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Traceability in the U.S. Food Supply: Economic Theory and Industry Studies

Elise Golan, Barry Krissoff, Fred Kuchler, Linda Calvin,
Kenneth Nelson, and Gregory Price

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Abstract

This investigation into the traceability baseline in the United States finds that private-sector food firms have developed a substantial capacity to trace. Traceability systems are a tool to help firms manage the flow of inputs and products to improve efficiency, product differentiation, food safety, and product quality. Firms balance the private costs and benefits of traceability to determine the efficient level of traceability. In cases of market failure, where the private sector supply of traceability is not socially optimal, the private sector has developed a number of mechanisms to correct the problem, including contracting, third-party safety/quality audits, and industry-maintained standards. The best-targeted government policies for strengthening firms' incentives to invest in traceability are aimed at ensuring that unsafe or falsely advertised foods are quickly removed from the system, while allowing firms the flexibility to determine the manner. Possible policy tools include timed recall standards, increased penalties for distribution of unsafe foods, and increased foodborne-illness surveillance.

Keywords: traceability, tracking, traceback, tracing, recall, supply-side management, food safety, product differentiation

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Summary

U.S. food producers have developed an enormous capacity to track the flow of food along the supply chain, though individual systems vary. Some traceability systems are deep, tracking food from the retailer back to the farm, while others extend back only to a key point in the production process. Some systems are very precise, tracking food products to the minute of production or the exact area of a field where they were grown. Others are less precise, tracking product to farms in a large geographical area, such as the area served by a single grain elevator. Some traceability systems collect and track information on a broad range of attributes, while others track only a few. For example, some coffee producers may market and track attributes such as fair trade, fair wage, and shade grown, while others track none of these attributes.

This report describes the results of an investigation into the amount, type, and adequacy of traceability systems in the United States, focusing particularly on the fresh produce sector, the grains and oilseeds sector, and the cattle/beef sector. The results stem from research into the market studies literature, interviews with industry experts, and on-site interviews with owners, plant supervisors, and/or quality control managers in fruit and vegetable packing and processing plants; beef slaughter plants; grain elevators, mills, and food manufacturing plants; and food distribution centers. In some cases, site visits were conducted while in the company of auditors for USDA procurement programs. In these cases, the firms' complete traceability records were accessed.

U.S. traceability systems tend to be motivated by economic incentives, not government traceability regulation. Firms build traceability systems to improve supply-side management, to increase safety and quality control, and to market foods with credence attributes (attributes that are difficult for consumers to detect, such as whether a food was produced through genetic engineering). The benefits associated with these objectives include lower-cost distribution systems, reduced recall expenses, and expanded sales of high-value products. In every case, the benefits of traceability translate into larger net revenues for the firm. These benefits are driving the widespread development of traceability systems across the U.S. food supply chain.

Traceability is not, however, the only means to these objectives – and it alone cannot accomplish any of them. Simply knowing where a product is in the supply chain does not improve supply management unless the traceability system is paired with a real-time delivery system or some other inventory-control system. Tracking food by lot in the production process does not improve safety unless the tracking system is linked to an effective safety control system. And of course, traceability systems do not create credence attributes, they simply verify their existence.

Firms use traceability systems together with a host of other management, marketing, and safety/quality control tools. The dynamic interplay of the costs and benefits of these tools has spurred different rates of investment in traceability across sectors – and continues to do so. Such variation is not an indication of inadequacy but of efficiency, the result of a careful balancing of costs and benefits. Such variation is evident in the three food sectors at the center of this investigation.

In the *fresh produce industry*, the development of traceability systems has been greatly influenced by the characteristics of the product. Perishability of and quality variation in fresh fruits and vegetables necessitate the boxing and identification of quality attributes

early in the supply chain, either in the field or packinghouse. This has facilitated the establishment of traceability for a number of objectives including marketing, food safety, supply-side management, and differentiation of new quality attributes.

Virtually all *grains and oilseeds* produced in the United States are traceable from production to consumption—for the most part, however, quality and safety variation in grain and oilseeds has not warranted the cost of precise traceability systems. Systems tracking product to elevators, at which point quality and safety are monitored, have been largely sufficient for the efficient operation of grain and oilseed markets. Growing demand for specialty crops, including non-genetically engineered products, has spurred the development of more precise traceability systems, though the elevator still operates as an important quality-control point.

The *cattle/beef sector* has a long history of identifying and tracking animals to establish rights of ownership and to control the spread of animal diseases. Producers in the meat sector have also developed traceability systems to improve product flow and to limit quality and safety failures. Recent developments are motivating firms to bridge separate animal and meat traceability systems and to establish systems for tracking meat from the farm to the retailer. Though technological innovations are helping to reduce the costs of such systems, institutional and philosophical barriers have slowed their adoption.

In some instances, the private costs and benefits of traceability may not be the same as the social costs and benefits so that the private supply of traceability falls below socially desirable levels. Instances of such market failure could lead to a sub-optimal supply of traceability for product differentiation or for food safety. Both industry and government have a number of options to help correct market failure. The best options are those targeted at increasing firms' incentives to build and maintain traceability systems. Government-imposed systems tend to be ill suited to this task.

In cases where markets supply too little traceability for product differentiation, individual firms and industry groups have developed systems for policing and advertising the veracity of credence claims. Third-party safety/quality auditors are at the heart of these efforts. These auditors provide consumers with verification that traceability systems exist to substantiate credence claims. Government may also require that firms producing foods with credence attributes substantiate their claims through mandatory traceability systems. If firms are not required to prove that credence attributes exist, some may try to gain price premiums by passing off standard products as products with credence attributes. One difficulty with mandatory traceability proposals is that they often fail to differentiate between valuable quality attributes, those for which verification is needed, and less valuable attributes for which no verification is needed.

In cases where markets supply too little traceability for food safety traceback, a number of industry groups have developed food safety and traceback standards. In addition, buyers in every sector are increasingly relying on contracting, vertical integration, or associations to improve product traceability and facilitate the verification of safety and quality attributes. Again, third-party auditors help verify that safety and traceback standards and obligations have been met.

Government may also consider mandating traceability to increase food safety, but such a mandate may impose inefficiencies on already efficient private traceability systems. The already widespread voluntary use of traceability complicates the application of a central-ized system because firms have developed so many different approaches and systems of tracking. If mandatory systems fail to allow for variations in traceability systems, they will likely end up forcing firms to make adjustments to already efficient systems or to create parallel systems.

Other policy options can encourage firms to strengthen their safety and traceability systems without requiring any specific process for doing so. For example, standards for mock recalls (in which firms must prove that they can locate and remove all hypothetically contaminated food from the food supply within a certain amount of time) give firms the freedom to develop efficient traceback systems while ensuring that such systems satisfy social objectives.

Policy aimed at increasing the cost of distributing unsafe foods, such as fines or plant closures, or policies that increase the probability of catching unsafe food producers, such as increased safety testing or foodborne illness surveillance, will also provide firms with incentives to strengthen their traceability systems. When the cost of distributing unsafe food goes up, so too do the benefits of traceability systems.

One area where industry has no incentive to create traceability systems is for tracking food once it has been sold and consumed. No firm has an incentive to monitor the health of the Nation's consumers in order to speed the detection of unsafe product. Government-supplied systems for monitoring the incidence of foodborne illness are one option for helping close this gap in the food system's traceability network. By better providing this public good, the government could increase the capability of the entire food supply chain to respond to food safety problems before they grow and affect more consumers.

Traceability in the U.S. Food Supply:
Economic Theory and Industry Studies

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I. Introduction and Methodology

Traceability systems are recordkeeping systems designed to track the flow of product or product attributes through the production process or supply chain. Recently, policymakers have begun weighing the usefulness of making such systems mandatory so as to address issues ranging from food safety and bioterrorism to consumers' right to know. For example, policymakers in many countries have proposed or adopted mandatory systems to track animal feed to control the risk of mad cow disease and to improve meat safety. Other proposals involve mandatory tracking of food transportation systems to reduce the risk of tampering. Numerous proposals involve mandating traceability to help provide consumers with information on a variety of food attributes including country of origin, animal welfare, and genetic engineering.

Food producers, manufacturers, and retailers have many of the same concerns as government policymakers and in fact already keep traceability records for a wide range of foods and food attributes. The questions before policymakers are, does the private sector provide enough traceability to meet social objectives? If not, what policy tools are best targeted to increasing the supply of traceability?

The objective of this study is to provide a framework to answer those questions. To do that, we first needed an accurate description of the extent and type of traceability maintained by private firms, that is, the traceability baseline. We could not begin to assess the adequacy of private sector traceability systems without a clear understanding of how typical it is for firms to establish these systems, why they establish them, and how they function. We began our investigation by reviewing market studies, interviewing government officials, and talking with industry associations. Next, we conducted telephone interviews with a wide range of food industry representatives, including grain and food processors, fast-food retailers, safety auditors, and food distributors. We conducted several site visits in each of the three major food sectors: fresh produce, grains, and livestock. During these visits, we interviewed owners, plant supervisors, and/or quality control managers in fruit and vegetable packing and processing plants, beef slaughter plants, grain elevators, mills and food manufacturing plants, and food distribution centers.

In each interview, we asked about the company's traceability system, including its bookkeeping records, lot or batch sizing, computer use, and tracking technologies. We asked about the cost of the traceability system and about how long it had been in use. We received a high level of voluntary cooperation from these firms, sometimes getting a tour of their facilities. However, our discussions were informal and we generally did not review firms' records to confirm the information provided. Our discussions were often broad based about the firm's recordkeeping systems and we did not systematically collect specific data about a firm's traceability system.

A number of our site interviews were with firms that are eligible to submit bids for U.S. procurement programs. We received access to these firms by accompanying USDA auditors on their inspections to ensure that the firms were complying with procurement regulations and guidelines. We asked the firms' managers whether they thought the firms' traceability systems were typical for their industries. While most indicated that their systems were characteristic for their industry, some pointed out their innovative and state-of-the-art approaches to traceability. Our site-visit sample, thus, may be skewed to firms that are at least average or better in their use of good manufacturing practices, although we are confident that our conclusions hold for the majority of firms in each sector.

Our investigations led us to conclude that 1) traceability is an objective-specific concept; 2) the private sector in the United States has developed a significant capacity to trace; and 3) industry/product characteristics lead to systematic variation in traceability systems. We found that efficient traceability systems vary across industries and over time as firms balance costs and benefits to determine the efficient breadth, depth, and precision of their traceability systems. We examine the evidence leading to these conclusions in the second section of the report, where we look at the factors that influence the costs and benefits of traceability. The three chapters in Section III provide further elaboration of these conclusions by describing in detail the supply chain and traceability systems characterizing the fresh produce, grains and oilseeds, and cattle/beef sectors.

While private sector traceability systems are extensive, gaps may nevertheless exist. Some gaps are the result of an efficient balancing of traceability costs and benefits. Others, however, are the result of market failures and may warrant government intervention. To examine the possibility that market failure has resulted in gaps in the supply of traceability, we qualitatively analyzed and compared social and private costs and benefits of traceability. We found that asymmetric information problems have the potential to dampen firms' supply of traceability for food safety and for product differentiation. Section IV contains our analysis of market failure in the provision of food traceability and our investigation into the types of government policy tools that may correct market failure and encourage the development of private traceability systems. We also consider the characteristics of a government-mandated traceability system that would most efficiently mesh with private systems. The appendix to this section lists selected mandatory traceability laws in the United States. In section V, we provide some concluding thoughts.

II. Efficient Traceability Systems Vary

The ISO 9000:2000 guidelines define traceability as the "ability to trace the history, application or location of that which is under consideration" (ISO, 2000).[1] The ISO guidelines further specify that traceability may refer to the origin of the materials and parts, the processing history, and the distribution and location of the product after delivery.

This definition of traceability is quite broad. It does not specify a standard measurement for "that which is under consideration" (a grain of wheat or a truckload), a standard location size (field, farm, or county), a list of processes that must be identified (pesticide applications or animal welfare), where the information is recorded (paper or electronic record, box, container or product itself), or a bookkeeping technology (pen and paper or computer). It does not specify that a hamburger be traceable to the cow or that the wheat in a loaf of bread be traceable to the field. It does not specify which type of system is necessary for identity preservation of tofu-quality soybeans, for quality control of cereal grains, or for guaranteeing correct payments to farmers for different grades of apples.

Complete Traceability is Impossible

The definition of traceability is necessarily broad because traceability is a tool for achieving a number of different objectives. No single approach is adequate for every objective. Even a hypothetical system for tracking beef, in which consumers scan their packet of beef at the check-out counter and receive information on the date and location of the animal's birth, lineage, vaccination records, acreage of pasturage, and use of mammalian protein supplements, is incomplete. It does not provide traceability with respect to pest control in the barn (a potential food safety issue), use of genetically engineered feed, or animal welfare attributes like pasturage hours and playtime. There are hundreds of inputs and processes in the production of beef. A system for tracking each and every input and process with a degree of precision adequate for every objective would be virtually impossible.

The characteristics of good traceability systems vary and cannot be defined without reference to the system's objectives. Different objectives help drive differences in the *breadth*, *depth*, and *precision* of traceability systems.

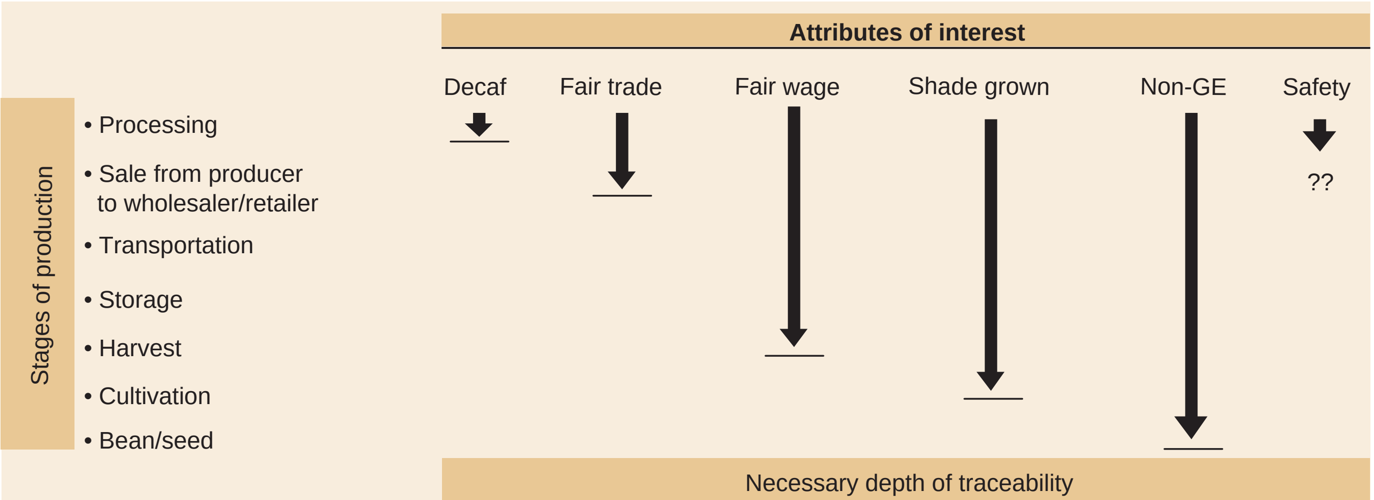
Breadth describes the amount of information the traceability system records. There is a lot to know about the food we eat, and a recordkeeping system cataloging all of a food's attributes would be enormous, unnecessary, and expensive. Take for example, a cup of coffee. The beans could come from any number of countries; be grown with numerous pesticides or just a few; grown on huge corporate organic farms or small family-run conventional farms; harvested by children or by machines; stored in hygienic or pest-infested facilities; decaffeinated using a chemical solvent or hot water. A traceability system for one attribute does not require collecting information on other attributes.

The *depth* of a traceability system is how far back or forward the system tracks. In many cases, the depth of a system is largely determined by its breadth: once the firm or regulator has decided which attributes are worth tracking, the depth of the system is essentially determined. For example, a traceability system for decaffeinated coffee would only need to extend back to the processing stage (figure 1). A traceability system for fair trade coffee would only need to extend to information on price and terms of trade between coffee growers and processors. A traceability system for fair wage would only need to extend to harvest; for shade grown, to cultivation; and for non-genetically engineered (GE), to the bean or seed. In other cases, the depth of the system is determined by quality or safety control points along the supply chain. In these cases, traceability systems may only need to extend back to the last control point, that is the point where quality or safety was established or verified. For example, a firm's traceability system for pathogen control may only need to extend to the last "kill" step—where product was treated, cooked, or irradiated.

Precision reflects the degree of assurance with which the tracing system can pinpoint a particular food product's movement or characteristics. Precision is determined by the unit of analysis used in the system and the acceptable error rate. The unit of analysis, whether container, truck, crate, day of production, shift, or any other unit, is the tracking unit for the traceability system. Systems that have large tracking units, such as an entire feedlot or grain silo, will have poor precision in isolating safety or quality problems. Systems with smaller units, such as individual cows, will have greater precision. Likewise, systems with low acceptable error rates, such as low tolerances for GE kernels in a shipment of conventional corn, are more precise than systems with high acceptable

[1] ISO is a worldwide federation of national standards bodies which promotes the development of standardization and international standards for a wide range of products. ISO 9000 guidelines are quality management system standards.

Figure 1
The depth of a traceability system depends on the attributes of interest



error rates. In some cases, the objectives of the system will dictate a precise system while for other objectives a less precise system will suffice.

The breadth, depth, and precision of private traceability systems will vary depending on the objectives of the systems and the corresponding benefits and costs to the firm. Though at first glance this variability may appear to indicate deficiencies in the private supply of traceability, it is actually an indication of efficiency. Firms collect information on an attribute and track its flow through the supply chain only if the net benefits (benefits minus costs) of doing so are positive. Likewise, they invest in precision only if the benefits outweigh the costs. Because firms balance the costs and benefits of traceability, they tend to efficiently allocate resources to building and maintaining these systems.

Firms Consider a Wide Range of Costs and Benefits

Traceability systems that yield positive net benefits to the firm are a worthwhile investment; those yielding negative net benefits are not worthwhile to the firm. Below, we examine the range of benefits and costs that firms consider when determining the efficient breadth, depth, and precision for their traceability systems.

Benefits of Traceability

Firms have three primary objectives in developing, implementing, and maintaining traceability systems: to improve supply management; to facilitate traceback for food safety and quality; and to differentiate and market foods with subtle or undetectable quality attributes. The benefits associated with these objectives range from lower-cost distribution systems, reduced recall expenses, and expanded sales of products with attributes that are difficult to discern. In every case, the benefits of traceability translate into larger net revenues for the firm. Firms establish traceability systems to achieve one or more traceability objectives—and to reap the benefits. These benefits are driving the widespread development of traceability systems across the food supply chain.

Objective/Benefits I: Traceability for Supply Management During 2000, American companies spent $1.6 trillion on supply-related activities, including the movement, storage, and control of products across the supply chain (State of Logistics Report, 2001). The ability to reduce these costs often marks the difference between successful and failed firms. In the food industry, where margins are thin, supply management is an increasingly important area of competition.

An indispensable element of any supply management strategy is the collection of information on each product from production to delivery or point of sale. The idea is "to have an information trail that follows the product's physical trail" (Simchi-Levi, 2003, pg. 267). Information trails, or in other words, traceability systems, provide the basis for good supply management. A business's traceability system is key to finding the most efficient ways to produce, assemble, warehouse, and distribute products. The benefits of traceability systems for supply management are greater the higher the value of coordination along the supply chain.

Electronic systems for tracking inventory, purchases, production, and sales have become an integral part of doing business in the United States. A few big retailers such as Wal-Mart and Target have even created proprietary supply-chain information systems that they require their suppliers to adopt. In addition to private systems, U.S. firms may also use industry-standard coding systems, such as UPC codes (see box, “From UPC to RSS: Tracking Technologies Drive Down the Costs of Precision”). These systems are not confined to packaged products. The food industry has developed a number of complex coding systems to track the flow of raw agricultural inputs to the products on grocery store shelves. These systems are helping to create a supply management system stretching from the farm to the retailer.

