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The value of genetic information in a whole-chain traceability system for beef

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Abstract:
An animal traceability system can help control disease, improve food safety, improve production practices and provide enhanced marketing opportunities. However, attempts to establish a beef traceability system in the U.S. has faced resistance from many beef producers. Some of the reasons for resistance were cost, lack of confidentiality, and lack of accuracy of the system. Moreover, those who incurred the costs would not necessarily have received the benefits of such a system.

This study evaluates the costs of a whole chain traceability system and compares them to the benefits of a traceability system in improving feed efficiency of cattle. We determine the cost saving from purchasing a higher proportion of high-efficiency cattle using the information available in the whole chain traceability system. We also determine the benefits that should be shared among cow/calf, stocker and feedlot operators to motivate them to adopt such a system.

Results show that while cow/calf producers would bear most of the cost of a traceability system, they would also receive the least benefits. To make participation in a traceability system profitable for cow-calf producers, the results indicate that $20 per head additional income should be transferred to the cow/calf and stocker producers. This additional income transfer will cover the costs of whole chain traceability system and also provide additional profit that will motivate the cow/calf and stocker producers to participate in such a system. The feedlot also gains a net cost saving of $19 per head after transferring the additional income and paying its own traceability cost. Thus, by reducing feeding cost, a whole chain traceability system that provides information about the feeding efficiency of cattle can provide additional profit to the cow/calf, stocker and feedlot operators even after covering the costs of implementing the traceability system.

Introduction

Traceability systems can play a great role in improving food safety (Fritz and Schiefer 2009). They can help to identify sources of contaminated food and reasons for contamination. This information can assist in minimizing the effect of food contamination and improving quality assurance programs. Hence, developing a traceability system is valuable for many food sectors, although for individual food producers participating in a traceability system may increase costs and required production activities.

The beef industry is one of the food sectors that gets much attention due to relatively long production cycles and high risk of epidemic disease outbreak. Traceability systems in the beef industry could potentially aid animal disease control, improve food safety, increase consumer confidence and reduce international trade restrictions (Schnepf, 2009). According to Schnepf (2009), traceability systems minimize animal health surveillance cost. Furthermore, traceability systems reduce the cost of controlling animal diseases outbreaks by quickly identifying the affected animals and minimizing the number of animals to be treated or destroyed. Currently, most major beef producing countries have already implemented mandatory beef traceability systems that enable them to have a high participation rate (Schroeder, 2011). In 2005, the U.S. implemented a voluntary national animal identification system (NAIS) for many species of animals including cattle. However, the beef traceability system faced much resistance from producers due to cost, lack of confidentiality, and lack of accuracy of the system (Schroeder and Tonsor, 2012). The resistance led to low producer participation and abandonment of the effort.

The low participation of the U.S. voluntary beef traceability system may cause serious adverse effects in controlling a major animal disease outbreak. In addition, the U.S. may lose substantial export markets in the time it takes to trace the source and control disease outbreak. For example, according to Schroeder and Tonsor (2012), the 2003 BSE case in the U.S. resulted in beef import restrictions on U.S. beef by almost all countries for at least one year. It also took at least seven years for the export market to reach approximately the same level it was at before the 2003 BSE case. Some countries may also refuse to accept any imports from the U.S. if they are not traceable. As a result, U.S. producers may lose competitive advantage in the international beef markets.

Several studies have estimated the economic benefits of a traceability system, particularly through enhanced export activity, and consumers' willingness-to-pay a premium for traceable beef (e.g., Dickinson and Bailey 2005, Resende-Filho and Buhr 2006, Loureiro and Umberger 2007, Pendell et al. 2010, Lee et al. 2011,). Although these benefits can be partially transferred to producers, the level of benefit might not be enough to convince individual beef producers to participate in a traceability system. While several studies have measured the overall economic benefit of a traceability system, few studies have estimated the benefits to individual beef producers. Therefore, the purpose of this research is to determine typical beef producers' costs and benefits of participating in a proposed beef traceability system.

Objectives

The purpose of this paper is to evaluate the net benefit to cow/calf producers of transferring parentage information from cow/calf producers to feedlot operators through a whole-chain traceability system. Not only must there be a large enough benefit in the supply chain to justify the cost of providing the information through a traceability system, there must be a way for feedlot operators to pass a sufficiently large price incentive through the chain to cow/calf producers to encourage them to supply high-feed-efficiency calves and to provide information about those characteristics.

The specific objectives are:

1) Determine the cost of traceability systems for cow/calf, stocker and feedlot operators.
2) Determine the benefit to cattle feeders from having information about parentage of the feeder animal that increases feed efficiency.
3) Determine the amount of benefit that would need to be transmitted back to the cow/calf producer for the producer to supply high-feed-efficiency animals and provide the accompanying information.

Review of Literature

According to Golan, Krissoff, and Kuchler (2004), traceability is defined by international standard organizations in broad terms as the "ability to trace the history, application or location of that which is under consideration." Traceability systems are also defined by Golan et al. (2004), as "recordkeeping systems designed to track the flow of product or product attributes through the production process or supply chain." Hence, cattle traceability systems show the history of individual animals from birth to meat products. The traceability system could be divided into two segments: the live cattle traceability system and the meat traceability system (Schnepf 2009). The live cattle traceability system provides the history of cattle from birth to slaughter. The meat traceability system provides the history of the meat from the slaughtered cattle until it reaches the consumer.

Cattle traceability systems in major beef producing countries

Many large beef producing and exporting countries have adopted some sort of cattle traceability system (Souza-Monteiro and Caswell 2004; Schroeder and Tonsor 2012). The type and level of beef traceability systems adopted in the world's major producing countries are summarized in table 1, adopted from Souza-Monteiro and Caswell 2004. The table shows that Japan and the European Union have implemented the most advanced mandatory traceability system. Their systems have higher depth, breadth and precision. They are capable of tracing beef product to a specific animal or group of animals. The farm where the animal was raised can also be traced in these countries' traceability systems. The precision of the system is also guaranteed by continuous inspection by government authorities. In Japan, DNA samples are taken to further improve precision of the system.

According to Sugiura and Onodera (2008), the Japanese traceability system was primarily adopted to improve cattle's health and food safety. The BSE outbreak in 2001 prompted quick

design and implementation of a traceability system. Review of the system at various times showed that the system achieved its objective of early identification of a suspected BSE affected cattle. The system also enables users to identify the group of animals that are in contact with the suspected animals. The database of the system is maintained by government namely the National Livestock and Breeding Center (NLBC).

Australia and Brazil were motivated to adopt traceability systems mainly by trade requirements by the major beef importing countries and concerns regarding animal disease (Souza-Monteiro and Caswell 2004). In 2004, Australia and Brazil implemented mandatory traceability for export beef. The Australian system is more accurate as it uses an electronic tag (RFID). The Brazilian system is also broader than those of the EU and Japan since it includes more animal characteristics. However, both the Australian and Brazilian traceability systems lack depth since they do not link retail beef to a carcass or a group of carcasses.

According to Lima, Bornstein, and Cukierman (2006), the Brazilian traceability system focuses on the export market. The Brazilian beef market share increased and they became the number one exporter of beef due to the implementation of a traceability system, Brazilian economic reform and other trade opportunities such as a decrease in the U.S. and Canadian market share due to the BSE outbreak. However, small beef producers did not like the system since they incurred extra costs and Brazilian consumers have little to no willingness-to-pay extra for traceable beef. Brazilian consumers favor less expensive beef due to their low income level. Hence, traceability systems faced huge resistance in the domestic market. The resistance resulted in difficulty of expanding the traceability system in Brazil.

The Australian traceability system was implemented in the entire beef producer industry. According to Tonsor and Schroeder (2006) the Australian traceability system is an advancement of the National Vendor Declaration (NVD). The NVD was a paper-based quality assurance certificate that was required when marketing beef cattle. The Australian traceability system is a centralized system in which the database is managed by a privately funded organization. The system uses RFID tags or rumen boluses to label each individual animal.

Argentina and Canada adopted a less advanced traceability system. (Souza-Monteiro and Caswell 2004). Their traceability system is less precise since it relies on information given by the producer and animal health professionals. Argentina's traceability system is mandatory only for beef exports targeted for the EU and Japan. As of 2004, the Canadian traceability system was only recording animal identifications without their movement records.

According to Carlberg (2010), the Canadian traceability system has undergone many modifications and updates. A major modification was made in 2006 that resulted in the design of a better system, called the Canadian Livestock Tracking System (CLTS). The CLTS included the capacity to record premise ID, better movement tracking and other advanced features. The Canadian Cattle Identification Agency is in the process of implementing the CLTS throughout the nation. The pace of implementation varies from region to region. Some of the regional governments of Canada like Quebec and Alberta have implemented most of the advanced

features of the system like mandatory premise ID recording and tracking of animals. Overall, the Canadian traceability system shows good performance. The system has a high participation rate, implemented across multiple species, and has provided valuable support in the investigation of reported animal diseases since 2003.

According to Ortega and Peel (2010), the Mexican national animal identification system has been carried out by SINIIGA which is a component of the Livestock Productivity Enhancement Program. SINIIGA's policies were managed and controlled by Mexican animal-related agencies including SAGARPA (the federal national animal organization). SINIIGA's operation is carried out by CNOG (the National Cattlemen's Association). CNOG has performed the successful tagging of about 19% of Mexican cattle. However, SINIIGA is not yet recognized by APHIS (Animal and Plant Health Inspection Service of USDA) and does not include a successful information database that could be used for the animal health system. These problems of SINIIGA inspired the creation of new animal identification systems by various Mexican states who want to expand their exports.

U.S. cattle traceability system

The U.S. is one of the largest beef producing countries without a mandatory animal traceability system (Murphy et al. 2008), although it does have a few private systems implemented by some producers to capture certain type of markets (Souza-Monteiro and Caswell 2004). Many beef producers are not interested in adopting traceability systems due to cost, fear of too much government intervention and technology constraints (Schroeder and Tonsor 2012). Those authors note that lack of a traceability system provides a competitive advantage to other major beef producing countries. In addition, major importing countries like the European Union, Japan, and South Korea have already developed beef traceability systems. These may allow them to put sanctions on exports to countries that are not implementing traceability in order to protect their animal and human health safety. Hence, it may create further challenges for U.S. beef exports.

Various forms of animal identification systems were used in the U.S. for a long time (Schroeder and Tonsor 2012). Animals were usually identified through tattoos or ear tags. The tattoo could be a brand name of the animal owner, which may not identify individual cattle. The ear tag identification was usually replaced with another when animals were sold so that the current owner standards of identification would be met. These old cattle identification systems were primarily used to prevent animal theft, and/or eradicate certain types of animal disease. The disease eradication and prevention programs often used different identification systems for each program.

The National Identification Task Force, which is organized by the National Institute for Animal Agriculture, developed the USAIP (United State Animal Identification Plan) in 2002 (Murphy et al. 2008). USAIP was designed to improve the identification system and develop a nationwide system. The 2004 BSE outbreak in the U.S. and Canada increased the perceived need for a more robust and nationwide identification system (Schroeder and Tonsor 2012). Thus, many modifications were made to the USAIP and in 2005 USAIP was renamed the National Animal

Identification System (NAIS). NAIS was designed for various animal species, namely, sheep, swine, chicken, turkey, hog and cattle (Schnepf 2009). Among the various animal species, the NAIS for cattle faced great resistance from producers. The resistance was due to the cost, confidentiality and accuracy of the system (Schroeder and Tonsor 2012). In 2006, the resistance led to changing mandatory participation in the system to voluntary participation in the system.

