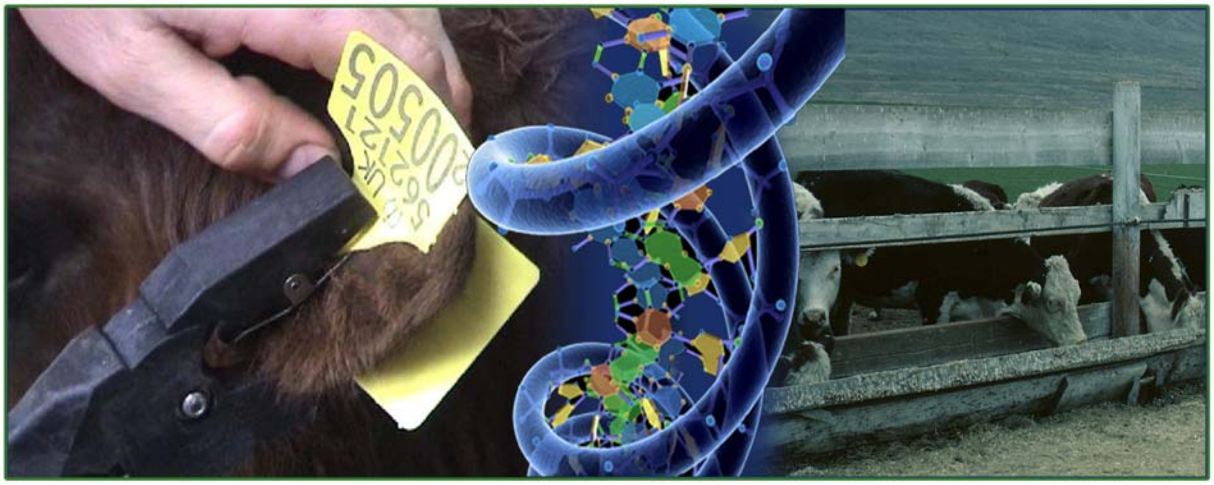

Value of Animal Traceability Systems in Managing Contagious Animal Diseases

Final Report to the Program of Research on the Economics of Invasive Species Management

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Executive Summary

Concerns regarding management of animal disease and related perceptions about food safety have escalated substantially in recent years. Terrorist attacks of September 2001, discovery of bovine spongiform encephalopathy in a dairy cow in December 2003 in Washington state and subsequent discoveries of BSE infected animals in Texas in 2005 and Alabama in 2006, and recent worldwide outbreaks of highly contagious animal diseases (i.e., Foot-and-Mouth Disease and Avian Influenza A (H5N1)) have made apparent the need for animal traceability in U.S. livestock production and marketing. In addition, animal identification and trace back systems are rapidly developing throughout the world increasing international trading standards.

This report's goal is to quantify and evaluate the economic impacts of different depths of animal identification/trace back systems in the event of a hypothetical highly contagious foot-and-mouth disease outbreak that poses a threat to U.S. livestock competitiveness. In addition, this report analyzes the local economic impact of a FMD outbreak under three different disease introduction scenarios. Specifically, an epidemiological disease spread model is used to evaluate the impact of a foot-and-mouth disease outbreak in southwest Kansas. The information obtained from the disease spread model is then integrated with an economic framework.

In the animal traceability study, results obtained from the epidemiological model indicate that as the depth of animal identification in cattle is increased, the number of animals destroyed is reduced as are the associated costs. Also, the length of the outbreak is reduced by approximately two weeks. The economic results suggest that as animal tracing ability is increased, decreases in producer and consumer welfare decline by approximately 60 percent.

Results for the regional economic impact study indicate as the size of the index herd that might be infected with FMD increases, the number of animals destroyed, associated costs, and length of outbreak increases by approximately 60 days. The input-output model indicates the losses to southwestern Kansas associated with a FMD outbreak originating in a cow-calf, medium-size feedlot, and five large feedlots scenarios were estimated to be $32 million, $193 million, and $942 million, respectively. The combined overall impact for the State of Kansas for the cow-calf, medium-size feedlot, and five large feedlots scenarios were estimated to be losses of $51 million, $284 million, and $1.3 billion, respectively.

Overall, this research demonstrates how widely different the epidemiological and economic implications could be with such a disease. Two things, total number of infected animals and the length of disease outbreak, are among the most important epidemiological factors that affect the economic impact of an infectious disease outbreak. As such, animal traceability, surveillance, disease management strategies, mitigation investment, and ways to deal with the disease, are critically important determinants of the economic impact if FMD were to occur.

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Introduction

Concerns regarding management of animal disease and related perceptions about food safety have escalated substantially in recent years. The terrorist attacks on the U.S. in September 2001 greatly increased awareness of the vulnerability of U.S. agriculture to bioterrorism. In response to these concerns, President Bush signed into law the *Public Health Security and Bioterrorism Preparedness and Response Act of 2002* in June 2002. The purpose of this Act is to "To improve the ability of the United States to prevent, prepare for, and respond to bioterrorism and other public health emergencies" (107th Congress, 2002). A major charge of the act includes:

> The President's Council on Food Safety (as established by Executive Order No. 13100) shall, in consultation with the Secretary of Transportation, the Secretary of the Treasury, other relevant Federal agencies, the food industry, consumer and producer groups, scientific organizations, and the States, develop a crisis communications and education strategy with respect to bioterrorist threats to the food supply. Such strategy shall address threat assessments; technologies and procedures for securing food processing and manufacturing facilities and modes of transportation; response and notification procedures; and risk communications to the public. (107th Congress, 2002)

The discovery of an infected dairy cow with bovine spongiform encephalopathy (BSE) in the U.S. in December 2003 and the subsequent loss of world markets for U.S. produced beef demonstrates the economic impact animal health can have on the livestock and related industries. The BSE incident resulted in almost immediate closure of both major (Japan, Korea, Mexico, and Canada) and minor U.S. beef export markets. Prior to the BSE discovery, the U.S. exported over 1 million metric tons of beef in 2003 compared to only 200 thousand metric tons in 2004 following discovery of the BSE infected animal in Washington State (Figure 1). Coffey et al. (2005) estimated that the U.S. beef industry losses due to export restrictions during 2004, ranged from $3.2 billion to $4.7 billion.

An animal disease, such as FMD, is of particular interest given its highly contagious nature that can cause severe production losses and its impact on the global market for animal products. Given the severity of this disease, FMD has divided the global markets in two broad segments: i) countries that are FMD free, and ii) countries that are FMD endemic. Countries that are FMD endemic can have production losses up to 10 percent of annual beef output and receive up to a 50 – 60 percent discount on beef prices (Ekboir et al., 2002). Thus, countries that are export oriented have enormous incentives to become or remain FMD free.

In the late 1990s FMD began to spread throughout the world. One of the hardest hit countries was Taiwan with over one-third of the hog population destroyed (i.e., 4 million head). Taiwan lost a major hog trading partner with Japan importing 41 percent of Taiwan's hogs. Other countries, Canada, Korea, Denmark, and the U.S., offset Japan's loss by increasing their exports. A decade later Taiwan has a smaller hog population and a much smaller export market (Blayney, Dyck, and Harvey, 2006).

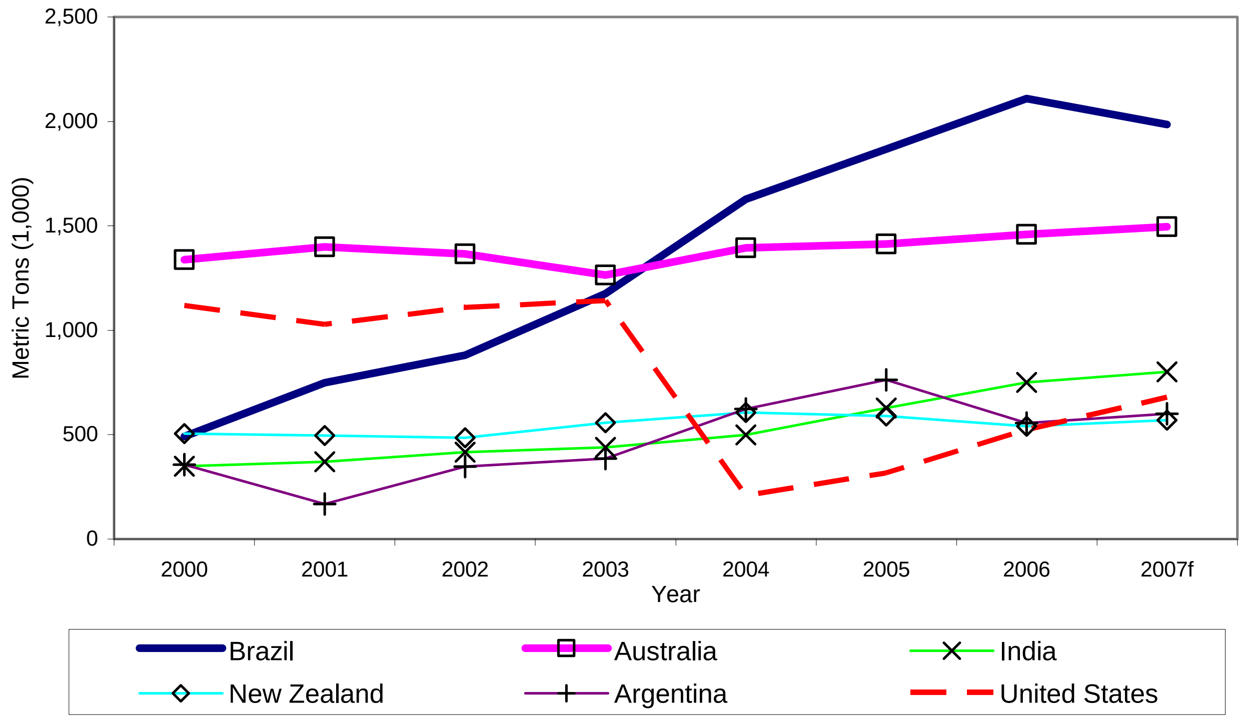

Figure 1. Beef and Veal Exports of Selected Leading Export Countries, 2001-2007 (1,000 Metric Tons)

Source: USDA, FAS (October, 2007).

The United Kingdom has experienced two recent FMD outbreaks, 2001 and 2007. Because the most recent outbreak (which was first confirmed on August 3, 2007) is still ongoing, the severity is not fully known. The other recent FMD outbreak was confirmed in cull sows at an abattoir in Great Britain on February 20, 2001. At least 57 premises were infected by the time the first case was identified (Scudamore and Harris, 2002). By September 30, 2001 when the outbreak was eradicated, 221 days after the initial outbreak, 2,026 cases of FMD had been confirmed, approximately 6.5 million animals were destroyed, and the disease had spread to Ireland, France, and the Netherlands. It took an additional 114 days (until January 22, 2002) for the UK to gain "FMD-free without vaccination" status by the Office International des Epizooties (Scudamore and Harris, 2002). Thompson et al. (2002) estimated losses from FMD in the UK at £5.8 to £6.3 billion ($10.7 to $11.7 billion U.S.). This illustrates the economic impact such a disease outbreak can have and the need to understand probable economic impacts of a highly contagious disease to develop effective public policy.