Evidence that American companies are embracing new sophisticated tracking systems can also be found in macro-economic statistics. The success of traceability systems in helping to control inventory costs is reflected in national inventory-to-sales ratio statistics. Over short time periods, inventories may rise or fall, but a consistent pattern in which inventories fall relative to a firm’s total sales indicates that the firm is getting better at keeping track of its inputs and outputs and it is taking advantage of that knowledge. Figure 2, showing the ratio of private inventories to final sales of domestic business, displays a declining time trend, falling by half since the end of WWII (U.S. Department of Commerce, 2003).

The same trend can be observed in many sectors of the domestic food industry. Figure 3 shows the ratio of end-of-year inventories to total value of shipments for proxies for the dairy, grain, and sugar industries (Bartlesman, Becker, and Gray, 2000). In every case, the inventory-to-sales ratio fell, with the largest decline in the cereal sector, where the ratio fell from over 8 percent to approximately 3 percent. The downward trend in inventories in major components of the food industry reflects growing efficiencies in supply management, including traceability systems.

Across the economy, firms are adopting systems to more efficiently manage resources. In many cases, new tracking/information systems are at the heart of these efforts. The depth, breadth, and precision of these systems vary across industries and firms, mirroring the distribution requirements of the enterprise.

Objective/Benefits 2: Traceability for Food Safety and Quality Control Product-tracing systems are essential for food safety and quality control. Traceability systems help firms isolate the source and extent of safety or quality-control problems. The more precise the tracing system, the faster a producer can identify and resolve food safety or quality problems. Firms have an incentive to invest in traceability systems because they help minimize the production and distribution of unsafe or poor quality products, which in turn minimizes the potential for bad publicity, liability, and recalls.

Traceability systems can help track product distribution and target recall activities, thereby limiting the extent of damage and liability. Most, if not all, voluntary recalls listed on USDA’s Food Safety and Inspection Service website refer consumers to coded information on products’ packaging to identify the recalled items. The advent of grocery store or club cards to track sales enhances the potential for targeted recall information. Grocery stores could use their sales data to identify and then warn buyers of recalled products. Some have

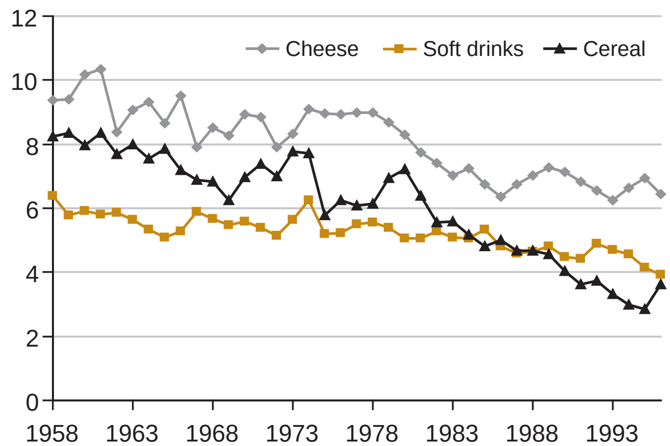
Figure 2

Ratio of private inventories to final sales of domestic business--seasonally adjusted, 1946(4)-2003(1)

Source: Bureau of Economic Analysis, National Income and Product Accounts.

Figure 3

Ratio of inventories to total value of shipments for selected food industries, 1958-1996



Source: Bartlesman, Eric J., Randy A. Becker, and Wayne B. Gray. “NBER-CES Manufacturing Industry Database.” www.nber.org/nberces/nbprod96.htm. Inventories are measured at end of year.

From UPC to RSS: Tracking Technologies Drive Down the Cost of Precision

Ever since a 10-pack of Wrigley's Juicyfruit gum was scanned at the checkout counter in 1974, bar codes have become ubiquitous in the U.S. grocery stores. Almost everything we buy has packaging with printed bar codes. In the food industry, the vast majority of packaged products bear bar codes, as do a growing number of bulk foods, like bagged apples and oranges.

The Uniform Code Council (UCC), a non-profit private company that establishes and promotes multi-industry standards for product identification, created bar codes in response to the needs of food manufacturers and retailers who were interested in speeding the checkout process at the grocery store and for improving inventory management (Uniform Code Council, 2003). Bar codes contain a series of numbers reflecting type of product and manufacturer (the UPC 12-digit code), and a series of numbers assigned by the manufacturer to nonstandard production or distribution details. Each product, including those with different size packaging, contains a unique UPC code. When a package is scanned under a laser beam at the checkout counter, the store's central computer reads the UPC number, records the sale, and marks the change in inventory. Recently, UCC has developed an extension of UPC codes to 14 digits called the Global Trade Item Numbers (GTIN) system, which contains expanded information about companies, products, and product attributes worldwide (Global Trade Item Numbers Implementation Guide, 2003).

The success of the original UPC system has combined with technological advances and e-marketing to spur the development of integrated systems that code, track, and manage wholesale and retail transactions within the United States and in the global community. In some cases, buyers manage these systems to monitor supply flow. In other cases, firms establish systems to link suppliers and buyers. For example, EAN.UCC, which is a subsidiary of the UCC and EAN International, a European commercial standard setting organization, has developed an open integrated system to standardize and automate information systems across a supply chain that includes GTINs, along with an industry standard set of 62 product attributes (EAN.UCC, 2003). With an integrated system, the process of entering information into retailers' systems is automated so when new information is logged into the system by the producer, it's added in real time to all systems across a network. With such systems, anyone along the chain can track inputs, production, and inventory by an array of characteristics.

New technologies are spurring the development of even more precise systems. One example of an upcoming technology is the expansion of bar codes to reduced space symbology (RSS) (Rowe, 2001). Currently, stickers with 4-digit price look-up codes on fresh produce identify the product and assist the retailer in inventory management. With RSS, 14-digit GTIN bar codes could be attached to individual items. An apple, a box, and a pallet could all be linked by the same product and grower-shipper codes, with an additional numeric indicating "item," "box," or pallet." Similarly a package of ground beef could be linked to a packinghouse. Other bar code application identifiers and numbers could be used as well, including price, weight, sell date, and lot. Having an electronic lot number on a package of ground beef would facilitate a traceback in case of a quality or safety concern. Moreover, customers who purchase specific foods using frequent shopper cards can be quickly identified even if they have discarded the food package. Thus, tracing forward or backward to facilitate supply chain management or quality and safety control would be more easily and swiftly accomplished

Bar codes have a few disadvantages (Brain, 2003). In order to keep up with inventories, companies must scan the bar code under a laser beam. A more proactive technology would allow a reader to scan a smart label—a computer chip embedded in each product's package, box, or pallet—whether the item remains on the shelf (in the front part of the shelf or hidden in the back) or is sold. For even more efficiency in retail store management, the store could have a "smart setup." In these stores, a consumer could carry out their shopping and exit the store without going to a checkout counter. Instead, a radio frequency identification (RFID) reader embedded in an exit door could read the smart tags simultaneously for each food package. Even detailed attributes could be read such as a 1-quart container of non-fat organic milk with a sale date of January 14, 2004. Inventories on each product with all its unique attributes even including "must sell by date" could be efficiently traced and managed at manufacturing locations, warehouses, distribution centers and grocery stores.

Furthermore, computers at the grocery store and its suppliers' facilities would know automatically which items had been purchased and needed to be replenished. The computers would also be able to automatically notify the consumer's bank of charges and debit the consumer's account.

While this scenario sounds like it may be far in the future, RFID technology is not new and currently is used to track livestock and container cargo on trucks and ships. With RFID tags, ranchers can determine the location and movements of cattle and more quickly round up any particular heifer or steer. With RFID tags, a distributor can determine precisely the location of a cargo ship or truck and the condition of produce in a controlled-atmosphere container. In July 2003, Wal-Mart issued a mandate to its top suppliers requiring the use of RFID tags on pallets and cases by the end of 2004 (Dunn, 2003). As the cost of RFID technology falls, it is possible that, several years from now, we may see RFID tags on many individual food items.

UCC and EAN International are facilitating the use of RFID technology with the establishment of standardized Electronic Product Codes (EPC) and an EPC network (EPCglobal, 2003). Unlike other electronic networks that are proprietary, these will be open to any firm. Already Wal-Mart is requiring its top suppliers to be EPC-compliant. With the use of electronics and widely accepted standards, the number of attributes that can be traced for each food product is nearly limitless.

already done that. For example, during the recent mad cow beef recall, one supermarket chain used its preferred customer cards to identify and warn shoppers who had bought the suspect meat (Anderson, 2004). Likewise, credit card information could be used to track purchases of contaminated foods. In fact, the Food and Drug Administration (FDA) has used credit card information in its traceback investigations.

The benefits of precise traceability for food safety and quality control are greater the higher the likelihood and cost of safety or quality failures. Where the likelihood and cost of failure are high, manufacturers have large financial incentives to reduce the size of the standard recall lot and to adopt a more precise traceability system. The likelihood of failure differs among food industries because some foods are more perishable or more susceptible to contamination than others. The costs of safety or quality breaches also vary among firms because the value of products and the value of firms' reputations vary. For high-value products, recall costs per item are higher than for low-value products. For firms with valuable reputations, the costs of recall or safety breaches are higher than for firms with little name-brand equity. The costs of safety or quality failures may also be larger in industries where government or consumer-group oversight is more stringent, meaning that the likelihood of detection in the case of a food safety problem is greater.

The benefits of traceability are also likely to be high if other options for safety control are few. If a firm can eliminate safety problems with a simple kill step or through inexpensive testing, then the marginal benefits of a traceability system for monitoring safety are likely to be small. For example, if a firm could use a chemical dip on incoming produce that completely eliminated the risk of pathogen contamination, there would be little value in a traceability system to identify producers of product with high levels of pathogen contamination. Likewise, if safety or quality problems are unlikely to arise in a specific stretch of the production or supply chain, there is little value in establishing traceability systems for that stretch.

Another benefit of traceability systems is that they may help firms establish the extent of their liability in cases of food safety failure and potentially shift liability to others in the supply chain. If a firm can produce documentation to establish that safety failure did not occur in its plant, then it may be able to protect itself from liability or other negative consequences. Traceability systems in themselves do not determine liability, but because they provide information about the production process, including safety procedures, they have a role in providing evidence of negligence or improper production practices.

Despite the important safety role they play, traceability systems are, however, only one element of a firm's overall safety/quality control system and are designed to complement and reinforce the other elements of the safety/quality system. In themselves, traceability systems do not produce safer or high-quality products—or determine liability. Traceability systems provide information about whether control points in the production or supply chain are operating correctly or not. The breadth, depth, and precision of traceability systems for safety and quality necessarily reflect the control points in the overall safety/quality system and vary systematically across industries and over time depending on safety and quality technologies and innovations.

Objective/Benefits 3: Traceability To Differentiate and Market Foods with Credence Attributes The U.S. food industry is a powerhouse producer of homogenous bulk commodities such as wheat, corn, soybeans, and meats. Increasingly, the industry has also begun producing goods and services tailored to the tastes and preferences of various segments of the consumer population. In the competition over micromarkets, producers try to differentiate one product from otherwise similar products in ways that matter to customers.

Food producers differentiate products over a wide variety of quality attributes including taste, texture, nutritional content, cultivation techniques, and origin. Consumers can easily detect some attributes—green ketchup is hard to miss. However, other innovations involve credence attributes, characteristics that consumers cannot discern even after consuming the product (Darby and Karni, 1973). Consumers cannot, for example, taste or otherwise distinguish between oil made from GE corn and oil made from conventional corn.

Credence attributes can be content or process:

> ***Content attributes*** affect the physical properties of a product, although they can be difficult for consumers to perceive. For example, consumers are unable to determine the amount of isoflavones in a glass of soymilk or the amount of calcium in a glass of enriched orange juice by drinking these beverages.
>
> ***Process attributes*** do not affect final product content but refer to characteristics of the production process. Process attributes include country-of-origin, free-range, dolphin-safe, shade-grown, earth-friendly, and fair trade. In general, neither consumers nor special-

ized testing equipment can detect process attributes.

Traceability is an indispensable part of any market for process credence attributes—or content attributes that are difficult or costly to measure. The only way to verify the existence of these attributes is through a bookkeeping record that establishes their creation and preservation. For example, tuna caught with dolphin-safe nets can be distinguished from tuna caught using other methods only through the bookkeeping system that ties the dolphin-safe tuna to the observer on the boat from which the tuna was caught. No test conducted on a can of tuna could detect whether the tuna was caught using dolphin-safe technologies. Without traceability as evidence of value, no viable market could exist for dolphin-safe tuna, fair-trade coffee, non-GE corn oil, or any other process credence attribute.

The benefits of traceability (and third-party verification) for credence attributes are greater the more valuable the attribute is to processors or final consumers. Attributes tend to be more valuable the more marketable they are, the higher the expected premiums, and the larger the potential market. Firms will only find it worthwhile to establish traceability to market attributes with the potential to generate additional revenue—and the larger the potential revenue, the greater the benefits of traceability.

Costs of Traceability

Traceability costs include the costs of recordkeeping and product differentiation. Recordkeeping costs are those incurred in the collection and maintenance of information on product attributes as they move through production and distribution channels. In some cases, the recordkeeping system necessary for traceability is very similar to that already maintained by the firm for accounting or other purposes. For example, in the United States, most firms keep records of their receipts and bills. For these firms, one-up, one-down traceability for a standard set of attributes would require little if any change in the firm's accounting system. In other instances, new traceability objectives may require expensive additions to existing recordkeeping systems.

Product differentiation costs are those incurred in keeping products or sets of product attributes separate from one another for tracking purposes. Product differentiation for tracking is primarily achieved by breaking product flow into lots or any other discrete unit defined over a set of common processes or content attributes (see box, "What's a Lot?"). When traceability requirements accommodate production-based lot sizes such as the amount of production from one shift or the product from one field, traceability differentiation costs are minimal. Likewise, when new traceability objectives accommodate differentiation systems that are already in place for other traceability objectives, the costs of the new traceability systems will be relatively small.

When traceability differentiation requires firms to adopt different or additional criteria for product differentiation, firms could incur large costs—at least in the short run. Such a situation may arise when firms instigate traceability for new credence attributes. For example, the desire to distinguish GE corn from conventional corn has prompted a number of growers and processors to establish new systems to identify and keep the two types of corn separate.

The longrun cost of separating products with different attributes depends on a number of factors, including underlying production technologies and the level of demand. In some cases, a change or addition to existing production lines is the low-cost solution to meet demand. For example, a packer-shipper may determine that installing scanner equipment on conveyer belts to separate fruit by color or size is the most efficient technology. In other cases, firms may choose to differentiate production by establishing separate product lines within the same plant or by sequencing production and thoroughly cleaning production facilities between differentiated product batches. A packer-shipper could run lines at separate times for conventional and organic produce or build separate lines for each attribute. Firms facing large demand may dedicate a whole plant or distribution channel to the production or distribution of one specific product line. Average costs increase when the separation of product lines creates unused capacity, such as underutilized trucks and storage facilities, or requires stopping, cleaning, and restarting production lines. If demand for the differentiated products is sufficient, however, the firm may realize economies of scope and increased net profits.

The level of precision also affects the type and cost of product differentiation. Systems requiring a high degree of accuracy also tend to require stringent systems for separating crops or products. There are two primary approaches for separating attributes:

- *A segregation* system separates one crop or batch of food ingredients from others. Though segregation implies that specific crops and products are kept apart, segregation systems do not typically entail a high level of precision. In the United States, white corn is chan-

What's A Lot?

Product differentiation for tracking is achieved by breaking product flow into lots, or any other discrete unit defined over a set of common process or content attributes. Lots are the smallest quantity for which firms keep records. Firms may choose among an infinite array of unit sizes, shapes, or time, defining their own lot size by the quantity of product that fits in a container, that a forklift can move on a pallet, or that fills a truck. A lot may be an individual animal or group of animals, or production from an entire day or shift. Firms that choose a large lot size for tracking purposes, such as a feedlot or grain silo, will have more difficulty isolating safety or quality problems than a firm that chooses a smaller size. A smaller lot size, such as an individual cow or container, will allow greater precision.

In choosing lot size, firms typically consider a number of factors, including accounting procedures, production technologies, and transportation. As these factors vary within and among industries, lot size varies from plant to plant. There is no standard traceability unit. Furthermore, a firm is likely to have a different lot size for incoming and outgoing products. Firms add value in their production and marketing practices by commingling, transforming, and processing products. Clearly the incoming products for a meat processor and slaughterhouse (for example, group of pigs) differ from the outgoing product (boxes of primal cuts and consumer-ready products). The size and shape of a lot is therefore likely to change at each processing juncture. Some firms may find it efficient to maintain depth of traceability by linking incoming and outgoing lots, while others may not.

Consider two examples. An apple packer-shipper may use accounting procedures to choose the incoming lot size. The shipper may receive apples from a number of growers and must pay each grower based on the type, size, and grade of the product. Since these attributes are known only after the apples have been sorted, each grower's apples need to be kept separate in the packing line. These accounting procedures thus influence the lot size of product entering the packinghouse. As apples are sorted, packed, and shipped, a packinghouse may choose to make a lot the number of boxes that can be loaded onto a truck. One or several growers' apples could be loaded together—it is most cost-effective to fully pack a truck. There may be food safety and quality concerns that motivate a shipper to keep a lot size no larger than a truckload. In the case of a food safety problem—for example, a piece of metal or glass found in an apple—the shipper may want to limit the size of a recall and limit the number of affected growers.

The lot for a farrow-to-finish operation, a farm where pigs are born, raised, and prepared for slaughter, might be a batch or group of pigs. When the batch is moved from one stage of production to another, the all-in, all-out production system allows for cleaning the facilities between batches. This method meets the farmer's objective of preventing disease from spreading from one batch of pigs to another (Hayes and Meyer, 2003). Commingling batches of pigs raises the potential for disease. The slaughterhouse may process several batches of pigs in a shift or day, packing the outgoing product—various cuts of pork—in boxes. Each box may specify the name and address of the packer, the lot number, and place and time of production, allowing the firm to track similar products. This reflects the packer's objective of efficiently managing large volumes of meat and concern for food safety. If the packer or Federal or State authorities discover that there is contaminated pork, they can identify product by lot number and inform retailers and/or consumers.

neled through the bulk commodity infrastructure, but it is segregated from other types of corn.

- An *identity preservation* (IP) system identifies the source and/or nature of the crop or batch of food ingredients. IP systems are stricter than segregation systems and often require containerization or other physical barriers to guarantee that certain traits or qualities are maintained throughout the food supply chain. Tofu-quality soybeans are put into containers to preserve their identity. Produce treated to meet phytosanitary requirements of foreign countries is segregated by box to preserve its identity.

The distinction between "IP" and "segregation" is often blurred and a "strict segregation" system may be more precise than a loose IP system. Regardless of the exact terminology, precise systems requiring that products be strictly separated will likely be more expensive than others because such systems are usually more expensive to develop and maintain than loose systems.

The level of precision of the traceability system may also influence recordkeeping costs. Recordkeeping expenses tend to rise with smaller lot sizes. Five tons of production broken into 5 one-ton lots require less paperwork than the same quantity broken into 1,000 ten-pound lots. In addition, the bookkeeping records required to maintain a highly accurate traceability system tend to require more detail and expense than those for less exacting systems. For example, a traceability system for stringent pathogen control will require more sampling, testing, and verification paperwork than a system designed for less stringent control.

Both recordkeeping and differentiation expenses tend to rise with the complexity of the production and distribution systems. Products that undergo a large number of transformations on their way to market generate a lot of new information and are typically more difficult to track than products with little processing. Food products vary considerably with respect to the number of handlers and manufacturers and the degree of commingling and processing. Lettuce picked in the field and sold directly to retailers is relatively easy to track. Tracking a chicken potpie is more challenging. The process of transforming the wheat to wheat flour, the chicken and the vegetables to bite size pieces, and combining all the raw ingredients into a pie generates a trail of numerous different lots that themselves are composed of commingled lots.

Products that are bought and sold numerous times also tend to generate higher bookkeeping and differentiation expenses than those that remain within the same company. Any time product is passed from one firm to another, new paperwork is generated as firms link receipts with product and reconcile or adjust lot numbers and sizes. New coding and software technologies are helping to drive down the costs of linking supply-management records across the food chain and of coordinating the flow of product along the chain. In many sectors of the food supply chain, new information technologies are helping push down the cost of recordkeeping and stimulating investment in traceability systems. As mentioned before, electronic systems for tracking inventory, purchases, production, and sales are becoming an integral part of doing business in the United States.