According to Schroeder and Tonsor (2012), NAIS for cattle was abandoned in 2010 and a new mandatory traceability system was developed for cattle crossing state lines. This new system is called Animal Disease Traceability (ADT) system. ADT system is strictly designed for preventing and controlling animal diseases. In this ADT system, only cattle that are going to be transported to other states for trade or other reasons have to participate in the mandatory traceability system. They note that the U.S. voluntary traceability system involved only 10% of produced beef. Moreover, the new mandatory ADT system will only be used for animals that are going to cross state lines. Hence, by not having a traceability system, they argue, the U.S. is missing not only the benefits of traceability but also is ceding a competitive advantage for other beef exporting countries.

Benefits of a cattle traceability system

Various studies show the benefits of beef traceability for the nation as well as the beef industry. Pendell et al. (2010) showed the adverse effects of a lack of a beef traceability system when an animal disease outbreak occurs. According to this study, the U.S. could lose a total consumer and producer surplus of $6.65 billion if at least 25% of its untraceable beef product is unacceptable in international trade. Furthermore, they showed that a 1% increase in domestic demand or 34.1% increase in export demand would fully cover the cost and surplus loss of adopting a traceability system with a 90% participation rate.

Resende-Filho and Buhr (2006) showed the positive impacts of traceability in the beef and pork industry when substantial negative food safety news is reported by the media. They estimated the demand for meat using a generalized almost ideal demand system model (GAI) that incorporates food safety incidence as an exogenous variable. The food safety incidence variable is measured by counting beef, pork, poultry, and other non-meat safety issues (such as news related to Bovine spongiform encephalopathy (BSE), zoonosis, salmonella, listeria, and E. coli) reported in the top 50 news articles. Using the estimated expenditure from the GAI demand model, revenue is compared under the assumption the country has adopted a beef and pork National Animal Identification System with an assumption of no traceability system.

In the scenario with traceability, they assumed adoption of NAIS would create consumer confidence, and there would be no reduction of sales due to a negative safety incidence report. They determined that the beef and pork industry could have generated additional revenue of $10.43 million per quarter if they had adopted the NAIS system. However, they noted that the extra revenue is insufficient to cover the $27 million per quarter estimated cost of implementing traceability. However, their model only shows demand shifts among meat categories. Consumers who stop or reduce meat purchases because of food safety concerns about beef and pork were not considered in the model.

The above study which focused on the aggregate benefits may not provide sufficient justification for each U.S. beef producer individually to participate in the voluntary traceability system (Golan, Krissoff, and Kuchler 2004). Hence, various studies were conducted on the consumer level in order to show the extra premium price that can be achieved from a traceable beef product. Lee et al. (2011) studied consumers' willingness to pay for beef traceability and the information impact on willingness to pay for imported U.S. beef in the Korean beef market. They used a random n^{th} price experimental auction to determine consumer willingness to pay for the traceable beef attribute. They found that consumers were willing to pay a 1.00 to 1.30 Australian dollar premium for 200 grams of imported beef that has a traceable attribute.

Loureiro and Umberger (2004) also studied U.S. consumers' willingness to pay using a nationwide mail survey. They asked participants to choose which ribeye steak they would want to purchase among steaks with varying attributes. Participants were also required to separately rate each attribute of beef. A choice experiment was used to convert the preference stated for each attribute on the survey to the price that the consumers were willing to pay for that attribute. The result showed that consumers were willing to pay an extra $1.031 per pound for a traceable ribeye steak holding constant the food safety and tenderness quality attributes of the steak. Although participants were willing to pay extra for traceability, they weren't willing to pay a sufficient amount for Country of Origin Labeling (COOL). The authors attribute this discrepancy to the extra food safety confidence provided by traceability.

In another consumer willingness-to-pay study, Dickinson and Bailey (2005) used an experimental auction to determine the amount consumers were willing to pay for beef traceability. The experiment was carried out in four countries (U.S., U.K., Canada and Japan) using a choice of lunches prepared with beef that had traceability, food safety, humane animal treatment, and a combination of all the mentioned attributes. The researchers found that participants were willing to pay extra for each attribute in all countries. Participants from U.S. and Canada were willing to pay a 7-9% premium for beef traceability. Furthermore, they concluded that consumers in U.K. and Japan were willing to pay more for traceability than U.S. and Canada probably because they experienced recent animal safety problems.

Angulo and Gil (2007), on the other hand, concluded that consumer willingness to pay was related to perceived beef safety risk. From a telephone survey of 652 participants in Spain, they found that 73% of respondents were not willing to pay extra for beef traceability. Those willing to pay extra said they would pay on average a 5% premium price for traceable beef products. Furthermore, the authors showed that willingness to pay decreased with a decrease in consumer risk perception of beef products. Hence, the majority of respondents who were not willing to pay extra may have lower perceived risks that make them think traceability is not a necessary attribute of beef.

Several articles have focused on the economic benefits of beef traceability from society's perspective or from a consumer's perspective. Pendell et al. (2010) and Resende-Filho and Buhr (2006) showed the positive impact of traceability on society's welfare and on the industry's

total revenue. Also, the studies by Lee et al. (2011), Loureiro and Umberger (2004) and Dickinson and Bailey (2005) showed that consumers on average are willing to pay some premium amount for traceable beef products. These benefits can be partially transferred to the producers. However, few studies have been conducted on the benefits of traceability to individual producers.

Costs, problems and concerns of cattle traceability system

Although cattle traceability systems have many benefits, opponents of traceability systems claim that they have weaknesses. One of the weaknesses of traceability systems is that they will result in higher costs to the cattle industry (Schnepf 2009). This additional cost may not be covered by the additional revenue that might be obtained from increase in willingness-to-pay for traceable beef. Moreover, the additional cost will greatly affect small scale producers and cow/calf producers (Schnepf 2009). The traceability cost is greatly affected by the size of the operation due to a high initial investment cost. A large portion of the traceability system cost is the cost of tagging, which would be undertaken primarily in the cow/calf stage, a stage characterized by many small producers who would have difficulty absorbing the cost.

Another criticism of NAIS is the potential lack of confidentiality of collected business data (Schnepf 2009). Producers fear that the information collected by the government might not be fully secure. The data stored could be accessed by others and the confidentiality of producers' sensitive information could be compromised.

The accuracy, speed, and technical complexity of the traceability system are also concerns of producers (Bolte et al. 2007). Producers want the traceability system to provide accurate information without affecting the speed of cattle trade. In addition, producers are concerned that the traceability equipment such as the RFID reader, the database, and computer hardware could provide potential complexity to producer activity (Schnepf 2009).

U.S. beef production system

Beef in the U.S. passes through a number of specialized companies before the final beef product reaches consumers at the retail shop or restaurant level. The first operation in the beef supply chain is the seed stocker company. The seed stocker specializes in producing sires and dams that have superior genetics (Gildersleeve 2010). The sires and dams from this company will produce healthy and highly productive calves that will satisfy customer demands. Cow/calf producers purchase these sires and dams from seed stock companies. In addition to purchasing dams, the cow/calf operator will also use heifers born at its' own facility to replace low performing cows.

Cow/calf operators usually keep cows until they fail to rebreed, wean light-weight calves, or become unsound. Cows are usually expected to produce one calf per year. Calves will be weaned when they reach 6 to 10 months old (http://www.explorebeef.org/ raisingbeef.aspx). To further add value to calves at this stage, a preconditioning process lasting 21 days or longer could be conducted to help prepare calves for better performance as stockers. Preconditioning is a set of management practices such as dehorning, vaccination, weaning, and castrating calves

that will help to produce healthy and productive steers, although Williams et al. (2013) report that few producers adopt these practices.

Stocker operators raise calves for 3 to 9 months, feeding them grass and other supplement feeds (Cattlemen's Beef Board and National Cattlemen's Beef Association 2009). Grass-fed stocker animals are typically sold to feedlots to produce grain-finished beef product. Feedlot operators feed calves high-nutrient food on the bunk for a 4- to 6-month period (Cattlemen's Beef Board and National Cattlemen's Beef Association 2009). When steers reach about 1,200-1,400 lbs, they are sold to a meat packer. The beef carcasses, primals, and package beef are sold to restaurants, supermarkets, international markets, or food processing companies.

Cattle feed efficiency

Feeding cattle is one of the major activities of cattle production. The cost incurred for feeding cattle is the single largest variable cost (Sherman, Nkrumah, and Moore 2010). A traceability system can provide information that will be used improve cattle feed efficiency, providing potentially large cost savings. Besides procuring cheaper feedstuff inputs and improving various management activities, feed efficiency could be improved by raising animals that have higher feed efficiency genetic performance.

Many feed efficiency genetic characteristics of cattle are moderately heritable (Herring 2003, Elzo et al. 2009). Thus the cow/calf operator and seed stocker operator could produce cattle with higher feed efficiency through selection or other genetic related management activities. However, feed efficiency improvement activities were not given enough consideration by the seed-stock producers due to the difficulty of measuring such variables related to feed efficiency (Herring 2003). Measuring the feed efficiency variable of cattle without interpreting the normal activities requires special technological equipment. New technology is available to perform such activities and has been used in research and testing facilities.

Feed efficiency levels can be measured through average daily gain (ADG), feed conversion (FC), daily feed intake (DFI) and or net residual feed intake (NRI) variables. Average daily gain is the amount of weight the calves gain per day. Daily feed intake is the amounts of feed calves consume per day. Feed conversion is the amount of weight the calves gain per unit of feed intake. According to Elzo et al. (2009) net residual feed intake measures the difference between the amount of feed the animals are expected to eat and the observed amount of feed intake. NRI is widely used to measure feed efficiency because the NRI avoids the effect of weight and other environmental variation.

Conceptual Framework and Procedures

Hypotheses

Implementation of a cattle traceability system is assumed to start from the cow/calf stage. The calf is tagged and registered in the producer's own database or in a third-party database. The registered data could include information such as parent's tag id, calf's sex, birth date, birth weight, medical history, performance improving drugs used, feeding details and other management practices. In a traceability system, the stocker operator in the next stage will also

register cattle information keeping the link that relates them with the records kept at the cow/calf operator stage. However, since the cattle are already tagged at the cow/calf stage, there will be no tagging costs except a small amount for replacement of lost tags. Moreover, the cost of tagging is a substantial component of a traceability system at the cow/calf stage (Schnepf 2009). Hence, we hypothesize that

- H1: The cost of traceability incurred by a cow/calf operator is more than the cost of traceability incurred by the stocker and feedlot operator.

Measuring feed efficiency levels at commercial feedlot operations requires special feeding facilities that might not be profitable for the feeder cattle. However, feed efficiency measurement of dams and sires could be profitable for cow/calf operators since it could save feeding cost and produce more efficient calves. Thus, feedlot operators could get information about feed efficiency of feeder cattle parents from cow/calf or stocker operators through the traceability system. From this parentage information, efficiency of feeder cattle could be determined. Feeders could get the parentage information by paying a premium, and use the information in selecting high-efficiency calves. The remaining low performing calves could be sold to the veal market or to other markets that don't require as much feed efficiency. Hence, we hypothesize that:

- H2: Feedlot operators will purchase a higher proportion of high-efficiency calves through participating in a traceability system.

