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Traceability in Food Systems:
An Economic Analysis of LGMA and the 2006 Spinach Outbreak

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Abstract

This case study presents an in-depth review of network structures and costs associated with the implementation of traceability systems in California leafy green production, distribution, and retailing. The 2006 spinach outbreak is used to assess the economic impact of trace back/forward response time of the LGMA system, an example of a tightly coupled, linear supply network. Results suggest that the benefits of traceability systems may far outweigh the costs and that costs vary significantly by technology used and by grower size. Implications are derived for cost-effectiveness of rapid response, targeted trace back/forward systems in other types of supply networks.

Key words: traceability, produce, supply networks, cost-effectiveness

JEL Classification: Q18, I18, L51

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Introduction

In the current climate of heightened awareness of foodborne illnesses from pathogens and chemical contamination, a major concern involves the actions taken by the industry and federal agencies to contain or trace the source of current and future outbreaks in a timely, targeted, and cost-effective manner. However, trace back and containment of catastrophic food events often take several weeks or months, resulting in greater economic loss to the industry, regional, and national economies. The duration and cost of trace back for food imports may be even more problematic. For example, the 2006 California spinach *E. coli* outbreak source was identified on September 20, 47 days after the first reported case on August 5 (See Appendix 1) while the 2008 *Salmonella enterica* outbreak of fresh jalapeño and Serrano peppers from Mexico took 81 days. To address these concerns the U.S. Food and Drug Administration is proposing a mandatory electronic traceability format for each point along the supply chain within 24 hours of an FDA request. The proposed rule suggests that, although implementing electronic traceability systems would come at an added cost to the industry, several benefits outweigh the cost.

There is little question that rapid response and targeted trace back systems can minimize economic damage inflicted by food safety events by speeding up and narrowing product recalls. Faster recalls avoid additional cases of illness or death, and targeted recalls avoid false alarms on products that are safe. Despite this awareness and the proliferation of traceability standards and systems, investigators in food supply networks often find that when faced with an unexpected failure, participants ‘scramble’ to produce the required information, leading to information losses or errors (Charlier & Valceschini, 2007) that turn into delays. One reason for these problems is that traceability systems are not uniformly implemented by all participants. As long as implementation is voluntary, some participants may try to avoid or reduce the costs of implementing traceability systems. This suggests that enforcing centralized or cooperative standards for rapid response among participants in food supply networks is a critical step in reducing trace back times and executing more targeted recalls.

We investigate the costs and benefits of implementing the 24 hours traceability rule by examining the development of the California Leafy Green Marketing Agreement (LGMA). The LGMA was officially formed in September of 2007 in response to the 2006 *E. coli* O157:H7 outbreak associated with bagged baby spinach produced on farms located in the Salinas Valley of central costal California (Stuart, Shennan and Brown, 2006). Presently, the LGMA consists of 120 growers, distributors and processors that account for approximately 99% of the volume of leafy greens (14 types of leafy greens) produced in California (See Appendix 2). Our case study provides an in-depth review of the costs and benefits associated with the implementation of traceability systems in California leafy green production, distribution, and retailing; an example of a tightly coupled, linear supply network. Costs are estimated for two electronic traceability systems (electronic barcode and RFID). The profit model developed by Pouliot and Sumner (2008) and data from the 2006 spinach outbreak is used to assess the cost-effectiveness of trace back response rate of the LGMA system.

Traceability and Supply Network Structure

Complex network structure is one potential reason why firms tend to delay investments in rapid response trace back systems. Although traceability in the food supply network is often regarded as a product level phenomenon, it is at least partially a function of the characteristics of the supply network structure (Roth, Tsay, Pullman and Gray, 2008). In the LGMA we develop the idea that traceability depends on characteristics of food supply networks that enable users to accurately reconstruct the chronology and flow of the steps in the production, distribution and retail of the network's products.

The California leafy greens supply network is an ideal setting for a study of this type, because it structure is likely to facilitate implementation of traceability systems. Skilton and Robinson (2009), adapting Perrow's theory of normal accidents (1999) to supply networks, proposed the leafy greens network as an example of a tightly coupled, linear supply system. Perrow (1999) defined systems network complexity between 1) complex systems and linear ones, and 2) tightly coupled and loosely coupled systems (Figure 1). He argued that system complexity is important because complex interactions multiply the opportunities for hard to understand accidents to occur. Complex systems have unplanned, unexpected, invisible, unfamiliar, ambiguous or incomprehensible sequences, often made more obscure by poorly understood transformation processes. Less complex systems are likely to be more transparent because interactions will be less complex, transformations will be fewer and the number and variety of components or actors involved will be less. As a result, linear systems afford a greater opportunity to get a clear picture of the whole system, making them easier to trace back.

