cost per lot includes the portion of safety failure costs that could not be allocated to the supplier.

design a safe contract, the buyer selects contract parameters that persuade the safe supplier to participate in the transaction, but deter the unsafe supplier. Contract parameters related to safety include the bid price, the safety standard (definition), premiums or discounts associated with deviation from the standard, the sampling plan, the diagnostic test used to measure safety, and provisions for sharing the cost of food safety failures. Of course, supply chain contracts include many other provisions in addition to those that influence safety.

These contract provisions influence safety because they influence the cost of delivering contaminated food. The supplier of contaminated food faces two kinds of costs. First, if a contaminated lot is delivered and fails inspection, the supplier faces an *inspection failure cost*. Inspection failure cost includes the cost of disposing of the contaminated food, penalties and fines that might be levied against the supplier, and the cost of the additional production that will be needed to replace the rejected lots. Second, if a contaminated lot is delivered and passes inspection, the supplier faces a *safety failure cost*. Safety failure cost is the cost associated with contaminated food entering the buyer's production system and, perhaps, causing an illness when it reaches the consumer. Estimates of the safety failure cost are difficult to come by (see Buzby, Frenzen, & Rasco, 2001) and are different for private firms that seek to maximize profit and public agencies that seek to maximize consumer welfare and public health. Safety failure costs affect suppliers only if the supplier responsible for the failure can be identified and made to pay a portion of the cost associated with the safety failure.

The probability that a supplier will have to pay an inspection failure cost or a safety failure cost depends on the accuracy of the inspection procedure. The probability of a false positive test result contributes to the probability that a supplier has to pay the inspection failure cost. The probability of a false negative test result influences the probability that a contaminated lot passes inspection. If a lot that passes inspection is contaminated, then the supplier may have to pay a portion of the safety failure costs.

Segregating Safe and Unsafe Suppliers

A safe contract appeals to safe suppliers and does not appeal to unsafe suppliers. The appeal of a contract depends on the supplier's production cost, the probability of inspection failure, the probability of a safety failure, and the costs of inspection and safety failures. To illustrate this relationship, we examine the hypothetical case of a buyer offering to buy a product for $1.03 per lot. (This price can be scaled up and down without changing the results.) The contract requires inspection with a pathogen test that exhibits 99% sensitivity and 99% specificity, and the buyer only pays for lots that pass inspection. The production cost is $1.00 per lot for suppliers with no contamination. Suppliers with higher contamination rates have lower production costs. If the product fails inspection, the supplier pays $0.50 per lot to dispose of the contaminated product, and if a contaminated lot passes inspection, the buyer must pay $100 in safety failure costs. The buyer can allocate half of this cost to the supplier responsible for the failure.

Table 1 shows how contamination rate influences supplier return per lot in this hypothetical case. Suppliers break even at a contamination rate between 4% and 6%. This threshold is called the *breakeven contamination rate* (BCR) in Figure 1. Suppliers with a contamination rate below the BCR will accept the contract because their return is positive, and suppliers with a contamination rate above this threshold will not because their return is negative. The