Livestock and meat production and trade play a significant role in the U.S. economy. In 2003, the U.S. exported approximately 9 percent (4.2 billion lbs.) of its red meat production. However, the state of Kansas is even more dependent on livestock and meat production. In 2003, Kansas was the leading state in the U.S. in the number of cattle slaughtered (7.4 million head) (USDA, NASS). Furthermore, Kansas imported 4.58 million head of cattle in 2003 for additional finishing (approximately 88,000 head per week) and about 2 million additional head directly for slaughter. The large number of cattle and beef shipments in and out of Kansas suggests a FMD outbreak would be widespread and economically devastating. With a FMD outbreak in Kansas, not only would all animal inshipments be stopped at the border and not allowed in the state, but all in-state animal movements would be halted (Kansas Department of Health and Environment, 2006).

This research focuses on a hypothetical FMD outbreak in one particular region in Kansas where livestock production is particularly concentrated. This region, Southwest Agricultural Statistic District of Kansas, is comprised of 14 counties located in southwestern Kansas (Figure 2). This region contained 1.99 million head of cattle and 650,000 head of hogs in late 2004/early 2005 (USDA, NASS).

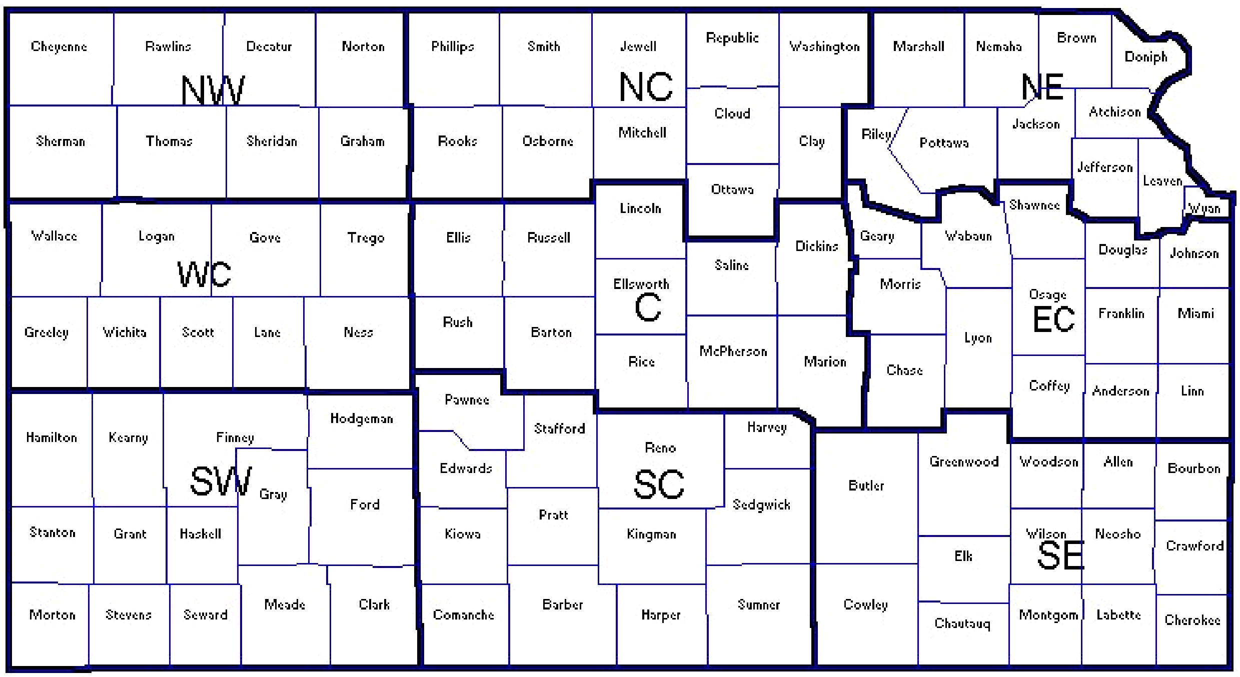

Figure 2. Map of Kansas Agricultural Statistics Districts

Source: USDA, NASS (February 2006). Available at: http://www.nass.usda.gov/ks/distmap.htm.

A major livestock producing country such as the U.S. would face severe economic consequences if a livestock epidemic were to arise. Likewise, the large number of livestock in southwest Kansas would require the incurrence of large direct costs to quarantine and eradicate a contagious disease. Also, such an event would deter trade with and within the U.S. adding further to costs. There are a number of ways to manage livestock herds to reduce the probability of a contagious disease occurring and, if it occurs, to manage it quickly to reduce the probable economic devastation.

Objectives

The research presented here primarily focuses on the epidemiological and economic characteristics of FMD; however, this work can be applicable to a number of other contagious animal diseases (e.g., Highly Pathogenic Avian Influenza and Classical Swine Fever). The general objective of this report is to determine the economic implications of different depths (or increased improvements) of animal ID/trace back systems in the event of a foot-and-mouth disease (FMD) outbreak in southwest Kansas. Additionally, this report presents local economic impact of a hypothetical FMD outbreak in southwest Kansas under three different disease introduction scenarios.

Previous Foot-and-Mouth Disease Economic Literature

Garner and Lack (1995) assessed the role of regional factors in determining the impacts of an FMD outbreak in Australia using alternate control strategies. Their study focused on three regions in Australia: i) Northern New South Wales; ii) Northern Victoria; and iii) the Midlands region of Western Australia. They considered four control strategies: i) stamping-out infected herds only; ii) stamping-out infected and dangerous contact herds; iii) stamping-out infected herds in addition to early ring vaccination; and iv) stamping-out of infected herds in addition to late ring vaccination. Using output from the epidemiological model, an input-output analysis estimated direct and indirect economic impacts. Stamping-out both infected and dangerous contact herds reduced both the duration of epidemics and the number of infected premises, thus making it the most cost-effective control strategy.

Ekboir (1999) performed similar procedures as the previous study in assessing the impact of a FMD outbreak in California's South Valley (Fresno, Kerns, Kings and Tulare counties). This was done by using a state-transition model developed from a Markov chain similar to Garner and Lack (1995). Five health states used in this model include susceptible, latent, infected, immune, and depopulated. Ekboir linked the disease spread model with an economic model composed of three components. The first component of the economic model calculated the direct costs of depopulating, cleaning and disinfecting, and enforcement of the quarantine. The second component used an input-output model to compute direct, indirect, and induced losses for California. The third economic component estimated the losses attributed to trade restrictions.

The epidemiological and economic models were used to evaluate several alternative control strategies: i) partial stamping-out (remove only infected) with and without ring vaccination; ii) total stamping-out with ring vaccination; and iii) vaccination only. Ekobir concluded strategies that involve vaccination are more expensive, in most cases, compared to the non-vaccination strategies due to the control costs and lost access to the export markets. Depending on the scenario, predicted total losses range from \$6.7 to \$13.5 billion. As found in other studies, Ekboir noted that the control strategy employed would need to begin immediately to control FMD.

Disney et al. (2001) analyzed the impact of improved animal identification systems through a simulated FMD outbreak in the U.S.[1] They considered several levels of potential animal identification systems:

Cattle

Level 1 – No identification tag, paper trail only; Level 2 – Back tag and paper trail; Level 3 – Back tag, paper trail, and unofficial bangle tag; Level 4 – Back tag, paper trail, and official ear tag; and Level 5 – Back tag, paper trail, and brucellosis calf-hood vaccination ear tag.

Swine

Level 1 – No identification tag, paper trail only; Level 2 – Back tag and paper trail; Level 3 – Back tag, paper trail, and unofficial bangle tag; and Level 4 – Back tag, paper trail, and official individual animal identification ear tag.

Results from the disease spread model were used to perform a cost-benefit analysis. Enhanced levels of animal identification systems in cattle provided economic benefits. In contrast, the economic benefits, in terms of reduced FMD consequences, of improved animal identification systems in swine were not sufficiently justified.[2]

Bates, Carpenter, and Thurmond (2003a) assessed costs and benefits of vaccinating and preemptive slaughter to control FMD. This was performed by employing a spatial stochastic epidemic simulation model to characterize the size and duration of a hypothetical FMD outbreak in a three-county region in central California (Bates, Carpenter, and Thurmond, 2003b and 2003c). The spread of FMD was simulated by computing direct and indirect rates on livestock facilities and distance traveled between herds; this information was colleted via surveys and interviews of livestock producers, artificial insemination technicians, hoof trimmers, veterinarians, sale yard owners, and creameries (Bates, Thurmond, and Carpenter, 2001). Four alternate control strategies were simulated: i) destroy all infected herds and quarantining FMD-affected areas; ii) vaccinate all uninfected herds within a designated distance (5, 10, 25, and 50 km) of infected herds; iii) destroying all herds within a designated distance (1, 3, and 5 km) of infected herds; and iv) destroy the "highest-risk" herds. Ring vaccination strategies were the most favorable from a cost-benefit perspective (total costs ranged from \$60.6 to \$74.1 million). In contrast, stamping-out strategies were the most expensive control measure because of high indemnity payments (total costs ranged from \$97.2 to \$197 million). Their study did not consider losses from trade.

Schoenbaum and Disney (2003) simulated a hypothetical FMD outbreak in the U.S. to compare the epidemiologic and economic consequences of alternate control strategies. They constructed a stochastic, spatial state-transition model based on work from Garner and Lack (1995). Three different geographically circular regions that contained different livestock populations were

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[1] Documentation of this epidemiological spread model is discussed later in this section in Schoenbaum and Disney (2003).
[2] For additional studies that examine animal identification systems and Classical Swine Fever see Saatkamp et al. (1995) and (1997).

considered: south-central U.S., north-central U.S., and western U.S. Schoenbaum and Disney examined four stamping-out strategies: i) contagious herds only; ii) contagious herds plus herds with direct contact; iii) contagious herds and herds within 3 km of the contagious herds; and iv) contagious herds and herds that had direct and indirect contact with the contagious herds and three vaccination strategies: i) no vaccination; ii) vaccination of all animals within 10 km of the infected herds after two herds are detected (i.e., early vaccination); and iii) vaccination of all animals within 10 km of the infected herds after 50 herds are detected (i.e., late vaccination). Overall, they concluded the best control strategy depended on herd demographics and contact rates among herds. Specifically, ring slaughter was the most expensive slaughter strategy while stamping-out of infected, direct and indirect contact herds reduced costs of controlling FMD compared to slaughtering infectious herds only. Further, ring vaccination was more costly than slaughter, but early ring vaccination decreased the duration of FMD.

Rich (2004) constructed a dynamic and spatially integrated FMD epidemiological model with an economic component to analyze alternative mitigation strategies in the Southern Cone (Argentina, Uruguay, Paraguay, and Southern Brazil). Rich modified the deterministic state-transition model based on a study by Mahul and Durand (2000) to incorporate inter-regional spread of the disease. He used a partial equilibrium model (called a mixed complementary programming model) to examine the effects of the six alternate control strategies: (i) stamping-out of all infected animals; (ii) stamping-out of all infected animals in Paraguay and vaccination for the rest of the Southern Cone; (iii) stamping-out of all infected animals in Paraguay and preventative vaccination for the rest of the Southern Cone; (iv) vaccination in Paraguay and stamping-out of all infected animals for the rest of the Southern Cone; (v) preventative vaccination; and (vi) total vaccination. Although results show vaccination and stamping-out could be implemented and there would be no spillover effects from neighboring regions, he concludes disease control measures need to be carried out over the continent rather than a region because of regional externalities.

Zhao, Wahl, and Marsh (2006) constructed an economic framework that integrated an epidemiological process to analyze the impacts of FMD on alternate mitigation strategies. Foot-and-Mouth Disease spread was modeled with a deterministic state transition model. The economic component incorporated production, consumption, and international trade. The authors found as the effort levels of animal traceability and surveillance were increased, costs associated with FMD and the number of animals depopulated decreased. In addition, the loss to producer and consumer welfare measures was smaller. They also examined the impacts of ring vaccination. As the ring increased in size (i.e., a larger number of animals were vaccinated), the number of animals destroyed and vaccination costs increased. Further, changes in consumer surplus measures became smaller as the vaccination ring increased in size.