Insert Figure 1 about here

On the other dimension loosely coupled systems allow for processing delays, do not have fixed sequences or relationships, retain slack resources and exploit fortuitous substitution possibilities (Skilton and Robinson, 2009). In tightly coupled systems performance standards are enforced and unambiguous (e.g. marketing contract). Delays are minimized, sequences are invariant, methods are constrained, any buffers or redundancies are designed, and substitutions or commingling are limited. Loosely coupled systems are less likely to be transparent because sensitive information is more likely to be ambiguous and less likely to be visible to and understood by the various actors in the system. Tightly coupled systems thus facilitate trace back by ensuring that information is captured, maintained and readily available for rapid recall.

We argue that compared to other supply networks, the California leafy greens industry exhibited the characteristics of a linear, tightly coupled supply network. In the typical leafy greens network, as shown in Figure 2, multiple growers supply a packer, who ships product either to a distribution center or to a re-packer. If product is re-packed, it is shipped to a distribution center. Distribution centers, which can be controlled by third parties or by retailers, ship to retailers. The network is linearly structured, as can be seen by the limited number of transitive triadic relationships in the figure. A triadic relationship is transitive if A is connected to B, B is connected to C, and C is connected to A. In this case the only triadic relationships are between the packer, re-packer and distributors, and between the packer, distribution center and retailer distribution center. The entities depicted in the figure (such as growers' fields, packing facilities, distributors and retailers) are arranged in chains that are only sparsely linked to each other. Within these chains relationships are governed by rigorously enforced contracts that specify detailed information flows. In a network of this type the number of paths through the network is relatively small. Because information flows and material flows are tightly linked, data are more likely to retain their integrity.

Insert Figure 2 about here

Changing either coupling or complexity alters traceability. A loosely coupled, linear supply network would also consist of mostly intransitive triads, without the constraint of highly specified relationships. In a network of this type the number of paths through the network is relatively small, but, in the absence of tight coupling, information and material flows are less likely to retain their integrity. Examples of this type of network can be found in the supply of traditional and locally produced foods. There are typically only a few types of actor in these systems, which interact without contracts and without close supervision by regulators. Growers, processors and consumers are local and small. While coupling is loose, it should be noted that the simplicity of the network can make trace back easy.

Trace back is more difficult when supply networks are complex. A tightly coupled complex supply network would be made up of many types of actor, arranged in networks in which connections are relatively dense and connected by relationships that are governed by rigorously enforced contracts specifying detailed information flows. Skilton and Robinson (2009) suggest that networks of this type may be rare because of the competing pressures of network complexity and tight coupling. Complexity tends to make data integrity difficult to achieve, particularly when transformations and commingling are common. Trying to manage this by imposing tight coupling is likely to result in reductions in complexity.

This suggests that loosely coupled complex supply networks will be more common than tightly coupled complex ones. Many food supply networks have this form, which is the type in which traceability is most difficult. An example of this type of network is a broker based network supplying commodity inputs, particularly those that have been transformed, such as ground beef. While it is in these complex supply networks that trace back is most difficult (Moss, 2009), the fact that traceability is also a problem in tightly coupled linear ones leads us to try to understand the simpler case, represented by the LGMA, first. We make this attempt in the hope of arriving at a better understanding of the costs and benefits of system wide implementation that will be at least in part transferable to more complex cases.

Traceability systems within the LGMA

The LGMA, as described in Appendix 1, is extremely simple. It does not require members to implement specific systems. Although it encourages the use of tracking systems based on Radio Frequency Identification (RFID), no specific technology or information system is mandated by the agreement itself. Instead the agreement makes reference to federal law the only explicit specification for compliance with the agreement. The LGMA audit checklists' specific requirements are given as follows (LGMA, 2008):

1) GR 03 – Is an up to date growers list with contact and location information available for review?
2) GR 04 – Is the handler in compliance with the registration requirement of The Public Health Security and Bioterrorism Preparedness and Response Act of 2002?
3) GR 05 – Does the Handler have a traceability process?
    a. GR 05a – Does it enable identification of immediate non-transporter source?
    b. GR 05b – Does it enable identification of immediate non-transporter subsequent recipient?

While the implementation of a specific electronic traceability system is not required in the LGMA requirements, the majority of members have deployed barcode or RFID technologies to meet the requirements of the marketing agreement (Estrada-Flores, 2009). Barcodes are still the predominant technology used by leafy green growers, distributors and retailers, but because they require line of sight, barcode data is often captured using handheld devices. Handheld devices increase the probability of human error and require batch uploading, increasing the difficulty of ensuring data integrity. Cost limitations have been cited as a major reason why other real time technologies are not extensively used. RFID can enhance rapid response by improving and automating capture of logistics data, permitting near real-time tracking, which in turn enables logistic managers to proactively respond to events in the supply chain, such as breaches of the cold chain.