Improvement in feed efficiency saves feeding cost for the feedlot operator. Since the largest variable cost of feedlot operator is feeding cost, improving average feed efficiency will substantially increase the profit of raising cattle. Thus, we hypothesize that:

- H3: The reduction in cost of gain due to improvement in feed efficiency at the feeder stage is greater than the cost of traceability.

The feedlot operator wants to maximize profit by decreasing the cost of gain as well as the cost of purchasing feeder cattle. However, decreasing purchasing cost of calves will not motivate the cow/calf operators to find ways to improve feed efficiency level. Thus, the cow/calf operators require additional income to implement the traceability and management practices that improve feed efficiency. The additional income will enable them to cover the cost of implementing the practices and earn some additional profit. Thus, we hypothesize that:

- H4: The income transfer schedule will share profit and provide incentives for cow/calf operators to implement traceability systems and management practices that will increase feed efficiency.

Cost of adopting NAIS

Butler et al. (2008) developed a model that shows the cost of participating in NAIS for California beef producers. The model was adapted from a traceability cost model prepared for the European traceability system. The traceability cost model is expressed in the following function form:

$$Y = a + b/x \qquad (1)$$

where Y is total traceability cost per head,

x is the number of cattle which expresses the producer capacity level,
a is intercept
b is slope of the model.

The model was developed for each expense category, beef production stage and time period. Expense categories were labor, service, material, and equipment. Beef production stages were cow/calf phase, stocker phase, and feedlot phase. Time periods were classified as initial costs and ongoing costs. Butler et al. (2008) said that the slope and intercept coefficients for each category model were developed from data obtained through survey and published literature. We prepared traceability cost partial budget tables for cow/calf, stocker and feedlot operators using the values of slopes and intercepts reported in Butler et al (2008) for each expense category. Tables were developed for various production capacity levels. Selected production capacity levels for each production stage are similar to the levels reported on Blasi et al. (2009) so that we can easily compare the traceability costs. The traceability calculations are reported in tables 2-4 and in figure 2.

Although Butler et al. (2008) developed the cost model for RFID static, RFID dynamic, and Visual Identification systems, we focus on RFID static. RFID static is cheaper than RFID dynamic especially at lower production capacity levels since RFID static uses less equipment than RFID dynamic.

Figure 2 shows that per head traceability cost for all operation types decreases rapidly until a production size of 493 is reached; for operations bigger than that, per head traceability cost continues to decrease but at a slower pace. Costs decrease more quickly for smaller operations because equipment costs make up a relatively large portion of the total cost. For larger operations, traceability cost approaches $3/head for cow/calf operators, $1.28/head for stocker operators and $1.26/head for feedlot operators. Figure 1 also shows that traceability cost per head for cow/calf operators is less than the cost for stocker and feedlot operator up to a 493-head operation. Above 493 head, cow/calf operation cost is the highest. The traceability cost for cow/calf operation exhibited this behavior since the equipment proportion of the cow/calf operator cost is less than for the feedlot and stock operator.

Blasi et al. (2009) developed the traceability cost of participating in NAIS using data from surveys, internet and published literature. They studied costs of implementing RFID traceability system for cow/calf, stocker and feedlot operators separately. Costs for cow/calf operators are reported in tables 5 and 6. Table 5 shows traceability costs when the cow/calf operator already has some sort of tagging practice and only needs to upgrade the system to satisfy the NAIS system. Table 6 reports traceability cost when the cow/calf operator does not have a tagging system and needs to implement all system components. Traceability cost for stocker and feedlot operators which were determined by Blasi et al. 2009 are reported in tables 7 and 8. A summary of traceability costs for cow/calf, stocker and feedlot operators is shown in figure 2.

Figure 3 shows the traceability cost of implementing NAIS to cow/calf, stocker, feedlot operator based on Blasi et al. (2009) cost data. The figure also shows that traceability cost per head

decreases at a decreasing rate. As number of cattle sold increases, traceability cost approaches $5.44/head for cow/calf operators, $2.88/head for currently tagging cow/calf operators, $0.56/head for stocker operators and $0.30/head for feedlot operators. Traceability cost is highest for cow/calf operators that do not have previous tagging activity. Following non-tagging cow/calf operator cost, per head traceability costs were ordered as currently tagging cow/calf cost, stocker cost and feedlot operator cost. Traceability cost for cow/calf operators is higher since the major activity of tagging is undertaken at the cow/calf stage. Traceability cost for stocker and feedlot operator is almost equivalent since the traceability activities performed in those stages are similar.

Figure 4 shows traceability costs to cow/calf, stocker, and feedlot operators combining information from Blasi et al. (2009) and Butler et al. (2008) in the same graph. Traceability cost under Blasi (2009) is less than the traceability cost under Butler et al. (2008). The difference in traceability cost is greater at lower production capacities. These differences could be because some activities of traceability such as reading and tagging were outsourced in the calculations by Blasi et al. (2009). Outsourcing enables traceability costs to be under $8 per head. Figure 4 also shows that traceability cost to cow/calf operators under both Blasi et al. (2009) and Butler et al. (2008) approaches $3 per head as number of head increases. However, traceability cost to stocker and feedlot operators approaches $0.40/head (Blasi) and $1.25/head (Butler), a reduction of $2.60/head or $1.75/head, respectively.

Figure 5 shows the proportion of cattle sold per year by production capacity size for cow/calf, stocker and feedlot operators based on Blasi et al. (2009) data. More thFigure 3.4 for cow/calf operator shows that more than 85% of cattle were sold by operations with less than a 500-head capacity. That is, most calves were produced by small-scale producers. In contrast, for stocker and feedlot operators a larger proportion of cattle were sold by larger-size producers: fewer than 36% of stockers were sold by operators with fewer than 500 head and more than 80% of fed cattle were sold by feedlot operators with capacity over 2,000 head. The large sizes of stocker and feedlot operators would permit them to implement a traceability system with minimum per head cost compared to the higher per head cost incurred by cow/calf producers. Therefore, to increase cow/calf operators' willingness to participate in a traceability system, cow/calf operators must receive sufficient benefit to offset the large proportion of traceability costs they incur.

Procedures for determining cost of a whole chain beef traceability system

Whole chain beef traceability system is composed of the animal identification system and an animal tracing system. The animal identification system will be implemented using RFID ear tags. The animal tracing system keeps individual calves and parentage information along the supply chain of beef producing companies. In this traceability system, calves are tagged at birth and information regarding parentage, birth data, feed efficiency and other traits collected. This information is transferred to a third party and stored in a traceability database so that data can be linked with a specific animal at any level of the supply chain.

Some studies have investigated costs of adopting National Animal Identification System (NAIS) for participants in the different supply chain levels of beef production (e.g., Blasi et al. (2009), Butler et al. (2008)). Blasi et al. 2009 show the cost of traceability systems in a way that satisfies the guidelines of NAIS. Furthermore, they show impacts of scale as costs are reported for various production capacity levels. However, traceability system cost for this research is slightly different from their analysis since we are considering a typical beef producer interested in adopting the system not only for the disease control benefits of a traceability system but also for benefit of improving profitability. So, we adopt NAIS costs developed by Blasi et al. (2009).

Beef production stages in this traceability system are cow/calf, stocker, and feedlot operators. The operation size of the company selected as a typical beef producer is 100-499 cows for cow/calf operators, 345 calves for stocker operators and 1000-1999 feeder cattle for feedlot operators. These size cow/calf, stocker and feedlot operators produce on average 156 calves, 340 feeder cattle, and 968 fed cattle per year, respectively.

Traceability costs for adopting a whole chain traceability system can be divided into fixed costs and variable costs. These costs were calculated for cow/calf, stocker and feedlot operators separately using the following formula.

$$\mathrm{T}_k = \frac{\sum_{i=1}^{m} \left(\frac{FC_i*(1+\mathrm{r})^n}{n}\right) + \sum_{j=1}^{m} VC_j}{NH} \qquad (2)$$

where: FC_i is the ith equipment fixed cost of adopting the whole chain traceability system,
r = interest rate used for calculating the present value of fixed cost,
n = useful life in years of the fixed investment,
NH = average number of cattle produced per year.,
VC_j = annual variable cost of jth item or service, and
T_k = total per animal cost of adopting traceability for k^{th} producer (k = c for cow/calf, s for stocker, and f for feedlot) .

Fixed costs

Fixed costs include the RFID tag applicator, RFID reading equipment, and a computer which will be used for data storage. Blasi et al. (2009) reported costs of such equipment along with their useful life span based on internet surveys and previous literature. The cost of the RFID applicator reported in their study is $44.83. RFID applicators have a life span of four years. Furthermore, cow/calf operations 100-400 in size and stocker operations 350 in size require two RFID applicators; feedlot operations 1,000-1,999 in size require three applicators. The cost of the hand-held RFID reading equipment is $1,091. It is assumed to have a three-year life span. The reading equipment is expensive for a small number of cattle at the cow/calf and stocker operation level. Thus, it is outsourced for a reading fee of $1.88/head for cow/calf and $1.46/head for stocker operators. The cost of a laptop computer and basic software is $692. Those are assumed to have a four-year life span. We allocated only 50% of the cost of computers to the traceability system based on Blasi et al. (2009) suggestion that computers will

also be used for other activities of the company. The yearly present value of the above fixed costs for each operation is calculated based on an interest rate of 7.75%.

Variable cost

The variable costs of the traceability system reported by Blasi et al. (2009) can be divided into material, labor, service and other costs. The material cost includes the cost of RFID tags. The labor cost includes labor required for tagging, reading, and arranging the chute. The service cost includes the fee for database storage, and the chute. Other cost includes animal injury cost, human injury and animal shrinkage cost. In our study, we avoided shrinkage cost since our system has to tag animals starting from birth, and shrinkage of calves is likely minimal. (Shrinkage weight is the weight loss of calves that were shown in the difference between the seller measurement at the seller's premises and buyer measurement at the market place.) Also, the retagged animals in stocker and feedlot operations are expected to return to the production site and hence the lost weight will be regained. The shrinkage cost would be material if tagging were taken at the auction market and the cattle were not returned to the production site. This is because the sale value would be calculated based on shrink weight.

Blasi et al. (2009) reported the variable costs based on their findings from surveys and previous literature. The cost of RFID ear tags ranges from $2.00 to $3.00 per unit. The variation in cost is related to the volume discount and price policy of the companies selling tags. The largest portion of the tag cost will be incurred by cow/calf operators, since stocker and feedlot operators will only incur such costs for animals that have lost tags. The labor charge applied depends on number of employees and time spent on traceability related activities. The assumed labor charge is $9.80 per hour (US Department of Labor, 2007). The time spent on traceability related activities can be divided into tagging, reading and arranging the chute. It is assumed to take 30 seconds to tag an RFID tag onto a calf's ear. We also take the appropriate time required for arranging the chute and reading the tag from Blasi et al. (2009). The assumed service fee for the chute is $1 per head. The human injury cost is determined as 10% of the total labor charge paid following the Blasi et al. (2009) argument that employees can be insured against injury at this rate. The cost for animal injury that is incurred while undergoing tagging is taken from Blasi et al. (2009) based on the type of operation and number of animals found in that operation type. The assumed charge for database storage is $0.085 per head. Total costs for each operation were calculated by adding the fixed and variable costs. To find the per pound traceability cost, the total operation cost was divided by the average number of animals sold per year.