Vertical integration and contracting are other methods for reducing the costs of tracing and supply management. Vertically integrated firms and firms that contract along the supply chain for specific attributes are often better able to coordinate production, transportation, processing, and marketing. They are able to respond to consumer preferences for select quality attributes and provide consistency of product. Vertically integrated firms can also adopt the same recordkeeping system across the chain to streamline product coordination. Thus, these food suppliers can attain value and limit the cost of traceability systems.

Benefits and Costs Vary Across Industries and Time

The development of traceability systems throughout the food supply system reflects a dynamic balancing of benefits and costs. Though many firms operate traceability systems for supply management, quality control, and product differentiation, these objectives have played different roles in driving the development of traceability systems in different sectors of the food supply system. In some sectors, food scares have been the primary motivation pushing firms to establish traceability systems; in others, the growth in demand for high-value attributes has pushed firms to differentiate and track attributes; in yet other sectors, supply management has been the key driving force in the creation of traceability systems. Different types and levels of costs, reflecting differences in industry organization, production processes, and distribution and accounting systems affect traceability adoption.

The dynamic interplay of objectives, benefits, and costs has spurred different rates of investment in breadth, depth, and precision of traceability across sectors—and continues to do so. Table 1 summarizes key factors affecting the benefits and costs of traceability systems. These factors vary across industries and across time, reflecting market dynamics, technological advances, and changes in consumer preferences. Changes in the factors influence traceability benefits and costs, thereby influencing the private sector's tracking capabilities.

Table 1—Major factors affecting the costs and benefits of traceability

Factors affecting benefits	Factors affecting costs
■ The higher the value of coordination along the supply chain, the larger the benefits of traceability for supply-side management ■ The larger the market, the larger the benefits of traceability for supply side management, safety and quality control, and credence attribute marketing ■ The higher the value of the food product, the larger the benefits of traceability for safety and quality control ■ The higher the likelihood of safety or quality failures, the larger the benefits of reducing the extent of failure with traceability systems for safety and quality control ■ The higher the penalty for safety or quality failures, where penalties include loss of market, legal expenses, or government-mandated fines, the greater the benefits of reducing the extent of safety or quality failures with traceability ■ The higher the expected premiums, the larger the benefits of traceability for credence attribute marketing	■ The wider the breadth of traceability, the more information to record and the higher the costs of traceability ■ The greater the depth and the number of transactions, the higher the costs of traceability ■ The greater the precision, the smaller and more exacting the tracking units, the higher the costs of traceability ■ The greater the degree of product transformation, the more complex the traceability system, the higher the costs of traceability ■ The larger the number of new segregation or identity preservation activities, the higher the costs of traceability ■ The larger the number of new accounting systems and procedures, the more expensive the start-up costs of traceability ■ The greater the technological difficulties of tracking, the higher the cost of traceability

III. Industry Studies:

Private-Sector Traceability Systems Balance Private Costs and Benefits

In this section, we examine the development of traceability systems in three food sectors in the United States: fresh produce, grains and oilseeds, and cattle/beef. We describe the breadth, depth, and precision of each sector's traceability system and examine the influence that varying costs and benefits have had in the development of traceability in these sectors. We find that traceability systems are rapidly developing as traceability benefits increase in value and as technology drives down the cost of creating and managing information. We also find that the dynamic balancing of benefits and costs has led to wide variation in the development of traceability systems in the three food sectors.

Fresh Produce

The development of traceability systems in the fresh produce industry has been greatly influenced by the characteristics of the product. Perishability of and quality variation in fresh fruit and vegetables necessitate the boxing and identification of quality attributes early in the supply chain, either in the field or packinghouse. This has facilitated tracing capability for a number of objectives, including marketing, food safety, supply management, and differentiation of new quality attributes.

The history of traceability in the produce industry dates back to the early part of the 20th century. The development of refrigerated railcars in the late 1800s allowed produce from the West and other distant areas to be shipped to the major eastern population centers. As a result, local spot market produce sales with face-to-face transactions where both buyer and seller could verify the quality at the same time became less common. Instead, transactions over long distances became the norm (Dimitri, 2001). Problems began to arise due to the high perishability and fragility of most produce: produce quality could change substantially in transit. When produce deteriorated, it was not clear where the responsibility lay—the grower, shipper, transportation firm, intermediaries, or buyer. When delivered quality was less than expected, buyers demanded price adjustments. These long-distance transactions also introduced more intermediaries into the marketing chain. Buyers and sellers needed a system to verify quality at various points in the marketing chain and establish their legal rights in the case of a disputed transaction.

In response to these problems, produce growers urged Congress to provide legislation to regulate marketing practices for their industry, and in 1930 Congress passed the Perishable Agricultural Commodities Act (PACA). One part of the Act focused on recordkeeping requirements in produce transactions for shippers selling on behalf of growers—the most common marketing arrangement for fresh produce. The recordkeeping system provides growers with a paper trail to ensure they receive the proper price for their produce. A shipper must assign a lot number, or other positive identification, to all loads received so as to segregate and track produce from different growers from receipt of the product until the first sale. PACA regulations for shipper recordkeeping establish the first link in the fresh produce traceability system at the shipper level.

More recently, the impetus for further developing traceability systems for produce has come from the industry's concerns about food safety. In the event of a foodborne illness outbreak, damage can be limited if the contaminated product can be identified quickly, allowing other noncontaminated product to be marketed. In the mid-1990s a series of well-publicized outbreaks, traced back to microbial contamination of produce, raised public awareness of potential problems. In response, FDA developed voluntary guidelines for good agricultural practices (GAPs) for reducing the potential for microbial contamination of produce. One part of the guidelines focuses on improving traceability. Some retailers now want their produce growers to comply with GAPs and to provide third-party audits to verify compliance. Some farmers voluntarily provide these audits already. Third-party audits reduce the asymmetric information inherent in a transaction where food safety attributes are not obvious. But this new concern requires more traceback information than required by PACA. In a food safety crisis, retailers and the food service industry are concerned about identifying the shipper of a contaminated product but shippers and growers require more precision to uncover the source of the contamination problem and resolve it. Some have begun to track information on exactly where a product comes from—down to a part of a field in some cases.

The costs of establishing and maintaining traceability systems are generally lower for perishable produce than for other commodities because of the way produce is packaged. Most fresh produce is sold in small well-marked containers (generally boxes), as opposed to bulk sales, because much of it is easily damaged and must be protected during shipment. Containers are so small that they generally contain produce from only one grower. Compare this to the nut or dried bean industry, where the products can be stored in silos without damage until they are packed. In these industries, which are not covered by PACA since they are not considered perishable, product from more than one supplier may be mixed together in a silo.

Because produce is packed in boxes, the industry can easily segregate products with different characteristics of concern to buyers. Segregating various types of products has always been important to the produce industry. Unlike grains or meat, fresh produce is a consumer-ready product. Size and appearance matter. For some commodities, variety is also important. For example, a large Washington apple shipper today could be selling over 3,000 distinct apple products that vary by variety, grade, size, packaging, and other characteristics. Segregation is a necessity. The variation in products is also increasing. In 1987, the typical U.S. supermarket carried 173 produce items. By 2001, the number had grown to 350. The well-established ability to segregate and trace fruit and vegetables has allowed the produce industry to adjust relatively easily to new products with different characteristics such as organic or no-pesticide-residue items.

Tracing Produce Through the Marketing Chain

Figure 4 presents a diagram of the marketing chain for produce. In 2002, U.S. growers produced fruit and vegetables (both fresh and processed) worth $24.5 billion (see table 2). In general, growers can market their produce through shippers, sell it directly to consumers at farmers' markets and roadside stands, or sell it to processors. Shippers may sell directly to retailers and the food

Figure 4
Tracing fresh produce through the food marketing system

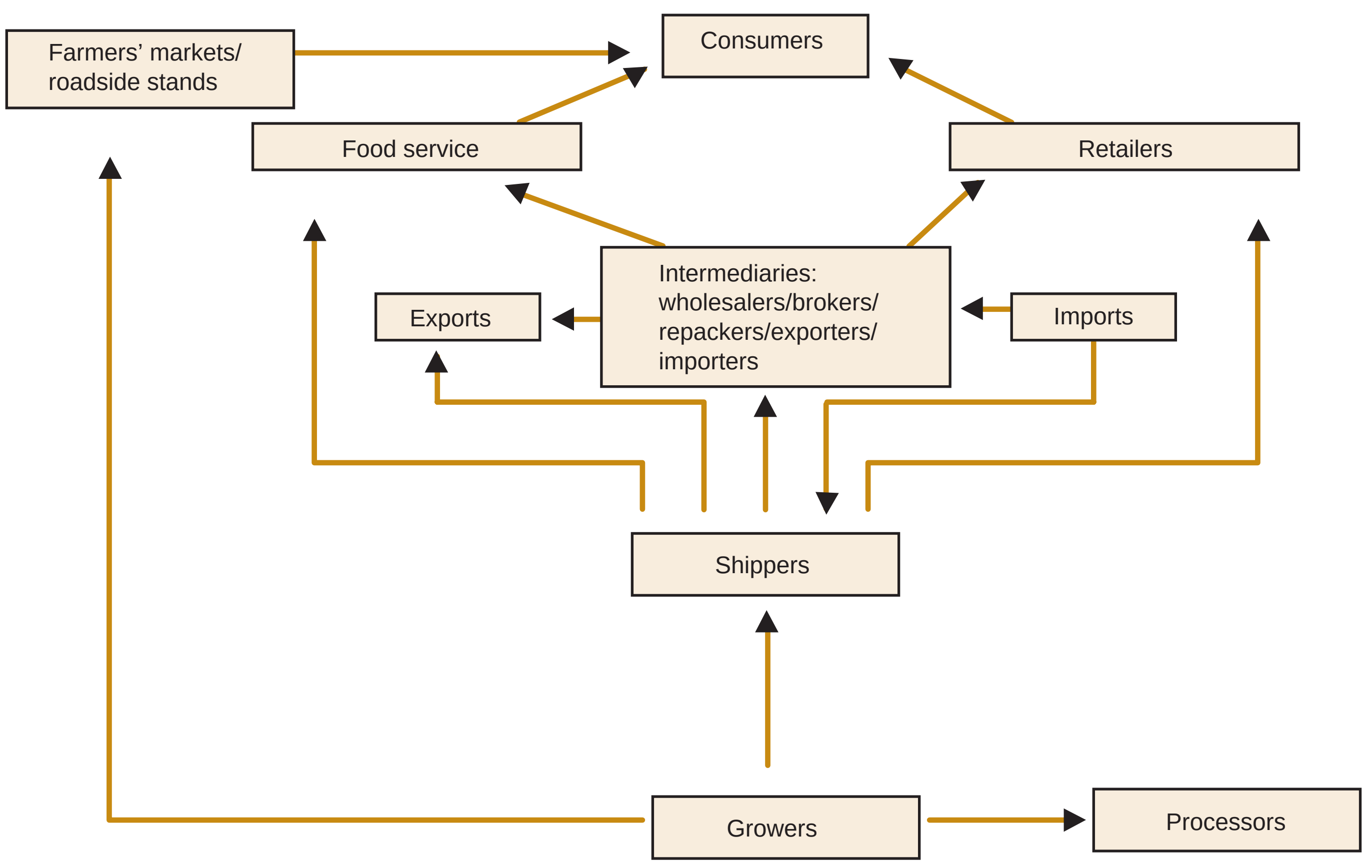


Table 2—U.S. fruit and vegetable industry, 2002

		Production		Imports	Exports
		$ billion	*million tons*	*$ billion*	*$ billion*
Vegetables[1]		13.7	21.4	3.3	1.8
	Fresh		3.0		
	Processed		18.4		
Fruit[2]		10.8	35.6	3.6	2.1
	Fresh		10.9		
	Processed		24.7		

[1] Vegetable trade numbers include fresh and frozen vegetables.
[2] Fruit production numbers contain information for 2002 for the noncitrus industry and the 2001/2002 season for the citrus industry. Fruit imports include fresh and frozen but exports include just fresh.

Sources: Noncitrus Fruits and Nuts, NASS; Citrus Fruits, NASS; Vegetables, NASS; Potatoes, NASS; and FATUS, ERS.

service industry (restaurants, hospitals, military institutions, schools, etc.) or to a range of market intermediaries who in turn sell to retailers and the food service industry. In 1997, 48 percent of fresh produce consumed in the United States was purchased at retail and 50 percent at food service establishments (Kaufman et al., 2000).

Direct sales to consumers are small, accounting for only about 2 percent of final fresh produce consumption in 1997. On the other hand, processing is an important part of the produce industry. In 2002, 86 percent of vegetables and 69 percent of fruit produced in the United States, by weight, went to processing. Trade is also important for the fresh produce industry. In 2002, fresh imports totaled 28 percent of the value of fruit and vegetable production, and the export share was 16 percent. Shippers and market intermediaries both import produce directly from foreign suppliers. Shippers may also sell directly to the export market or to intermediaries who then sell to that market.

This chapter focuses on fresh produce that is marketed by shippers. Fresh produce is more difficult to trace than a processed fruit or vegetable. A processed product, like a can of tomatoes in a consumer's cupboard, carries a wealth of traceback information embedded in its label and its product code printed on the bottom of the can (see box, "Traceability for Processed Fruit and Vegetables"). A fresh tomato on a consumer's countertop may display no identifying information at all. This chapter discusses how the produce industry provides traceability in a challenging environment.

The Grower to Shipper Link—Including Exports and Imports

The traceability chain begins with the grower to shipper link. Growers and shippers generally make marketing agreements before production begins. Growers want to be sure that someone is committed to selling their produce on their behalf. The shipper may want growers to follow specific practices since any problems traced back to the grower would damage the shipper's reputation too. The shipper markets the grower's produce and returns the proceeds to the grower after deducting the agreed-upon fees.

Typically, shippers market for growers and are covered by PACA regulations requiring produce to be identified by lot and accounted for until the first sale. PACA does not require a lot number to be marked on a box although many shippers do so. Also, PACA does not specify the size of a lot, it just requires that it be adequate to provide correct payment to growers. Lots can vary depending on the needs of the shipper and grower. At one end of the spectrum, a lot could be one grower's entire production of a particular crop over the length of a season. But identifying lots by smaller production units can be an important business tool. For example, a grower with several apple orchards may want each to be a separate lot to be able to compare yields with different production practices. From a food safety perspective, it is also important to narrow down where a contaminated product comes from and limit potential losses. If all contaminated product comes from a lot representing one orchard, a grower may be able to continue marketing from the others. On the other hand, there are diminishing benefits to precision. No one traces apples back to a particular tree. So far, there is no reason to do so. The costs would be high, and the benefits, compared to just being able to trace back to an orchard block (or part of one), would appear to be negligible, if not zero. Most things that would affect apples would generally affect more than one tree. So if an apple from a particular block had a problem, the entire block would be treated to be sure the problem was resolved.

Traceability for Processed Fruit and Vegetables

There is a critical difference in traceability between fresh and processed fruit and vegetables. Each processed item a consumer buys is generally individually identified unlike fresh produce. For example, when the consumer gets a fresh tomato home, he may not know where it came from, but a canned tomato product will be labeled and almost always has a product code. Processed products often have consumer-recognized brand names that are also helpful in a traceback situation even if the can or other container is no longer available.

Produce for processing is usually contracted for in advance with very specific requirements for varieties, production practices, and harvest time. The processor may harvest the product and take it directly to the processing facility. Like the fresh shipper, the processor records information about the grower and field for all arrivals. Each load is processed and the time noted by the processor. PACA rules apply for fresh-cut produce like bagged salads and frozen produce, but canned fruit and vegetables are generally exempt.

For canned tomatoes, for example, the recordkeeping challenge is to link the fresh tomatoes coming in to the canned tomatoes going out. Product codes are an important component of traceability. In the canned-tomato case, a product code would generally be inkjet printed or embossed on the bottom of the can. Then a firm would be able to say that the finished product with a certain range of product codes corresponds to fresh tomatoes processed at a certain time that came from a particular grower.

FDA provides guidelines for product codes that would aid a firm with a potential recall situation, but there are no requirements to use product codes. However, the benefits of product codes are so great that most firms use some kind of product code. A typical product code might contain information such as firm, plant, line, date, and time. If there is a recall, FDA needs to know which product is a problem. If firms cannot identify particular product codes that are contaminated, FDA would have no alternative but to recall all the firm's products. Firms want to keep any potential recall as small as possible, which requires more precise identification information. A firm would have to balance the costs of more precise information with the cost of a potential recall to determine the appropriate amount of information.

PACA also does not specify the form of the recordkeeping or accounting system. Some systems are quite sophisticated and others less so, depending on the firm's capabilities and needs. A large company may have a state-of-the-art computer system. In some cases, retailers require their suppliers to use specific computer software to aid invoicing or electronic ordering and other procurement activities. A smaller company may have a less complex system. Some firms do not need much information. If they sell produce for just a few growers or sell to a limited number of buyers, a simple system may be adequate.

PACA establishes the depth of traceability in the fresh produce industry—generally produce can be traced back to the individual grower. But there are some exceptions. For example, growers may agree to pool their produce and receive an average price for the pooled product. In this case, traceback would be less precise, going back to a small group of growers rather than the actual grower. If produce is sold and then repacked by another shipper or market intermediary, PACA laws would not apply, and the origin of the produce could be lost if careful records were not kept. However, in a traceback situation, a repacker could identify the sources of the different items packed on a particular day and narrow the search to several growers.

Shippers who do not sell on behalf of growers are not covered by PACA requirements to identify produce by lot. These include vertically integrated grower/shippers who market only their own production. However, most grower/shippers market for at least a few other growers. Produce purchased by shippers instead of marketed for growers would also not be covered. Both of these groups are probably quite small. But the general business benefits of a traceability system are so great that most firms likely maintain a level of traceability even if not required to do so.

At harvest time, growers send their produce for the fresh market to shippers. Some fruit and vegetables are harvested and transported to a central packinghouse or shed for cleaning, grading, and boxing. Apples, citrus, stone fruit, tomatoes, and potatoes are examples of crops that are shed-packed. When a grower brings in a load of fruit or vegetables to a central packinghouse, the packing line is cleared of all other loads. The grower's whole load then goes through the packing line all at once or, in the case of storable products, like apples or potatoes, the produce may first go into storage until packing at a later date. Information about how much is graded into different qualities and sizes, including culls, is recorded for each lot. The shipper may also collect other data on the lot such as specific field or orchard, pickers, harvest date, etc. This information facilitates payment to the grower, operations management, and, if necessary, traceback. The shipper packs and labels the cartons, usually with an ink jet printer.

Other fruit and vegetables are packed in the field. For example, lettuce, berries, broccoli, and melons are typically harvested, wrapped, and boxed in the field. The shipper uses stickers on each box, or on each pallet of boxes, that generally identify the grower, packing crew, and date. Handheld ink jet printers are available for use in field packing but are used infrequently because they are expensive.

Containers are printed with various types of information relevant to different people along the marketing chain. Pallets of boxes may also be labeled. Because fresh produce is not transformed before it gets to the consumer (unlike grains and livestock), it is easy to add stickers, tags, and other special labels to the produce to appeal directly to consumers. Each of these methods of identifying produce is discussed below. The exact type of information provided will depend on various laws that apply and the needs of the shipper and buyer.

Information on Boxes PACA does not require any information on boxes, just that everything printed on the box be true. In practice, boxes provide a wealth of information, some required by law and some voluntary. Typically, States require that certain information be included on a box. For example, California State law requires each produce box to identify the commodity and variety, responsible party (entity, town, and State), and quantity (weight, count, or size).

Although not required, most shippers voluntarily mark boxes with lot numbers. It is easier to look up records by lot number than to have to search through other records to identify a particular grower's product. FDA would like to see growers also add lot information to invoices to help speed up traceback in a food safety outbreak (FDA, 1998). If a shipper is selling only for himself and a neighbor and can keep the boxes separate, there would be no need for lot numbers on boxes. Recordkeeping alone could indicate whose boxes were sold to which buyer.

In addition to ensuring proper payment, the traceability system that identifies boxes by lot can also be important for general business operations because not all produce is of equal quality. For example, if someone liked a particular purchase and wanted more from the same grower, a shipper would need to know whose product, identified by lot number, was sent. Alternatively, if a product does not hold up well and a buyer complains, a shipper wants to know which grower's product was involved. The shipper may dock the price for that load, decide to not ship for that grower again, or ship only to nearby markets. Similarly, if produce is exported but fails phytosanitary inspections because of the presence of pests, an exporter might request no more loads from the lot with problems.