Regardless of the specific technology deployed, identifying tags are placed on boxes, pallets, and/or the product packaging, in which the assigned unique number provides the information necessary to trace the product back to the immediately preceding stage of production. Tag data frequently records, but is not limited to, grower, ranch location, planting block/lot, planting date, harvesting date, harvesting crew, ship date, ship-to locations, manufacturing plant, production shift and line, production date, and a “Best if Used By” date (Church Brothers Produce, 2009; Estrada-Flores, 2009; Sunridge Farms, 2009).

As depicted by the audit requirements of the LGMA and by the description of a number of LGMA members’ traceability systems, the success of a traceability system relies heavily on comprehensive documentation and record-keeping procedures. For example, Growers Express’ field managers maintain records regarding staff and all products and materials used during the production process. These records are primarily electronically stored. Growers Express maintains that pertinent trace back data can be made available for review by investigators within two hours of notice (Growers Express 2009). The tightly coupled linear network of LGMA participants involves as many as five stages that link the retailer to the farm (see Figure 1). These linkages represent both information flows and the physical distribution and storage of food shipments (Estrada-Flores, 2009).

A survey conducted by Tootelian (2007) revealed that prior to the 2006 *E. coli* outbreak, 89.8% of all growers indicated they had traceability in place. It should be noted that 100% of growers shipping more than 1,000,000 lb had traceability systems. However, the predominant traceability systems were paper trail and barcode technology, making it challenging to conclude that these systems were able to trace back within 24 hours for each participant involved. The survey indicated that after the 2006 outbreak 60.5% of growers indicated they had expanded their traceability programs to more electronic form systems, including real time tracking. The following two examples provide insight on trace back rate for current electronic users. In August 2007, Metz Fresh, LLC employed their traceability system after finding that 8,000 cartons of fresh spinach tested positive for *Salmonella*. Within three days of harvest, stores and restaurants were notified of the product recall, whereby more than 90 percent of the tainted spinach never reached the market (CIDRAP, 2007). In the summer of 2009, Tanimura & Antle Inc. recalled romaine lettuce after random testing conducted by Wisconsin Department of Agriculture found traces of *Salmonella*. Tanimura & Antle was informed of the possible contamination on July 20, which was the same day that the product was distributed to 29 states, Canada and Puerto Rico (Withers, 2009). Tanimura & Antle was able to identify that the potentially contaminated lot (code 531380) was harvested between June 25 and July 2 and alerted their customers of the recalled product within hours of being notified (FDA, 2009).

Because the kinds of technology deployed can alter the ability to achieve 24 hour trace back, in the next section we provide traceability cost estimates for two trace back technologies currently or potentially used by Leafy Green members; barcodes (which are the most commonly deployed base technology) and RFID (which we use to provide an upper cost range).

Cost of the LGMA Traceability System

Adhering to the LGMA standards and meeting the audit compliance requirements can be costly for members. Paggi (2008) noted that LGMA compliance costs range between $210 and $260 per acre. Of this cost, approximately $50 per acre is estimated to be record keeping costs. Annual investment in food safety for LGMA members have almost tripled since the introduction of LGMA. According to the 2007 LGMA status report, total LGMA annual food safety investments prior to September 2006 was $23.7 million, compared to $71.3 million after September 2006 (Tootelian, 2008). This translates to an average annual investment of $604,545 per member enterprise after September 2006. Combining the estimated annual operating costs for LGMA audit compliance (food safety employee costs, annual water testing expenses, annual LGMA membership funding), and the total estimated annual investment for LGMA compliance, the estimated total costs for LGMA members' compliance range from approximately $80 -$91 million per year (Table 1). These costs would cover expenses incurred by growers and handlers, and the traceability systems in this tightly coupled, linear network system could represent costs for tracing production forward from production to distributor. This estimate implies that average annual expenses relating to compliance to the LGMA range from $0.0128 to $0.0158 per pound (Table 1).

Insert Table 1 Here

We estimate that a significant percent of the food safety cost (20 to 45 percent of the total LGMA compliance cost) is attributed to record keeping and traceability. However, the actual cost share varies widely for individual enterprises based on the type of traceability systems used (paper records, barcodes and RFID).

Traceability cost with alternative food system network technologies

Table 2 shows a summary breakdown of traceability costs by technology used and by grower size. Costs for two technologies (barcode and RFID) were estimated for representative firms by size, and then aggregated to obtain the estimated industry costs. Each system's costs include both variable and fixed costs were computed for representative firms of three sizes measured in shipment volume (1= 0 - 100,000 pounds; 2 = 100,001 – 999,999 pounds; 3 = 1 million or more pounds) and are shown in Table 2. Among the actual LGMA membership (n=118), 34.3% were in size category 1; 36.3% in size category 2; and 29.4% in category 3 (Tootelian, 2008). The related costs for firms in each of the three size categories were aggregated by their share of the industry members to get the total industry costs. Industry costs and parameters were based on Tootelian's report (2008), state/industry statistics, and other published documents. The cost estimates were estimated from the volume of leafy greens of the California leafy greens industry, which represents approximately 75% of the total U.S. volume (LGMA, 2008).