Procedure for determining cattle feeding cost

The feeding cost required to produce beef cattle varies based on the feed efficiency of the cattle. However, getting feed efficiency data is difficult since it is expensive to measure individual feed intake. Thus, we use the feed efficiency data from Elzo et al. (2009) and assume the industry feed efficiency data will be comparable with these data. Elzo et al. (2009) was carried out on 581 calves that consisted of 31 bulls, 317 heifers, and 233 steers. The study was carried out using GrowSafe® technology that measures the individual feeding performance of calves. The calves were born in 2006 (n = 330) and 2007 (n = 251). After preconditioning and

adjustment feeding for 21 days, they were randomly put on 3 different experiment stations located in Florida. Feeding performance data was gathered for 70 days. The calves born in 2006 were fed a concentrate diet composed of "whole corn, soybean hulls, corn gluten feed, cottonseed hulls, and a protein, vitamin, and mineral supplement (FRM, Bainbridge, GA)" (Elzo et al, P3878 2009). The calves born in 2007 were fed a diet that has higher fiber content since it replaced the soybean hulls with chopped bermudagrass.

The data taken from Elzo et al (2009) include the residual feed intake (RFI), daily feed intake (DFI), feed conversion ratio (FCR) and post weaning body weight gain (PWG). These data are categorized based on the RFI level as high-, medium- and low-efficiency cattle. The average daily gain is calculated by dividing the post-weaning gain by the 70 days the cattle were on the experiment. As there is no feeding cost data in the Elzo et al (2009) literature, we use cost data reported in other experiments. The cost per kg of feed is calculated by dividing the $2.43 daily feeding cost per kg by 1.63kg average daily gain and 6.73 feed gain ratios (Kumar et al. 2012).

The total feed cost is calculated by multiplying the unit feeding cost, feed conversion ratio and total weight gain in the feedlot. The total weight gain in the feedlot is assumed to be 226kg as many feedlot operators put feeder cattle at 318kg weight to produce a 544kg animal. The feeding cost per kg of weight gain is calculated by multiplying the feed conversion ratio by the per kg cost of feed. The feeding cost per kg of weight gain is converted to cost per cwt. using the appropriate conversion rate. The proportion of calves in each feed efficiency category is calculated by dividing the number of cattle in the respective category by the total number cattle in the experiment.

Procedures for determining income incentive schemes

Feedlot operators could minimize the total feeding cost through procuring a higher proportion of high-efficiency feeder cattle. Feeder cattle that have a high feed efficiency level will reach the required level of weight with less cost. Thus, feedlot operators could pay a premium for such cattle in order to motivate the cow/calf and stocker operators to produce and sell more high-efficiency cattle. A traceability system will help implement the income incentive scheme through passing feed efficiency information from the cow/calf to the feedlot operator. The process of using an income incentive scheme across time is shown in Figure 1.

Stocker and cow/calf operators could increase the proportion of high-efficiency cattle produced if they were paid a high enough premium to cover their expenses and gain additional profit for undertaking the risk of implementing certain management practices. Thus, we assumed that the proportion of efficient cattle shown in the feeding experiment will be improved when we implement the income incentive scheme.

Expression 3 calculates the aggregate probability of purchasing all feed efficiency levels of calves when the efficiency measurement system fails. The measurement system is said to fail when it can't relate the specific animal with the appropriate feed efficiency level. The second equation (4) verifies that the probabilities of purchasing each efficiency level of calves sum to 1.

$$P_{0*} = P_{0h} + P_{0m} + P_{0l} \quad (3)$$
$$P_{0*} + P_{1h} + P_{1m} + P_{1l} = 1 \quad (4)$$

Where: $P_{s(j)}$ is the probability of purchasing j level of feed efficiency calves at s traceability success event.

j is the level of feed efficiency where h= high, m= medium, l=low and * is for the aggregate of high, medium, and low feed efficiency level.

s is the feed efficiency measurement success event where 1= correctly identify the measurement level, 0= fails to identify the feed efficiency level of the animal.

The income incentive scheme will be designed using a model developed by Resende-Filho and Buhr (2008). The model objective function is to determine the income incentive for each feed efficiency level that minimizes the cost of purchasing and feeding calves, and is solved using nonlinear programming methods. The objective function is constrained by the cow/calf operator utility functions that should be greater than the utility obtained from the market price plus some additional payment for covering part of the risk premium. The cow/calf operator utility should also be greater than the utility obtained from the previous feed efficiency proportion of calves. In addition, income when producing high-efficiency cattle should be greater than that obtained with lower-efficiency cattle, the producer would have no incentive to provide more high-efficiency cattle. Before we describe the model mathematically we will first discuss the utility function for the cow/calf operators in the next sections.

Expression 5 calculates the utility of a specific net income to the cow/calf or stocker operator. The net income is calculated by subtracting the cost of undertaking a certain type of feed efficiency improvement action from the selling price of calves. Expression 5 is the inverse equation that determines the income level.

$$u\left(I_{s(j)}\right) = -e^{-k\left(I_{s(j)} - c_a\right)} \text{ with } k > 0. \quad (5)$$
$$I_{s(j)} = \frac{\ln -u\left(I_{s(j)}\right)}{k} \quad (6)$$

Where: $I_{s(j)}$ is the income transfer from the feedlot to cow/calf producer for j level of feed efficiency at s feed efficiency measurement success event.

$u\left(I_{s(j)}\right)$ is the utility level of cow/calf operator for each individual income transfer at given feed efficiency level and selected actions.

K is the risk aversion level of cow/calf operator under the constant risk averse(CARA) condition.

c_a is the cost of undertaking an action A, which could impact the calves feed efficiency level.

Expressions 7 and 8 calculate the expected utility of cow/calf operators from given income incentive levels and the cost of actions taken to improve feed efficiency. Resende-Filho and Buhr (2008) simplified this equation using multiplicative separable utility function conditions and specifying k as a constant absolute risk aversion (CARA) parameter. The utility level in this

equation is the weighted average of individual utility level of each net income a cow/calf operator receives from specific level of feed efficiency. Expression 7 represents the feed efficiency level probability of current calves sold, whereas expression 8 represents the feed efficiency level probability of calves before undertaking the improvement action.

$$\begin{aligned} EU(\, a_1 \backslash I_{0*}, I_{1h}, I_{1m}, I_{1l}) &= K(a_1)\left(P_{0*}\, u(I_{0*}) + \sum_{j=0}^{h,m,l} P_{1(j)}\, u\big(I_{1(j)}\big) \right) - d(a_1) \\ &= e^{k(c_{a1}+c_{c1})}\left(P_{0*} * -e^{-k(I_{0*})} + \sum_{j=0}^{h,m,l} P_{1(j)} * -e^{-k(I_{1(j)})} \right) \end{aligned} \tag{7}$$

$$\begin{aligned} EU(\, a_0 \backslash I_{0*}, I_{1h}, I_{1m}, I_{1l}) &= K(a_0)\left(P'_{0*}\, u(I_{0*}) + \sum_{j=0}^{h,m,l} P'_{1(j)}\, u\big(I_{1(j)}\big) \right) - d(a_0) \\ &= e^{k(c_{a0}+c_{c0})}\left(P'_{0*} * -e^{-k(I_{0*})} + \sum_{j=0}^{h,m,l} (P'_{1(j)} * -e^{-k(I_{1(j)})}) \right) \end{aligned} \tag{8}$$

Where: $P'_{s(j)}$ is the probability of purchasing j level of feed efficiency calves at *s* traceability success event when a_0 actions are selected by the cow/calf.

$EU(\,.\,)$ is the expected utility level of cow/calf operator from a given income incentive scheme level and type of actions selected.

a_0 is feed efficiency management practice action when a is not implemented.

a_1 is feed efficiency management practice action when a is implemented.

Expression 3.2.7 calculates the feedlot operators' average cost of purchasing and feeding certain feed efficiency level calves. The purchasing cost is determined by the average income transfer to the cow/calf operator based on the income incentive level and the probability of feed efficiency levels. The feeding cost is determined by calculating the total feed only costs required to raise calves from 700 lbs. to 1,200 lbs.

The nonlinear model that determines the incentive scheme is as follows

$$\begin{aligned} \text{Min } EU_c\ (I_{0*}, I_{1h}, I_{1m}, I_{1l}) = {} & P_{0*}\ I_{0*} + P_{0h}\ FC_h + P_{0m}\ FC_m + P_{0l}\ FC_l + +P_{1h}\ (I_h + FC_h) + \\ & P_{1m}\ (I_m + FC_m) + P_{1l}\ (I_l + FC_l) + C_f \end{aligned} \tag{9}$$

Subject to:

$$e^{k(c_{a1}+c_{c1})}\left(P_{0*} * -e^{-k(I_{0*})} + \sum_{j=0}^{h,m,l} P_{1(j)} * -e^{-k(I_{1(j)})} \right) \geq E\overline{U} \tag{10}$$

$$e^{k(c_{a1}+c_{c1})}\left(P_{0*} * -e^{-k(I_{0*})} + \sum_{j=0}^{h,m,l} P_{1(j)} * -e^{-k(I_{1(j)})}\right) \geq e^{k(c_{a0}+c_{c0})}\left(P'_{0*} * -e^{-k(I_{0*})} + \sum_{j=0}^{h,m,l} (P'_{1(j)} * -e^{-k(I_{1(j)})})\right) \quad (11)$$

$$I_{1h} \leq I_{0*} \quad (12)$$
$$I_{1h} \leq I_{1m} \quad (13)$$
$$I_{1m} \leq I_{1l} \quad (14)$$
$$I_h - I_m \leq FC_h - FC_m \quad (15)$$
$$I_m - I_l \leq FC_m - FC_l \quad (16)$$

where: EU_c is the expected utility for cost incurred in purchasing and feeding calves by the feedlot operator.
FC_j is the feeding cost incurred at the feeder level for j level of feed efficiency calves.
C_f is total traceability cost incurred in the feedlot stage.
C_c is total traceability cost incurred in the cow/calf and stocker stages.
$E\overline{U}$ is the expected utility level of cow/calf operator obtained from the income level based in the market price.

The expressions 10 - 16 show the constraints of linear programing that should be met to design a good income incentive schedule. These constraints make sure that the cow/calf and feedlot operators achieve their goals. In addition, the constraints make sure that the assumptions made in designing the simulation scenarios are met. The specific purpose of each equation is as follows:

Expression 10 ensures that the cow/calf utility level obtained from the income incentive schedule is greater than the utility level obtained from the current calf's market price. That is, this constraint checks whether or not the cow/calf operator gets more satisfaction by participating in the payment schedule than not participating.

Expression 11 ensures that the cow/calf producer's utility when taking action to improve feed efficiency is greater than utility obtained when those actions are not taken. This constraint makes sure that the incentive schedule provides sufficient income to motivate the participating cow/calf operator to implement the feed efficiency improvement action.

Expressions 12, 13, and 14 make sure that the calculated income transfer is higher for more efficient cattle. Expressions 15 and 16 compare the difference between income transfers and feeding cost. The feedlot operator will be willing to transfer more income for higher efficient

cattle up to the amount of feed cost saved. Expressions 15 and 16 ensure that this constraint is met.