Labeling on boxes is important for marketing. Produce growers and shippers are always looking for ways to distinguish their product and raise its price above that of an undifferentiated commodity. Currently there are several characteristics that consumers are particularly concerned about. If organic produce is to be marketed as such, it must be marked to verify that production practices meet USDA's organic standards. Similarly, produce with no pesticide residues can be marked with a third-party certifying seal to verify its status.

Marketing orders, which allow producers to collectively regulate certain marketing activities for an industry, may also require additional label information. A marketing order may require that shippers market only produce of a certain quality or size. Quality standards can bolster a product's reputation, which benefits all growers in the order. Restriction of supply can also raise the price for all producers. This type of program can involve additional mandatory markings on boxes to ensure that the marketing order can regulate the program by identifying producers who are not complying and undermining the integrity of the program.

In the case of California peaches, the marketing order requires positive lot identification (PLI) which means that each box of peaches is inspected by a USDA inspector to verify that the quality meets the marketing order specifications. The size of the lot is specified in the marketing order and is not necessarily the same lot used by shippers to comply with PACA. Some marketing orders require additional information. The California peach marketing order also requires that each box be marked with the packinghouse number and date. The additional information allows the shipper to identify whose product was packed at that location and time.

Marketing orders can also be used to provide more precision in traceback. In addition to individual grower efforts to improve traceback capabilities, grower organizations have become more concerned about the reputation of their crops for food safety. Several grower organizations have developed systems to strengthen traceability, which encourages grower responsibility and reduces the free-rider problem in developing a positive industry reputation—a public good. In the case of an outbreak, a grower organization that encourages traceback can prove to the public that their product is not responsible for the problem. Or, when the industry is responsible for the outbreak, the problem grower or growers can be identified and damage can be limited to that group. The California cantaloupe industry has developed a more precise traceback system to deal with potential food safety issues (see box, "Cantaloupe Industry's Response to Food Safety Problems").

Another set of mandatory labels relates to products exported to other countries. Produce that is grown or treated for export may be required to bear a mark from USDA's Animal and Plant Health Inspection Service verifying that the product meets certain phytosanitary provisions. Foreign countries requiring the phytosanitary provisions would not accept a box without the correct markings. In the case of Washington apples, only those that have passed a cold treatment process may be exported to Mexico, and boxes must be marked with the number of the registered treatment facility.

Shippers may also import produce directly to market with their domestic production as a means to extend their marketing season or provide more variety in product offerings. Almost all imported produce, like domestic produce, is marketed on behalf of the foreign growers so the transactions are also covered by PACA. Typically, the produce is packed and labeled in the foreign country to comply with U.S. labeling requirements, but it may be repacked in the United States as well. The only additional labeling requirement for a box of imported fresh produce is that it show a country-of-origin label. For produce in consumer-ready containers, such as raspberries in plastic boxes, grapes in bags, and shrink-wrapped greenhouse cucumbers, each container must be labeled with the country of origin.

Information on Pallet Tags After initial packing, boxes are formed into pallets, and a pallet tag with a barcode is sometimes attached. The number of shippers using pallet tags is increasing. Pallet tags are for internal accounting and logistics; they are not required by law. The tags reflect shipper needs. A typical pallet tag might indicate the date packed, packing shift, grower, lot number, variety, grade, style of pack, and size. Pallet tags allow staff moving pallets in cold storage with forklifts to easily find the exact product they are looking for without having to read the small print on the boxes. Scannable pallet tags are also used to verify that orders contain the correct products. Pallet tags are also useful in narrowing the scope of a quality or food safety problem beyond just the lot. If the only problem products in a lot were on a pallet shipped to one distribution center, the focus of the investigation would concentrate on contamination sometime after the pallet left the shipper. If the only problem pallets from the lot were packed during a particular shift at the packinghouse, some kind of postharvest contamination might be suspected. While there are voluntary Universal Code Council standards for pallet tags, very few U.S. produce firms use them. Most barcodes are internal systems that can be read only by the shipper. Pallet tags are discussed again below.

Cantaloupe Industry's Response to Food Safety Problems

Beginning in 2000, the California Cantaloupe Advisory Board (a marketing order for California cantaloupe grown north of Bakersfield) began requiring additional traceback information on cantaloupe boxes as part of the State marketing order (this program was voluntary in 1999). This was not a very difficult process. California cantaloupe is field-packed and the Board had already contracted with the California Department of Food and Agriculture to inspect cantaloupe during harvest for quality control and apply an inspection sticker to every box (growers pay the Board a per-box fee for this service). Cantaloupe from this area cannot be sold without the sticker identifying the county and shipper.

The new program requires information on the packing date, field, and packing crew which allows a grower to trace a problem back to a particular part of a field. This would allow a grower to determine if contamination perhaps originated with a sanitation problem with a particular packing crew or was more widespread and perhaps originated with irrigation water. Some growers had already been providing this additional information on a voluntary basis. Adding this additional traceback information to the box was neither particularly costly nor complicated. It did take some administrative changes, however. To be able to require traceback, the members of the Board had to propose a change to the marketing order and vote on it. The original marketing order covered grades and quality standards.

The new marketing order specifically approves "such grade and quality standards of cantaloupes as necessary, including the marking or certification of cantaloupes or their shipping containers to expedite and implement industry practices related to food safety" (California Department of Food and Agriculture, 2003). If a foodborne illness outbreak were to occur, this program would allow the industry to immediately confirm or deny that the problem is due to California cantaloupe and help growers pinpoint the source of the problem. This may be the only grower-organized program for produce in the United States that requires such detailed traceback information on each box. To date, the system has not been necessary for a food safety outbreak.

Information on Individual Produce Items By the time fresh produce reaches retailer shelves, many products have lost their identity. A bin of loose potatoes is completely anonymous unless displayed in its shipping box. But some products do retain at least some of their identity—potatoes packed in bags, bagged salads, berries in plastic consumer-ready containers, and items, such as bananas, that are marked with stickers emblazoned with their brands. The trends toward more fresh-cut produce, consumer-ready packaging, and branded products ensure a continued increase in the information available to consumers when selecting fresh produce. In 1997, 19 percent of retail produce sales were branded products, compared with only 7 percent in 1987 (Kaufman et al., 2000).

Retailers often request that fruit and vegetables sold loose (as opposed to those in consumer-ready packages like a bag of carrots) carry stickers with the product's price-look-up (PLU) code. Stickers work relatively well for some products such as large tomatoes and apples. Stickers do not adhere as well to other products with a rough texture such as cantaloupe. Some products, such as chili peppers, are too small to use stickers although they could be packaged instead of being sold loose and then a sticker could be applied. The primary motivation for PLU codes on loose produce is to ensure that the retail cashier rings up the right price code for each item and charges the right price—identification of the item, not traceability *per se*. Shippers charge for this service. Some shippers use stickers with their company, brand name, or additional product attributes, as well as the PLU code. This can also convey useful information to the savvy consumer. For example, greenhouse tomatoes sold loose in bins usually have stickers with the firm name applied. Consumers may prefer one firm's tomatoes to another's. Such information could prove useful in a food safety traceback situation, if consumers paid attention to it.

Since the only product information for produce sold loose that actually reaches the consumer is the PLU sticker, there is some interest in trying to put more traceability information on it. Retailers want scannable PLU stickers to reduce labor costs and cash register keying errors. With reduced space symbology (RSS), additional information such as a shipper code, and perhaps even lot, could be incorporated into a barcode. There are, however, constraints to sticker size and the amount of information that can be included. The newest stickers also require newer scanning machines; that requirement could delay retail adoption of RSS.

The Shipper to Retailer or Food Service Establishment Link—Direct Sales and Intermediate Sales

Shippers sell produce to a wide range of final commercial customers—retailers and food service establishments—and market intermediaries. If a shipper sells directly to a retailer or a food service buyer (an increasing trend in the industry), traceability can be straightforward since PACA requires recordkeeping to the first buyer. Recent research shows that shippers' share of sales made directly to retailers and mass merchandisers increased between 1994 and 1999. For example, 63 percent of total grape sales and 54 percent of orange sales were direct sales in 1999, up from 60 percent and 48 percent, respectively, in 1994 (Calvin et al., 2001).

While the shipper has a wealth of information about the product, only a limited amount of information is forwarded to commercial buyers in accounting records. Information on the box and pallet is generally not entered into the buyer's database since it is not in a standardized machine-readable form. The commercial buyer creates a new tracking system. The link between the shipper and buyer databases is the purchase order number for each transaction. If the buyer calls up about an order and has the purchase order number, the shipper can access all his records about the product including lot and pallet numbers.

As a commercial buyer receives each load, information is entered into the firm's data system that tracks the entry and eventual disposition of the product. For example, a large retailer might have a central warehouse that receives produce from shippers and then distributes produce in smaller volume to its local stores. The more sophisticated distribution centers add new internal pallet tags specific to the retailer's tracing system. For example, it would link to information on the purchase order number, the date of receipt for use in rotation of the stock, and information on storage location in the warehouse. The pallets received from the shipper may be broken down and then reformed into mixed pallets (a pallet of different products and/or different suppliers) to be shipped off to a local retail store or food service firm. The outgoing pallets also need pallet tags. These outgoing tags do not, however, link individual boxes back to their purchase order number, so the commercial buyer does not necessarily know which suppliers' product went where. In a traceback, commercial buyers would look through their records to see what they had in stock in the warehouse during the relevant time period, identify the purchase order numbers associated with that product, and contact the shippers. If there is only one supplier, there is no problem. If there are two or more, traceback becomes more difficult.

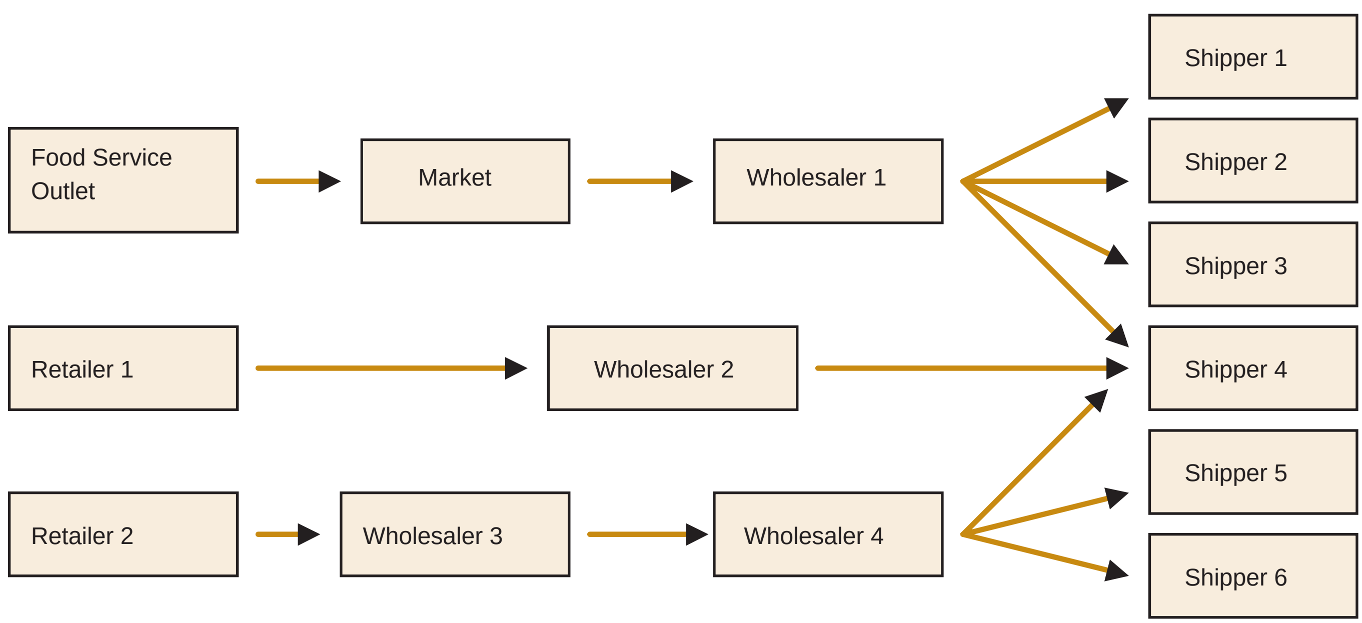
In foodborne illness cases where there is more than one supplier, multiple outbreaks may provide additional information to identify the source of contamination. Consider a hypothetical example of a traceback where multiple outbreaks would help to pinpoint the most likely source of contaminated product (see figure 5). Looking at just the Food Service Outlet or just Retailer 2, both of which received produce from multiple sources, would provide insufficient information to allow FDA to determine the source of contamination. Looking at both together, however, shows that Shipper 4 is likely to be the source of the problem. If FDA had information only on Retailer 1, which received produce from just one shipper, that information alone would be sufficient to identify the probable source.

Better traceback requires a system that maps out the exact path a box of produce follows through the distribution center. If there were a standardized machine-readable data system, the shipper's pallet tag could be read as the pallet entered the system and linked to the buyer's pallet tag to carry data such as shipper pallet and lot number. Similarly, as boxes left the buyer in new mixed pallets, the lot information on the box could be tracked to record exactly where that box went. If such a system were in place, a food safety problem in a particular store could be uniquely linked back to the distribution center and the original shipper's pallet, lot, and purchase order.

There is growing recognition in the industry of the potential efficiency gains from developing a traceability system that is standardized across individuals up and down the marketing chain. The U.S. Produce Marketing Association and the Canadian Produce Marketing Association are collaborating to develop a strategy for adopting the UCC.EAN standardized barcode system. Bolstering the shipper-commercial buyer link involves standardized machine-readable information on pallet tags and boxes (*The Packer*, 2003).

In a more complicated transaction, produce may also pass through other hands, including one or more intermediaries such as brokers, wholesalers, repackers, terminal markets, or exporters before reaching the final point of consumer sale. These indirect sales can sometimes pose traceability challenges. Nearly all firms in the produce marketing chain require a PACA license which imposes recordkeeping requirements, but each layer of transaction adds another chance for human error, and a different tracking system may be used at each stage in the marketing chain. Traceability depends on the recordkeeping standards of the market intermediaries. Many of these intermediaries are large companies with sophisticated traceability systems that track incoming and outgoing shipments in the same way that large retailers do. Some are smaller firms and may have less comprehensive systems. As produce passes through many hands, the information on the box becomes potentially more important for identifying its source.

Figure 5
Hypothetical traceback scenario with multiple outbreaks



A standardized traceability system up and down the marketing chain would make traceback for sales with intermediate buyers much easier. If the last commercial buyer could identify the lot, pallet, and shipper immediately, FDA could avoid the delay of having investigators wade through information on several transactions to determine the original shipper.

Certain types of markets can also pose problems for tracing. Terminal wholesale markets, for example, serve a number of types of buyers: large retailers or food service firms that need to make an emergency purchase to fill in a sudden hole in their supplies, small firms that rely on the terminal market for their main purchases, and sidewalk food stands. The last category, although probably a very small share of sales, can pose a particular problem for tracing sales because they are often cash transactions that are not necessarily well documented.

Likewise, certain types of market intermediaries (repacking operations for example) can present traceability difficulties. Frequently, tomatoes are sold and shipped from their production regions to repackers or wholesalers who ripen, resort, and repackage for uniform color and then sell to local retailers and food service buyers. On any day, repackers may use tomatoes from several different sources to create a new box of tomatoes. In a traceback situation, a repacker might be unable to identify the exact grower but could at least identify a small group of growers whose tomatoes could have been in the box.

Shippers also sell fresh produce to the food service industry, either directly to the food service firms or their specialized warehouses, or via wholesalers and other intermediaries. Big fast food companies are particularly concerned about food safety and will often deal directly with a shipper to ensure the product meets their exact production standards, which could be specified in a contract. For tomatoes, fast food firms might use an integrated shipper/repacker (one that is repacking only with its own tomatoes), which maintains a higher level of traceability than an unaffiliated repacker. But the food service industry also consists of many small restaurants with small produce purchases. These firms are probably buying from wholesalers or other intermediaries.

To the Consumer

The final step in produce traceability is from the last commercial buyer—generally the retailer or food service institution—to the consumer. This can be a weak link in traceability. Many consumers might be uneasy about the idea of retailers' keeping records of what they buy. But this information is important for traceback, particularly for a food safety problem.

Many observable quality issues can be resolved if a consumer returns produce in poor condition to the retailer. For example, if a consumer brings in a package of bagged lettuce that has spoiled before its sell-by date, traceback would also be a routine process since all the information is printed on the bag. Even a head of lettuce may have a plastic sleeve with the shipper name or a twist tie with a firm name to identify its origin. Traceback for a food safety problem is more problematic. Food with microbial contamination generally looks fine. Even testing cannot always pick up contamination problems because microbial contamination is often sporadic and present at low levels. By the time someone becomes ill and consults a physician, and health authorities identify the contaminated product and the place and date of purchase (or consumption in the case of food service institutions), the perishable produce is usually long gone. Even when the produce comes in consumer-ready packages, such as a bag of apples marked with the shipper's name, the packaging is also usually discarded. For a branded processed product, consumers may know that they always buy a particular brand, but for a fresh product, most people have no idea who provided it. In cases where the box or other container is no longer available, traceback relies on good recordkeeping by all the firms in the marketing chain.

If the Centers for Disease Control and Prevention or State/local health departments can identify the contaminated product and the place and date of purchase, commercial buyers can usually identify the shipper. In the best case scenario, where a firm was using only one supplier of the problem product on that date, the retailer or food service firm could call up the shipper, who would have all the information about the product. But in practice there can be a lot of uncertainty about whose product was sold.

One potential solution to this problem of tracing from the retailer to the consumer and back is the RSS sticker with barcode identifying the shipper as well as the PLU code. If a retailer knew only the day the problem produce item was sold, the firm could look at all the product sold that day and perhaps reduce the number of shippers that could potentially be involved. If a consumer used a consumer purchase card, a retailer might be able to look up just what the sick consumer bought and know the shipper to contact. In the case of club stores, where only members can make purchases, traceability is more complete.

Conclusions

Traceability has been a critical component of the produce industry for many years. Historically, the perishability of produce and the potential for deterioration during cross-country shipment demanded better recordkeeping to ensure correct payment to growers. Because produce must be packed in relatively small boxes to minimize damage, implementation of traceability has also been relatively low cost. The industry is in a much better position to adapt to new concerns than industries where bulk sales have been the norm and segregation and traceability would involve new costs.

Currently, there are two systems of information involved in produce. First, there are physical labels on boxes and sometimes on pallets. For general business purposes, it is important to be able to identify the product in the boxes. There are various State laws requiring box information, and marketing orders also often require additional box information. Pallet tags are completely voluntary. Second, a paper or electronic trail allows traceback between different links in the marketing chain, though each link may use a different traceability system. U.S. and Canadian produce organizations are looking at ways to promote a universal traceability system between links in the chain. They recommend that shipper name, pallet tag number (if available), and lot number be part of the paperwork at each link. This would effectively combine information on boxes and the paper or electronic trail. Such a system would require developing a standardized system of barcodes or other machine-readable information, as well as shipper and buyer investment in machines to apply and read codes. One of the challenges to developing a compelling technical solution that all market participants would use voluntarily is to ensure that all segments of the industry can afford the costs of a new system.

Grain and Oilseeds

Virtually all grains and oilseeds produced in the United States are traceable from production to consumption. For the most part, however, quality and safety variation in grain and oilseeds has not warranted the cost of precise traceability systems. Systems to track product to elevators, the point at which quality and safety are monitored, have been largely sufficient for the efficient operation of grain and oilseed markets. Growing demand for specialty crops, including products not genetically engineered, has spurred the development of more precise traceability systems, although the elevator still operates as an important quality-control point.

The history of the grain supply chain in the United States chronicles the growth of an infrastructure built to manage large flows of product differentiated on a limited number of variety or class attributes and then blended or processed to meet quality and safety standards. In most cases, the blending and homogenization of product begins as soon as farmers deliver their crop to the local elevator and continues until the crop is transformed into animal feed or into the loaf of bread, cereal, or other grain product on grocery-store shelves. In most cases, grain and oilseeds are mixed and transformed all along the chain, so that safety and quality characteristics are redefined at each step. As a result, processors need information on the characteristics of the product as delivered only from the last stage of processing. The high level of processing necessary to produce consumer-ready grain products eliminates most safety and quality problems stemming from mishandling or contamination early in the supply chain and often eliminates the need to establish traceback to the farm for safety or quality reasons.