Insert Table 2 Here

For each of the technologies, total fixed cost is the sum of the individual fixed cost components. The fixed costs were depreciated over 5 years and using a discount rate of 10% as the discount value for the cost of working capital. Variable costs differ by the size of the member groups. Total variable costs include the sum of the variable costs based on their assignment to the traceability system. As example, a barcode based system has variable costs for the three size groups of $1,868,819 (sum of $91,405, $192,281 and $1,585,133). These costs are simulated from the volume of shipments for all members in that size category. The variable costs include costs for barcode labels, barcode label printer, barcode handheld reader and employee training. The total fixed cost for the barcode system is $1,393,258. Total cost is the sum of fixed and variable costs. For the barcode system, the total cost is $3,262,077, and apply if all firms adopted the barcode system.

The total industry costs were estimated for each of the two technologies (RFID and bar code) by aggregating the costs incurred by the firms in the industry across the three sizes of firms. For both technologies, total fixed and variable costs were highest for the RFID system ($109 million for Passive Tags and $1,372 million for Active Tags). As shown in Table 2, costs also vary by firm size or sales volume (firm size categories assigned to member type 1, 2 or 3). For example, the RFID variable cost range for small and large sales volume varied between $132,905 and $87.5 million for Passive Tags. The variable costs for the barcode system ranged from nearly $91,000 to $1.6 million for the small and large sales volume, respectively (Table 2).

In estimating cost and technology configurations for traceability systems, it should be noted that when commingling is prevalent (for loosely coupled, linear and complex systems), then multiple barcodes would be needed. Bar code technology was determined to be the least expensive in a tightly coupled, linear system, such as spinach. However, the usage of active RFID tags and technologies that enable data to be rewritten at multiple locations could become cost-effective when a requirement for multiple barcodes exists. Hence, requiring and enforcing information one step back and one forward has implications in this example for both cost and technology selected depending on the firm’s size and processes done by each enterprise.

Simulated Benefits of LGMA Traceability System & the E. coli O157:H7 Outbreak

The severity of the widely-publicized 2006 *E. coli* O157:H7 outbreak continues to be startling, in which 204 persons were infected, including 31 cases of hemolytic-uremic syndrome (a serious complication that can cause kidney failure) and three deaths (Table 3). Moreover, in the decade preceding the 2006 epidemic, nine other *E. coli* O157:H7 outbreaks were linked to lettuce or spinach grown in the Salinas Valley region of California (Cooley et al.). The personal injury and lives lost continue to be the utmost regrettable consequence from this outbreak, yet the economic and financial fallout have also severely impacted the public. The entire U.S. spinach industry experienced financial losses and reputation damage, while consumers' confidence in food safety diminished and public funding was allotted to recoup the costs of the outbreak.

The estimated benefits of having a traceability system in place result from avoiding losses to the firm, public and industry, which are associated with an outbreak, such as the 2006 *E. coli* O157:H7 incident. We estimate the failure costs associated with the 2006 *E. coli* O157:H7 outbreak based on the U.S. spinach industry losses and the total costs associated with the product recall to be approximately $129 million USD (Table 3). The industry cost of the outbreak was estimated at $80 million USD but some studies have reported industry loses in the range of $100 million to over $350 million (McKinley, 2006; Weise and Schmit, 2007).

Insert Table 3 Here

The total volume of contaminated product that caused the outbreak and the product recalls was approximately 15,750 pounds of bagged Dole Baby Spinach, which are identified by the code P227A. The code indicates that the spinach was produced at Natural Selection's south plant (P) on the 227th day of the year (August 15) during the first of two shifts (A) (Weise and

Schmit, 2007). Although several leafy green products were recalled due to the outbreak, the 15,750 pounds of bagged Dole Baby Spinach was deemed responsible for the outbreak and product recalls. Losses due to false alarm for commingled products or spinach produce out of California could have been avoided if trace back were rapid (occurred within 24 hours for each segment in Figure 1) and technology could lead to more targeted recall.

In order to simulate the traceability benefits and cost-effectiveness of the LGMA systems we assume that trace forward response rates could improve significantly from 47 days to less than 50% (24 days) and 75% (12 days) with rapid response, targeted systems like RFID and GS1 systems (Appendix 2). This assumption is realistic as the survey by Tootelian (2007) revealed that about 60.5% of those who had paper trail or barcode traceability systems expanded their systems. This expansion should include better electronic tracking systems. The assumptions of increased use of electronic systems and availability of linking the electronic information across agents in the food system are consistent with the program recommended by the panel for 24-hour electronic data availability (IFT, 2009).