Results and Discussion

The cost of traceability is adapted from Blasi et al. (2009) in a way that the whole chain traceability system under consideration achieves the requirements necessary for implementing an income incentive schedule. The traceability costs were mainly calculated for production scale sizes which in aggregate produce most of the U.S. cattle. The costs of implementing a whole chain traceability system for each phase of beef production are reported in Table 9. The reported traceability cost is classified into fixed and variable costs for easier comparison of costs across various stages of production.

Table 9 shows the cost of adopting the whole chain traceability system for the cow/calf, stocker, and feedlot operations. The total costs per year are $848.99, $422.07 and $808.53, respectively. The per unit traceability cost for each respective operation is $5.44 per head, $1.24 per head, and $0.84 per head. The cow/calf per head traceability cost is 5 to 6 times higher than the stocker and feedlot per head traceability cost. This difference is because the cow/calf operator pays for the major costs of the traceability system by undertaking the tagging activity. The stocker and feedlot operator only need to tag a small number of animals, those who have lost their tags. The traceability costs reported here are comparable with the findings of Blasi et al. (2009) and Butler et al. (2008) .

Cattle feed efficiency parameters were taken from Elzo et al. (2009). They measured the feed efficiency for 581 calves using GrowSafe® technology for 70 days. Measures of feed efficiency were estimated for all of the cattle that belong to various breeds as well as each distinguished breed type namely Angus, Brangus, Brahman and a cross between the Angus and Brahman breeds. The presences of different breed in the experiment make the aggregate data more resemble the commercial cattle data. The total breed results are reported in table 10.

Table 10 shows that 24.78%, 45.09% and 30.12% of the cattle belong to the low, medium and high category of efficiency, respectively. According to Elzo et al. (2009), the efficiency level of cattle is categorized based on the residual feed intake (RFI) level for which the positive, zero, and negative RFI belong to low, medium and high feed efficiency cattle, respectively. The positive RFI means that the calves consumed more than the expected level of feed based on the physiological and growth needs of the cattle. The near zero value of RFI belongs to the medium-efficiency level. The negative RFI means that the cattle consumed less than the expected level of feed. Table 10 also shows that the feeding cost for putting 100 lbs. weight on cattle with low, medium, high, and average feed efficiencies is $105.44, $74.60, $66.74, and $79.87, respectively. These values were calculated by multiplying the feed conversion ratio (FCR) by the per cwt. cost of purchasing feed.

The whole chain traceability system will help in keeping parent data as well as calf data. This record can be shown to the feedlot operator at the time of purchase as proof of genetic potential feed efficiency of the calf. The proof of parentage data can further be strengthened through a certification system. The certifications can guarantee that the traceability system and information reported by the cow/calf and stocker operations are accurate to the best knowledge of the certifier. It is assumed that calves which are born from high-efficient parents can be categorized in the high-feed-efficiency group. This assumption is in line with the conclusion by Herring (2003) and Elzo et al. (2009) that the feed efficiency trait is moderately heritable. The information found on the whole chain traceability system will enable the feedlot operator to implement the income incentive schedule payment and achieve a decrease in the feeding cost of cattle. The income incentive schedule payment was developed with a nonlinear programing model designed by Resende-Filho and Buhr (2008). The nonlinear programing model is described in expressions 9 - 16. The results of optimizing this model are reported in tables 11 and 12.

Table 11 shows income incentive schedule payments for various levels of feed efficiency at various traceability success rates. The traceability success rate is the percentage of cattle for which feed efficiency levels were correctly identified using the whole chain traceability system. The nonlinear program is optimized for 100%, 70% and 50% traceability success rate.

In table 11, the proportions of cattle of each efficiency level before incentives were taken directly from table 10, which is based on Elzo et al (2009). For the proportions of each efficiency level after incentive, we did not find literatures that showed the possible improvement of feed efficiency proportions achievable through selection activities. Thus, we assumed a 10% decrease in feeding cost could be achieved through selection management practices and sorting using information provided in a whole chain traceability system. The 10% decrease in feeding cost could be achieved from an increase in the proportion of high-efficiency cattle from 30% to 65%. The increase in high-efficiency cattle comes from a decrease in the proportion of medium-efficiency cattle from 45% to 28% and of low-efficiency cattle from 25% to 7%. These values are multiplied by each of the alternative success rates to determine the proportions for the “failed sorting” and each of the “feed efficiency level” categories as shown in table 11.

With 100% traceability success rate, the feeding cost to raise cattle from 700 lb.-feeders to 1,200 lb.-fed cattle decreases from $398.55 to $358.07, a reduction of $40.48 per head. The feeding cost is calculated by multiplying cattle weight gain at the feedlot and feeding cost for each feed efficiency by the respective proportion of cattle at each feed efficiency level. The decreased feeding cost after implementing selection and whole chain traceability system is equal to $40.48 per head. This decreased amount was achieved as the selection activities may enable the feedlot operator to procure more high feed efficiency cattle.

The income transfer that motivates cow/calf producers to provide high-efficiency cattle and participate in a whole chain traceability system is obtained from optimizing the nonlinear program in expressions 9 through 16. With a 100% traceability success rate, an income transfer of $1.48/lb., $1.52/lb., $1.48/lb., and $1.41lb., is required for failed sorting, high-efficiency,

medium-efficiency, and low-efficiency cattle to improve the proportion of high-efficiency cattle to the level shown in the table. This income transfer will increase the average per head cost to the feeder from $1,031.63 (roughly, market price) to $1,051.96 per head, an increase of $20.33/head.

This amount is an income transfer from feedlot operations to cow/calf or stocker operations, and is almost three times higher than the $6.68 per head cost of whole chain traceability system required for both the cow/calf and stocker phases. Thus, it could sufficiently reward the cow/calf and stocker operators for implementing the whole chain traceability system and implementing the management practices necessary to increase the the proportion of high-efficiency cattle.

At the same time, the total purchase and feeding cost to feedlot operator decreases from $1,430.18 per head to $1,410.87 per head, a decrease of $19.30 per head. Although the feeding cost decrease is $40.48 per head, the feedlot operator shares $20.34 of this with the cow/calf and stocker operations to provide incentives for them to participate, and spends $0.84 per head to implement the traceability system. Therefore, by implementing the incentive schedule the feedlot operators not only increase their profits but also increase the profit level of the cow/calf operator through higher level of income transfer. Thus, the income incentive schedule could enable cow/calf, stocker and feedlot operators to implement a whole chain traceability system.

With traceability success rate reduced to 70% or 50%, the feeding cost savings are reduced from $40.48/head to $24.75 and $14.27 per head, respectively. The income transfer to cow/calf and stocker producers for 70% and 50% is $20.50 and $20.69 per head, respectively, about the same as with 100% traceability success. This transfer amount is required to achieve their participation. The reduced savings in feed cost are absorbed by the feeder, resulting in a net gain to feeders of $3.41/head with 70% traceability success, but a loss of $7.26 at a 50% traceability success. The 50% traceability success rate is not able to provide enough high-feed-efficiency cattle, so that the savings in feed cost could not cover the additional income transfer level and provide profit.

The change in feeding cost and net gain to feeders decreases as the traceability success rate decreases. However, the transfer of income to cow/calf and stocker increases as the traceability success decreases, although the increase is slight. The individual income transfer figures also changes as the traceability success rate changes. For high-efficient cattle, the income transfer increases from $1.52/lb. with the 100% traceability success rate to $1.53/lb. with the 70% traceability success rate and $1.55/lb. with the 50% traceability success rate. In contrast, for low-efficiency cattle, the income transfer decreases from $1.41/lb. with the 100% traceability success rate to $1.35/lb. with the 70% traceability success rate and $1.29/lb. with the 50% traceability success rate. These changes in income transfer are due to decreases in the proportion of successfully sorted cattle as the percentage of traceability success decreases. In other words, the more uncertain is the proportion of successfully sorted cattle the greater the income transfer (amount paid) for high-efficiency and the less the income transfer (amount

paid) for low-efficiency cattle. This means that the difference in income transfer between high- and low-efficiency cattle increases as the sorting effectiveness decreases.

To compare the above results with other change in feeding efficiency proportion, we also assumed a 5% decrease in feeding cost. The 5% decrease in feeding cost could be achieved by an increase in the proportion of high-efficiency cattle from 30% to 50%. This increase would come from a decrease in the proportion of medium-efficiency cattle from 45% to 35% and of low-efficiency cattle from 25% to 15%.

The results are shown in table 12. For all rates of traceability success, the feeding cost differences in table 12 are less than those in table 11 since in table 12 the proportion of high-efficiency cattle after incentive is less than that of table 11. The smaller proportion of high-feed-efficiency cattle caused greater differences in income transfers between high- and low-efficiency cattle. For example, with 100% traceability success the incentive level for high-, medium- and low- efficiency calves is $1.52, $1.48, and $1.41 per pound in table 11 and $1.57, $1.46, and $1.39 per pound in table 12. In table 11 the difference in incentive between high- and low- efficiency cattle is $0.11 per pound whereas in table 12, it is $0.18 per pound.

The income transfer to cow/calf and stocker operators in table 12 is between $21.28 and $22.82 per head. This figure is only about $1 per head higher than the table 11 figures which are around $20.34 to $20.69 per head. The net gains for the feedlot operator decrease in table 12, though, due to the lower improvement in the proportion of cattle with high feed efficiency. In fact, the reduction causes feeders to gain only $1.01/head with 100% traceability success, and lose $10.21/head and $18.07/head for the 70% and 50% traceability success rates, respectively.

Conclusions

A whole chain beef traceability system could play a major role in controlling animal disease, improving production practices and providing marketing opportunities (Schnepf 2009). However, beef producers, especially cow/calf and stocker operators, are concerned with cost, reliability, confidentiality, and free riders of the traceability system (Schulz and Tonsor 2010). Cow/calf producers would bear the largest portion of the cost of implementing a whole chain traceability system, but most of the benefits will likely be obtained by downstream beef producers. As a result, upstream producers will not participate in a whole-chain beef traceability system if downstream benefits are not shared with the upstream producers.

In this paper, we studied the costs and benefits of a whole chain traceability system that could motivate all beef producers to participate in such systems. We estimated the cost of implementing a whole chain beef traceability system at the cow/calf, stocker and feedlot stages. The results showed that the cow/calf operators incur five to six times the traceability cost that stockers or feedlot operators incur. This is because the largest cost, tagging each individual calf, occurs primarily at the cow/calf stage.

We also reported impacts of implementing a whole chain traceability system on beef production. Specifically, we focus on improved feed efficiency since Elzo et al. (2009) showed that there is about 57% difference in feeding cost between high- and low-efficiency cattle. A whole chain traceability system could assist in improving the average feed efficiency level at the feedlot by providing incentive for cow/calf producers to provide more high-efficiency cattle. The income incentive transfer schedule could motivate the upstream producers to implement the whole chain traceability system, sell more efficient cattle, and invest in other feed efficiency improvement practices.