Epidemiological Model

This section describes the epidemiological disease spread model used in this project. An overview of the input and output parameters are discussed below.

North American Animal Disease Spread Model

The epidemiological disease spread model used in this study is the North American Animal Disease Spread Model (NAADSM) which was originally developed by the Animal Plant Health Inspection Service of the U.S. Department of Agriculture (North American Disease Spread Model, 2007). Several recent studies including Pendell et al. (2007), Lee, Setizinger, and Paarlberg (2006), Pendell (2006), and Reeves et al., (2006) have used the NAADSM to analyze impacts of FMD outbreaks.

NAADSM is a stochastic simulation model that simulates an outbreak of foot-and-mouth disease. NAADSM is a flexible tool allowing for simulating temporal and spatial spread of FMD at the herd level. This simulation model incorporates both epidemiologic and economic models. Outputs of the epidemiological model are linked to an economic component that tracks various costs. This state-transition model was based in part on Garner and Lack (1995).

Stochastic components are incorporated by using distributions and relationships. Some input parameters are described as distributions which include the length of infectious period and the distance that animals are likely to be transported. Other input parameters are described by relationships, where a relationship is defined as one variable is a function of another.

Input parameters described as relationships include the probability of detecting an infectious herd and number of herds that can be depopulated per day. Descriptions of the parameters modeled in this study are described below.

Overview of NAADSM Input Parameters

There are six broad input parameter categories in the NAADSM: (i) animal population; (ii) disease manifestation; (iii) disease transmission; (iv) disease detection and surveillance; (v) disease control; and (vi) direct costs (Hill and Reeves, 2006). A herd is a group of animals at a given location, and is the smallest animal unit. Each herd has the following characteristics: location (latitude and longitude), size (number of animals in the herd), production type, and initial disease state. A production type is defined as a collection of herds with similar disease progression, probabilities of disease detection and transmission, control measures, and costs. The production types used in this study include cattle feedlots, cow/calf, swine, and dairy cattle.

Five health or disease states in herds are categorized in this model: i) susceptible; ii) latently infected; iii) infectious and subclinically infected; iv) infectious and clinically infected; and v) immune. Susceptible describes a herd as vulnerable to the FMD virus, but does not contain the virus. In the NAADSM, the latently infected variable is a probability density function (pdf) defining the duration (in days) of the latent stage within the herd. The infectious and subclinically infected variable is a pdf defining the duration of the period (in days) when the herd is infectious, yet not clinically ill (i.e., infected with the virus but showing no or few clinical signs and can shed the virus). Similar to the infectious and subclinically infected variable, the infectious and clinically infected variable is a pdf defining the duration of this period (in days) when the herd in clinically ill. The last disease state is the naturally immune period. This variable is a pdf defining the duration (in days) of immunity following natural infection.

There are three ways in which the infection can be transmitted in the NAADSM. First, NAADSM can simulate direct contact spread (i.e., direct contact among herds). The variables involved with direct contact spread include: (i) spread of FMD via latent herds; (ii) spread of FMD via subclinical herds; (iii) mean rate of movement (recipient herds/herd/day); (iv) distance distribution of recipient herds (km); (v) probability of infection transfer; and (vi) movement controls rates after detection (days). The first two parameters (i and ii), are simple yes or no questions (e.g., Can FMD spread during the latent and subclinical states? Yes or No). The mean rate of movement variable describes how often different production types come in direct contact each day. The distance distribution of the recipient herd variable is a pdf defining the distance between herds that come in direct contact with each other. Probability of infection transfer describes the likelihood a herd will become infected if it has direct contact with an infected herd. The movement control rates after detection variable is a relationship variable that describes herd movement following an outbreak.

The second way to transmit FMD using the NAADSM is through indirect contact. Indirect contact can occur via movement of people, vehicles, equipment, animal products, etc. The variables involved with indirect contact are similar to direct contact variables, except latent herds cannot spread the infection. The parameters for indirect contact are independent of those for direct contact and can be discovered later during trace back investigations.

The final way the infection can spread is through airborne spread. The variables used in simulating airborne spread include: (i) probability of infection (at 1 km from source); (ii) wind direction; and (iii) maximum distance of spread (km). The probability of infection variable describes the likelihood of a herd becoming infected within one day of another herd becoming contagious located one km away. The wind direction parameter is a range of degrees (i.e., 0-359 degrees) which describe the directions the disease can spread by air. Unlike direct and indirect contact, airborne spread can occur to and from quarantined units.

Passive and active disease surveillance can both be modeled in the NAADSM. Passive disease surveillance refers to the probability that FMD infection will be diagnosed and reported to the proper authorities by producers and practitioners. This probability depends on two variables: (i) probability of reporting given the number of days the herd is infectious and (ii) probability of reporting given the day since first detected. The first parameter (probability of reporting given the number of days the herd is infectious) describes the likelihood that an infected herd will be detected as a function of time since the herd became infected. The second parameter (probability of reporting given the day since first detected) describes the probability that an infected herd will be detected as a function of time since the outbreak was originally detected.

Active disease surveillance or targeted surveillance have several parameters and are of particular interest in this study (i.e., direct and indirect trace back). The model allows the user to choose a number of contact days before detection (i.e., the number of days a susceptible herd comes in direct or indirect contact with an infected herd and shows clinical signs of FMD). In addition, the probability of a successful trace back for each production type is chosen.

In the epidemiological spread model there are three means to control for FMD: (i) vaccination; (ii) movement restriction; and (iii) destruction. Vaccinating animals to control for FMD is a timely and interesting topic and has been examined in many studies. There are several parameters associated with destruction. The first parameter allows for destruction of herds of any production type to begin a certain number of days after the first case is detected. In an outbreak, resources may not be able to keep up with demand for depopulating infected herds, so another parameter allows the user to determine how destruction is prioritized. This parameter is further divided into two subcategories, primary priorities and secondary priorities. Under the primary priorities there are three broad categories: production type, days holding, and reason for destruction. Within each of the three broad categories for primary priorities, a secondary priority exists. For example, under production type the user is allowed to determine which production type would be destroyed first (i.e., destroy swine units first, followed by feedlot units second, etc.). The longer the herd has been listed for destruction (days holding), the higher priority it will be destroyed first. The last primary priority parameter is reason for destruction which can be further subdivided into additional parameters: disease detected, being within a ring (circle) around an infected herd, direct contact with an infected herd, and indirect contact with an infected herd. Specifically, a user can trigger pre-emptive destruction of an infected herd upon detection of FMD. Ring destruction is defined as the destruction of all herds within a specified distance (km) of the infected herd. If a herd has direct and/or indirect contact with an infected herd as detected by trace surveillance, the model allows for pre-emptive destruction of those herds.

The NAADSM calculates direct costs associated with a FMD outbreak. Specifically, destruction and vaccination costs are tabulated by the model. Destruction costs tabulated by NAADSM are as follows: (i) cost of appraisal/herd; (ii) cost of euthanasia/animal; (iii) indemnification payment/animal; (iv) cost of carcass disposal/animal; and (v) cost of cleaning and disinfecting/herd. Vaccination costs include: (i) cost of site setup (per unit); (ii) baseline vaccination cost (per animal); (iii) number of animals that may be vaccinated before the costs increases; and (iv) additional cost for each animal vaccinated beyond the threshold (per animal):

Overview of NAADSM Output Parameters

The output statistics generated by the NAADSM fall into one of the two main categories, i) epidemiological outputs (e.g., total number of animal that were destroyed, length of the outbreak, etc.) and ii) cost accounting outputs (e.g., total cost of cleaning and disinfection, total cost of euthanasia, etc.). A list of the epidemiological disease related outputs can be found in Hill and Reeves (2006).

Economic Model

This section describes in detail the economic analysis. This section begins with an overview of past studies analyzing animal diseases with alternate economic frameworks. Next, a structural model of demand and supply equations describing the U.S. beef, pork, and poultry industries is presented. An equilibrium displacement model (EDM) is then constructed to calculate changes in consumer and producer surplus measures for alternate marketing levels with the U.S. beef, pork, and poultry sectors. Following the EDM discussion, estimation of elasticities and sensitivity analysis are discussed.

Economic analyses play a crucial role in assessing alternative policies regarding management of potential contagious animal diseases. Models that integrate epidemiology and economics are increasingly prevalent in the literature, and as a result, sophistication of economic methods employed is increasing. Rich, Miller, and Winter-Nelson (2005) present an overview of five types of economic models used in conjunction with epidemiological modeling. The five types of economic models include: i) benefit-cost analysis; ii) linear programming; iii) input-output; iv) partial equilibrium analysis; and v) computable general equilibrium.

One of the most popular economic methods is benefit-cost analysis (BCA) which is based on budgets and typically measures costs of disease outbreaks under alternative control measures (e.g., Bates, Carpenter, and Thurmond, 2003a; Disney et al., 2001; Horst, 1998; Meuwissen et al., 1999; Miller et al., 1995; Nielen et al., 1999; Perry et al., 1999; Perry et al., 2003; Randolph et al., 2002). Results using this approach are often summarized through net present value, benefit-cost ratio, and internal rate of return (Rich, Miller, Winter-Nelson, 2005). Although this method is popular and has its advantages (i.e., useful at herd/farm level and easy to use), it is not well suited for long-term dynamic problems or impacts on a broader scale because the use of fixed budgets with pre-determined input-output coefficients and the lack of links to other sectors of the economy.

Linear programming (LP), a tool that maximizes or minimizes an objective function, has been used less frequently partly because of data requirements. An advantage of LP over BCA is it allows for a range of different activities with LP determining the optimal combination of activities rather than assuming a certain activity at a particular level. In addition, risk can be incorporated in the LP method. See Bicknell et al. (1999), Galligan and Marsh (1988), Habtermariam et al. (1984), and Stott et al. (2003) for applications of LP in animal diseases.

Input-Output (I-O) methods are another popular economic tool used in modeling animal disease outbreaks. Similar to BCA models, I-O models are based on budgets and accounting relationships. However, I-O models analyze the flow of inputs and outputs of an economy rather than inputs and outputs of an activity or farm. Although the I-O approach is able to capture linkages between different economic sectors, it is not effective when considering medium and long-term effects. Additionally, changes in the economy as measured by I-O are all attributed to shifts in demand rather than supply which can be problematic in agriculture studies. Three studies that have used the I-O framework to examine FMD outbreaks are Ekboir (1999), Garner and Lack (1995), and Mahul and Durand (2000). Caskie, Davis, and Moss (1999) analyzed BSE using I-O models.

Computable general equilibrium (CGE) models are used to evaluate economy wide impacts. The CGE is a sophisticated method that is based on optimization behavior of consumers and producers. The CGE model incorporates aspects of the I-O and partial equilibrium models. The CGE model uses an accounting matrix to adjust relationships in the entire economy. In addition to incorporating the relationships used in a partial equilibrium analysis (PEA), the CGE model also adds additional markets not modeled by the PEA. An advantage of the CGE model is its ability to capture economic linkages across sectors and the amount of information one can obtain. In a FMD outbreak, a CGE model would allow policy makers to gain insights on how the economy would be affected. Although the CGE models provide more information relative to other models, a vast amount of information can make the results difficult to understand and interpret (Goletti and Rich, 1998). Furthermore, because the CGE model uses an accounting matrix (or an I-O table), the imprecise nature of the I-O data (and multipliers) can give inaccurate estimates (Rich, Miller, and Nelson, 2005). Recent applications of the CGE model have examined impacts of FMD and BSE (Blake, Sinclair, and Sugiyarto (2002); O'Toole, Matthews, and Mulvey (2002); Perry et al. (2003)).