We simulated cost-effectiveness using the profit model developed by Pouliot and Sumner (2008) and the assumptions on trace forward response rates above. Their model include three main components for net profits; gross revenue less cost of providing traceable and safe produce, less expected loss associated with unsafe food delivery (Table 3). Simulated benefits suggest that rapid response targeted systems could have mitigate between $9,795,564 and $93,562,205 USD.

Although the range of improved benefits is large, the study indicates the significant improvement possible through having access to supplies and product destination information through electronic means. The estimated costs and simulation employed in the case of the LGMA for spinach indicates that there are significant savings from more rapid response. This response results from information technologies that improve the ability to track product flow. Compliance costs of LGMA membership (of \$0.0128 - \$0.0158 per pound, with the associated record keeping and traceability costs ranging from \$0.0026 to \$0.0071 per pound) are significantly lower than the potential benefits of avoiding the 2006 *E. coli* O157:H7 outbreak and product recall. The costs are lower than the benefits achieved when more rapid and targeted recall systems (24 hour system for each participant) reduce the trace forward response time by 50 percent (24 days) or 75 percent (12 days) in this case. Some of these costs are expected to be passed forward to consumers. For firms, costs of having a system in place would be recurring costs to the industry. Any individual firm may not experience a recall within a year. It is likely to be a relatively rare event. However, for the industry, having a rapid response system in place reduces the costs (provides benefit) across the industry when a recall does occur.

Again, these are conservative benefit estimates but appropriate since not all LGMA members currently have 24 hours rapid response trace back systems in place. It is true that the benefits could be even larger if recall are made before products even enter the retail outlet or sold to end consumers. These results reveal that with advancement in policy and adoption of rapid response trace back technology adoption industry benefits may by far outweigh the costs. Net present value and dynamic analysis suggest even more savings as cost of technology will continue to decline.

Conclusion and Food Policy Implications

The important policy debate in the U.S. and other countries is whether or not to mandate traceability for domestic and international food supply chain. In the U.S. for example, the Food and Drug Administration (FDA) is considering a 24 hour rapid response trace forward and backward electronic system. The emphasis of such a program in prior studies has mostly been on the cost of implementation. We expand the discussion to show that in the case of California LGMA there are clear benefits to implementing rapid response and targeted traceability systems in food supply networks. If recalls are not conducted in a timely and targeted manner, even participants whose product is not contaminated suffer economic losses.

Following Skilton and Robinson (2009) we proposed that traceability is partly a function of the characteristics of the food supply network, and system complexity could not be overlooked. The LGMA supply network structure is tightly coupled and linear, which we have argued is the most desirable structure for achieving traceability. Estimating the cost of traceability of such a system is less complicated and direct. The problem that is revealed by introducing network structure as a predictor of mandating traceability is that many food supply networks are either loosely coupled or complex. Both of these structural characteristics impede traceability. One of the most important implications of this theory is that traceability systems must be tailored to the supply networks they are deployed in. Tightly coupled linear networks present the fewest challenges to systems developers, so it is no surprise that effective traceability systems are already common in these networks. Formal systems are much less common in loosely coupled linear networks, in part because there are very few steps between the raw material and the final consumer. Because of this the costs to small players of implementing formal systems are high relative to the benefits in terms of traceability.

As networks become more complex, traceability systems must follow suit. In complex networks the challenge is how the traceability system would preserve information through transformative processes, co-mingling of shipments and other information degrading processes that characterize complex networks. Effective trace back/forward in complex tightly coupled systems may depend on the presence of large, powerful players such as global food companies or global retailers in the network. These participants have an interest in rapid trace back because they have investments in brand that are put at risk by adverse events. Strong central participants would have to create a climate of enforcement throughout the network. Wal-Mart has begun to take this approach as evidenced by the retailer's recently announced sustainability initiative (Rosenbloom, 2008). This initiative will result in a network with fewer suppliers operating in more tightly coupled relationships. A key issue for firms seeking to influence network practices will be their 'reach' or how far their influence extends into the network of suppliers. Since controlling a complex network requires information intensive relationships with a greater variety of counterparties, there is a risk of information overload for the controlling firm. In tightly coupled networks, reducing complexity and assigning an enforcement role to a central player would make traceability systems possible, but only at a high cost in terms of system resources, data quality and the opportunity costs of committing to a smaller supplier base for any product.