More recently, consumer and processor demand for specialty grains, including products not genetically engineered, has introduced the need to differentiate product over a new set of quality characteristics. In a few cases, these new quality demands are accompanied by demands for traceability systems to track product back to the farm. For the most part, just as it has many times before, the grain and oilseed infrastructure is adjusting to accommodate new quality variations and ensure the delivery of homogeneous product meeting new quality and safety standards.

From the Farm to the Elevator

With the exception of a small amount of on-farm feed use (mainly corn), most grains and oilseeds are marketed through a supply chain that includes country elevators, sub-terminal elevators, processors, river elevators, export port elevators, and retailers (fig. 6). This supply chain handles a wide range of bulk commodities distinguished by variety or class, such as No. 2 yellow dent corn and hard red winter, hard red spring, soft red winter, white, and durum wheat. Large-scale marketing affords efficiencies in terms of lower per-unit handling costs.

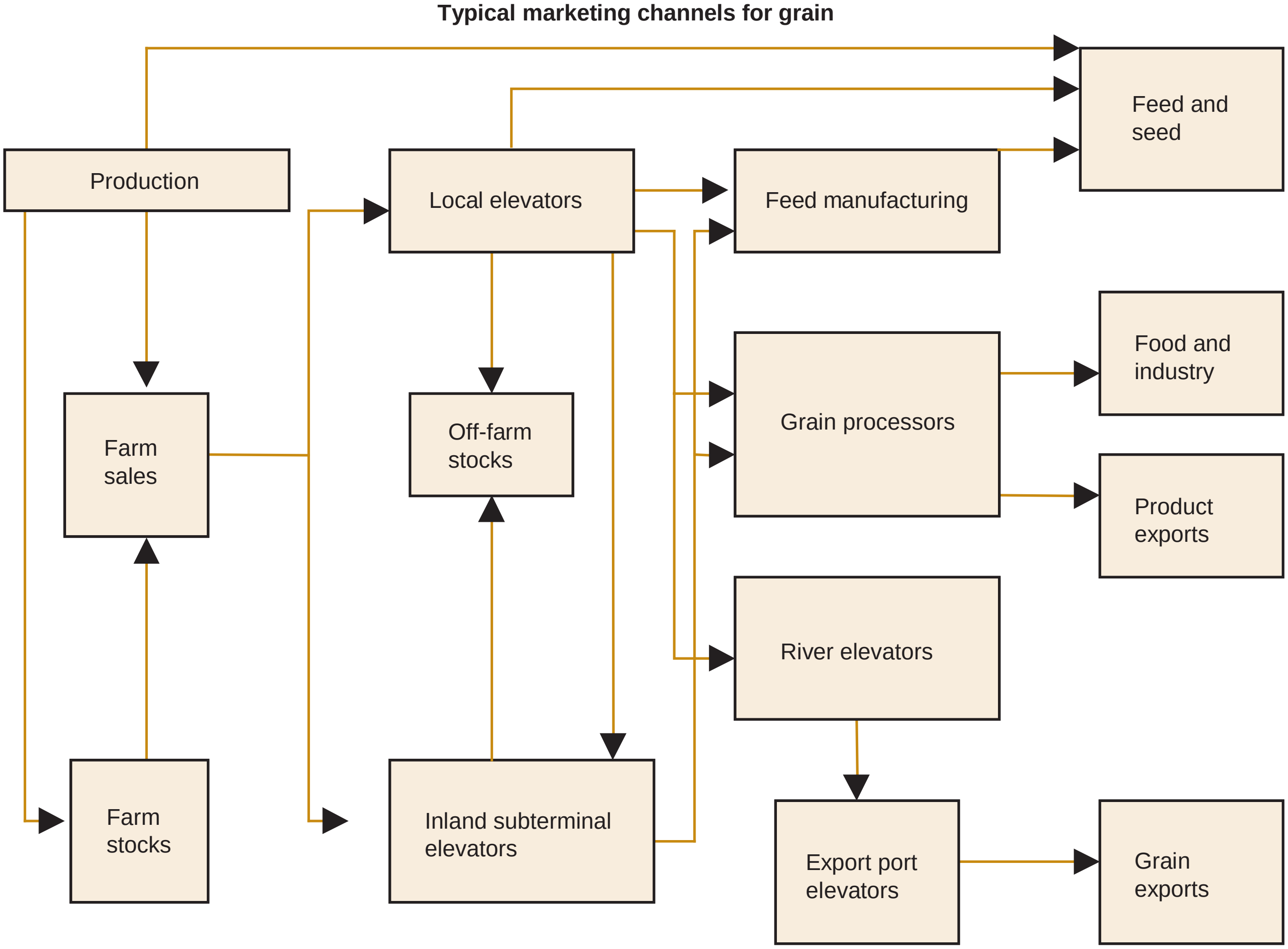
Conventional Crops

When farmers harvest standardized crops, they usually store the grains and oilseeds in large storage units (or bins) on their farms. Crops of a certain type—for example, wheat—are typically commingled, even though producers may have grown several different varieties. These may differ in terms of yield, maturity, resistance to adverse weather conditions (e.g., drought), and other factors, but often do not have quality attributes valued by buyers and are not sold at a premium.

Producers sell their crops to local (country) elevators. In 1997, there were 9,378 wholesale handlers (particularly country and export elevators) of grains and oilseeds operating in the United States (U.S. Dept. Commerce, Bureau of the Census, 2000). When farmers deliver their crops to local elevators, they are given receipts that indicate the commodity sold, its weight, price received, time of purchase, and any premiums or discounts for quality factors such as extra moisture, damage, pests, or dockage (easily removable foreign material). Country elevators keep this information, thus establishing a record-keeping link from the product in an elevator at a point in time to the farmers who supplied the product. An elevator operator knows the farmers who delivered grain and oilseeds at that location and the geographic area from which they came.

This rather imprecise system of traceability from the elevator to the farm is sufficient because quality variations that may exist at the farm level are mostly eliminated at the elevator level. The elevator serves as a key quality control point for the grain supply chain. Elevators clean each shipment to remove the foreign material and lower quality kernels or beans. If the moisture level is too high, the shipment may be dried before being placed in the silo. Elevators also sort deliveries by variety and quality, such as protein level. Different quality, variety, or classes of crop are either segregated at the silo or bin level

Figure 6
The grain marketing system



Source: Adapted from *The Organization and Performance of the U.S. Food System* by Bruce W. Marion, 1986

depending on the size of the elevator and anticipated volumes of production. Elevators then blend shipments to achieve a homogeneous quality. Once blended, only the new grading information is relevant—there is no need to track back to the farm to control for quality problems. Strict segregation by farm would thwart the ability of elevators to mix shipments for homogeneous product and would not be necessary for safety or quality assurance.

Country elevators strive to market crops of homogeneous quality to millers, feed manufacturers, and oilseed crushing facilities. Millers and crushers, in turn, sell processed grains (such as corn grits), flours, and oil to food processors. Crushers also sell soybean meal to feed manufacturers. Country elevators send grain and oilseeds to inland sub-terminal and/or river elevators, which collect crops from different regions. River elevators then ship crops to port elevators that load grain and oilseeds onto vessels for export to foreign countries.

Precision in traceback to the farm declines the further one goes down the production chain. As grain is funneled from a wider geographic area, it is more difficult to pinpoint from where and from whom the commodities came. For example, grain held at port elevators may have originated from a number of country elevators serving a large number of farmers across a wide geographic area. Traceability at the port elevator level typically extends only back to the country or sub-terminal elevator.

Recordkeeping systems for conventional grains and oilseeds can therefore be best characterized as "one step forward, one step backward." That is, handlers know from whom they bought grain and to whom it was sold. This one-step-forward, one-step-backward system means that a given handler is acquainted only with the entities that it deals with directly. Retrieving information from further up or down the marketing chain forces the handler to rely on the recordkeeping ability of others in the chain. For example, if a river elevator needed information on the farmers who produced the soybeans stored in its silo, the river elevator would need to look up in its own files the identity of the local elevators that supplied the soybeans. Each local elevator would have to check its accounting information on which farmers had made deliveries. Thus, traceability to the farm, or handful of farms, in conventional grain marketing is possible only with the collection of records from each handler along the supply chain.

Grain or oilseed handlers that are vertically integrated have access to more information. That is, such firms operate at more than one stage in the grain marketing chain. For example, a large grain company may own local elevators as well as river and export port elevators. The depth of information is greater for vertically integrated firms simply because records from different stages are maintained in-house. Vertically integrated firms can more easily retrieve information from their operating units.

Whether vertically integrated or not, elevators serve an important role as a quality-control point in the grain supply chain and as the linchpin in the traceability system. They monitor and control product quality and safety and keep records on the flow of product from farms to the elevator. Since the bulk system fulfills buyers' demands with cleaning and blending, there is no need for information to be collected throughout the supply chain: information from the next immediate step in the supply chain is sufficient.

Specialty Crops

While most grains and oilseeds in the United States are produced and marketed in bulk, there are growing markets for more specialized commodities. Some examples include high-value crops (e.g., high-oil corn), organic foods, and non-genetically engineered crops (Dimitri and Richman; 2000; Lin, Chambers, and Harwood, 2000). Traceability systems are becoming more extensive in these markets, reflecting customers' demands to verify the presence of the specialty attribute, particularly when it is a credence attribute. These traceability systems document the efforts of each segment in the supply chain to segregate the high-value specialty product from conventional or other specialty products.

Segregation and traceability documentation for specialty attributes may begin as early as the seed. At this point, documentation verifies the existence of specific crop traits and purity levels. In general, seed is tested and lots are tracked using identification numbers. If necessary, specific information about parent genes is obtained from the seed developers.

At the farm level, farmers must segregate crops to ensure that cross-pollination does not result in a crop that does not meet required specifications. For example, producers of non-genetically engineered crops, particularly corn, may be required to keep genetically engineered varieties away from other fields by a minimum distance to prevent cross-pollination. In addition, farmers must either dedicate certain storage, harvesting, and other equipment to each specialty crop or thoroughly clean equipment and storage units between different crop types. Some farmers specialize in particular specialty crops thereby avoiding commingling problems.

To verify that adequate precautions have been taken at the farm level to assure the quality of the specialty grain, farmers may be asked to provide elevators with third-party certification. For example, for organic crops, third-party certifiers accredited by the U.S. Department of Agriculture work with individual farmers to determine the requirements for organic production for each crop and then verify that these requirements have been fulfilled. Farmers provide this certification to buyers.

For some crops, farmers may be asked to submit their shipments for testing. For example, the oil content of corn and the protein level in wheat are routinely tested. Tests may be performed by the elevator or by independent third-party verifiers. Elevators usually keep records of test results, including the identity of the farms that sold the commodities to them. For some specialty crops, buyers may simply require farmers to "certify" that the crops are as specified. This was the case early in the development of differentiated markets for non-genetically engineered crops.

As the repository of documentation certifying attributes or the point of attribute testing, elevators play an important quality-control function in the specialty crop supply chain. In many cases, testing results and certifications are not sent further up the supply chain because elevators essentially certify the quality and homogeneity of their products. As with the conventional supply chain, elevators blend shipments to achieve a homogeneous quality and meet sanitation and quality standards. Once blended, only the new attribute information is relevant;

there is no need to track back to the farm to control for quality problems.

At the elevator level, segregation of specialty crops is achieved with dedicated elevators (those specializing in one type of specialty crop, such as organic, waxy corn, non-genetically engineered crops, and food-grade soybeans), multiple bins, or by thoroughly cleaning bins and equipment after each crop has passed through. If identity preservation is required, shipments may be containerized in order to minimize handling and the number of points at which quality could be compromised.

A key constraint in the ability of the bulk-system infrastructure to supply specialty grains is the ability of elevators to adjust their product flow in response to consumer demand. Large grain companies with a large infrastructure at their disposal, including country and export elevators as well as railcars and barges, may have more flexibility in managing flows and creating segregated systems. Likewise, smaller producers with access to a number of small elevators may be able to efficiently manage specialty flows. However, as the number of specialty attributes grows, investments in elevator infrastructure may be required, raising the costs of segregation.

Segregation and documentation for specialty crops continue from the elevator to the final producer or consumer. Trucks, railcars, and barges must all be thoroughly cleaned between specialty crops or be dedicated to a particular specialty crop, as must sub-terminal, river, and export port elevators. All along the line, either testing or process certification guarantees that quality attributes are maintained. As with conventional crops, such verification is usually of the "one-step-forward, one-step-back" variety. Each player in the specialty chain is usually required to retain information on product identity, volume, lot numbers, test results, and suppliers/customers to ensure quality and allow for traceback if problems arise in the marketing chain. How far back a given elevator can trace a shipment depends on the extent to which the firm is vertically integrated. As with conventional grain production, vertical integration in handling—whereby a firm owns operations in more than one level of the marketing chain (e.g., country and export elevators)—eases traceback, since information can be retrieved from internal suppliers and/or buyers. If elevators are not vertically integrated, they must rely on other handlers to retain much of the information.

A number of third-party certifiers offer services to verify that specialty quality attributes have been adequately safeguarded throughout the supply chain. In the case of organic products, farmers, handlers, processors, and retailers are certified by third-party firms that must be accredited by the U.S. Department of Agriculture. Wholesalers and retailers must prove that the organic product came from certified sources satisfying the organic labeling and handling requirements. As a result, organic products can be traced throughout the supply chain.

Generally, the cost of establishing and verifying supply chains for specialty grains makes them more expensive to produce than conventional grains. As a result, farmers, elevators, and handlers may be reluctant to construct these chains and produce these grains without some guarantee that they will receive adequate compensation. A large segment of the specialty crop market is therefore built on contracts. Contracts not only allow buyers to specify the attributes they desire, they also provide sellers with assurances that their costs will be covered through price premiums or long-term sales. Premiums must cover the additional physical costs associated with segregation and traceability, and also customer service and coordination activities.

Elevators typically contract with producers to grow certain varieties, such as high-oil corn or food-grade soybeans, with the delivery volumes and times being predetermined. The contracts may specify that producers follow certain production and handling practices that are consistent with the traced products. Contracts are also drawn up between the elevator and the buyer. Contracts provide a type of paper trail by which commodities can be traced.

Manufacturers may require information on a host of characteristics, such as color, variety, grind, etc. For example, a cereal manufacturer that uses a specific class and grade of wheat to produce the desired flake curl may require special coding. Larger food processors may also require that suppliers use codes that signify that the ingredients are specifically for the food manufacturer. All these steps are taken to ensure high and consistent quality over time—and to facilitate efficient ingredient management. For efficient output management, firms may also track final products. This information allows companies to understand which products are popular and where they are selling well. This information helps companies produce the right mix of products and the best distribution.

In general, traceability systems for specialty crops are more precise than for conventional ones. The paperwork generated with contracting and the existence of relatively few producers and handlers who deal with specialty crops make it easier to track shipments; a railcar filled with a certain commodity can be traced back to a small set of handlers and producers. However, in most cases, one could not likely associate an individual kernel or bean with a particular producer, since even specialty crops are commingled by elevators. There are a few cases for which one can trace shipments back to individual farmers. For example, food-grade soybeans are containerized on-farm and shipped directly to Japan.

Conclusion

Regardless of whether they involve specialty or conventional grains, vertically integrated firms or independent operators, most traceability systems for grains do not extend back beyond the country elevator. For most manufacturers and consumers, this depth of traceback is sufficient to ensure quality and safety, even for specialty quality attributes. As long as elevators continue to ensure the safety and quality of the shipments they receive from farmers, manufacturers will likely not demand farm-level traceability.

If elevators fail to monitor the safety of the system, manufacturers and consumers may demand better control and maybe even farm-level traceability. The StarLink incident in 2000 highlights the economic consequences of inadequate quality control at the farm and elevator level. StarLink is a genetically engineered corn variety that was approved for animal feed and industrial uses but not for human consumption (Lin, Price, and Allen, 2003). In 2000, a portion of the StarLink crop was commingled with other corn varieties, contaminating millions of bushels stored on farms and in elevators. Moreover, as a precaution, food manufacturers took hundreds of food products off the market along with nearly 100 products served at restaurants. Disruptions occurred in domestic marketing and exports to foreign countries in the initial stage of the incident as commingled corn was rerouted to approved uses and contaminated food was removed from shelves. Had StarLink been properly segregated at the elevator, this incident would probably have been at most a minor issue.

In the wake of the StarLink incident, many consumer groups called for complete traceability for StarLink and other genetically engineered crops. Better quality control at elevators may actually be a more cost-effective means of ensuring the quality of the Nation’s grain and oilseed supply. However, with the growth in the variety and type of credence quality characteristics, the ability of elevators to continue to serve as the system’s quality-control monitors hinges on advances in testing technologies and improvements in verification services.

Cattle and Beef

The cattle/beef sector has a long history of identifying and tracking animals to establish rights of ownership and to control the spread of animal diseases. Producers in the meat sector have also developed traceability systems to improve product flow and to limit quality and safety failures. Recent developments are motivating firms to bridge animal and meat traceability systems and establish systems for tracking meat from the farm to the retailer. Though technological innovations are helping to reduce the costs of such systems, institutional and philosophical barriers are slowing their adoption.

A number of recent events, including the emergence of bovine spongiform encephalopathy (BSE, commonly known as mad cow disease) and the country-of-origin labeling provisions included in the 2002 U.S. Farm Bill, have focused attention on traceability in the cattle/beef sector. Policymakers, producers, and consumers are reassessing the value of systems to track animals and meat from the farm to the consumer. These events, however, are not the first to motivate livestock owners and meat processors and retailers to establish traceability systems for livestock and meat. Ownership disputes, animal health concerns, and meat foodborne illness outbreaks have all motivated the development of systems to identify the ownership and health status of animals and the safety attributes of meat and meat products.

The result of these historical motivations has been to create two largely distinct sets of traceability systems in the livestock/meat sector: one set for live animals and another for meat. The current challenge for the cattle/beef sector is to link these systems and develop a system for identifying farm-level attributes in finished meat products—in other words, to trace meat back to the farm.

Traceability for Live Animals

Livestock owners have three primary motives for establishing traceability systems for live animals. First and foremost, owners want to protect their property from theft or loss by clearly identifying which animals belong to them. Whenever animals are commingled, as is common in the open ranges of the United States, owners may be motivated to use identifying marks to distinguish their cattle from those belonging to others.

A second primary motive driving livestock owners to establish traceability systems for live animals is to control the spread of animal diseases. Efficient control or eradication of disease depends on the ability of owners to identify and track healthy and unhealthy animals. This information is vital in calculating contagion and in designing effective vaccination, segregation, and indemnity programs.

A third motive for establishing traceability systems for cattle lies in the fact that many valuable animal attributes are not evident to the naked eye—or even to specialized testing equipment. Credence attributes such as up-to-date vaccinations, proper medical care, animal welfare provisions, or feeding regimens may increase the value of an animal. Farmers who can prove, through traceability documentation, that their animals possess such valuable attributes are more likely to be able to negotiate higher prices for their animals.