We developed the income incentive transfer schedule based on Resende-Filho and Buhr (2008), who determined the premium a beef packer must pay in order to motivate a feedlot operator to implement an injection method that damages less meat. In our work, an optimization model determines the income incentive schedule that could motivate cow/calf and stocker operators to provide the most efficient cattle to the feedlot operator. The model minimizes the feedlot operator cost of purchasing feeder cattle and feed while maximizing the utility of the cow/calf or stocker operator. In order to maximize the utility of the cow/calf and stocker operators, the average amount of income transfer should be greater than the market price and provide a premium that at least covers the whole chain traceability cost. Moreover, the income transfer should provide some additional profit to cow/calf and stocker operators so that they will be motivated to participate in such systems.

The results of the model showed that the information available within the whole chain traceability system enables the feedlot operator to purchase a higher proportion of high-efficiency cattle. Increasing the proportion of high-efficiency cattle could decrease the feeding cost by about 10%. The income transfer schedule that motivates cow/calf and stocker operators to supply the higher proportion transfers about $20.34 per head from feedlots to cow/calf and stocker producers. This transfer amount is 3 times the cost of the whole chain traceability system incurred by the cow/calf operator. The results also showed that the feedlot operator could still save up to $19.30 per head after transferring the income and covering its own traceability cost.

The results of our paper show that the benefits obtained by better information availability in the whole chain traceability system are more than the costs of implementing the traceability system. These benefits could be shared among all levels of the beef supply chain. Benefit sharing of this type could motivate all stages of beef producers to participate in the whole chain traceability system, since the cost saving and income transfer provides additional profit even to the cow/calf operators who incur the largest cost of implementing a traceability system.

Using the results of this study, feedlot operators could prepare sales contract agreements. The sale contract agreements could be prepared in a way that the feedlot operator purchase more high-efficiency cattle, decreasing its feeding cost. The reduction in feeding cost could be used to transfer income to the cow/calf and stocker operator and also to provide additional profit for the feedlot operator. The income transfer to the cow/calf and stocker operator would be used to cover the costs of traceability, the costs of feed efficiency improvement practices and to

provide additional profit that will motivate them to participate in such systems. The costs of feed efficiency improvement could be the premium payment for bulls with higher residual feed efficiency level (RFI) or costs for other efficient cattle selection activities.

This research could be extended by undertaking sensitivity analysis with the results of various efficiency improvement level and traceability cost. The sensitivity analysis should address the impact of cattle and feed price changes, various levels of risk aversion and various levels of cattle feed efficiency. Such sensitivity study could also be analyzed using statistical regression so that we can know how each change affects the income incentive level. The research could also be replicated in various feed efficiency experiment data so that the conclusions could be generalized for the entire U.S. commercial cattle industry. Furthermore, this study could be extended through simulating the payment system for cow/calf, stocker and feedlot operator with any kind of new management practices that can improve the feed efficiency level.

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Table 1. Comparisons of traceability system in major beef producing countries

Country	System Type	Depth						Breadth		Precision		Integrity Verification	
		Feed producer to retail	Retail to farm	Farm to abattoir	Abattoir to retail	Abattoir to import	Abattoir to export	Safety and origin	Safety origin animal welfare feed	Individual animals to their place of birth	Groups of animals to place of birth	DNA	Other
EU	B	P	X	X	X			X	P	X	X	P	X
Japan	B	P	X	X	X			X		X		X	
Australia	ME			X			X	X	P	X		P	
Brazil	ME			X					X		X		X
Argentina	ME			X		X		X			X		
Canada	M			X		X		X			X		
U.S.	V		P	P	P			P		P			

Source: Souza-Monteiro and Caswell 2004.

M=Mandatory V= Voluntary, B=Both Mandatory and Voluntary, ME= Mandatory For Export

X=Characteristic of present system, P= potential characteristic of the system

Integrity verification means of checking the accuracy of the system

Table 2. RFID static traceability cost for cow/calf producers

No of Cattle	**30**	**103**	**342**	**493**	**717**	**1,432**	**2,943**	(a) Intercept	(b) Slope
Labor $/hd.	-	-	-	-	-	-	-	0	0
Service $/hd.	-	-	-	-	-	-	-	0	0
Material $/hd.	-	-	-	-	-	-	-	0	0
Equipment $/hd.	52.25	15.27	4.63	3.24	2.24	1.15	0.59	0.06	1565.75
Initial Total $/hd.	52.25	15.27	4.63	3.24	2.24	1.15	0.59	0.06	1565.75
Labor $/hd.	1.61	0.49	0.17	0.13	0.10	0.06	0.05	0.03	47.31
Service $/hd.	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	-0.02
Material $/hd.	1.11	1.13	1.14	1.14	1.14	1.14	1.14	1.14	-0.79
Equipment $/hd.	3.56	1.05	0.32	0.23	0.16	0.08	0.05	0.01	106.64
Ongoing Total $/hd.	6.31	2.70	1.66	1.52	1.42	1.32	1.26	1.21	153.14
Total trac. Cost/hd.	**58.57**	**17.96**	**6.29**	**4.76**	**3.67**	**2.47**	**1.85**	**1.27**	**1,718.89**
Total trac. Cost/operation	1,757	1,850	2,154	2,345	2,630	3,538	5,456		

Table 3. RFID static traceability cost for stocker operations

No of Cattle	**13**	**56**	**151**	**544**	**1016**	**2160**	**6742**	(a) Intercept	(b) Slope
Labor $/hd.	0.61	0.18	0.10	0.06	0.06	0.05	0.05	0.05	7.54
Service $/hd.	-	-	-	-	-	-	-	0	0
Material $/hd.	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2	0
Equipment $/hd.	58.00	14.07	5.37	1.66	0.99	0.59	0.35	0.23	776.72
Initial Total $/hd.	60.62	16.26	7.48	3.73	3.06	2.65	2.41	2.29	784.26
Labor $/hd.	0.40	0.11	0.05	0.03	0.02	0.02	0.02	0.02	5.08
Service $/hd.	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	-0.03
Material $/hd.	0.58	0.61	0.62	0.62	0.62	0.62	0.62	0.62	-0.5
Equipment $/hd.	3.92	0.96	0.37	0.12	0.07	0.04	0.03	0.02	52.5
Ongoing Total $/hd.	4.93	1.71	1.07	0.79	0.75	0.72	0.70	**0.69**	**57.05**
Total trac. Cost/hd.	**65.55**	**17.97**	**8.55**	**4.53**	**3.81**	**3.37**	**3.10**	**2.98**	**841.31**
Total trac. Cost/operation	881	1,009	1,292	2,464	3,870	7,278	20,934		

Table 4. RFID static traceability cost for feedlots

No of Cattle	**45**	**985**	**2,513**	**5,821**	**14,159**	**28,532**	**42,600**	**62,353**	**120,720**	(a) Interc.	(b) Slope
Labor $/hd.	-	-	-	-	-	-	-	-	-	0	0
Service $/hd.	-	-	-	-	-	-	-	-	-	0	0
Material $/hd.	-	-	-	-	-	-	-	-	-	0	0
Equipment $/hd.	29.69	1.37	0.5	0.26	0.12	0.08	0.06	0.05	0.04	0.03	1320.56
Initial Total $/hd.	29.69	1.37	0.56	0.26	0.12	0.08	0.06	0.05	0.04	0.03	1320.56
Labor $/hd.	5.38	0.27	0.12	0.07	0.05	0.04	0.04	0.03	0.03	0.03	238.28
Service $/hd.	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	-0.12
Material $/hd.	1.06	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	-3.86
Equipment $/hd.	2.08	0.09	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0	92.56
Ongoing Total $/hd.	8.56	1.55	1.35	1.28	1.24	1.23	1.23	1.23	1.22	1.22	326.86
Total trac. Cost/hd.	**38.25**	**2.92**	**1.91**	**1.53**	**1.37**	**1.31**	**1.29**	**1.28**	**1.26**	**1.25**	**1,647.42**
Total trac. Cost/operation	1,703	2,879	4,788	8,924	19,346	37,313	54,897	79,589	152,547		

Table 5. Summary of RFID Costs for Beef Cow/Calf Operations by Size of Operation - Currently Tagging Cattle

	Size of Operation, number of head						
	1-49	50-99	100-499	500-999	1000-1999	2000-4999	5,000+
Total annual cost, $/operation	$80	$215	$529	$1,655	$3,019	$6,350	$19,418
Average head sold	**13.45**	**56.14**	**151.14**	**544.41**	**1,016.50**	**2,159.86**	**6,742.36**
cost,$/head sold(currently tagging)	**$5.95**	**$3.83**	**$3.50**	**$3.04**	**$2.97**	**$2.94**	**$2.88**
Total annual cost,$/cow	$5.12	$3.30	$3.01	$2.61	$2.55	$2.53	$2.48
Total number of operations	228,755	58,867	50,889	2,985	700	207	39
Total industry cost, thousand $	$18,365	$12,649	$26,944	$4,939	$2,112	$1,315	$763

Table 6. Summary of RFID Costs for Beef Cow/Calf Operations by Size of Operation - Currently Not Tagging Cattle

	Size of Operation, number of head						
	1-49	50-99	100-499	500-999	1000-1999	2000-4999	5,000+
Total annual cost, $/operation	$97	$340	$883	$3,022	$5,585	$11,792	$36,605
Average head sold	**13.53**	**56.01**	**151.46**	**544.50**	**1,017.30**	**2,159.71**	**6,728.86**
cost,$/head sold (currently non Tagging)	**$7.17**	**$6.07**	**$5.83**	**$5.55**	**$5.49**	**$5.46**	**$5.44**
Total annual cost,$/cow	$6.16	$5.22	$5.02	$4.77	$4.72	$4.69	$4.68
Total number of operations	356,295	35,623	21,966	1,195	280	83	16
Total industry cost, thousand $	$34,436	$12,124	$19,385	$3,613	$1,565	$978	$576

Source: Blasi et al. (2009), p.30

Table 7. Summary of RFID Costs for Backgrounding (Stocker) Operations by Size of Operation

	Size of Operation, number of head						
	31	104	345	496	722	1,453	2,963
Total annual cost, $/operation	$51	$104	$250	$335	$502	$931	$1,648
Average head sold	**30.00**	**102.97**	**342.47**	**492.65**	**717.14**	**1,432.31**	**2,942.86**
cost,$/head sold	**$1.70**	**$1.01**	**$0.73**	**$0.68**	**$0.70**	**$0.65**	**$0.56**
Total annual cost, $/head purchased	$1.67	$1.00	$0.72	$0.68	$0.69	$0.64	$0.56
Total number of operations	21,438	11,334	6,333	4,333	3,329	2,316	1,787
Total industry cost, thousand $	$1,096	$1,175	$1,580	$1,453	$1,670	$2,155	$2,944

Source: Blasi et al. (2009), p.49.

Table 8. Summary of RFID Costs for Feedlot Operations by Size of Operation

	Size of Operation, number of head								
	1-999	1000-1999	2000-3999	4000-7999	8000-15999	16000-23999	24000-31999	32000-49999	50000+
Total annual cost, $/operation	$61	$670	$1,583	$2,736	$5,805	$9,701	$14,058	$18,706	$36,216
Average Number of cattle head sold	**44.53**	**985.3**	**2,512.7**	**5,821.3**	**14,158.5**	**28,532.4**	**42,600.0**	**62,353.3**	**120,720**
cost,$/head sold	**$1.37**	**$0.68**	**$0.63**	**$0.47**	**$0.41**	**$0.34**	**$0.33**	**$0.30**	**$0.30**
Total annual cost, $/head purchased	$1.36	$0.67	$0.62	$0.46	$0.40	$0.34	$0.32	$0.29	$0.30
Total number of operations	85,000	809	564	343	182	78	55	71	58
Total industry cost, thousand $	$5,174	$542	$893	$939	$1,057	$757	$773	$1,328	$2,101

Source: Blasi et al. (2009), p.57.