In a loosely coupled complex network, we think solutions are limited to very simple logistics approaches similar to the one deployed by the LGMA. The problem in these networks is the absence of a central player, which suggests that government intervention, perhaps on an international scale, will be necessary. It is also possible that solutions will emerge from technology suppliers. There is a global consortium designing a standard protocol for logistics traceability based on RFID tags (IBM, 2007), but systems cost continues to be limiting. Electronic barcode are a fraction of RFID costs, but do not have the same capabilities for enabling rapid response. However, advances in technologies will continue to drive cost of RFID and other rapid response targeted technologies lower and more affordable over time.

Rapid response, targeted technologies have significant long-run benefit potentials. Potential savings from a single outbreak like the 2006 *E. coli* O157:H7 outbreak indicates benefits of minimizing recall loss may by far outweigh the cost of compliance of the LGMA traceability investments (except in the implementation of Active RFID Tags for large growers in this case). Noticeably, the compliance costs of LGMA membership ($0.0128 -$0.0158 per pound, with the associated record keeping and traceability costs ranging from $0.0026 to $0.0071 per pound) are significantly lower than the potential benefits of avoiding the 2006 *E. coli* O157:H7 outbreak and product recall. Since the implementation of the LGMA and its traceability system there has been several timely interventions and fewer recalls, mostly voluntary lower class recall. This study makes its primary contribution to the goal of greater traceability by trying to show how the conditions that enable or impede traceability emerge from supply network structure. The study also suggests that investments in rapid response, targeted trace back systems could be cost-effective by minimizing trace back response rates.

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Table 1. Estimated Annual Industry Costs Relating to LGMA Compliance

Food Safety Employee Wages	Range
Average salary for food safety inspectors in the U.S.	$37,599
Approximate number of dedicated food safety employees	267
TOTAL ANNUAL FOOD SAFETY EMPLOYEE WAGES	*$10,038,933*
Irrigation Water Testing Expenses	
Average cost for water testing (per test)	$42-$70
Approximate number of annual water tests	73,956
TOTAL ANNUAL WATER TESTING EXPENSES	*$3,106,152-$5,176,920*
TOTAL ANNUAL LGMA MEMBERSHIP FUNDING	*$4,500,000*
Total Estimated Annual Operating Costs (LGMA Audit Compliance)	*$17,645085-$19,715,853*
Total Estimated Annual Investment Expenses	*$62,092,780-$71,000,000*
Total Estimated Costs Relating to LGMA Membership	***$79,737,865-$90,715,853***
Approximate annual volume of leafy greens in pounds (approx. 22-24 pounds per carton)	5,720,000,000-6,240,000,000
Total Estimated Annual Costs (LGMA Audit Compliance) per lb	***$0.0128-$0.0158***
Total Estimated Annual Costs attributed to traceability per lb (20-45%)	***$0.00256-$0.00711***

Source: Compiled from Tootelian (2008), USDA (2009), Cline (2007), and *Collards and Kale* (2002).

Table 2. Annual Costs Relating to Implementing a Traceability System, by Technology and Size

Type of Cost/Variables	Estimated cost	Comments
RFID System Components and Costs		
Passive Tag Average Cost	$0.16 per tag	Firms choose either Passive or Active
Active Tag Average Cost	$5.00 per tag	
RFID Label Average Cost	$0.175 per label	Average range $0.095 - $0.255 based on 1m tags
UHF Handheld Readers Average Cost	$800.00 per reader	Stationary readers average cost $900
Employee Training	$85.60 per employee	Training ranges between 6 and 10 hours per employee (Average of 8 hours) at $10.70 per hour
Fixed Costs		
RFID Strategy and Application	$170,000	50 - 200 person days of labor (100,000 - 240,000)
Third-party Service Provider Fee	$75,000	EPCglobal ($75,000 for annual sales $1B to $10B)
Employee RFID Certification Course	$1,249	RFID600: CompTIA RFID + Certification Course
Middleware License Average Cost	$400,000	One time investment in Middleware
Edge Servers Average Cost	$10,400	List price is $5,200/server (IBM rec two for RFID)
Information System Operating Costs	$210,000	Average of $17,500 monthly system maint. & mgt
RFID Maintenance and Consulting Costs	$70,000	15% to 20% of acquisition cost (middleware lic)
RFID System Integration Average Cost	$50,000	One time cost for system integration
Total Fixed Cost Depreciated Over 5 Years	**$21,168,106**	
Total Variable Costs (Passive Tag)		**Total Costs (Passive Tag): Fixed + Variable**
Total Variable Cost (Members 1)	$132,905	
Total Variable Cost (Members 2)	$518,006	
Total Variable Cost (Members 3)	$87,450,419	
Total Variable Costs (Active Tag)		**Total Costs (Active Tag): Fixed + Variable**
Total Variable Cost (Members 1)	$536,238	
Total Variable Cost (Members 2)	$4,853,840	
Total Variable Cost (Members 3)	$1,345,652,954	
Barcode System Components and Costs		
Variable Costs		
Barcode Label Average Cost	$0.005 per label	Can be as inexpensive as 0.005 (print your own)
Barcode Label Printer Average Cost	$850 per label printer	Zebra printers average between $400 - $1,500 in 09
Barcode Handheld Readers Average Cost	$400 per reader	Stationary readers average cost $700
Employee Training	$10.70 per hour	Estimate 1 hour of training per employee
Fixed Costs		
Strategy and Integration Costs	$5,600.00	Software develop and integration 2,800 respectively
Barcode Software Average Cost	$90.00	Reviewing products for sale
Barcode Software License Average Cost	$5,000	xPOSe Site License
Software Support/Hosting/Maintenance	$1,500	xPOSe Annual Maintenance fee per site
General Barcode Hardware Average Cost	$2,750	Ranges between $2,000 and $3,500
Barcode System Integration Average Cost	$50,000	Ranges between $40,000 and $60,000