The final method discussed in Rich, Miller, and Winter-Nelson (2005) is the partial equilibrium approach (PEA). The partial equilibrium model is represented by mathematical functions for supply and demand. The objective of the PEA is to maximize welfare subject to constraints that are embedded in the supply and demand functions. Some advantages of PEA approach include measuring price changes, linkages across markets, and welfare measures. However, unlike the BCA models, detailed farm-level information cannot be obtained. A few studies that have used PEA include Berentsen, Dijkhuizen, and Oskam (1992), Mangen and Burrell (2003), Miller, Tsai, and Forster (1996), Paarlberg, Lee and Seitzinger (2002), Schoenbaum and Disney (2003), Rich (2004, 2005), and Zhao, Wahl, and Marsh (2006).

Structural Model

The structural model develops a set of supply and demand equations that provides horizontal and vertical linkages between different marketing levels. Wohlgenant (1989) demonstrated the importance of variable input proportions by concluding derived demand elasticities can be underestimated by using fixed input proportions. Therefore, the model permits variable input proportions by not imposing fixed proportions of quantities among the vertical sectors. The use of quantity transmission elasticities allows for variable input proportions (Brester, Marsh, and Atwood, 2004).

This structural model of the U.S. beef, pork, and poultry industries consists of four marketing levels for beef within the farm-retail marketing chain, three marketing levels for pork, and two levels for poultry. The four marketing levels within the beef sector that are modeled are retail, wholesale, slaughter (fed cattle level), and farm (cow/calf producer level). Wholesale-level refers to beef processors while slaughter-level is cattle feeding. Slaughter cattle and fed cattle are used interchangeably throughout the rest of this report while farm-level cattle are used interchangeably with feeder cattle. Because the pork industry is more vertically integrated compared to the beef industry, there are only three marketing levels within the pork sector (i.e., retail, wholesale, and slaughter). Similar to beef, wholesale refers to pork processors and slaughter-level is hog finishing. Slaughter hogs and market hogs are used in the rest of this thesis to represent swine at the slaughter-level. The poultry marketing chain is highly integrated and has only two marketing levels, retail and wholesale.

Trade is also integrated into the structural model because one of the main issues surrounding FMD is the United State's ability to trade with other countries. An outbreak in Kansas would halt all animal movement in and out and within the State. Because this animal movement ban and border closing would affect Kansas producers differently than the rest of the U.S. producers, this is incorporated into the structural model by disaggregating Kansas from the rest of the United States (which is referred to as Other States throughout the rest of this report) (Paarlberg, Lee, and Seitzinger, 2003). The following is a structural demand and supply model for U.S., Other States, and Kansas beef, pork, and poultry sectors with multiple marketing levels and international trade:

Beef Sector:

Retail

1) U.S. retail beef demand: $Q_B^r = f_1(P_{BUS}^r, P_{KUS}^r, P_{YUS}^r, Z_{BUS}^r)$
2) U.S. retail beef supply: $Q_B^r = f_2(P_{BUS}^r, Q_B^w, W_{BUS}^r)$

Wholesale

3) U.S. wholesale beef demand: $Q_{BUS}^{wd} = f_3(P_{BUS}^w, Q_B^r, Z_{BUS}^w)$
4) Export wholesale beef demand: $Q_{BE}^w = f_4(P_{BE}^w, Z_{BE}^w)$
5) U.S. wholesale beef supply: $Q_{BUS}^{ws} = f_5(P_{BUS}^w, Q_B^s, W_{BUS}^w)$
6) Import wholesale beef supply: $Q_{BI}^w = f_6(P_{BI}^w, W_{BI}^w)$
7) Total wholesale beef demand: $Q_B^w = Q_{BUS}^{wd} + Q_{BE}^w$
8) Total wholesale beef supply $Q_B^w = Q_{BUS}^{ws} + Q_{BI}^w$

Slaughter

9) Total fed cattle demand: $Q_B^s = f_7(P_{BUS}^s, Q_B^w, Z_{BUS}^s)$
10) KS fed cattle supply: $Q_{BKS}^s = f_8(P_{BKS}^s, Q_B^f, W_{BKS}^s, N_B^s)$
11) Other States fed cattle supply: $Q_{BO}^s = f_9(P_{BUS}^s, Q_B^f, W_{BO}^s)$
12) Total U.S. fed cattle supply: $Q_{BUS}^s = Q_{BKS}^s + Q_{BO}^s$
13) Import fed cattle supply: $Q_{BI}^s = f_{10}(P_{BI}^s, W_{BI}^s)$
14) Total fed cattle supply: $Q_B^s = Q_{BUS}^s + Q_{BI}^s$
15) KS fed cattle inventory: $N_B^s = f_{11}(F_B^s)$

Farm

16) Total feeder cattle demand: $Q_B^f = f_{12}(P_{BUS}^f, Q_B^s, Z_B^f)$
17) KS feeder cattle supply: $Q_{BKS}^f = f_{13}(P_{BKS}^f, W_{BKS}^f, N_B^f)$

18) Other States feeder cattle supply: $Q^f_{BO} = f_{14}(P^f_{BUS}, W^f_{BO})$

19) Total U.S. feeder cattle supply: $Q^f_{BUS} = Q^f_{BKS} + Q^f_{BO}$

20) Import feeder cattle supply: $Q^f_{BI} = f_{15}(P^f_{BI}, W^f_{BO})$

21) Total feeder cattle supply: $Q^f_{B} = Q^f_{BUS} + Q^f_{BI}$

22) KS feeder cattle inventory: $N^f_{B} = f_{16}(F^f_{B})$

Price Relationships

23) Kansas and Other States slaughter prices: $P^s_{BKS} = P^s_{BO} + S^s_{B}$

24) Kansas and Other States feeder prices: $P^f_{BKS} = P^f_{BO} + S^f_{B}$

Pork Sector:

Retail

25) U.S. retail pork demand: $Q^r_{K} = f_{17}(P^r_{BUS}, P^r_{KUS}, P^r_{YUS}, Z^r_{KUS})$

26) U.S. retail pork supply: $Q^r_{K} = f_{18}(P^r_{KUS}, Q^w_{K}, W^r_{KUS})$

Wholesale

27) U.S. wholesale pork demand: $Q^{wd}_{KUS} = f_{19}(P^w_{KUS}, Q^r_{K}, Z^w_{KUS})$

28) Export wholesale pork demand: $Q^w_{KE} = f_{20}(P^w_{KE,} Z^w_{KE})$

29) U.S. wholesale pork supply: $Q^{ws}_{KUS} = f_{21}(P^w_{KUS}, Q^s_{K}, W^w_{KUS})$

30) Import wholesale pork supply: $Q^w_{KI} = f_{22}(P^w_{KI}, W^w_{KI})$

31) Total wholesale pork demand: $Q^w_{K} = Q^{wd}_{KUS} + Q^w_{KE}$

32) Total wholesale pork supply: $Q^w_{K} = Q^{ws}_{KUS} + Q^w_{KI}$

Slaughter

33) Total market hog demand: $Q^s_{K} = f_{23}(P^s_{KUS}, Q^w_{K}, Z^s_{KUS})$

34) KS market hog supply: $Q^s_{KKS} = f_{24}(P^s_{KKS}, W^s_{KKS})$

35) Other States market hog supply: $Q^s_{KO} = f_{25}(P^s_{KUS}, W^s_{KO}, N^s_{K})$

36) Total U.S. market hog supply: $Q^s_{KUS} = Q^s_{KKS} + Q^s_{KO}$

37) Import market hog supply: $Q^s_{KI} = f_{26}(P^s_{KI}, W^s_{KI})$

38) Total supply of market hog: $Q^s_{K} = Q^s_{KUS} + Q^s_{KI}$

39) KS market hog inventory: $N^s_{K} = f_{27}(F^s_{K})$

Price Relationships

40) Kansas and Other States slaughter prices: $P^s_{KKS} = P^s_{KO} + S^s_{K}$

Poultry Sector:

Retail

41) U.S. retail poultry demand: $Q_Y^r = f_{28}(P_{BUS}^r, P_{KUS}^r, P_{YUS}^r, Z_{YUS}^r)$

42) U.S. retail poultry supply: $Q_Y^r = f_{29}(P_{YUS}^r, Q_Y^w, W_{YUS}^r)$

Wholesale

43) U.S. wholesale poultry demand: $Q_Y^w = f_{30}(P_{YUS}^w, Q_Y^r, Z_{YUS}^w)$

44) U.S. wholesale poultry supply: $Q_Y^w = f_{31}(P_{YUS}^w, W_{YUS}^w)$

where the variables P_i^j and Q_i^j indicate price and quantity for at the *j*th marketing level for commodity *i*, respectively. Superscript *r* denotes retail, *w* denotes wholesale, *s* denotes slaughter, and *f* denotes farm-level, respectively, while subscripts *B*, *K*, and *Y* denotes the beef, pork, and poultry sectors, respectively. Subscripts *US*, *O*, *KS*, *I,* and *E* denote U.S., Other States, Kansas, Imports, and Exports, respectively. Additional superscripts were added to some of the quantity variables to distinguish between supply and demand equations. For example, Q_{il}^{jn} where *j* represents the marketing level (*r*, *w*, *s*, or *f*), *n* denotes supply or demand (*s* or *d*), *i* indicates type of commodity (*B*, *K*, or *Y*), and *l* represents the location (*US*, *KS*, *O*, *E*, or *I*). The variables, z_i^j and w_i^j, are elements of the demand and supply shifters (*Z* and *W*) which represent the exogenous cost shocks from the initial equilibrium as a result of FMD. These shifts are determined from the epidemiological model. Cattle and hog inventories (N_i^j) are reduced by the amount of cattle and hogs that are destroyed due to FMD (i.e., denoted by F_i^j). The variable, F_i^j, is the number of animal destroyed, determined by the epidemiological model, divided by the original number of *i*th commodity for the *j*th marketing level. S_i^j represents transfer costs for shipping commodity *i* at marketing level *j* (e.g., S_B^s represents transfer costs for beef at the slaughter level). Equations 7-8, 14, 21, 31-32, and 38 are incorporated to allow for marketing clearing for the commodities at the market levels.

Given the nature of the swine and cattle industries in southwestern Kansas, it is important to acknowledge the possible existence of market power and how it could affect cash prices. The structural model above assumes price-taking behavior. This assumption is a plausible assumption for Kansas market hogs given recent findings in North Carolina by Wohlgenant (2005). Given North Carolina's large proportion of swine operations that are company-owned or contracted with producers, Wohlgenant tested to see if the large captive supplies lowered the spot market price. He concluded the market for finished hogs in North Carolina followed a price-taking behavior. Although there is less vertical integration in the beef industry compared to its counterparts, increasing concentration in beef packing have concerned some producers. There have been several studies (i.e., Morrison Paul, 2001; Azzam and Schroeter, 1995) that have examined market power in the beef packing industry. However, most studies have found little to no discernible market power.