Table 9. Cost of adopting whole chain traceability system

		Cow/Calf operation (100-499)			**Stocker avg buy (345)**			**Feed yard (1000-1999)**		
		Quantity	Unit Cost	Total cost per operation	Quantity	Unit Cost	Total cost per operation	Quantity	Unit Cost	Total cost per operation
	Average heard size, head =n	175.90			345.30			981.00		
	RFID Tag Applicator, $/unit, year	2	$14.02	$ 28.04	2	$ 14.02	$ 28.04	3	$14.02	$ 42.06
	RFID reading equipment, $/unit,							1	422.22	422.22
	Laptop and Software, $/unit, year	1	108.21	108.21	1	108.21	108.21	1	108.21	108.21
Total fixed cost				136.25			136.25			572.49
	RFID Tag, $/tag	179.8	2.20	395.56	8.5	2.50	21.25	24.5	2.50	61.25
	RFID putting Labor, $/head	175.9	0.08	14.37						
	Chute labor retag, $/hr.	1.29	9.8	12.6	0.79	9.80	7.77	1.40	9.80	13.7
	Chute, $/head	179.8	1.00	179.8	9	1	9.00	24.5	1	24.5
	Injury-human	1	2.70	2.70	1	1.00	1.00	1	4	4.00
	Injury animal	184.40	0.15	27.66	1	1.00	1.00	1	10	10.00
	Reading outsource fee, $/head	13.6	1.88	25.57	121.4	1.46	177.24			
	Clerical cost, $/hr.	4	9.8	39.20	4	9.80	39.20	4	9.8	39.20
	Database, $/head	179.80	0.085	15.28	345.3	0.085	29.35	981	0.085	83.39
Total Variable cost				712.74			285.82			236.04
Total cost $/operation				848.99			422.07			808.53
	calves available for sale			156.20			340.80			968.20
	Average cost per head			**5.44**			**1.24**			**0.84**
	Weight of calves in lb.			524			700			1200
	Total Traceability Cost/lb.			0.0104			0.0018			0.0007

Table 10. Feeding cost

		All Breeds in Experiment			
Variable		**Low-Efficiency**	**Medium-Efficiency**	**High-Efficiency**	**Average**
No of cattle [a]	581	144	262	175	
Proportion of cattle		24.78%	45.09%	30.12%	
Post weaning gain in 70d, Kg [a]		82.78	95.52	82.66	88.49
Dry matter feed intake, Kg/day [a]		11.94	9.56	7.4	9.5
Residual Feed Intake (RFI) [a]		2.45	-0.1	-1.89	-0.01
Feed:Gain FCR [a]		10.6	7.5	6.71	8.03
Average Daily Gain ADG [b]		1.18	1.36	1.18	1.26
Cost of feed per Kg [c]	$ 0.2188				
Feeding to reach certain weight [e]	226.80				
Total feed Kg		2,404.04	1,700.97	1,521.80	1,821.17
Total cost of feed [d]		**$526.08**	**$372.22**	**$333.02**	**$398.53**
Percentage difference from average		**32%**	**-7%**	**-16%**	
Feeding cost per kg		**$ 2.32**	**$ 1.64**	**$ 1.47**	**$ 1.76**
Feeding cost per cwt.		**$ 105.44**	**$ 74.60**	**$ 66.74**	**$ 79.87**

Table 11. Income incentive schedule payment for after incentive feed efficiency cattle ratio of 65%; 28%; 7%

		Feed efficiency level				Before	After	Difference
		Failed sorting	**High**	**Medium**	**Low**	**Average per head**	**Average per head**	**Average per head**
100% Traceability success rate	**Feeding cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	358.07	(40.48)
	Income Transfer	1.48	1.52	1.48	1.41	1,031.63	1,051.96	**$20.34**
	Proportion after incentive [a]	0%	65%	28%	7%			
	Proportion before incentive	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,410.87**	**(19.30)**
70% Traceability success rate	**Feed cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	373.80	(24.75)
	Income Transfer	1.49	1.53	1.49	1.35	1,031.63	1,052.13	**$20.50**
	Proportion after incentive	30%	46%	19%	5%			
	Proportion before incentive [a]	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,426.77**	**(3.41)**
50% Traceability success rate	**Feed cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	384.29	($14.27)
	Income Transfer	1.49	1.55	1.49	1.29	1,031.63	1,052.32	**$20.69**
	Proportion after incentive	50%	33%	14%	4%			
	Proportion before incentive [a]	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,437.44**	**7.26**

[a] Data taken from table 4.2 [b] Data taken from table 4.1

Table 12. Income incentive schedule payment for after incentive feed efficiency cattle ratio of 50%; 35%; 15%

		Feed efficiency level				Before	After	Difference
		Failed sorting	**High**	**Medium**	**Low**	**Average per head**	**Average per head**	**Average per head**
100% Traceability success rate	**Feeding cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	375.42	(23.13)
	Income Transfer	1.46	1.57	1.46	1.39	1,031.63	1,052.90	**$21.28**
	Proportion after incentive [a]	0%	50%	35%	15%			
	Proportion before incentive	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,429.17**	**(1.01)**
70% Traceability success rate	**Feed cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	385.95	(12.61)
	Income Transfer	1.48	1.60	1.48	1.32	1,031.63	1,053.60	**$21.97**
	Proportion after incentive	30%	35%	25%	10%			
	Proportion before incentive [a]	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,440.39**	**10.21**
50% Traceability success rate	**Feed cost** [a]	$0.82	$0.67	$0.74	$1.05	398.55	392.96	($5.59)
	Income Transfer	1.48	1.65	1.48	1.24	1,031.63	1,054.44	**$22.82**
	Proportion after incentive	50%	25%	18%	7%			
	Proportion before incentive [a]	0%	30%	45%	25%			
	Traceability cost [b]						0.84	
	Total purchase and feed cost					**1,430.18**	**1,448.25**	**18.07**

[a] Data taken from table 4.2 [b] Data taken from table 4.1

Time

Feedlot sets feed efficiency measure average success rate, and contingent income transfers.	Feedlot operator informs stockers & cow/calf operators on terms of the trade.	Cow/calf operators invest in selection and traceability; deliver calves knowing efficiency measure success rate and contingent payment scheme.	Feed efficiency is tested or confirmed through comparison of actual ADG with parentage feed efficiency information on feedlot site.	Contingent income transfer is made by feedlot operator to stocker & cow/calf operators

Figure 1. Time line for income incentive implementation

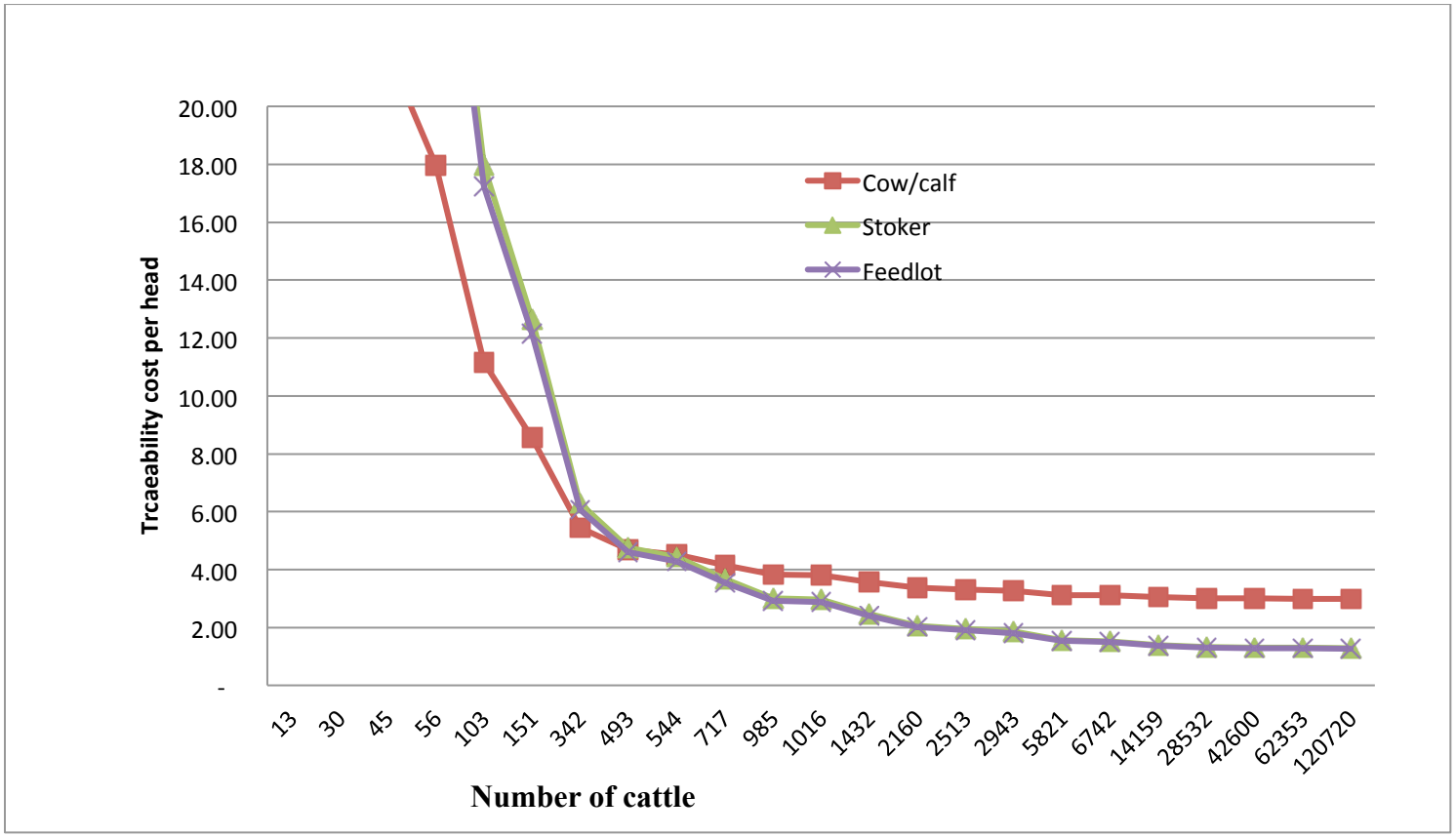

Figure 2. RFID static traceability cost per head for cow/calf, stocker, and feedlot operator by operation size based on Butler et al. (2008)