Total Fixed Cost Depreciated Over 5 years	**$1,393,258**	
Total Variable Costs		**Total Costs: Fixed + Variable**
Total Variable Cost (Members 1)	$91,405	
Total Variable Cost (Members 2)	$192,281	
Total Variable Cost (Members 3)	$1,585,133	
Shipment Volume Category (Pounds)	***Number of Members***	***Total Cartons***
0 to 100,000 (Member 1)	40	83,333
100,001 to 999,999 (Member 2)	43	895,833
More than 1 million (Member 3)	35	259,959,201
Standard Carton of Packed Leafy Greens	24-count	(Approximately) 24 pounds/carton
Leafy Greens Volume/Acre	29,000 lbs per acre	Range 13,000 to 45,000 pounds per acre (average)
Number of total Cartons (AZ) - 15% of LGMA	52,000,000	
Number of Total Cartons (CA) - 75% LGMA	260,938,368	
Total Volume of L.G. in CA	6,240,000,000	
Average Number Acres per Employee	62	farm example: 3000 acres with 49 employees
(Approx.) Total CA Leafy Greens Employees	4,540	
Variable Costs Individual Calculations		
Passive Tag Cost	$41,750,138.89	Based on number of cartons (one tag per carton)
Active Tag Cost	$1,304,691,840.28	
RFID Tag Cost	$45,664,214.41	
Barcode Label Cost	$1,304,691.84	
UHF Handheld Readers ($800 per reader)		
0 to 100,000 (3 readers)	$2,400	
100,001 to 999,999 (6 readers)	$4,800	
More than 1 million (12 readers)	$9,600	
Barcode Label Printer ($850 per printer)		
0 to 100,000 (1 printer)	$850	
100,001 to 999,999 (2 printers)	$1,700	
More than 1 million (4 printers)	$2,550	
Barcode Handheld Reader ($400 per reader)		
0 to 100,000 (3 readers)	$1,200	
100,001 to 999,999 (6 readers)	$2,400	
More than 1 million (12 readers)	$4,800	
Employee Training ($10.70/hr/employee)		
0 to 100,000 (840 employees)	$8,988	
100,001 to 999,999 (1,075 employees)	$11,502	
More than 1 million (2,625 employees)	$28,087	

Table 3. *Estimated Failure Costs Linked to the 2006 E. coli O157:H7 Outbreak and Recall*

Recall Related Costs	
Retail value of Dole Baby Spinach (per unit of 3 lbs)	$3.89
Approximate number of units recalled	42,000
TOTAL RECALL RELATED COSTS	*$163,380*
Lost Productivity Expenses	
Lost productivity due to E. coli O157:H7 (per case)	$1,871.96
Approximate number of E. coli O157:H7 cases linked to outbreak	204
TOTAL LOST PRODUCTIVITY EXPENSES	*$381,879.84*
Medical and Loss of Life Calculations	
Did not visit physician and survived (per case)	$28
Estimated unreported cases	6,000
TOTAL	$168,000
Visited physician and survived (per case)	$495
Approximate number of cases	100
TOTAL	$49,500
Did not have HUS and survived (per case)	$6,550
Approximate number of cases	70
TOTAL	$458,500
Had HUS and survived (per case)	$36,525
Approximate number of cases	31
TOTAL	$1,132,275
Had HUS and did not survive (per case)	$6,766,498
Approximate number of cases	3
TOTAL	$20,299,494
TOTAL MEDICAL AND LOSS OF LIFE COST	*$22,107,769*
Industry Lost Sales Following Outbreak and Recall	*$80,000,000*
Federal Funding (within Iraq Bill) to Compensate "Innocent" Farmers	*$25,000,000*
USDA Grant Funding to Identify Source of Outbreak	*$1,200,000*
Total Estimated Failure Costs (2006 E. coli Outbreak)	***$128,853,028.84***
Approximate vol. of contaminated product (pounds)	15,750

Source: Compiled from CIDRAP (2007), McKinley (2006).