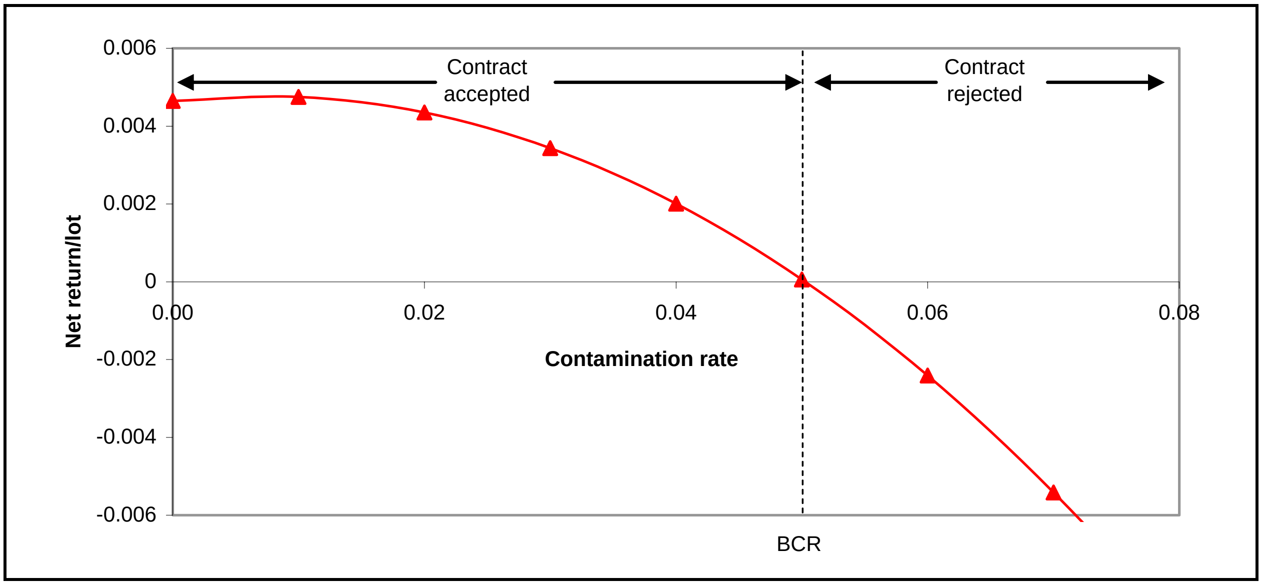

Figure 1. The breakeven contamination rate (BCR).

lower the BCR, the safer the ingredients entering the food supply chain.

Buyers and policy makers can influence the BCR by changing the parameters of the contract: the inspection and safety failure costs, the type and accuracy of the inspection procedure, or the bid price. Figure 2 shows the influence of inspection and safety failure costs on the BCR in our hypothetical case. As the inspection failure cost increases, the threshold declines. The threshold also declines when the safety failure cost increases. Suppliers who have a contamination rate above the threshold are dissuaded from participating unless, of course, they make the investment or exert the effort required to reduce their contamination rate.

An Opportunity for Buyers and Policy Makers

Private firms and public agencies often use contracts to regulate transactions with suppliers. Prudent contract design can segregate safe and unsafe suppliers and lead to an improvement in the safety of food

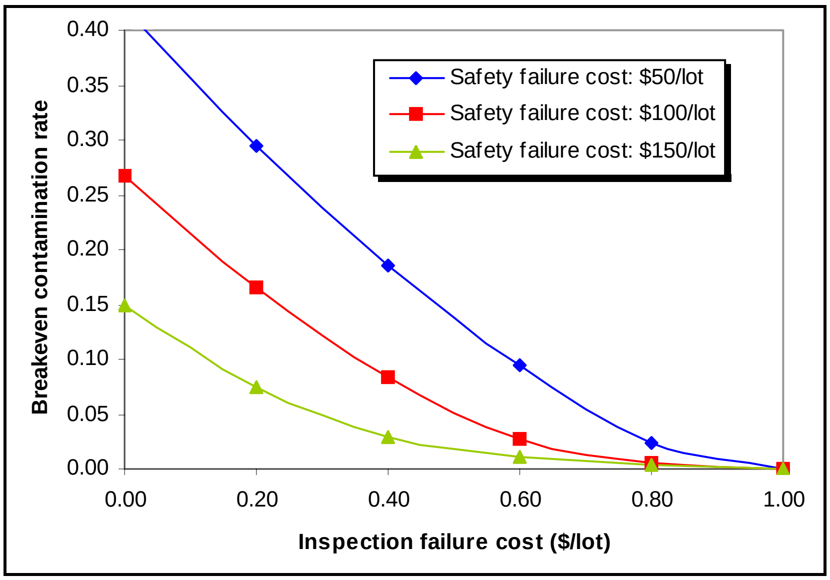

Figure 2. The effect of inspection and safety failure costs on the BCR.

purchased for school lunch programs, the military, food service, and other distribution channels. This opportunity exists even if suppliers know more about product safety than buyers do. Imperfect information about safety exposes both suppliers and buyers to significant financial risks. In a carefully designed contract, these financial risks can be used to deter unsafe suppliers from delivering harmful product.

However, poor contract design can lead to problems. First, if the safety failure and inspection failure costs are too high, the market will fail because no suppliers will participate. Second, if the safety failure and inspection failure costs are too low, then segregation is infeasible because all suppliers will accept the contract. Third, even if a contract effectively segregates suppliers, adverse selection can exist for the set of suppliers below the threshold. When the buyer cannot tell the difference between suppliers with nearly zero contamination and suppliers with contamination near the BCR, the buyer will offer a price that the safest suppliers find unsatisfactory. If this happens, the safest suppliers are likely to relax their efforts directed toward food safety. Finally, if suppliers have the option of avoiding inspection (because of a third-party certification of safety, for instance), perverse incentives that lead to cheating and less safe food can enter the supply chain (see van Ravenswaay & Bylenga, 1991, for an example).

Buyers have several strategies available for ensuring that suppliers deliver safe food ingredients. These strategies include reducing measurement error through improved diagnosis, vertical integration, and motivating suppliers to provide safety signals. These strategies are not possible in all supply chains, and even when they are possible, they can be expensive. Careful contract design is a relative inexpensive alternative that has promising potential for improving food safety.

For More Information

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