Another economic issue important to note is the economic concept of the law of one price (LOP). The idea behind the LOP is that "if regional prices are adjusted for transfer costs, they should be identical, and with passage of time, these prices should move up and down together" (Tomek and Robinson, 2003, p. 168). This study assumes the LOP is present for market hogs, fed and feeder cattle and allows for the analysis of the regional supply/demand relationships to be conducted as if there is a single-market (Wohlgenant, 2005). In Wohlgenant's recent study, he found finished hog markets for 15 States were highly integrated. Pendell and Schroeder (2006) examined the impacts of mandatory price reporting (MPR) on fed cattle market integration. They concluded the five major fed cattle markets were highly integrated and became even more so since the inception of mandatory price reporting in April 2001. Equations 23 and 24 are included to show the relationship between Other States and Kansas prices for cattle at the slaughter and farm-levels, respectively, while equation 40 shows the relationship between Other States and Kansas prices for slaughter hogs.

Equilibrium Displacement Model

One frequently used tool in agricultural economics is a model developed by Muth (1964), more commonly known as the equilibrium displacement model (EDM). Gardner (1975) used this model to analyze the relationship between farm prices and retail food prices. Mullen, Wohlgenant, and Farris (1988) used the EDM to examine the distribution of surplus gains in substitution between farm and non-farm inputs. Lemieux and Wohlgenant (1989) studied the potential impact of introduction of a new growth hormone on the U.S. pork industry using an EDM. Holloway (1989) used this framework to determine the distribution of research gains in a multistage production setting. The EDM has also been used in international trade issues (Beghin, Brown, and Zaini (1997); Duffy and Wohlgenant (1991); Shui, Wohlgenant, and Beghin (1993); Sumner and Alston (1987); Sumner, Alston, and Gray (1994)). Brester, Marsh, and Atwood (2004), Cranfield (2002), Hill, Piggott, and Griffith (1996), Kinnucan and Belleza (1995), Lusk and Anderson (2004), Piggott (2003), and Richards and Patterson (2000) have all used the EDM framework when evaluating the effects of advertising/promotion on markets and welfare measures.

An EDM is a linear approximation to unknown supply and demand functions. The magnitude of deviations from the initial equilibrium and the degree of non-linearity of true supply and demand functions will determine the model's accuracy. If deviations from the initial equilibrium are relatively small, then the linear approximation of the unknown supply and demand curves are a relatively accurate measure of the true supply and demand functions (Wohlgenant, 1993).

To illustrate this EDM framework, totally differentiating equations (1) through (44) and converting to elasticity form results in the following equilibrium displacement of the U.S. beef, pork, and poultry markets from a FMD outbreak:

<u>Beef Sector:</u>

Retail Level

45) $EQ_B^r = \eta_{BB}^r EP_{BUS}^r + \eta_{BK}^r EP_{KUS}^r + \eta_{BY}^r EP_{YUS}^r + Ez_{BUS}^r$

46) $EQ_B^r = \varepsilon_{BUS}^r EP_{BUS}^r + \tau_B^{rw} EQ_B^w$

Wholesale Level

47) $EQ^{wd}_{BUS} = \eta^{w}_{BUS} EP^{w}_{BUS} + \tau^{wr}_{B} EQ^{r}_{B}$

48) $EQ^{w}_{BE} = \eta^{w}_{BE} EP^{w}_{BE}$

49) $EQ^{ws}_{BUS} = \varepsilon^{w}_{BUS} EP^{w}_{BUS} + \tau^{ws}_{B} EQ^{s}_{B} + Ew^{w}_{BUS}$

50) $EQ^{w}_{BI} = \varepsilon^{w}_{BI} EP^{w}_{BI}$

51) $EQ^{w}_{B} = \left(Q^{w}_{BUS} / Q^{w}_{B}\right) EQ^{wd}_{BUS} + \left(Q^{w}_{BE} / Q^{w}_{B}\right) EQ^{w}_{BE}$

52) $EQ^{w}_{B} = \left(Q^{w}_{BUS} / Q^{w}_{B}\right) EQ^{ws}_{BUS} + \left(Q^{w}_{BI} / Q^{w}_{B}\right) EQ^{w}_{BI}$

Slaughter Level

53) $EQ^{s}_{B} = \eta^{s}_{BUS} EP^{s}_{BUS} + \tau^{sw}_{B} EQ^{w}_{B}$

54) $EQ^{s}_{BKS} = \varepsilon^{s}_{BKS} EP^{s}_{BKS} + \tau^{sf}_{B} \left(Q^{f}_{BKS} / Q^{f}_{BUS}\right) EQ^{f}_{B} + EN^{s}_{B} + Ew^{s}_{BKS}$

55) $EQ^{s}_{BO} = \varepsilon^{s}_{BUS} EP^{s}_{BUS} + \tau^{sf}_{B} \left(Q^{f}_{BO} / Q^{f}_{BUS}\right) EQ^{f}_{B} + Ew^{s}_{BO}$

56) $EQ^{s}_{BUS} = \left(Q^{s}_{BKS} / Q^{s}_{BUS}\right) EQ^{s}_{BKS} + \left(Q^{s}_{BO} / Q^{s}_{BUS}\right) EQ^{s}_{BO}$

57) $EQ^{s}_{BI} = \varepsilon^{s}_{BI} P^{s}_{BI}$

58) $EQ^{s}_{B} = \left(Q^{s}_{BUS} / Q^{s}_{B}\right) EQ^{s}_{BUS} + \left(Q^{s}_{BI} / Q^{s}_{B}\right) EQ^{s}_{BI}$

59) $EN^{s}_{B} = EF^{s}_{B}$

Farm Level

60) $EQ^{f}_{B} = \eta^{f}_{BUS} EP^{f}_{BUS} + \tau^{fs}_{B} EQ^{s}_{B}$

61) $EQ^{f}_{BKS} = \varepsilon^{f}_{BKS} EP^{f}_{BKS} + EN^{f}_{B} + Ew^{f}_{BKS}$

62) $EQ^{f}_{BO} = \varepsilon^{f}_{BUS} EP^{f}_{BUS} + Ew^{f}_{BO}$

63) $EQ^{f}_{BUS} = \left(Q^{f}_{BKS} / Q^{f}_{BUS}\right) EQ^{f}_{BKS} + \left(Q^{f}_{BO} / Q^{f}_{BUS}\right) EQ^{f}_{BO}$

64) $EQ^{f}_{BI} = \varepsilon^{f}_{BI} EP^{f}_{BI}$

65) $EQ^{f}_{B} = \left(Q^{f}_{BUS} / Q^{f}_{B}\right) EQ^{f}_{BUS} + \left(Q^{f}_{BI} / Q^{f}_{BO}\right) EQ^{f}_{BI}$

66) $EN^{f}_{B} = EF^{f}_{B}$

Price Relationships

67) $EP^s_{BKS} = \left(P^s_{BUS}/P^s_{BKS}\right)EP^s_{BUS}$

68) $EP^f_{BKS} = \left(P^f_{BUS}/P^f_{BKS}\right)EP^f_{BUS}$

Pork:

Retail Level

69) $EQ^r_K = \eta^r_{KB}EP^r_{BUS} + \eta^r_{KK}EP^r_{KUS} + \eta^r_{KY}EP^r_{YUS} + Ez^r_{KUS}$

70) $EQ^r_K = \varepsilon^r_K EP^r_{KUS} + \tau^{rw}_K EQ^w_K$

Wholesale Level

71) $EQ^{wd}_{KUS} = \eta^w_{KUS}EP^w_{KUS} + \tau^{wr}_K EQ^r_K$

72) $EQ^w_{KE} = \eta^w_{KE}EP^w_{KE}$

73) $EQ^{ws}_{KUS} = \varepsilon^w_{KUS}EP^w_{KUS} + \tau^{ws}_K EQ^s_K + Ew^w_{KUS}$

74) $EQ^w_{KI} = \varepsilon^w_{KI}EP^w_{KI}$

75) $EQ^w_K = \left(Q^w_{KUS}/Q^w_K\right)EQ^{wd}_{KUS} + \left(Q^w_{KE}/Q^w_K\right)EQ^w_{KE}$

76) $EQ^w_K = \left(Q^w_{KUS}/Q^w_K\right)EQ^{ws}_{KUS} + \left(Q^w_{KI}/Q^w_K\right)EQ^w_{KI}$

Slaughter Level

77) $EQ^s_K = \eta^s_{KUS}EP^s_{KUS} + \tau^{sw}_K EQ^w_K$

78) $EQ^s_{KKS} = \varepsilon^s_{KKS}EP^s_{KKS} + EN^s_K + Ew^s_{KKS}$

79) $EQ^s_{KO} = \varepsilon^s_{KUS}EP^s_{KUS} + Ew^s_{KO}$

80) $EQ^s_{KUS} = \left(Q^s_{KKS}/Q^s_{KUS}\right)EQ^s_{KKS} + \left(Q^s_{KO}/Q^s_{KUS}\right)EQ^s_{KO}$

81) $EQ^s_{KI} = \varepsilon^s_{KI}EP^s_{KI}$

82) $EQ^s_K = \left(Q^s_{KUS}/Q^s_K\right)EQ^s_{KUS} + \left(Q^s_{KI}/Q^s_K\right)EQ^s_{KI}$

83) $EN^s_K = EF^s_K$

Price Relationships

84) $EP^s_{KKS} = \left(P^s_{KUS}/P^s_{KKS}\right)EP^s_{KUS}$

<u>Poultry:</u>

Retail Level

85) $EQ_Y^r = \eta_{YB}^r EP_{BUS}^r + \eta_{YK}^r EP_{KUS}^r + \eta_{YY}^r P_{YUS}^r + Ez_{YUS}^r$

86) $EQ_Y^r = \varepsilon_{YUS}^r EP_{YUS}^r + \tau_Y^{rw} EQ_Y^w$

Wholesale Level

87) $EQ_Y^w = \eta_{YUS}^w EP_{YUS}^w + \tau_Y^{wr} EQ_Y^r$

88) $EQ_Y^w = \varepsilon_{YUS}^w EP_{YUS}^w$

where E in the above equations denotes a relative or percentage change operator (i.e., $EQ_B^r = dQ_B^r / Q_B^r = d \ln Q_B^r$). The variables, P_i^j , Q_i^j , N_i^j , f_i^j , z_i^j , and w_i^j are defined above. The superscripts *r*, *w*, *s*, and *f* and subscripts are also defined above. The remaining parameters, ε , η , and τ , are demand, supply, and transmission elasticities, respectively.

Shifts

Exogenous percentage changes associated with a hypothetical FMD outbreak in southwest Kansas at different marketing levels within the beef and pork industries are estimated. These shifts are estimated from results obtained from the disease spread model. Specifically, the number of animals destroyed as a percentage of total animal inventories is used in equations 15, 22, and 39 while equations 5, 10, 11, 17, 18, 29, 34, and 35 use the cost information provided by NAADSM.

Surplus Measures

The most commonly used approach in analyzing welfare effects in a partial equilibrium framework is the concept of consumer and producer surplus. Consumer surplus is defined as "the difference between the maximum amount that a consumer is willing to pay for a good and the amount that the consumer actually pays" (Pindyck and Rubinfeld, 2001, p. 123). Producer surplus for a firm is "the sum over all units produced of the differences between the market price of the good and the marginal costs of production" (Pindyck and Rubinfeld, 2001, p. 269). In other words, producer surplus comprises the amount of revenue contributed to fixed costs and profit for that part of the industry since the supply curve is the marginal cost. Thus, when surplus declines the amount of money producers can allocate to fixed costs and investment decline.