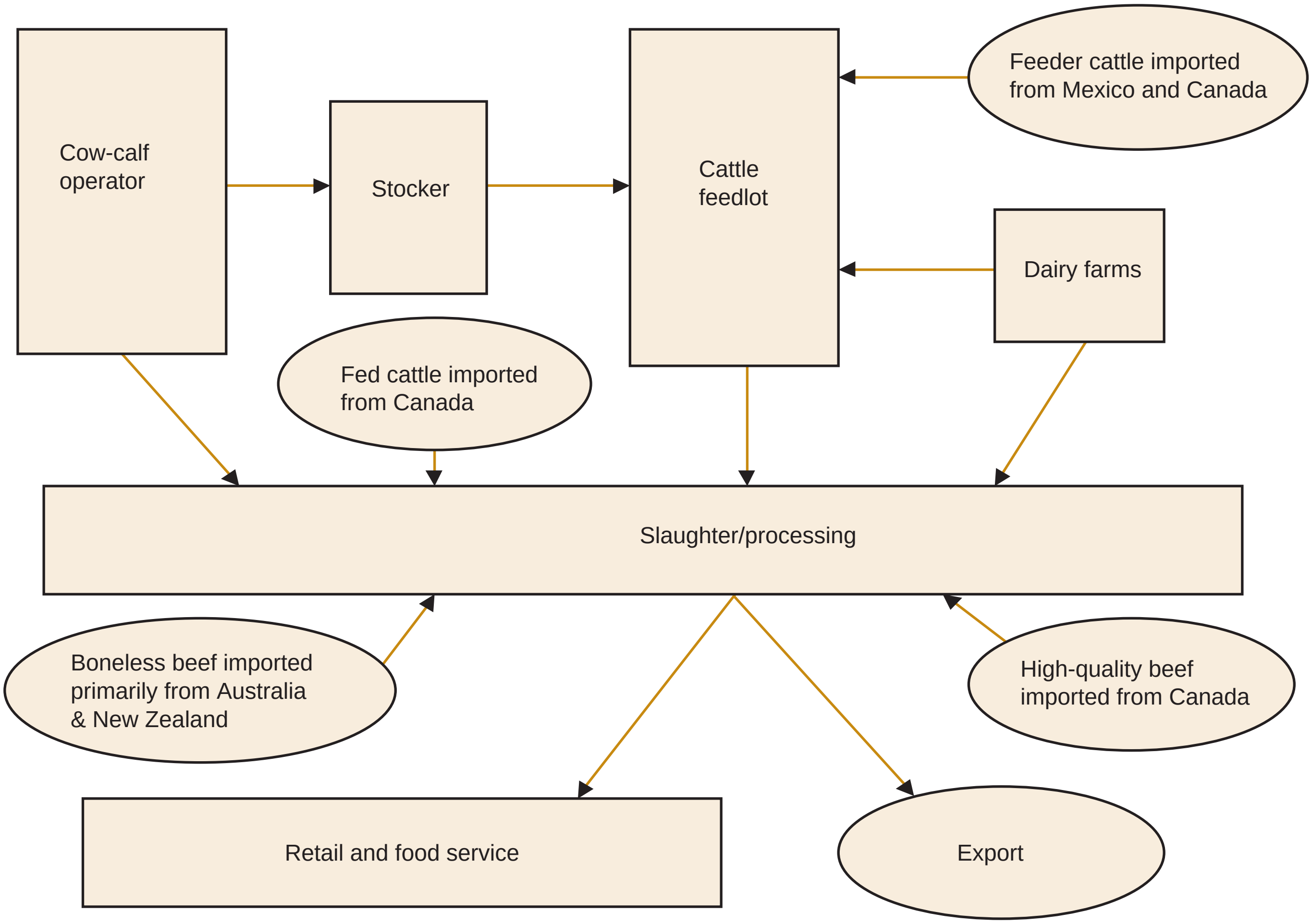
These three motives have influenced the development of traceability systems in the livestock sector in the United States. Livestock owners have established animal traceability systems to meet one or many of these objectives—and have expanded or contracted systems to reflect dynamics in animal management, disease outbreaks, and consumer preferences for credence attributes.

Traceability at the Cow-Calf and Stocker Level

Most of the beef that Americans consume originates from cattle born and raised on one of the country’s 800,000 cow-calf farms (fig. 7), with lesser amounts coming from U.S. dairies (culled dairy cows) and from Mexico and Canada. While the American West is traditionally recognized as “cattle country,” the majority of the beef cattle in this country are in fact raised in the center of the country between the Mississippi River and the 100th meridian. And, contrary to general perceptions, the majority of cows are raised by small and mid-sized operators. In 2002, the 5,390 large cow-calf operations, those with more than 500 head, accounted for only 14 percent of the beef cows in this country. The 630,000 smallest operations, those with fewer than 50 head, accounted for 29 percent of cows. In 2002, the average herd of beef cows in the United States totaled only about 41 animals (USDA/NASS, 2003).

Cow-calf operations require large amounts of pasture and range land to feed the cows and growing calves. The cows and calves may graze on land owned or leased by the cow-calf operator or, for a fee, on Federal lands.

Figure 7
Cattle/meat marketing system



Grazing lands may be adjacent and not separated by fencing, meaning that animals belonging to different people may get mixed. Many farmers find it worthwhile to brand or otherwise identify their cattle to avoid ownership disputes.

The traditional method of identification for cattle is branding, whether hot branding, freeze branding, hide branding, or horn branding. As early as the Roman Empire, competitors employed branding irons to burn their names onto horses used in chariot races (Blancou, 2002). In the 7th century, the Chinese used branding irons to identify horses used by the postal service. Branding is also the traditional method of animal identification used in the United States. Most Western States still have branding laws that require brands to be registered and to be inspected when animals are moved or sold.

Other methods of animal identification include tattooing, retina scanning (Optibranding™), iris imaging, and, currently the most common method, tagging. Tags may have simple printed numbers, imbedded microchips, or machine-readable codes, such as radio frequency identification (RFID). Ear tags cost in the neighborhood of $1 or $2 apiece. RFID technology is more costly, with instruments for reading RFID tags costing several hundred dollars apiece, though prices have been rapidly falling.

Increasingly, tags include more information than just animal ownership. Coded information on tags may provide information on vaccination records, health history, breeding characteristics, and other process attributes. This information is either encoded directly on the tag or kept in separate records that are linked to the animal via codes on the tag. Larger cow-calf operations are much more likely to use individual or group calf identification systems than smaller operations because it is more difficult to remember characteristics of individual cattle when there are many animals. Information on individual animal characteristics is also valuable in cases where calves are sold to other cow-calf operators—a common occurrence as calves are moved to operations with available forage. New owners may demand information on vaccination records and other animal characteristics.

APHIS/USDA estimates that in 1997, 65 percent of calves were individually identified on large cow-calf operations (USDA/APHIS, 2000a,b). Overall estimates suggest that about 49 percent of all cow-calf operators use some form of individual identification with an estimated 52 percent of calves and about 65 percent of beef cows individually identified. More operations use some form of group identification, so that about 74 percent of cows are group identified at the cow-calf level.

Identification systems not only facilitate transactions between sellers and buyers, they also help safeguard the health of the livestock sector as a whole. Animal identification and tracking systems help ensure that unhealthy animals are not allowed to contaminate healthy herds. Nearly all States require a Certificate of Veterinary Inspection (CVI) for livestock entering the State. The CVI for interstate commerce is an official document, issued and signed by a licensed, accredited, and deputized veterinarian. The CVI provides documentation that an animal or a group of animals was apparently healthy and showed no signs of contagious or communicable diseases on the date the inspection took place.

Animal identification is also an important element of Federal programs for animal disease control and eradication. For example the program targeted at eradicating brucellosis, a costly and contagious disease that can affect ruminant animals and also humans (USDA/APHIS, Dec. 2003), hinges on "Market Cattle Identification (MCI)." With MCI, numbered tags called backtags are placed on the shoulders of marketed breeding animals from beef, dairy, and bison herds. MCI, along with testing procedures, provides a means of determining the brucellosis status of animals marketed from a large area and eliminates the need to round up cattle in all herds for routine testing. In the case of test-positive animals, ownership can be more easily identified and herds that may be affected can be efficiently isolated and tested. For cattle and bison in heavily infected areas or replacement animals added to such herds, officials recommend vaccination. At the time of vaccination, a tattoo is applied in the ear; identifying the animal as an "official vaccinate." The tattoo identifies the year in which vaccination took place.

The brucellosis eradication program has had dramatic results. In 1956, testing identified 124,000 affected herds in the United States. By 1992, this number had dropped to 700 herds, and as of June 30, 2000, there were only 6 known affected herds remaining in the entire United States (USDA/APHIS, Dec. 2003).

The success of the Federal animal-disease eradication programs has not only dramatically reduced the number of diseased livestock but also reduced the motivation for animal identification for these diseases. These programs demonstrate the ability of the industry to establish traceability systems for disease control—and the ability of the industry to jettison such systems when the benefits no longer outweigh the costs.

Traceability at the Feedlot

At 6 to 18 months old and weighing 500 to 900 pounds, calves are moved to a cattle feeding operation. Cattle feeding operations, or feedlots, are enterprises largely unique to the United States and Canada. The extensive production of soymeal and corn in the United States provides an inexpensive source of animal feed and an economic rationale for feedlots. Animals are fed until they reach slaughter weights in the 1,200-1,300 lb. range—for most cattle this corresponds to 90 to 180 days in the feedlot depending on their initial weight.

Feedlots are of two major types: farmer feedlots and commercial feedlots, with the latter gaining greatly in dominance over the last three decades. The approximately 93,000 small farmer feedlots (under 1,000 head capacity) are typically one part of a grain-farm operation and may feed home-raised or purchased calves with home-raised feed. The average small farmer feedlot had an average inventory of only about 25 head in 2002 (USDA, NASS Dec. 2003).

Most commercial feedlots are located in the Western Cornbelt and Plains States of Texas, Kansas, Nebraska, Colorado, and Iowa. Commercial feedlots feed both cattle owned by the feedlot as well as other people's cattle for a fee (custom feeding). Custom-fed cattle can be owned by a cow-calf producer (called retained ownership) or by outside investors. Because of mixed ownership, identification of cattle on large commercial feedlots is more important than on farmer-owned feedlots, and consequently there is likely to be more branding or ear-tagging on commercial operations. Branding or ear-tagging also helps feedlot operators to more easily sort animals by vaccination records and breeding and other characteristics. Table 3 shows that over 98 percent of cattle on large commercial feedlots (8,000 head of cattle or more) have individual or group identifiers (large commercial lots account for 66 percent of cattle) while almost 80 percent of cattle on small commercial feedlots have such identifiers (USDA, APHIS, 2000).

Table 3—Percent of cattle identified in commercial feedlots, by size of operation[1]

	Small feedlots	Large feedlots
	Percent of cattle	
Tagged with a unique number such that each animal was individually identifiable (excluding tagging of sick animals)	29.6	31.1
Individually identified using a method other than tagging such that each animal was individually identifiable (excluding tagging of sick animals)	1.6	2.1
Identified with a group or owner identifier (pen tag, brand, hot tag, ear notch, etc.)	49.7	80.0
Not identified	21.9	1.6

[1]Small operations 1,000-7,999 head, large operations, 8,000 head or more.
Source: USDA, APHIS, 2000.

Traceability from Feedlot to Slaughter

Cattle ready for slaughter are trucked to slaughter plants. Most fed cattle are sold in direct transactions between the cattle owner (or agent) and the packing company. A typical transaction for cattle sold on a liveweight basis involves the feedlot's placing cattle on a "showlist" and packer-buyers' viewing and placing bids on cattle with a final spot price arrived at by negotiation. Many other cattle are sold on a carcass basis (payment delayed until animal is slaughtered and carcass weighed), increasingly under a contract or agreement specifying the source for a base published price and an agreed-upon schedule or "grid" of premiums and discounts based on actual carcass characteristics. Of course, in these cases, the carcass basis can be determined only after the packer slaughters the animal. The base price and adjustments produce the final "formula" price adjusted for quality.

When valuable animal characteristics are unobservable at the point of sale, traceability records linking a particular animal to records on health and other characteristics help establish the premium grid and facilitate efficient market transactions. At sale from feedlot to slaughter plant—and at every point of sale in the chain—traceability documentation enables producers to sell their cattle at a price that more accurately reflects quality. Traceability documentation is the only way to verify the existence of credence attributes such as animal "playtime" and non-genetically engineered feed.

Though traceability documentation is a valuable tool for farmers who wish to appropriate the benefits of investments in animal health or quality, it may also entail some unwelcome side effects. Traceability documentation may force farmers to "appropriate" the costs of failures in animal health or quality. The possibility that traceability could be used to place liability for unhealthy or low-quality animals on farmers makes many in the livestock sector uncomfortable. Many producers adhere to an ethic that a seller should not knowingly sell diseased or defective feeder or breeder livestock without disclosing such to the buyer, but that after an honest sale, if any problems arise with the animals' health or fitness, including death, the seller is not liable. The buyer assumes all risks associated with long-term animal health.

Livestock producers have accordingly long enjoyed some legal protection from liability for factors over which they have little or no control after the sale. Livestock has traditionally been exempt from commercial implied-warranty laws partly because farmers were considered not to be "merchants." As farms became more commercialized, and buyers more litigious, this protection has become less secure; in response many States passed specific exemptions for livestock. Some version of the statutory exclusion of implied warranties has now been adopted in almost half of the States, in particular those States where the livestock industry is of major economic importance. The Kansas statute is typical of the modification (McEowen, 1996, p. 7):

> Kan. Stat. Ann. § 84-2-316(3)(d):
>
> *[W]ith respect to the sale of livestock, other than the sale of livestock for immediate slaughter, there shall be no implied warranties, except that the provisions of this paragraph shall not apply in any case where the seller knowingly sells livestock which is diseased.*

Traceability at Slaughter

There are over 3,000 small and large firms slaughtering cattle in the United States. Most cattle slaughtered are fed steers and heifers, typically slaughtered by one of the four large major packers located in the feeding States that dominate the industry and account for about 82 percent of steer and heifer slaughter and 69 percent of all cattle. Culled cow and bull slaughter tends to occur in smaller firms, less concentrated geographically and less likely to be vertically integrated (USDA/GIPSA, 2001). In addition to domestic cattle, U.S. plants slaughter imported cattle, mainly from Canada,[2] although calves are also imported from Mexico and fed on pasture and in feedlots to slaughter weights.

FSIS (Food Safety and Inspection Service) regulations require that slaughter plants keep the head and certain organs of slaughtered animals, plus all identifying tags, until all parts of the animal pass inspection. Slaughter plants must be able to identify which head and organs belong with which carcass. In most plants this is done by keeping them physically synchronized on separate chain and conveyors. The identity of individual animals is frequently lost once inspection takes place. At this point, the health and safety of the animal has been "verified" and the focus shifts to the safety of the meat.

Traceability for Meat

Two primary motives have driven the development of traceability systems for meat and meat products: supply management and safety and quality control. Traceability systems enable slaughter plants and processors to more efficiently track the flow of product and coordinate production. Traceability systems also help plants minimize the extent of safety or quality failures, thereby minimizing damages.

A number of large foodborne illness outbreaks and heightened awareness of food safety issues have led many producers to adopt increasingly precise traceability systems. These systems reflect not just the fact that the benefits of traceability are rising, but also the fact that technological innovations are reducing the costs of traceability. These trends are expected to continue as retailers and importers demand safer food and as the science and technology of pathogen control improves, thereby spurring additional demand for traceability and additional incentives for innovation.

Meat Tracking from Slaughter/Processor to Retailer

Most large firms convert beef carcasses into primal and subprimal cuts or "boxed beef." Ground beef is processed from mixes of boneless beef imported primarily from Australia and New Zealand and trimmings from domestic animals to attain a desired fat content. Boxed beef and ground beef are shipped to retailers, food service firms, and exporters, sometimes through specialty processors, institutional processor/distributors, and meat wholesalers. Increasingly, most large firms also further cut and package "case-ready" retail cuts ready to drop into the display case in the grocery store.

Slaughter plants and processors have developed a number of sophisticated systems for tracking the flow of production and monitoring quality and safety. In accordance with ISO 9000 guidelines, most track inputs by batch or lot and then assign new batch or lot numbers to track product as it is transformed. To control foodborne pathogens such as *E. coli* O157:H7 and *Salmonella*, a number of processors have established very precise sampling, testing, and tracking protocols.

For example, one of the largest independent ground beef producers in the United States begins its traceability documentation with the trimmings entering the plant. Incoming combo bins (2,000 lbs.) of raw material are sampled at least every 100,000 pounds, which for most raw material suppliers is daily. All raw materials are routinely screened for Aerobic Plate Counts (APC), generic coliforms, generic *E. coli*, *Staphylococcus aureus*, *Salmonella*, and *Listeria monocytogenes*. If lots test higher than standards, the supplier is notified immediately and testing is intensified. Samples are next taken at the final grind head, where each batch of 3,000 pounds of ground beef is tested for *E. coli* O157:H7. Finally, samples of the finished product are taken from each process line every 15 minutes. Every hour, composites of the four samples are tested to detect *E. coli* O157:H7. These samples are also combined to make a "half-shift" composite, which is tested for an entire microbial profile. If the half-shift composites show spikes or high counts, more tests are run on the backup samples also collected every 15 minutes (Golan et al., 2004).

As a result of its testing protocol, traceability documentation is extensive for this producer. This documentation enables the producer to monitor the quality and safety of its inputs and to work with suppliers to improve the quality of inputs, or drop suppliers that cannot comply. The producer's documentation also serves to provide buyers with assurances about the quality and safety of the producer's products. As a result, this producer has been able to shift from being a commodity producer selling on a week-to-week basis to being a contract supplier to major hamburger restaurants. This shift has allowed this producer to improve its operational efficiency through better planning for capacity utilization, capital investment, spending plans, and other business activities.

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[2] Or they did until the ban on importation of animals from Canada due to the discovery of mad cow disease in a single cow in western Canada, May 2003. The United States and Canada are negotiating to begin bringing cattle under 30 months of age into the United States for immediate slaughter, or to designated feedlots for slaughter at less than 30 months of age (www.usda.gov/news/releases/2003/10/0372.htm).

Though not every processor or slaughter plant maintains records as precise as in the above example, virtually all meat sold in the United States is traceable from retail back to the processor or slaughter plant. Regulations require that USDA inspection numbers for the processing plant remain on the labels of meat as they pass through the distribution systems along with other information, depending on ingredients in the meat product and marketing chain. Other firm and lot number information can be placed on labels to identify a particular processing batch from a package of meat. Most, if not all, voluntary recalls listed on USDA's Food Safety and Inspection Service website, refer consumers to coded information on products' packaging specifying the lot or batch of items included in the recall. Good product tracing systems help minimize the production and distribution of unsafe or poor-quality products, thereby minimizing the potential for bad publicity, liability, and recalls.

Linking Animal and Meat Traceability Systems

Traditionally, once carcasses have passed USDA inspection, slaughter plants have not maintained information on the identity or characteristics of each animal. Until very recently, there have not been market or human-health reasons to do so. Now, however, meat-quality pricing has begun to expand beyond characteristics that can be judged by examining the meat itself. Meat prices have begun to reflect credence attributes related to farm-level, live-animal characteristics, such as animal welfare, type of feed, and use of antibiotics and growth hormones. In addition, diseases such as mad cow have established a link between animal health and human health—and have motivated many consumers, including those represented by foreign governments, to demand traceability back to the farm and animal feeding records (see box, "Animal Identification").

In response to these new motivations, the livestock sector has begun to build traceability systems to bridge animal tracking systems with those for meat tracking. Several systems can and have been incorporated into slaughtering lines to link group or individual animals with their meat products. These include sequence-in-slaughter order, carcass tagging, trolley-tracking, and RFID devices. Some systems are capital intensive and favor larger firms that can capture economies of scale, while others are labor intensive and may actually confer an advantage to smaller operations. For example, carcass tagging may require a human to apply the tag(s) while trolleys can be tracked optically and electronically. Small low-speed operations may have an advantage in maintaining animal identification because they can more likely use physical separation and tagging. Regardless of which technology is cost effective, the success of the system depends on appropriate operating procedures and traceability recordkeeping to keep sequences and identification numbers synchronized.

Scientific advances in animal identification will continue to reduce the cost and increase diffusion of animal-to-meat traceability. A variety of high-tech, rapid animal identification methods such as electronic implants, banding, or tagging have been developed and science is advancing to a point where DNA testing could be used to help identify and trace animal products. Unlike electronic tags and animal "passports," biological signatures would be virtually impossible to falsify and could follow the product after processing.

Though technological barriers to animal-meat traceability are rapidly dissolving, philosophical and in some cases, legal barriers remain or are being erected. As previously mentioned, livestock has traditionally been exempt from commercial implied-warranty laws. Many in the livestock sector worry that traceability systems linking meat to animals will break this tradition and shift at least some of the liability for foodborne illness back to cow-calf operators and feedlots. Some livestock organizations have even publicly called for limits on liability that may arise from animal identification. For example, the Kansas Livestock Association (2003), a nonprofit trade association representing nearly 6,000 livestock producers, has recommended:

Animal Identification

A national animal identification plan is being developed through a cooperative effort of USDA, State animal health officials, and livestock industry groups (see: http://www.usaip.info#.). Called the National Identification Development Team, its goal is to develop a national standardized program that can identify all premises and animals that had direct contact with a foreign animal disease within 48 hours of discovery. The plan is aimed at quickly identifying animals exposed to disease and the history of their movements in order to rapidly detect, contain, and eliminate disease threats (Wiemers, 2003). The first phase of the work requires establishing standardized premise identification numbers for all production operations, markets, assembly points, exhibitions and processing plants. The second phase calls for individual identification for cattle in commerce. Other food animal and livestock species in commerce would be required to be identified through individual or group/lot identification.