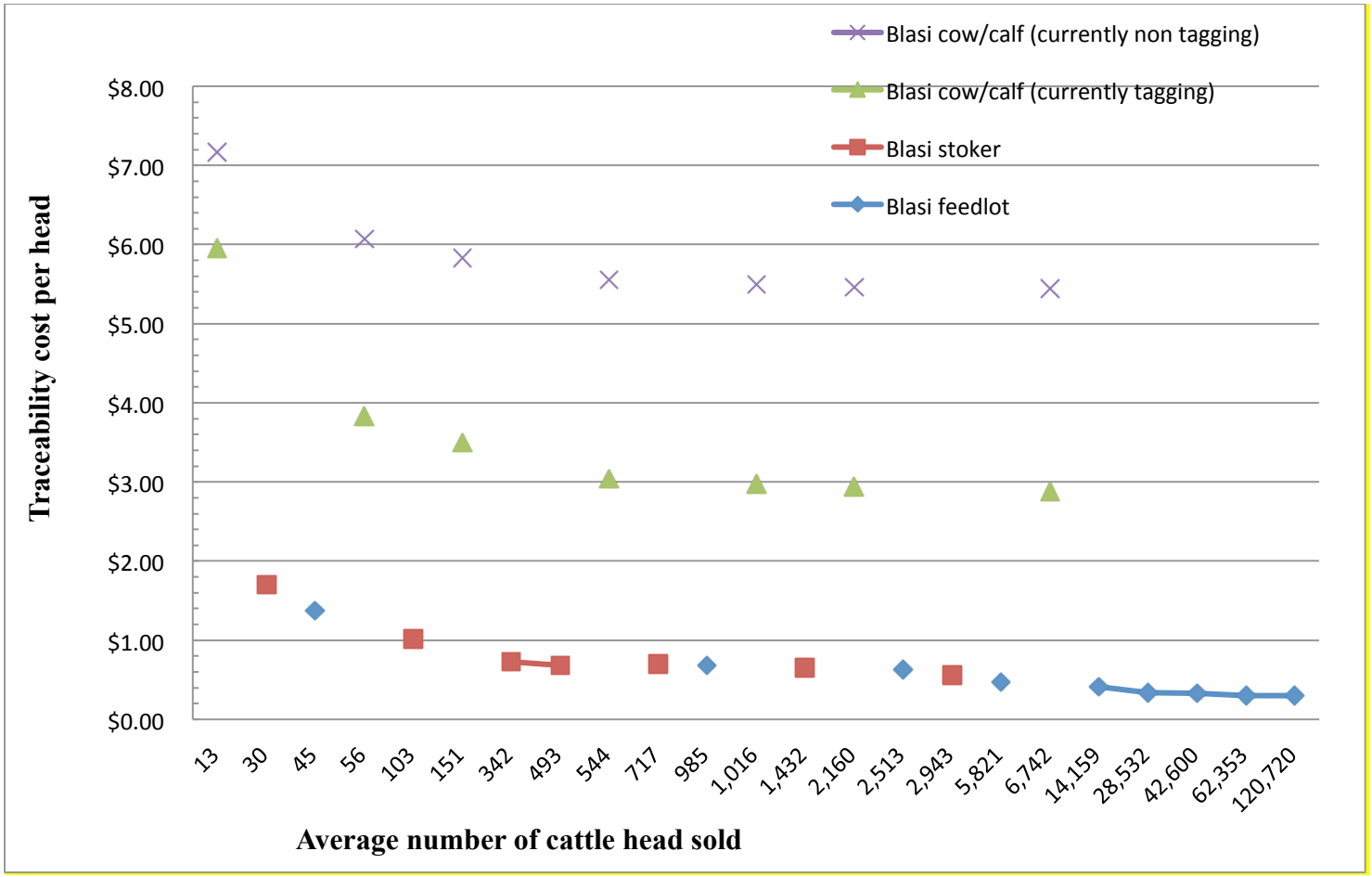

Figure 3. Traceability cost per head for cow/calf, stocker, and feedlot operator by operation size based on Blasi et al. (2009).

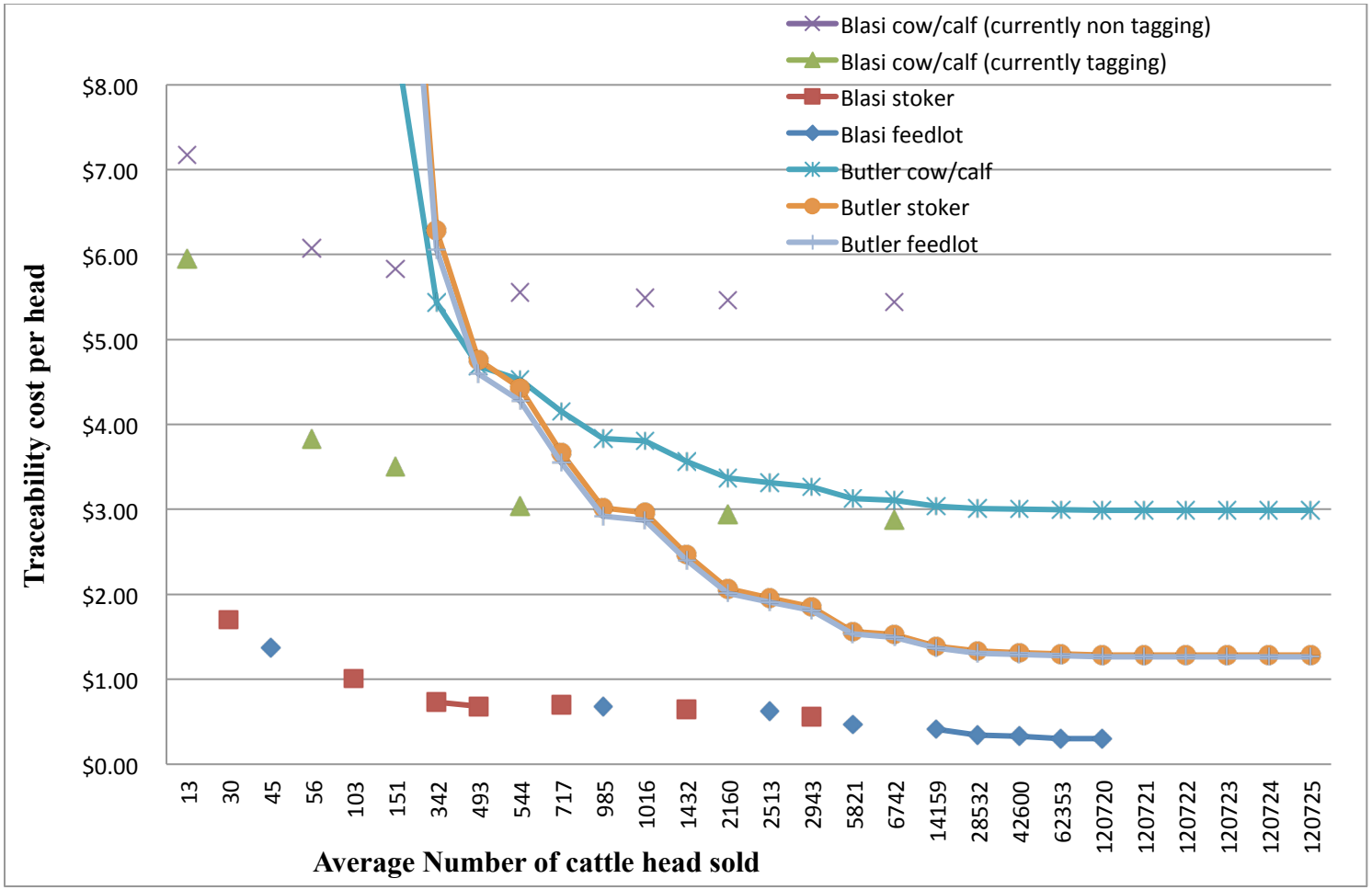

Figure 4. Traceability cost per head for cow/calf, stocker, and feedlot operator by operation size based on Blasi et al. (2009) and Butler et al (2008)

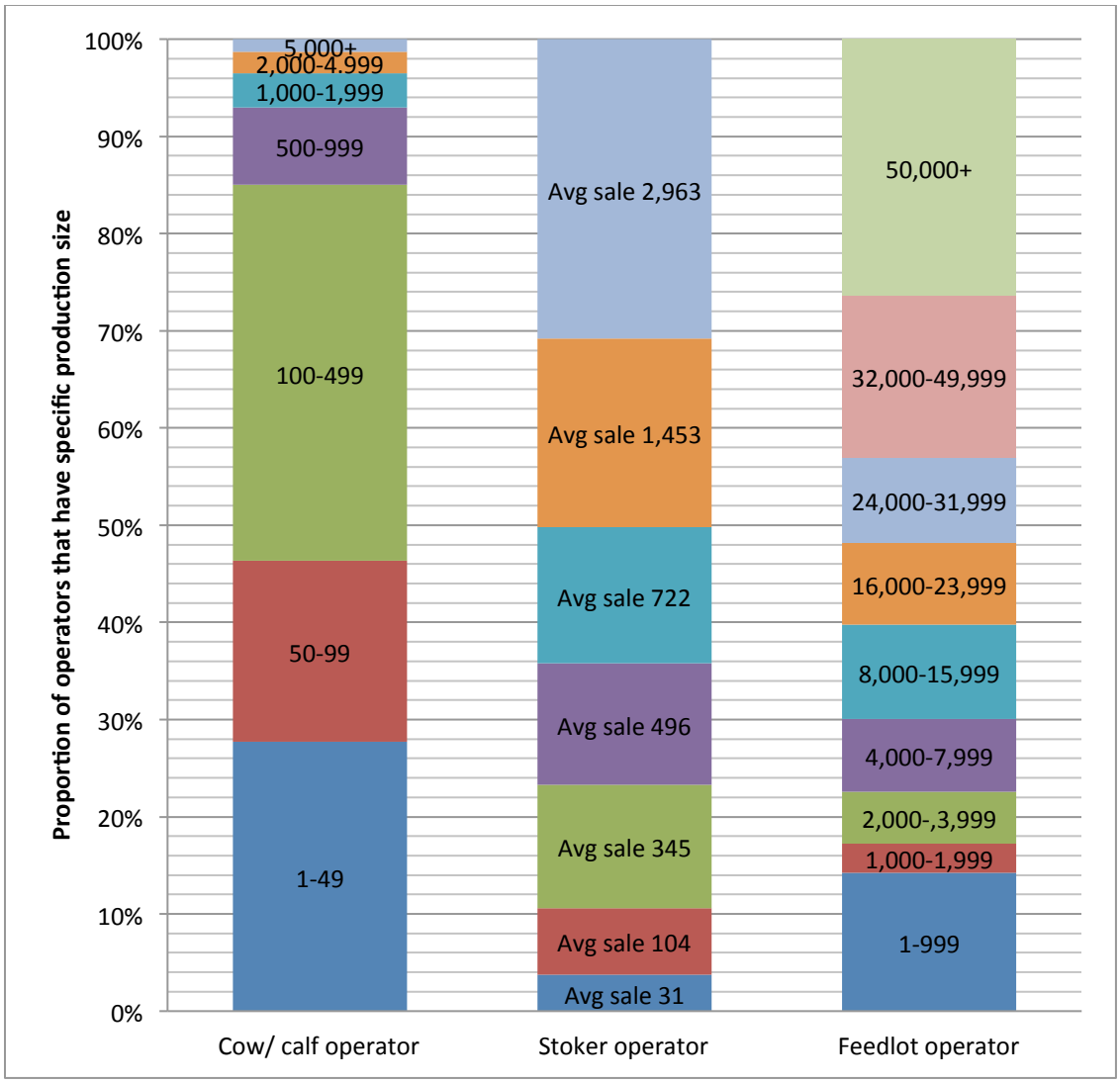

Figure 5. Proportion of cattle sold per year by production capacity size for cow/calf, stocke
feedlot operator.