Despite the popularity of calculating welfare effects through the concept of economic surplus, this approach has not been without criticism. Alston, Norton, and Pardey (1995) group the criticisms into six types: i) normativeness; ii) measurement error; iii) partial welfare analysis; iv) externalities and free riders; v) transaction costs and incomplete risk markets; and vi) policy irrelevance. Some of these criticisms can be partially addressed while others that cannot be addressed can be made more explicit. The procedures used in this research are consumer and producer surplus. These procedures are approximations to the "true" metric measure. Alternatives to economic surplus analysis include cost-benefit analysis, econometric models, and domestic resource cost models (Alston, Norton, and Pardey, 1995).

Elasticities

To determine the percentage changes in the endogenous variables, elasticity values need to be assigned to the model parameters. There are several approaches that have been used in determining elasticity estimates. These approaches include direct estimation via econometric methods, "borrow" from previously published studies, or "guesstimate" by using a combination of published results, intuition, and economic theory (James and Alston, 2002).

The approach used in this study follows that of a number of recent studies such as Brester, Marsh, and Atwood (2004), Cranfield (2002b), James and Alston (2002), Lusk and Anderson (2004), Lusk and Norwood (2005), Wittwer and Anderson (2002), and Wohlgenant (1993) which mostly use previously published elasticity estimates. Although most of the elasticity parameters were obtained from previous literature, several parameters were estimated via econometric methods.

Cattle Supply Elasticities for Kansas

The economic model used to estimate supply elasticities for Kansas feeder and slaughter cattle assumes producers are profit maximizers. This model consists of a system of demand and supply equations which examines the feeder and slaughter cattle sectors in Kansas. Similar to Marsh (2003), the structural demand and supply model for Kansas slaughter and feeder cattle are as follows:

Slaughter:

89) Inverse Demand: $P_s^d = f_1(Q_s^d, P_y, D, M)$

90) Slaughter Supply: $Q_s^s = f_2(P_s^s, P_f, P_c, I, T_s)$

91) Market Clearing Equations: $Q_s^s = Q_s^d = Q_s$ and $P_s^s = P_s^d = P_s$

Feeder:

92) Inverse Demand: $P_f^d = f_3(P_s, P_c, Q_f^d, I, T_s)$

93) Slaughter Supply: $Q_f^s = f_4(P_f^s, P_h, P_u, T_f)$

94) Market Clearing Equations: $Q_f^s = Q_f^d = Q_f$ and $P_f^s = P_f^d = P_f$

where Q and P represents quantity and price, respectively. The superscripts *s* and *d* represent supply and demand, respectively, while the subscripts *s* and *f* represent slaughter-level and feeder-level, respectively. The remaining subscripts, *y*, *c*, *h*, and *u*, on the price variables indicate beef by-product, corn, hay, and utility or cull cows, respectively.

Equations (89) and (90) represent the demand and supply equations for Kansas slaughter cattle level, respectively. The inverse slaughter demand equation represents the demand for Kansas slaughter cattle. The price of Kansas slaughter cattle (P_s^d) is a function of the quantity of Kansas slaughter cattle demanded by processors (Q_s^d), demand for retail beef (D), the price of beef by-products (P_y), and food marketing costs (M). Demand for retail beef, given by a retail beef demand index, is included because shifts in primary demand affects derived demand (Wohlgenant, 1989). Changes in technology and input prices are accounted for with the inclusion of the index for food marketing costs. The slaughter supply equation represents the supply of fed cattle marketed in Kansas. Slaughter supply (Q_s^s) is specified as a function of the output price of slaughter cattle (P_s^s), price of corn (P_c), prime interest rate (I), and feedlot technology (T_s). The cattle finishing technology variable, T_s, is approximated by using fed cattle marketings for Kansas feedlots $\geq$ 32,000 head as a percentage of total fed cattle marketings for Kansas. This variable allows for scale economies, mechanized systems, and management (Marsh, 2003; Duncan et al., 1998).

The demand and supply equations for Kansas feeder cattle are defined by equations (92) and (93), respectively. The price for Kansas feeder cattle (P_f^d) is specified as a function of the quantity demanded by feedlots (Q_f^d), the output price of slaughter cattle (P_s), the input price of corn (P_c), the prime interest rate (I), and feedlot technology (T_s). The feeder supply equation represents the supply of Kansas feeder cattle. Feeder cattle quantity (Q_f^s) represents Kansas calf crop lagged one year (*t*-1) less beef and dairy heifers kept as replacements. Feeder supply is a function on the output price of feeder cattle (P_f^s), input price of hay (P_h), price of utility slaughter cows (P_u), and feeder technology (T_f). The utility cow variable (i.e., cull cow) is incorporated in the feeder supply equation to account for opportunity costs of the breeding herd. If the price of cull cows increases, then producers will reduce the breeding herds resulting in lower feeder cattle. The technology variable for feeder cattle production is estimated by using average live weight of slaughter cattle. This technology variable accounts for genetics and producer management (Marsh, 2003).

The system of supply and demand equations allows for an exogenous shift in primary demand to affect derived demand (i.e., affect the inverse demand for Kansas slaughter cattle and then affect the inverse demand for Kansas feeder cattle). The shift in primary demand (i.e., changing the slaughter and feeder cattle prices) will cause producers to respond.

Cattle producers face biological and technical constraints, hence, the supply equations incorporate some form of dynamics (Marsh 1994, 2003). Because of constraints, cattle producers cannot make instantaneous production adjustments to price shocks. The adjustment process used in this model assumes producer output and input price expectations depend on current and past prices (i.e., lagged prices). Lags on the independent variables represent the period of time between a price shock and supply response while lags on the dependent variable indicate an infinite lag process. The quantity equations estimated in this study are modeled with an autoregressive distributed lag (ARDL) model (Greene, 2003).

The feeder cattle supply equation was estimated with one- and two-year (*t*-1 and *t*-2) lags on all independent variables (except the feeder technology variable) and the dependent variable. Studies by Marsh (1999) and Rosen, Murphy, and Scheinkman (1994) indicate estimating breeding herd and feeder cattle supplies are similar because of biological lags, herd building, and culling decisions. Because the length of time it takes feeder cattle to be fed to slaughter weight is less than the time is takes feeder cattle to reach the feedlot (i.e., gestation and backgrounding), the lag adjustments used in estimating slaughter cattle supply are less. Lags for the slaughter supply equation are the current-period (*t*) and one-period (*t*-1) for the right hand side variables, except for the feedlot technology variable.

With potential statistical problems of simultaneity and contemporaneously correlated errors in the model, estimation via an Iterative Three Stage Least Squares (I3SLS) is performed. The following model represents the initial empirical model that is estimated using I3SLS. The specification was estimated using log transformations on all variables.

Slaughter Demand Price:

$$95)\quad \ln P_s^d = a(0) + a(1)*\ln Q_s^d + a(2)*\ln P_y + a(3)*\ln D_b + a(4)*\ln M$$

Slaughter Supply:

$$96)\quad \begin{aligned}\ln Q_s^s &= b(0) + b(1)*\ln P_s^s + b(2)*\ln P_{s-1}^s + b(3)*\ln P_f + b(4)*\ln P_{f-1} + b(5)*\ln P_c \\ &+ b(6)*\ln P_{c-1} + b(7)*\ln I + b(8)*\ln I_{-1} + b(9)*\ln T_s + b(10)*\ln Q_{s-1}^s\end{aligned}$$

Feeder Demand Price:

$$97)\quad \ln P_f^d = c(0) + c(1)*\ln P_s + c(2)*\ln P_c + c(3)*\ln Q_f^d + c(4)*\ln I + c(5)*T_s$$

Feeder Supply:

$$98)\quad \begin{aligned}\ln Q_f^s &= d(0) + d(1)*\ln P_{f-1}^s + d(2)*\ln P_{f-2}^s + d(3)*\ln P_{h-1} + d(4)*\ln P_{h-2} \\ &+ d(5)*\ln P_{u-1} + d(6)*\ln P_{u-2} + d(7)*T_f + d(8)*Q_{f-1}^s + d(9)*Q_{f-2}^s\end{aligned}$$

Quantity Transmission Elasticities

In addition to estimating own-price Kansas feeder cattle and own-price derived fed cattle supply elasticities; six quantity transmission elasticities are calculated. The methods used to estimate these elasticities are similar to Brester, Marsh, and Atwood (2004). Each quantity transmission elasticity is estimated using ordinary least squares (OLS) with corrections for first-order autocorrelated errors. These models are estimated using annual data from 1970 to 2005 in double-log functional forms. The following models are the empirically estimated models:

Quantity Transmission Elasticities for Beef:

99) $\ln Q_B^r = \text{a}(0) + \text{a}(1) * \ln Q_B^w$

100) $\ln Q_B^w = \text{a}(0) + \text{a}(1) * \ln Q_B^s$

101) $\ln Q_B^s = \text{a}(0) + \text{a}(1) * \ln Q_B^f$

Quantity Transmission Elasticities for Pork:

102) $\ln Q_K^r = \text{a}(0) + \text{a}(1) * \ln Q_k^w$

103) $\ln Q_K^w = \text{a}(0) + \text{a}(1) * \ln Q_k^s$

Quantity Transmission Elasticities for Poultry:

104) $\ln Q_Y^r = \text{a}(0) + \text{a}(1) * \ln Q_Y^w$

Additional Elasticities

Additional elasticities that are not prevalent in the literature that need to be determined including own-price derived Kansas market hog supply elasticity and supply elasticities concerning imports for wholesale beef and pork, fed cattle, feeder cattle, and market hogs. This study assumes the short- and long-run own-price derived Kansas market hog supply elasticity is the same as the U.S. own-price derived market hog supply elasticity which is taken from Lemieux and Wohlgenant (1989).

Modeling the supply response of imported wholesale beef and pork, market hogs, fed cattle, feeder cattle follow that of Wohlgenant (2005). Total supply of fed cattle consists of supply produced in the U.S. and imports. This holds true for feeder cattle and market hogs. Virtually all fed cattle and market hogs are imported from Canada while most of the feeder cattle imports are from Mexico. Conceptually, the supply curve for imported fed (feeder) cattle and market hogs can be viewed as the excess supply curve of fed (feeder) cattle and market hogs from Canada (Mexico) (Wohlgenant, 2005). The elasticity of excess supply uses the standard trade elasticity formula as found in Alston, Norton, and Pardey (1995) and is calculated as follows:

105) $\varepsilon_{iI}^{j} = \left(Q_{ia}^{js} / Q_{ia}^{jx} \right) \varepsilon_{ia}^{j} + \left(Q_{ia}^{jd} / Q_{ia}^{jx} \right) \eta_{ia}^{j}$

where *j* represents the marketing level (*j* = wholesale, slaughter, and farm), *i* denotes commodity (*i* = beef, swine), *a* indicates the country (*a* = Canada, Mexico), *s* and *d* are supply and demand in country *a*, respectively, and *x* is exports. Absolute demand elasticity for country *a* is denoted by η_{ia}^{j} while ε_{ia}^{j} is country *a*'s supply elasticity.