WHEREAS, livestock producers and government officials are researching the feasibility of a national individual animal identification program, and

WHEREAS, such a program, on a voluntary or mandatory basis, could provide the livestock industry a tool to quickly trace animal disease sources and enhance a breeder's ability to identify genetics that meet consumer demands, and

WHEREAS, animal trace-back technology can increase the liability exposure for owners of animals whose food and by-products threaten or cause damages to consumers, and

WHEREAS, liability in these circumstances can often be classified as "strict liability," even though an animal owner may not be at fault for such damages.

THEREFORE, BE IT RESOLVED, the Kansas Livestock Association supports state and federal legislation to limit animal owners' liability exposure that may arise under a private or public animal identification program.

In part to overcome some of the gaps in tracing documentation and quality assurance that may arise in the system, a small but growing segment of the cattle/beef industry has entered into alliances, associations, cooperatives, or marketing groups in which groups of cattle raisers, cattle feeders, producers, slaughter plants, and processors share some combination of decisions, responsibilities, information, costs, and returns. In many cases, alliances set quality and/or safety standards and provide systems to verify that quality standards for credence attributes exist. These types of alliances or vertically integrated operations such as those found in the pork (see box, "Traceability in Hogs and Pork") and poultry sectors, use contracts and incentives to link stages of production. Links are created between entities under separate ownership to help coordinate the efforts of those entities. Alliances attempt to create a market identity with a goal of producing a product that consumers desire and for which they are willing to pay a premium and sharing that premium with upstream entities (Florida Cooperative Extension Service, 2002).

Many of the products marketed through alliances entail credence attributes that the alliance certifies to exist. In some cases, alliances or even individual producers choose to use third-party certifiers to help establish credible claims. One such certifier is USDA's Agricultural Marketing Service (AMS). AMS's service is a voluntary fee-based program that certifies claims on items such as breed, feeding practices, or other process claims. The AMS "USDA Process Verified" label provides buyers with assurances that the advertised credence attributes actually exist (USDA, AMS 2004).

Traceability in Hogs and Pork

There are traditionally three basic types of hog enterprises. The first is feeder-pig production in which the farmer specializes in farrowing operations that produce 10- to 40-pound pigs. Feeder pig producers sell or transfer pigs to others for finishing. At farrow-to-finish operations, all phases of slaughter hog production are carried out by the same operation, though not necessarily in the same physical location. Third is feeder-pig finishing, in which feeder pigs are obtained from others and fed to slaughter weights. In the last decade, hog production has become even more specialized with separate nursery and growing phases appearing between farrowing and finishing. Increasingly, hogs are raised on a batch basis—"all in all out" which facilitates cleaning facilities between batches.

In 1950, over 2 million U.S. farmers sold hogs and pigs with average sales of 31 head per farm per year. By 2002, the number of farms had fallen to around 75,000 operations. More than half of these operations had fewer than 100 head, but this small-size group had only 1 percent of the hogs. In contrast, the 2,300 operations with more than 5,000 head accounted for more than half of the hogs in 2002 (USDA, NASS, Dec. 2003). Much larger mega-farms have been evolving into more important players; the 200 or so mega-farms are highly integrated. Some have more than 30,000 sows under tightly contracted or integrated arrangements from breeding to slaughter or even retail. Identification by herd or batch is therefore much higher today than 50 years ago.

Many hog operations, both large and small, not just mega-farms, are integrated by ownership or contractually connected to slaughtering firms. Less than 20 percent of slaughter hogs were sold in the spot market in 2002. Another large group of slaughter hogs are sold on a formula basis, sometimes under a continuing agreement. Hogs produced by or under contract for slaughter firms require no market transaction between the finisher and the slaughtering firm. Thus, the road from hogs to pork is far more integrated than in the cattle/beef sector—as are traceability systems.

Conclusions

The livestock industry has successfully developed and maintained a host of traceability systems: some for live animals and some for meat. Ranchers, cow-calf operators, and feedlot operators have had at least three motives in developing live-animal traceability: to establish ownership; to control animal diseases and quality; and to facilitate quality-based pricing. Livestock owners have established animal traceability systems to meet one or more of these objectives—and have expanded or contracted systems to reflect dynamics in animal management, disease outbreaks, and consumer preferences for credence attributes.

Slaughter plants and processors have had two primary motives for establishing traceability for meat products: to manage their supply chains and assure quality control and food safety. Traceability systems enable slaughter plants and processors to more efficiently track the flow of product and to coordinate production. Traceability systems also help plants minimize the extent of safety or quality failures, thereby minimizing damages. A number of large foodborne illness outbreaks and heightened awareness of food safety issues have led many producers to adopt increasingly precise meat traceability systems—a trend that is expected to continue with ever-increasing demands for food safety.

The challenge facing the industry now is to coordinate and link many disparate animal and meat traceability systems and priorities and develop a standardized system for identifying farm-level, live-animal attributes in finished meat products. Two institutional barriers may hinder these efforts. First, because USDA determines and certifies an animal's health and its suitability for the human food chain, meat processors may not have as much of an incentive to retain information on the origin of each piece of meat as they would if they were solely responsible for ensuring animal health.

Second, livestock has traditionally been exempt from commercial implied-warranty laws and many institutional or legal barriers are being constructed to safeguard this tradition. Limiting the liability of the cow-calf operator or feedlot will dampen incentives to establish traceability from meat to animal. Traceability to the animal supplier is less valuable if the supplier cannot be held legally accountable for diseased animals.

In part to overcome some of the gaps in tracing documentation and quality assurance that may arise in the system because of limits to liability, a small but growing segment of the cattle/beef industry has turned to alliances, associations, cooperatives, or marketing groups to help establish and enforce quality and safety standards and facilitate linking animal-tracking systems and traceability of meat products. The U.S. Animal Identification Plan is another major effort in this direction.

IV. Market Failure in the Supply of Traceability:

Industry and Government Response

It is not surprising to find systematic variation in traceability systems across sectors of the food industry because the costs and benefits of traceability vary systematically. Each sector has confronted different motivations for and constraints to erecting traceability systems. Different food safety problems, supply management concerns, and demands for credence attributes have motivated different sectors of the food industry to build traceability systems that vary in breadth, depth, and precision. Differences in product characteristics and infrastructure have led to differences in traceability costs that have also influenced the breadth, depth, and precision of the different systems.

Variation in traceability systems tends to reflect an efficient balancing of private costs and benefits. Are there, however, cases where variation actually signals market failure? Does the private sector supply of traceability fail to satisfy important social objectives?

The economic literature on market failure suggests that insufficient traceability in food markets could arise as a result of asymmetric or missing information problems in markets for food or as a result of externality or public good aspects of traceability. We find that though these possibilities arise, they do not typify the three food sectors we investigated. In all three food sectors, the private sector has developed methods to address costly market failure problems. We do find, however, that public good aspects of traceability may result in a less than optimal supply of traceability for identifying contaminated food once it is has been bought and consumed. In the sections below, we examine areas of potential market failure and industry and government response.

Market Failure and Differentiated Markets for Quality and Safety

Though firms have an incentive to use traceability systems to help generate information on credence attributes of value, they do not have an incentive to generate information about credence attributes that are not of value or have a negative value. As a result, the market may produce too little information about negative attributes. This potential is mitigated through the process of competitive disclosure. For example, though a food product may not sport a "high fat" label, the fact that rival brands are labeled "low fat" may lead consumers to conclude that the unlabeled product is in fact high in fat. This competitive disclosure, which Ippolito and Mathios (1990) named the "unfolding" theory, results in explicit claims for all positive aspects of products and allows consumers to make appropriate inferences about foods without claims.

However, competitive unfolding tends not to work when an entire product category has an undesirable characteristic that cannot be changed appreciably or for which the costs of alteration are too high, or where disclosure of the attribute may have negative repercussions. One area where product differentiation may be lacking is food safety. Very few firms seek to differentiate their product for consumers with respect to food safety (Golan et al., 2004). This may reflect the fact that foodborne pathogens are a commonly shared problem that is difficult to control with precision (Roberts et al., 2001). Firms may want to avoid specific safety guarantees that could expose them to additional liability because there is always the possibility that even the most careful producer could experience a safety problem. As a result, even the best producers may refrain from marketing safety to final consumers or trying to differentiate themselves from less safe producers.

Firms may also shy away from differentiating themselves and their safety records through traceability or other mechanisms if there is value in some level of anonymity (Starbird and Amanor-Boadu, 2003). If traceability systems increase the probability that a firm will be identified as a source of food safety problems and exposed to liability and bad publicity, then the firm may have an incentive to remain anonymous even if it has a good safety record. The benefits of product differentiation may not outweigh the costs of being more easily linked to a food product in the case of safety problems. In these cases, the market solution results in less disclosure than desired by consumers or less traceability than is socially optimal.

The amount of traceability offered by private firms for product differentiation may also be less than socially optimal if the benefits to the firm of establishing traceability for credible product differentiation is dampened by the existence of partial disclosure and innuendo. In some cases, the possibility of deception may erode producers' incentives to establish traceability systems because widespread deception makes consumers doubt the veracity of claims made by all producers, even honest ones. For some honest producers, the benefits of overcoming this high degree of consumer doubt will not outweigh the costs. For example, prior to the introduction of national organic standards, the proliferation of organic standards and labels—some more "organic" than others—may have made it difficult and costly for true organic producers to differentiate their product. Since credence attributes are inherently difficult to verify, they may be especially susceptible to fraud and unfair competition.

Industry Efforts To Bolster Differentiation

In the three food sectors we investigated, producers seem to be responsive to consumer demand for product differentiation. When consumer demand was strong enough to cover the cost of product differentiation, producers responded with new products and new traceability systems to substantiate credence attribute claims. While producers have difficulties marketing safety attributes directly to consumers, producers routinely market safety at earlier stages in the supply chain. The rich variety of differentiated products for sale in the fresh fruit and vegetable, grain, and livestock and meat sectors of the food industry—and the size and diversity of the industry—argue against the conclusion that market failure is stifling product differentiation in any of these markets. And, where market failure may have begun to emerge with respect to credence attributes, individual firms and industry groups have developed systems for policing the veracity of credence claims and for creating markets for differentiated products. Third-party safety/quality auditors are at the heart of these efforts.

Third-party entities (neither the buyer nor the seller) provide objective validation of quality attributes and traceability systems. They reassure input buyers and final consumers that the product's attributes are as advertised. Third-party verification of credence attributes can be provided by a wide variety of entities, including consumer groups, producer associations, private third-party entities, and international organizations. For example, Food Alliance and Veri-Pure, private for-profit entities, provide independent verification of food products that are grown in accordance with the principles of sustainable agriculture. Third-party entities certify attributes as wide ranging as kosher, free-range, predator-friendly, no-hormone use, location of production, and "slow food." Governments can also provide voluntary third-party verification services. For example, to facilitate marketing, producers may voluntarily abide by commodity grading systems established and monitored by the government.

Third-party entities also offer services to validate safety procedures and bolster market differentiation with respect to food safety. A growing number of buyers, including many restaurants and some grocery stores, are beginning to require that their suppliers establish safety/quality traceability systems and to verify, often through third-party certification, that such systems function as necessary. A growing number of firms are beginning to try to differentiate the safety of their products and processes for input buyers.

Most, if not all, third-party food-safety/quality certifiers such as the Swiss-based Société Générale de Surveillance (SGS) and the American Institute of Baking (AIB) recognize traceability as the centerpiece of a firm's safety management system. For example, AIB's standard food safety audit specifies a number of traceability-specific activities including (American Institute of Baking, 2003):

- Records were maintained for all incoming materials indicating date of receipt, carrier, lot number, temperature, amounts, and product condition.
- A documented, regularly reviewed, recall program was on file for all products manufactured. All products were coded, and lot or batch number records were maintained. Distribution records were maintained to identify the initial distribution and to facilitate segregation and recall of specific lots.
- All raw materials were identified in the program and work in progress, re-work, and finished products were traceable at all stages of manufacture, storage, dispatch and, where appropriate, distribution to the customer.

Third-party standards and certifying agencies are employed across the food industry. In 2002, AIB audited 5,954 food facilities in the United States and was slated to audit 6,697 in 2003 (Wohler, 2003); SGS expected to perform over 1,000 U.S. food safety audits in 2003 (Guidry and Muliyil, 2003); and ISO management standards are implemented by more than 430,000 organizations in 158 countries (ISO website). Food sectors employing third-party verifiers cover the spectrum from spices and seasoning to fruit and vegetables to meat and seafood to bakery products and dough. The growth of third-party standards and certifying agencies is helping to push the whole food industry—not just those firms that employ third-party auditors—toward documented, verifiable traceability systems.

Third-party audits provide customers, buyers, and in some cases, governments with assurances that a firm's safety management systems, including its traceability systems, have met some objective standards for quality. These assurances have potential to translate into increased demand because they foster confidence in the safety of the firm's products on the part of downstream and final customers. These assurances are helping to reduce the potential for market failure and to bolster markets for safety and quality.

Government Efforts To Bolster Differentiation

Government may also try to stimulate the supply of information and product differentiation. Mandatory traceability has been suggested as one possible policy option for supplying consumers with more information about credence attributes, including such diverse attributes as country of origin and genetic composition. One difficulty with such proposals is that they often fail to differentiate between valuable quality attributes, those for which verification is needed, and other less valuable attributes. For example, a government policy requiring that producers of valuable organic foods provide verification that these foods are indeed organic could protect consumers from fraud and producers from unfair competition. No such verification would be necessary for conventionally produced foods. Consumers do not need proof that conventional foods are indeed conventional—there is no potential for fraud in this case, no danger that producers would try to cheat consumers by misidentifying organic as conventional. A mandatory traceability system for both organic and conventional foods is unnecessary to protect consumers from fraud or producers from unfair competition.

Likewise, government may have an incentive to require that producers of foods that are not genetically engineered verify that these foods are in fact not genetically engineered, if that attribute is of value to some consumers. However, no such verification would be necessary for the genetically engineered foods currently on the market, because this attribute is not of value to consumers (most genetically engineered products currently on the market have producer, not consumer attributes). A mandatory traceability system for both genetically engineered and non-genetically engineered foods is unnecessary to protect consumers from fraud or producers from unfair competition. Such a system would raise costs without generating compensating benefits. Mandatory traceability for product differentiation that is not targeted to specific attributes of value to consumers will be costly and unnecessary.

Another difficulty with mandatory traceability lies in the propensity for government programs to require uniformity. As our industry review illustrates, private firms operate a wide variety of complex, highly sophisticated traceability systems. A government-mandated system that required all firms to adopt the same template could be highly costly and inefficient. For example, mandatory traceability systems requiring a common or standard lot size could result in enormous, unnecessary costs to industry. One meat processor found that, by working with USDA to develop a sub-lot sampling system, it was able to reduce the amount of product that needed to be destroyed in cases of contamination and, as a result, substantially reduced its destruction costs. In another case, a fruit producer found that USDA safety requirements specifying a particular lot size led to the development of a complicated traceability system that did not mesh with the plant's production/transportation system.

A flexible government-mandated system would likely be more efficient and less burdensome than one that required that all firms revamp their traceability systems to conform to a standard template. In the United States, both AMS and FSA rely on industry-developed traceability and bookkeeping systems to monitor the domestic origin of food purchased for Federal procurement programs. Programs such as the U.S. national organic food standard depend on private certifiers to provide flexibility to the system. Organic food certifiers, approved by the U.S. Department of Agriculture, work with growers and handlers to develop individualized recordkeeping systems to assure traceability of food products grown, marketed, and distributed in accordance with national organic standards.

Market Failure and Traceability for Food Safety

Though failure by private markets to supply adequate traceability for product differentiation is a concern to regulators, an even bigger concern is failure by private markets to supply adequate traceability systems for basic food safety control and monitoring. In some cases, the amount of traceability supplied by firms may be less than the social optimum because the public health benefits of traceability for food safety are larger than the firm's benefits. A firm's food safety traceability benefits include the reduction in the potential for lost markets, liability costs, and recalls, while the potential social benefits include a long list of avoided costs, including medical expenditures and productivity losses due to foodborne illness, costs of pain and suffering, and the costs of premature death.

Social benefits may also include the avoided costs to firms that produce safe products but lose sales because of safety problems in the industry. A firm's traceability system not only helps minimize potential damages for the individual firm, it also helps minimize damages to the whole industry and to upstream and downstream industries as well. For example, a series of widespread ground meat recalls has the potential to hurt the reputation and sales of the entire meat industry, including downstream industries such as fast food restaurants and upstream suppliers such as ranchers. The benefits to the industry of a traceability system pinpointing the source of the bad meat and minimizing recall (and bad publicity) could therefore be much larger than the benefits to the individual firm.

As mentioned in the section on differentiation, the amount of traceability supplied by firms may also be lower than the social optimum because firms may find value in some level of anonymity. If traceability systems increase the probability that a firm will be identified in the case of food safety problems and exposed to liability, then the firm may have an incentive to underinvest in traceability: the value of anonymity may reduce the firm's incentives to invest in traceability systems.

Private cost-benefit calculations may also differ from social calculations if the costs of erecting traceability systems are lower when industry groups or governments undertake these projects than when individual firms build them on their own. Or, once built, the marginal cost of including other firms or foods in the traceability system may be small or nothing. In these cases, the private benefits of such systems may not outweigh the private costs while the social benefits do outweigh the social costs. Public defense and libraries are classic examples of such a situation; traceability systems for detecting and tracing foodborne illness outbreaks to their source may be another.

Firms have an incentive to identify and isolate unsafe foods and to remove them from the supply chain as quickly as possible. Few firms, however, have an incentive to monitor the health of the Nation's consumers in order to speed the detection of unsafe product. Such a traceability system would be extremely expensive and would be poorly targeted to any individual firm's needs. The benefits to an individual firm of building a system to monitor all foodborne illness outbreaks just in case one is linked to the firm's product would certainly not outweigh the costs. However, the collective benefits to industry and to consumers may well outweigh the costs. Early detection and removal of contaminated foods can reduce the incidence of foodborne illness and save lives.

Industry Efforts To Increase Traceability for Food Safety

A host of new food safety concerns have pushed food industries to reevaluate their safety protocols, including their traceability systems. For the most part, industry has worked to strengthen safety systems in response to new threats, though the speed and success of industry response has varied. The fresh fruit and vegetable sector has probably been the most successful in adjusting traceability systems in response to new safety problems. This reflects the fact that firms in the sector have already established robust traceability systems and that the industry has experienced a series of foodborne illness outbreaks.

In the mid-1990s a series of well-publicized outbreaks, traced back to microbial contamination of produce, raised public awareness of potential problems. Recent outbreaks like the one traced to scallions served at a restaurant chain, continue to focus public attention on safety of fresh fruit and vegetables. Good-agricultural-practice audits, including traceability audits, are becoming a necessary part of doing business, as more and more buyers demand safety assurances. In addition, several grower organizations have developed systems to strengthen traceability. In the case of an outbreak, a grower organization that encourages traceback can prove to the public that their product is not responsible for the problem. Or, in the unfortunate case where the industry is responsible for the outbreak, the problem grower or growers can be identified and damage can be limited to that group.

The grain industry has yet to experience a well-publicized, pivotal safety problem. There have not been any major safety scares that would warrant the reevaluation of the industry's safety system, including its traceability systems. The highly processed nature of the product, and the large number of critical safety points along the production chain, largely eliminate safety problems that may arise early in the production process, thereby reducing the need for detailed traceability systems.

The beef sector may be experiencing the most difficulty of the three sectors in responding to new safety threats. These difficulties can be traced to uncertainties in the science of food safety and pathogen control in meat and institutional and philosophical barriers to traceability in the sector. Despite these difficulties, the industry has developed a number of approaches for strengthening food safety accountability and traceability. For example, the Beef Industry Food Safety Council (BIFSCo) has taken on the task of organizing representatives from all segments of the beef industry to develop industry-wide, science-based strategies to solve the problem of *E. coli* O157:H7 and other foodborne pathogens in beef. Industry groups are also cooperating to develop the national animal identification plan (see box, "Animal Identification," p. 32).