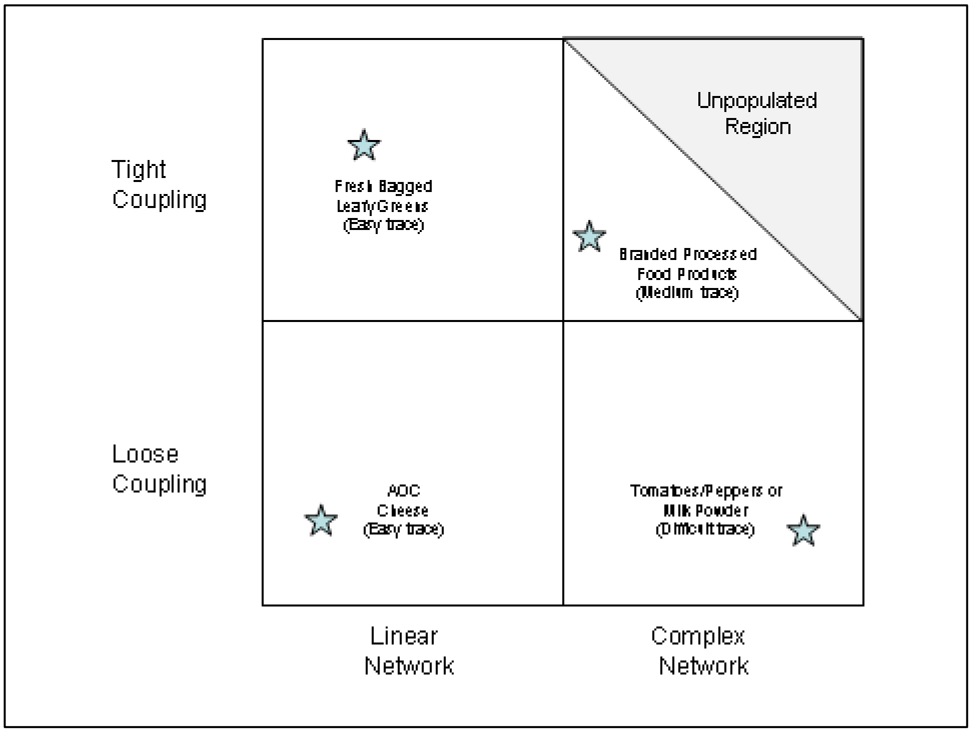

Figure 1 Supply Network Complexity/Coupling and Ease of Traceability
Source: Skilton and Robinson (2009).

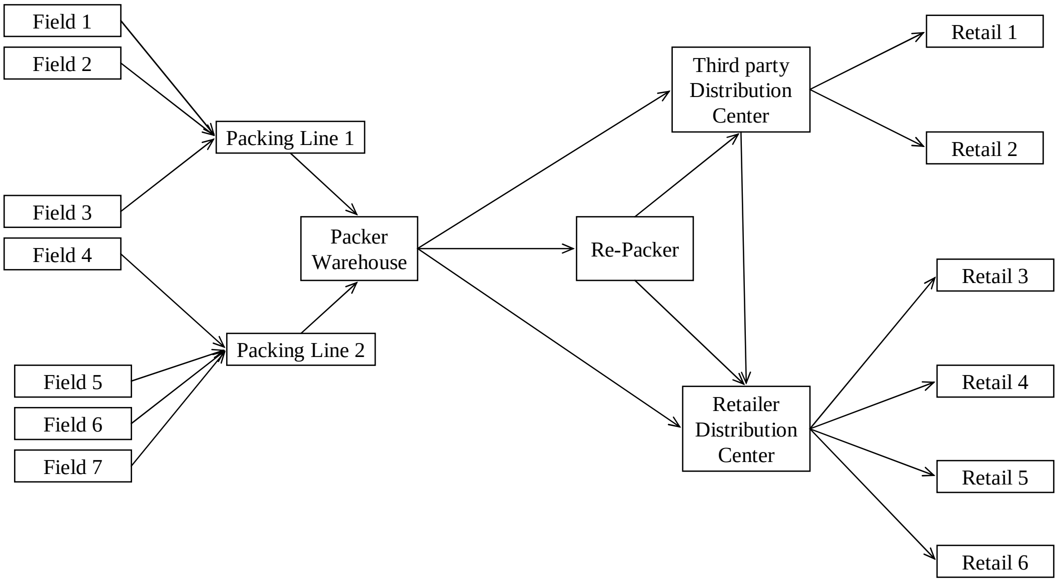

Figure 2. Leafy Greens Supply Network