Sensitivity Analysis

Davis and Espinoza (1998) demonstrate the importance of performing sensitivity analysis in the EDM. Because many of the variables are borrowed from previous literature, this report extends the common practice of imposing certain probability distributions for elasticities in the EDM to generate stochastic estimates for endogenous variables (as well as producer and consumer surplus). Monte Carlo simulations of the EMD are conducted by selecting prior distributions for each of the supply and demand elasticities. The truncated normal distribution was chosen for all of the supply and demand elasticities. The truncated normal distribution will allow for theoretical restrictions (i.e., negative own-price demand elasticity). In addition to a mean value, this distribution also requires a standard deviation for each elasticity estimate. However, estimated standard deviations for each elasticity estimate are not available. Therefore, the average of the reported standard deviations for the demand and short-run supply elasticities is used for the missing standard deviations. The long-run supply elasticity standard deviations are generated by Beta(4, 4) distributions with a range of three standard deviations of the respective short-run elasticities standard deviations (e.g., the long-run standard deviation for farm-level supply elasticity is generated by a Beta(4, 4) distribution with the upper and lower bounds established by three standard deviations from the short-run standard deviation of the farm-level supply elasticity). The missing standard deviations for the quantity transmission elasticities are based on the standard deviations from the quantity transmission elasticities calculated in this study. All of the Monte Carlo simulations are the result of 1,000 iterations. Empirical distributions are generated for each percentage change endogenous variable and consumer and producer welfare measures. Following Davis and Espinoza (1998), this report provides means, Chebychev 95% confidence intervals, and *p*-values for the results generated from the empirical distributions.

Data

This section contains the descriptions, sources, and derivations of data used in this report. The Data section is divided in two major sections, epidemiological and economic models. The section containing the data information for the economic models is subdivided into two additional categories, elasticities model and equilibrium displacement model.

North American Animal Disease Spread Model

The data used in the epidemiological model consists of herd location (latitude and longitude), species (cattle feedlot, cow-calf, dairy, and swine) and density. Data for the disease spread model are obtained from several sources. The Kansas Department of Health and Environment (KDHE) provided facilities latitude and longitude along with capacity for each facility for cattle feedlots, dairies, and swine operations. KDHE obtains these data through permits and certificates. The data used include active certificates of compliance and water pollution control permits for confined animal feeding operations through April 6, 2006. Because certificates and permits are only required of operations exceeding 300 animal units, very few cow-calf operations are included in the dataset from KDHE. Table 1 contains summary statistics of the data obtained from KDHE.

Table 1. Summary Statistics of Herd and Animal Data used in the Epidemiological Model

Species	Operations[a]	Mean Head[b]	Min. Head[b]	Max. Head[b]
Cattle Feedlot	200	11,446	200	140,000
Cow-Calf	1,495	85	1	999
Dairy	23	5,651	120	16,000
Swine	53	18,133	100	129,600

[a] Number of operations or premises.
[b] Number of animals per premise.

The procedure to determine herd location and density for the cow-calf operations is as follows. First, the number of cow-calf operations with size categories (number of head) for each county (i.e., 8 beef farms fall within the 1-9 head category for Clark County) is obtained from the 2002 Census of Agriculture (USDA, NASS).[3] Next, these cow-calf data are adjusted using 2004 cow-calf numbers obtained from NASS. Third, all 14 counties boundaries (latitude and longitude of each county line) are obtained via Google Earth and the randbetween() function in Excel was used to simulate the latitude and longitude of each herd. Summary statistics for the cow-calf data are included in Table 1.

Economic Models

Cattle Supply Elasticities for Kansas

Annual data are used in the estimation of the Kansas slaughter and feeder cattle supply elasticities from 1970 to 2005. All of the price data (slaughter and feeder cattle, by-product, utility cows, retail beef price, marketing costs, corn, hay, and prime interest rate) are deflated by the Consumer Price Index to a base year of 1982-1984=100. Kansas slaughter cattle (million head) are the number of cattle marketed from Kansas and is obtained from the USDA's *Cattle on Feed* reports. Kansas feeder cattle (million head) are the Kansas calf crop lagged one year less breeding heifer and dairy replacements and are from the Livestock Marketings Information Center (LMIC). Kansas slaughter cattle prices are of slaughter steers, Choice 2-3, 1100-1300 lbs. Western Kansas ($/cwt) and are obtained from the LMIC. Kansas feeder cattle prices are of feeder steers, 500-600 lbs., Western Kansas ($/cwt) and are from the LMIC. The price of beef by-products, hide and offal (cents/lb.), are reported in the USDA's *Red Meat Yearbook*. Slaughter cow price data are of boning utility cows, Western Kansas ($/cwt). Data for the beef demand index which are comprised of per capital beef consumption (lbs.) and choice retail beef prices ($/lb.) are obtained from the *Red Meat Yearbook*. The index of marketing costs (1967=100) is from the USDA's *Agricultural Outlook* series. Kansas corn price ($/bu.) and hay ($/ton) data are obtained from the USDA's *Agricultural Price* reports. The U.S. prime interest rate is from the Board of Governors of the Federal Reserve System and the CPI (1982-1984 = 100) is from the U.S. Bureau of Labor Statistics. The cattle finishing technology variable is obtained from the USDA *Cattle on Feed* reports. The technology variable for feeder cattle

[3] The size categories (number of head) for the cow-calf operations are as follows: 1-9, 10-19, 20-49, 50-99, 100-199, 200-499, and 500+.

production is obtained from USDA's *Livestock Slaughter* reports. Table 2 contains summary statistics for the data used in estimating the I3SLS.

Quantity Transmission Elasticities

Data used in the estimation of the quantity transmission elasticities are annual data from 1970 to 2005. Beef, pork, and poultry per capita consumption data (i.e., retail level) and total disappearance data (i.e., wholesale level) are from USDA's *Red Meat Yearbook*. The U.S. population data are the *Monthly National Population Estimates for the United States* reported by U.S. Department of Commerce and provided by the *Red Meat Yearbook*. Fed cattle and market hogs are the number of head and pounds marketed and are from USDA's *Meat Animals Production, Disposition, and Income* reports. Feeder cattle are the U.S. calf crop lagged one year less breeding heifer and dairy replacements plus feeder imports and are from USDA's *Livestock, Dairy, and Poultry Outlook* reports. Table 3 contains summary statistics for the data used in estimating the OLS models.

Table 2. Summary Statistics of Price and Quantity Data Used in Estimating I3SLS for Cattle Supply Elasticities for Kansas, 1970-2005

Variables	Mean	Std. Dev.	Min.	Max.	Deflated Log Mean
Q_s^s, Q_s^d	3.93 (million head)	1.14	1.89	5.50	1.32[a]
Q_f^s, Q_f^d	1.31 (million head)	180.52	1.085	1.691	0.26[a]
P_s^s, P_s^d	62.90 ($/cwt)	14.64	30.88	87.81	4.07
P_f^s, P_f^d	75.11 ($/cwt)	24.28	32.18	128.69	4.22
P_y	16.30 (cents/lb.)	4.53	5.94	22.03	2.70
D	73.35 (1970=100)	29.48	33.34	118.64	4.21[b]
M	352.30 (1967=100)	130.49	116.10	553.80	5.74
P_c	2.32 ($/bu.)	0.50	1.12	3.32	0.78
I	8.74 (percent)	3.12	4.12	18.87	2.07
T_s	34.12 (percent)	8.57	20.32	50.02	3.50[c]
P_h	60.83 ($/ton)	17.16	24.00	89.00	4.06
P_u	40.43 ($cwt)	10.19	21.09	55.17	3.63
T_f	1,125.97 (lbs.)	72.96	1,013	1,260	7.02[c]

[a] The quantity variables are not deflated.
[b] Although the retail beef price (used in calculating the beef demand index) is deflated, the demand index itself is not deflated.
[c] The technology variables are not deflated.

Table 3. Summary Statistics Quantity Data Used in Estimating OLS Models for Quantity Transmission Elasticities, 1970-2005

Variables	Mean	Std. Dev.	Min.	Max.
Q_B^r	74.6 (lbs.)	8.8	64.8	94.3
Q_B^w	25.4 (billion lbs.)	1.4	23.1	27.9
Q_B^s	54.1 (billion lbs)	24.2	49.5	58.5
Q_B^s	48.6 (million head)	2.9	43.8	56.6
Q_B^f	31.8 (million head)	3.3	28.0	38.7
Q_K^r	51.8 (lbs.)	3.3	42.9	60.6
Q_K^w	16.4 (billion lbs.)	2.0	12.0	19.4
Q_K^s	22.7 (billion lbs.)	3.1	17.0	28.5
Q_Y^r	57.3 (lbs.)	15.9	36.3	85.8
Q_Y^w	16.4 (billion lbs.)	7.2	7.6	30.2

Excess Supply Elasticities

In modeling the impacts of a FMD outbreak in Kansas, excess supply elasticities are also required in the EDM. Quantity data used in calculating the excess supply elasticities are from several sources. The quantity of production, imports, and exports of Canadian wholesale beef and pork is from the USDA's Foreign Agricultural Services (FAS). Quantity demanded for Canadian wholesale beef and pork is derived by adding imports to and subtracting exports from production. Canadian fed cattle supply data are provided by CanFax while USDA's ERS provided import and export slaughter cattle information. USDA's FAS provided production data of Mexico's feeder cattle. Supply of Mexican feeder cattle is denoted by Mexico's calf crop. Import and export data for Mexican feeder cattle was provided by the ERS. Table 4 lists quantity data and supply and demand elasticities used in estimating the excess supply elasticities.

Table 4. Variable Definitions and Values Used in Estimating Excess Supply Elasticities

Variable	Definition	Quantity
$Q_{BCanada}^{ws}$	Quantity supplied of wholesale beef in Canada (billion. lbs.)	3.25
$Q_{BCanada}^{wd}$	Quantity demanded of wholesale beef in Canada (billion. lbs.)	2.33
$Q_{BCanada}^{wx}$	Quantity exported of wholesale beef from Canada (billion. lbs.)	1.22
$Q_{KCanada}^{ws}$	Quantity supplied of wholesale pork in Canada (billion. lbs.)	4.22
$Q_{KCanada}^{wd}$	Quantity demanded of wholesale pork in Canada (billion. lbs.)	2.14
$Q_{KCanada}^{wx}$	Quantity exported of wholesale pork from Canada (billion. lbs.)	2.39

Table 4. Variable Definitions and Values Used in Estimating Excess Supply Elasticities, Cont.

Variable	Definition	Quantity
$Q^{ss}_{BCanada}$	Quantity supplied of fed cattle in Canada (million head)	3.55
$Q^{sd}_{BCanada}$	Quantity demanded of fed cattle in Canada (million head)	3.11
$Q^{sx}_{BCanada}$	Quantity exported of fed cattle from Canada (million head)	0.46
$Q^{ss}_{BMexico}$	Quantity supplied of feeder cattle in Mexico (million head)	7.50
$Q^{sd}_{BMexico}$	Quantity demanded of feeder cattle in Mexico (million head)	6.26
$Q^{sx}_{BMexico}$	Quantity exported of feeder cattle from Mexico (million head)	1.26
$\varepsilon^{w}_{BCanada}$	Canadian own-price derived wholesale beef supply elasticity	0.28, 3.43[a,b]
$\eta^{w}_{BCanada}$	Canadian own-price derived wholesale beef demand elasticity	-0.57[a]
$\varepsilon^{w}_{KCanada}$	Canadian own-price derived wholesale pork supply elasticity	0.44, 1.94[a,b]
$\eta^{w}_{KCanada}$	Canadian own-price derived wholesale pork demand elasticity	-0.71[a]
$\varepsilon^{s}_{BCanada}$	Canadian own-price derived slaughter cattle supply elasticity	0.43, 1.83[b]
$\eta^{s}_{BCanada}$	Canadian own-price derived slaughter cattle demand elasticity	-0.60
$\varepsilon^{f}_{BMexico}$	Mexican own-price derived feeder cattle supply elasticity	0.22, 2.82[a,b]
$\eta^{f}_{BMexico}$	Mexican own-price derived feeder cattle demand elasticity	-0.62[a]
$\varepsilon^{s}_{BCanada}$	Canadian own-price derived slaughter cattle supply elasticity	0.43, 1.83[b]
$\eta^{s}_{BCanada}$	Canadian own-price derived slaughter cattle demand elasticity	-0.60
$\varepsilon^{f}_{BMexico}$	Mexican own-price derived feeder cattle supply elasticity	0.22, 2.82[a,b]
$\eta^{f}_{BMexico}$	Mexican own-price derived feeder cattle demand elasticity	-0.62[a]

[a] The supply elasticities are assumed to be the same as the U.S. for the *j*th marketing level.
[b] The first value is the short-run supply elasticity while the second value is the long-run supply elasticity.