Buyers in the beef industry are also increasingly relying on contracting or associations to improve product traceability and safety. Fast food restaurants and other retailers have begun adopting the role of channel captains, monitoring the safety of products up and down the supply chain. By demanding safer products from their suppliers, these restaurants have successfully created markets for food safety. The success of these markets rests on the ability of these large buyers to enforce standards through testing and process audits—and to identify and reward suppliers who meet safety standards and punish those who do not. These large buyers have spurred the development of traceability systems throughout the industry.

Government Efforts To Increase Traceability for Food Safety

Mandatory traceability is one possible policy tool for increasing the food system's traceback capability. However, since the government's primary objective for food safety traceback is the swift identification and removal of unsafe foods, other policy tools may be more efficient than mandatory traceability. Policy aimed at ensuring that foods are quickly removed from the system, while allowing firms the flexibility to determine the manner, will likely be more efficient than mandatory traceability systems. For some firms, plant closure and total product recall may be the most efficient method for isolating production problems and removing contaminated food from the market. For other firms, detailed traceback, allowing the firm to pinpoint the production problem and minimize the extent of recall may be the most efficient solution. In either case, contaminated food is quickly removed from distribution channels and the social objective is achieved.

A performance standard, such as a standard for mock recall speed, is one possible policy tool for providing firms with incentives to establish efficient traceability systems. Mock recalls are a good tool for checking the ability of a system to quickly and accurately identify and remove contaminated product. In the United States, the two Federal agencies responsible for food safety, the U.S. Department of Agriculture (USDA) and the U.S. Food and Drug Administration (FDA), encourage firms to perform mock or simulated recalls to ensure that potentially contaminated foods can be tracked and removed from the system in an expedient manner. In addition, most, if not all, third-party safety/quality control certifiers require traceability documentation and mock recalls as part of their safety audits. Depending on the needs of the client, many also monitor and time mock recalls to evaluate the speed and precision with which facilities can identify potentially contaminated product. Société Générale de Surveillance monitors a 2-hour mock recall for many of its clients.

One area where industry has not had any incentive to create traceability systems is in tracking food once it has been sold and consumed. Firms have an incentive to identify and isolate unsafe foods and to remove them from the supply chain as quickly as possible. But, few firms have an incentive to monitor the health of the Nation's consumers in order to speed the detection of unsafe product. Such a traceability system would be extremely expensive and would be poorly targeted to any individual firm's needs. The benefits of building a system to monitor all foodborne illness outbreaks just in case one is linked to the firm's product would certainly not outweigh the costs. However, the collective benefits to industry and to consumers may outweigh the costs. Government-supplied foodborne illness sentinel systems could, therefore, play an important role in closing gaps in the food systems traceability system. By providing this public good, the government could increase the capability of the whole food supply chain to efficiently and quickly respond to food safety problems.

In the United States, the Federal Government and other public health entities have taken strides in building the infrastructure for tracking the incidence and sources of foodborne illness. The Foodborne Diseases Active Surveillance Network (FoodNet) combines active surveillance for foodborne diseases with related epidemiologic studies to help public health officials better respond to new and emerging foodborne diseases. FoodNet is a collaborative project of the Centers for Disease Control and Prevention (CDC), nine States, USDA, and the FDA. Another network, *PulseNet*, based at CDC, connects public health laboratories in 26 States, Los Angeles County, New York City, the FDA, and USDA to a system of standardized testing and information sharing.

With better surveillance of foodborne illness outbreaks, regulators can increase the likelihood that unsafe foods and unsafe producers will be more quickly identified. Better surveillance therefore reduces the risk of foodborne illness in two ways: by more quickly removing unsafe food from the food supply and by putting additional pressure on suppliers to produce safe foods. By increasing the likelihood that unsafe producers are identified, surveillance systems increase the likelihood that these producers will bear some of the costs of unsafe production, including recall, liability, and bad publicity. Increased surveillance therefore increases the potential costs of selling unsafe food, providing producers with increased incentive to invest in safety systems, including traceability systems.

V. Conclusions

In our investigation into the adequacy of the private-sector supply of traceability, we found that the private sector has a number of reasons to establish and maintain traceability systems and, as a result, the private sector has a substantial capacity to trace. This does not mean that the wheat in every slice of bread is traceable to the field or that the apples in every glass of apple juice are traceable to the tree. Firms evaluate their costs and benefits with respect to supply management, safety, and credence-attribute marketing to determine the efficient breadth, depth, and precision for their traceability systems. The net benefits of establishing and maintaining traceability systems are not necessarily positive for every attribute, for every step of the supply chain, or for the highest degree of precision.

Traceability systems are a tool to help firms manage the flow of inputs and product to improve efficiency, food safety and product quality, and product differentiation. However, traceability systems do not accomplish any of these objectives by themselves. Simply knowing where a product is in the supply chain does not improve supply management unless the traceability system is paired with a real-time delivery system or some other inventory-control system. Tracking food by lot in the production process does not improve safety unless the tracking system is linked to an effective safety control system. And of course, traceability systems do not create credence attributes, they simply verify their existence. Traceability systems are one element of a firm's supply side management system, safety system, and production strategy. Traceability systems are built to complement the other elements in each system.

The development of traceability systems throughout the food supply system reflects a dynamic balancing of benefits and costs. Though many firms operate traceability systems for supply management, quality control, and product differentiation, these objectives have played varying roles in driving the development of traceability systems in different sectors of the food supply system. In the fresh produce sector, quality control and food scare problems have been the primary motivation pushing firms to establish traceability systems. In the grain sector, supply management and growing demand for high-value attributes is pushing firms to differentiate and track production. In the beef sector, food scares and demand for high-value traceability systems have only recently begun to motivate firms to adopt traceability systems tracking production from animal to final meat product.

The varying costs of traceability systems, reflecting different product characteristics, industry organization, production processes, and distribution and accounting systems, have also influenced the development of traceability systems across the food supply. The development of traceability systems in the fresh produce industry has been greatly influenced by the characteristics of the product. Perishability of and quality variation in fresh fruits and vegetables necessitate that the product be boxed and its quality attributes identified early in the supply chain, either in the field or in the packinghouse. This practice has facilitated the establishment of traceability for a number of objectives including marketing, food safety, supply management, and differentiation of new quality attributes. In grains, safety and quality are largely controlled at the elevator level, greatly reducing the need for traceability throughout the sector. For beef, institutional and philosophical barriers have slowed the adoption of traceability systems for tracking animals from farm to table. In every sector, technological innovations are helping to reduce traceability costs and to spur the adoption of sophisticated systems.

Our investigation of the private supply of traceability in the United States has led us to conclude that for the most part, the food industry is successfully developing and maintaining traceability systems to meet changing objectives. In the three food sectors we investigated, producers seem to be responding to consumer demand for product differentiation. When final or input demand is strong enough to cover the cost of product differentiation, producers have responded with new products and new traceability systems to substantiate credence attribute claims, including food safety claims. To control for potential fraud or unfair competition, industry groups and individual firms are increasingly relying on the services of third-party auditors to verify the existence of credence attributes.

For the most part, industry has also worked to strengthen food safety systems in response to new threats, though the speed and success of the response has varied. The fresh fruit and vegetable sector has probably been the most successful in adjusting traceability systems in response to new safety problems, while the beef industry, with its history of limited liability, seems to have had the most difficulties. In all three food sectors, alliances, vertical integration, and contracts are facilitating traceability for safety and other quality attributes.

Our analysis suggests that government mandated and managed traceability is usually not the best-targeted policy response to potential market failures involving traceability. Even in those cases where traceability is necessary for the development of differentiated markets, mandatory traceability systems often miss the mark. Systems that include attributes that are not of value to consumers generate costs without any corresponding benefits. Only systems that focus on attributes of value to consumers actually facilitate market development. In addition, the widespread voluntary adoption of traceability may complicate the application of mandatory systems. Mandatory systems that prescribe one traceability template and fail to allow for variation across systems are likely to impose costs that are not justified by efficiency gains.

One area where the government may be able to increase the supply of a valuable public good is by augmenting tracking systems for contaminated food once it has been bought and consumed. By strengthening foodborne illness surveillance systems to speed the detection of foodborne illness outbreaks and the identification of the source of illness, the government could increase the capability of the whole food supply chain to efficiently and quickly respond to food safety problems. In addition, because they increase the likelihood that unsafe producers are identified, surveillance systems may provide producers with increased incentive to invest in safety systems, including traceability systems. In fact, any policy that increases the cost and probability of getting caught selling unsafe food provides producers with incentives to increase their traceback capabilities. These types of policies will encourage the development of more efficient systems for the swift removal of unsafe foods and for investment in safer food systems—which is the ultimate objective of food safety policy.

Appendix

Select Milestones in U.S Traceability Requirements for Foods

The U.S. Federal Government has a long, albeit limited, history of mandating programs that contain traceability requirements. Government regulations have a diverse set of objectives. Often, they take into consideration ensuring a level of food safety, preventing and limiting animal diseases, or facilitating market transactions. Some of these regulations entail establishing traceability systems for select attributes in particular food subsectors, while other regulations have broader objectives but, in effect, require firms to develop tracing capacity. Whether the intent of the regulation is to address food safety or animal disease concerns or other issues, Government-imposed demands for traceability usually require information about the sellers and buyers (name, address, phone, etc.) and product-related information. The demands on recordkeeping are usually one-up, one-back traceability. Less frequently required are traceability systems for quality credence attributes that have become more prevalent in the private sector, although there are exceptions, such as the national organic food standard.

Below we briefly highlight some important regulations that require traceability systems. We indicate the relevant legislation, the objectives of the regulations, the product coverage and the recordkeeping that is required. The list is not intended to be encyclopedic but, instead, illustrative of important and recent legislation that affects tracing by food suppliers.

Meat, Poultry, and Egg Inspection Acts

Key Legislation and Dates: Legislation was passed in 1906 for meats, 1957 for poultry, and 1970 for eggs. The Wholesome Meat and Poultry Acts of 1967 and 1968 substantially amended the initial legislation.

Objective: The Meat, Poultry, and Egg Inspection Acts have the primary goals of preventing adulterated or misbranded livestock and products from being sold as food and to ensure that meat and meat products are slaughtered and processed under sanitary conditions. The Food Safety and Inspection Service (FSIS), USDA, is responsible for ensuring that these products are safe and accurately labeled.

Coverage: Livestock, meat, poultry, and shell eggs and egg products.

Recordkeeping Required: The Acts call for complete and accurate recordkeeping and disclosure of all transactions in conducting commerce in livestock, meat, poultry, and eggs.

For example, packers, renderers, animal food manufacturers, or other businesses slaughtering, preparing, freezing, packaging, or labeling any carcasses must keep records of their transactions. Businesses only need to maintain one-up, one-back records.

For imported meat, poultry, and egg products, importers must satisfy requirements of two USDA agencies—FSIS and the Animal and Plant Health Inspection Service (APHIS)—and the U.S. Customs Service (USDA, FSIS, October 2003). Imported meat and poultry must be certified, not only by country but by individual establishment within a country. Certificates are issued by the government of the exporting country and are required to accompany imported meat, poultry, and egg products to identify products by country and plants of origin, destination, shipping marks, and amount. FSIS demands that the country of origin provide a health certificate indicating the product was inspected and passed by the country's inspection service and is eligible for export to the United States. To meet APHIS requirements, the product must not come from countries where certain animal diseases are present. USDA requirements are binding as the U.S. Customs Service demands that the importer post a bond, including the value of the product plus duties and fees, until FSIS notifies the Service of the results of its reinspection. Failure to meet U.S. requirements may lead to forfeiture plus penalties.

Perishable Agricultural Commodities Act

Key Legislation and Dates: Perishable Agricultural Commodities Act (PACA) was enacted in 1930.

Objective: PACA was enacted to promote fair trading practices in the fruit and vegetable industry. The objective of the recordkeeping is to help facilitate the marketing of fruit and vegetables, to verify claims, and to minimize any misrepresentation of the condition of the item, particularly when long distances separate the traders.

Coverage: Fruit and vegetables.

Recordkeeping Required: PACA calls for complete and accurate recordkeeping and disclosure for shippers, brokers, and other first handlers of produce selling on behalf of growers. PACA has extensive recordkeeping requirements on who buyers and sellers are, what quantities and kinds of produce is transacted, and when and how the transaction takes place. PACA regulations recognize that the varied fruit and vegetable industries will have different types of recordkeeping needs, and the regulations allow for this variance. Records need to be kept for 2 years from the closing date of the transaction.

National Shellfish Sanitation Program

Key Legislation and Dates: Federal Food, Drug, and Cosmetic Act, portions revised or new as amended by the Food and Drug Administration (FDA) Modernization Act and various State health regulations.

Shellfish must comply with the general requirements of the Federal Food, Drug, and Cosmetic Act and also with requirements of State health agencies cooperating in the National Shellfish Sanitation Program (NSSP) administered by the FDA in cooperation with the Interstate Shellfish Sanitation Conference (ISSC) (FDA, CFSAN, January 2003).

Objective: A key objective is to mitigate the adverse effects of a disease outbreak. Regional FDA specialists with expert knowledge about shellfish assist State officials with traceback. When notified rapidly about cases, they are able to sample harvest waters to discover possible sources of infection and to close waters when problems are identified.

Coverage: Shellfish.

Recordkeeping Required: Shellfish plants certified by the State Shellfish Sanitation Control Authority are required to place their certification number on each container or package of shellfish shipped. The number indicates that the shipper is under State inspection, and that it meets the applicable State requirements. It is central to tracing and identifying contaminated shipments. Shippers are also required to keep records showing the origin and disposition of all shellfish handled and to make these records available to the control authorities.

Organic Foods Production Act

Key Legislation and Dates: Organic Foods Production Act was enacted in 1990. Act was subsequently amended and rules went into effect October 2002.

Objective: The objective is to establish national standards governing the marketing of certain agricultural products as organically produced products, to assure consumers that organically produced products meet national production, handling, and labeling standards, and to facilitate commerce in fresh and processed food that are organically produced.

Coverage: Organic foods.

Recordkeeping Required: Organic food certifiers work with growers and handlers to develop an individualized recordkeeping system to assure traceability of food products grown, marketed, and distributed in accordance with national organic standards (USDA, AMS, October 2002). Records can be adapted to the particular business as long as they fully disclose all activities and transactions in sufficient detail to be readily understood, have an audit trail sufficient to prove that they are in compliance with the Act, and are maintained for at least 5 years. Many different types of records are acceptable. For example, documents supporting an organic system may include field, storage, breeding, animal purchase, and health records, sales invoices, general ledgers, and financial statements.

In order for the attribute "organic" to be preserved, growers and handlers must maintain traceability from receiving point to point of sale and ensure that only organic or approved materials are used throughout the supply chain. Thus, for a traceability system for organic products to be viable it must confer depth.

Food Assistance Programs

Key Legislation and Dates: The National School Lunch Act was enacted in 1946 after World War II.

Objective: To reduce malnutrition and improve poor eating habits, the U.S. Department of Agriculture provides food assistance to schools, Native American reservations, and needy families, the elderly, and the homeless through Federal Food Assistance Programs. In addition to financial subsidies for food purchases, the institutions receive entitlement and bonus commodities. The bonus commodities are procured to support the farm community in specific commodity markets that are experiencing weak market conditions.

Coverage: Flour, grains, oils and shortenings, dairy, red meat, fish, poultry, egg, fruit, vegetable, and peanut products.

Recordkeeping Required: To guarantee that foods are strictly American, producers who win U.S. Department of Agriculture contracts must provide documentation establishing the origin of each ingredient in a food product (USDA, AMS, 2003). The producer pays USDA inspectors to review the traceability documents and certify the origin of each food. Starting with the "code" or lot number on a processed product, inspectors use producer-supplied documentation to trace product origins all the way back to a grower's name and address.

Country of Origin Labeling

Key Legislation and Dates: The legislation amends the Agricultural Marketing Act of 1946 by incorporating country of origin labeling (COOL) in the Farm Security and Rural Investment Act of 2002 (Public Law 107-171). Specific guidelines for voluntary labeling were issued in 2002 and are currently in effect (USDA, AMS, October 11, 2002). Mandatory labeling rules were proposed in October 2003. The Farm Act states that mandatory COOL is to be promulgated no later than September 30, 2004. However, the 2004 Omnibus Appropriations Act delays until September 20, 2006, implementation for all covered commodities, except wild and farm raised fish, which must be labeled beginning September 30, 2004.

Objective: The objective is to provide consumers with more information regarding the country where covered commodities originate.

Coverage: The legislation affects the labeling of beef, pork, lamb, fish, shellfish, fresh fruit, vegetables, and peanuts. COOL is not required if these foods are ingredients in processed food items or are a combination of substantive food components. Examples include bacon, orange juice, peanut butter, bagged salad, seafood medley, and mixed nuts.

Food service establishments such as restaurants, food stands, and similar facilities including those within retail stores (delicatessens and salad bars, for example) are exempt from the requirements. Moreover, grocery stores that have an annual invoice value of less than $230,000 of fruits and vegetables are exempt from COOL requirements. Consequently, retail food outlets, like butcher shops and fish markets that do not sell fruit and vegetables, are not included under COOL requirements.

Recordkeeping Required: Retailers may use a label, stamp, mark, placard, or other clear and visible sign on the covered commodity, or on the package, display, holding unit, or bin containing the commodity at the final point of sale.

The Act and the proposed rules have stringent requirements on the depth of recordkeeping. First, the supplier responsible for initiating the country-of-origin declaration must establish and maintain records that substantiate the claim. If a firm already possesses records, then it is not necessary to create and maintain additional information. As a vertical supply chain, there must be a verifiable audit trail to ensure the integrity of the traceability system, that is, firms must assure the transfer of information of the country-of-origin claim. As a consequence, firms along the supply chain must maintain records to establish and identify the immediate previous source and the immediate subsequent recipient of the transaction. For an imported product, the traceability system must extend back to at least the port of entry into the United States. Firms have flexibility in the types of records that need to be maintained and systems that transfer information. Records need to be kept for 2 years.

The proposed rules provide flexibility in the type of recordkeeping. The Act states that the Secretary shall not use a mandatory identification system to verify country of origin. The U.S. Department of Agriculture provides examples of documents and records that may be useful to verify compliance with the Country of Origin Labeling provisions of the 2002 Farm Bill. (See http://www.ams.usda.gov/cool/records.htm.) These records vary depending on the business activities. As an example, a ship catching wild fish may keep records of site maps, and vessel, harvesting, and U.S. flagged vessel identification records. A distributor of wild fish may keep records of invoices, receiving and purchase records, sales receipts, inventories, labeling requirements, a segregation plan, and UPC codes.

Public Health Security and Bioterrorism Preparedness and Response Act

Key Legislation and Dates: The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 provides new authority to the Federal Drug Administration.

Objective: The objective is to protect the Nation's food supply against the threat of serious adverse health consequences to human and animal health from intentional contamination.

Coverage: All foods are subject to the legislation except meat, poultry, and eggs (which are under U.S. Department of Agriculture's jurisdiction).

The Act requires both domestic and foreign facilities to register with the FDA no later than December 12, 2003 (FDA, CFSAN, 2002). Facilities subject to these provisions are those that manufacture, process, pack, transport, distribute, receive, hold or import food. The Act exempts farms, restaurants, other retail food establishments, nonprofit food establishments in which food is prepared for or served directly to the consumer; and fishing vessels from the requirement to register. Also, foreign facilities subject to the registration requirement are limited to those that manufacture, process, pack, or hold food, only if food from such facility is exported to the United States without further processing or packaging outside the United States.

Recordkeeping Required: The Act requires the creation and maintenance of records needed to determine the immediate previous sources and the immediate subsequent recipients of food (i.e., one-up, one-down). For imported food the rules also require prior notice of shipment and a description of the article including code identifiers, the name, address, telephone, fax, and email of the manufacturer, shipper, and the grower (if known), the country of origin, the country from which the article is shipped, and anticipated arrival information. Records are required to be retained for 2 years except for perishable products and animal foods (for example, pet foods) where 1 year of recordkeeping is allowed. Records may be stored offsite.

Food Safety and Inspection Service, USDA, has jurisdiction of meats, poultry, and eggs. FSIS has been issuing guidance to businesses engaged in production and distribution of these USDA-regulated foods. Among the guidance principles for slaughter and processing facilities, FSIS recommends validated procedures to ensure the traceback and traceforward of all raw materials and finished products.

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