Welfare Measures

In estimating welfare measures, equilibrium price and quantity values are required. The baseline data used are annual data from 2005. Retail quantities of beef, pork, and poultry are estimated by multiplying per capita consumption of the respective commodities by the U.S. population. U.S. population data are from the U.S. Census Bureau and provided by the ERS *Red Meat Yearbook*. Retail prices are from the Bureau of Labor Statistics (BLS) Consumer Price Index (CPI). Per capita consumption data, wholesale quantities, import and export quantities of beef, pork, and poultry are from ERS *Livestock, Dairy, and Poultry Outlook*. Wholesale beef price is the average price of boxed beef Choice 600-900 and Select 600-900 and are obtained from the LMIC. Wholesale pork price is the pork carcass cut-out value (51-52% lean) while wholesale poultry price is the broilers, 12 City and both are obtained from the ERS *Red Meat Yearbook*. Quantities of domestic fed cattle and market hogs are total lbs. marketed and are obtained from NASS *Meat Animals Production, Disposition, and Income*. Quantities of domestic feeder cattle and imported fed cattle, feeder cattle, and market hogs are obtained from the Livestock Market Information Center (LMIC). Prices for Kansas fed cattle are the weighted-average of Kansas steers and heifers for Choice 2-3 and Select 2-3 for 11-13 lbs.[4] Fed cattle prices for the Other States follow the same calculation for Kansas, but are the weighted average from four regional fed cattle markets (i.e., Texas-Oklahoma, Colorado, Nebraska, Iowa-Southern Minnesota) reported by the USDA Agricultural Marketing Service (AMS) and obtained from LMIC. Prices for Kansas market hogs are from the Western Corn Belt price series for barrows and gilts while Other States market hogs are the weighted average of barrow and gilts from the Eastern Corn Belt and Western Corn Belt price series and are reported by the USDA AMS and obtained from LMIC. Prices of Kansas feeder cattle are medium no. 1, 500-600 lbs. steer cash price from Dodge City, KS. Other States feeder cattle prices are an average of the medium no. 1, 500-600 lbs. steer cash price from Montana, Oklahoma City, Colorado, Washington-Oregon-Idaho, and Amarillo. The baseline price and quantities are reported in Table 5. In the derivations, it is assumed that import, export, and Other States prices equal the average U.S. prices for the respective commodity at the respective marketing level. Table 6 provides model parameters (i.e., elasticities), definitions, and sources.

[4] For more information on these prices and the calculations, see Pendell and Schroeder (2006).

Table 5. Prices and Quantities Used in this Report

	Baseline Quantities (Million lbs.)	Baseline Prices ($/lb.)
Retail level		
US Beef	19,395.3	4.090
US Pork	14,768.9	2.827
US Poultry	25,385.9	1.741
Wholesale level		
US Beef	24,695.0	1.409
US Pork	20,682.8	0.699
US Poultry	35,293.0	0.708
Import Beef	3,598.9	1.409
Export Beef	688.7	1.409
Import Pork	1,023.7	0.699
Export Pork	2,659.9	0.699
Slaughter level		
KS Beef	6,758.4	0.874
OS Beef	46,310.5	0.869
KS Pork	809.7	0.469
OS Pork	27,652.7	0.470
Import Beef	390.9	0.869
Import Pork	676.0	0.470
Farm level		
KS Beef	900.0	1.293
OS Beef	21,768.1	1.272
Import Beef	517.0	1.272

Table 6. Parameter Definitions, Values, and Sources Used in this Report

Parameter	Definition	Value Short Run	Value Long Run
η^r_{BB}	Own-price elasticity of retail beef demand[a]	-0.56	
η^r_{BK}	Cross-price elasticity of retail beef demand w.r.t. pork price[a]	0.10	
η^r_{BY}	Cross-price elasticity of retail beef demand w.r.t. poultry price[a]	0.05	
η^r_{KB}	Cross-price elasticity of retail pork demand w.r.t. beef price[a]	0.23	
η^r_{KK}	Own-price elasticity of retail pork demand[a]	-0.69	
η^r_{KY}	Cross-price elasticity of retail pork demand w.r.t poultry price[a]	0.04	
η^r_{YB}	Cross-price elasticity of retail poultry demand w.r.t to beef price[a]	0.21	
η^r_{YK}	Cross-price elasticity of retail poultry demand w.r.t to beef price[a]	0.07	
η^r_{YY}	Own-price elasticity of retail poultry demand[a]	-0.33	
η^w_{BUS}	Wholesale beef own-price derived demand elasticity[b]	-0.57	
η^s_{BUS}	Slaughter cattle Other States own-price derived demand elasticity[b]	-0.66	
η^f_{BUS}	Farm-level Other States own-price derived demand elasticity[c]	-0.62	
η^w_{KUS}	Wholesale pork own-price derived demand elasticity[d]	-0.71	
η^s_{KUS}	Slaughter hogs Other States own-price derived demand elasticity[e]	-0.51	
η^w_{YUS}	Wholesale poultry own-price derived demand elasticity[d]	-0.22	
η^s_{KUS}	Own-price derived retail beef supply elasticity[d]	0.36	4.62
η^w_{BUS}	Own-price derived wholesale beef supply elasticity[d]	0.28	3.43
ε^s_{BUS}	Own-price derived Other States slaughter cattle supply elasticity[f]	0.26	3.24
ε^f_{BUS}	Own-price derived Other States farm beef supply elasticity[g]	0.22	2.82
ε^s_{BKS}	Own-price derived Kansas slaughter cattle supply elasticity[h]	0.23	3.71
ε^f_{BKS}	Own-price derived Kansas farm beef supply elasticity[h]	0.18	1.35
ε^r_{K}	Own-price derived retail pork supply elasticity[d]	0.73	3.87
ε^w_{KUS}	Own-price derived wholesale pork supply elasticity[d]	0.44	1.94
ε^s_{KUS}	Own-price derived Other States slaughter pork supply elasticity[i]	0.41	1.8
ε^s_{KKS}	Own-price derived Kansas slaughter pork supply elasticity[i]	0.41	1.8
ε^r_{YUS}	Own-price derived retail poultry supply elasticity[d]	0.18	13.1
ε^w_{YUS}	Own-price derived wholesale poultry supply elasticity[d]	0.14	10.0
ε^w_{BI}	Import supply elasticities for beef at wholesale level[h]	1.83	10.24
ε^s_{BI}	Import supply elasticities for cattle at slaughter level[h]	7.38	18.19
ε^f_{BI}	Import supply elasticities for cattle at farm level[h]	4.40	19.92

Table 6. Parameter Definitions, Values, and Sources Used in this Report, Cont.

Parameter	Definition	Value Short Run	Value Long Run
ε_{KI}^{w}	Import supply elasticities for pork at wholesale level[h]	1.41	4.07
ε_{KI}^{s}	Import supply elasticities for pork at slaughter level[h]	1.60	4.13
τ_{B}^{wr}	% change in wholesale beef quantity given a 1% change in retail beef quantity[d]	1.03	
τ_{B}^{sw}	% change in fed cattle quantity given a 1% change in wholesale beef quantity[d]	1.02	
τ_{B}^{fs}	% change in feeder cattle quantity given a 1% change in fed cattle quantity[d]	0.78	
τ_{K}^{wr}	% change in wholesale pork quantity given a 1% change in retail pork quantity[d]	1.01	
τ_{K}^{sw}	% change in slaughter hog quantity given a 1% change in wholesale pork quantity[d]	1.00	
τ_{Y}^{rw}	% change in wholesale poultry quantity given a 1% change in retail poultry quantity[d]	0.98	
τ_{B}^{rw}	% change in retail beef quantity given a 1% change in wholesale beef quantity[h]	1.02	
τ_{B}^{ws}	% change in wholesale beef quantity given a 1% change in fed beef quantity[h]	0.94	
τ_{B}^{sf}	% change in fed cattle quantity given a 1% change in feeder cattle quantity[h]	0.97	
τ_{K}^{rw}	% change in retail pork quantity given a 1% change in wholesale pork quantity[h]	0.99	
τ_{K}^{ws}	% change in wholesale pork quantity given a 1% change in slaughter hog quantity[h]	0.923	
τ_{Y}^{rw}	% change in retail poultry quantity given a 1% change in wholesale quantity[h]	0.93	

Sources: [a]Brester and Schroeder (1996); [b]Marsh (1992); [c]Marsh (2001); [d]Brester, Marsh, and Atwood (2004); [e]Wohlgenant (1989); [f]Marsh (1994); [g]Marsh (2003); [h]Estimated; [i]Lemieux and Wohlgenant (1989).

Bioeconomic Modeling Studies

This section is divided into two sections: (i) procedures and results from an animal traceability study; and (ii) procedures and results from a regional economic impact study.

Value of Animal Traceability Systems in Managing a Foot-and-Mouth Disease Study

The 2003 BSE discovery made apparent the need for animal traceability in U.S. livestock production and marketing. Subsequent discoveries of BSE infected animals in Texas in 2005 and Alabama in 2006 further demonstrated the need for enhanced animal traceability as cohorts and offspring from these animals proved particularly difficult, if not impossible, to identify and locate. Efforts to develop animal identification systems were launched prior to the initial U.S. BSE discovery, but they gained considerable momentum afterwards. The National Animal Identification System (NAIS) is intended to identify specific animals in the U.S. and record their movement over their lifetime. The goal is to enable a 48-hour trace back of the movements of any diseased or exposed animal. This will help to limit the spread of animal diseases, enabling faster trace back of infected animals, limit production losses due to disease presence, reduce the costs of government control, intervention and eradication, and minimize potential international trade losses. Other potential benefits of trace back systems include better supply chain coordination, increased consumer confidence in meat products, and improved farm-level profitability.

A prerequisite for contagious disease control programs is the ability to trace the origin of an infected animal. The existence of an animal identification system is crucial for proper planning for disease prevention and control. Many livestock identification systems have traditionally been provided through eradication programs, such as the Michigan Bovine Tuberculosis Eradication Program. However, as contagious diseases are eradicated the level of identification correspondingly declines, requiring a new approach, such as the NAIS. Trace back systems are needed in order to maintain surveillance for eradicated diseases and to ensure complete eradication of potential contagious diseases.

This first study evaluates contagious animal disease spread for three different animal identification levels in cattle; referred to as high-, medium-, and low-levels of identification intensity. High animal identification intensity is a system that has a 90 percent success rate of both direct and indirect trace back within 24 hours. In other words, the trace back of a herd will be successful 90 percent of the time when coming in direct and indirect contact with an infected herd. Such a system represents the case where animal identification is fully adopted by all producers, the system is accurate, operating on a national scale, and is able to trace animal movements quickly (Golan et al., 2004). Medium- and low-level identification systems have 60 percent and 30 percent trace back success rates, respectively. A 60 percent success rate represents a system that is widely adopted but may not be operational on a national scale. A 30 percent trace back success rate in a short period is what we might typically expect to be able to do today with current animal identification and tracing methods in place. Because a majority of the swine are owned and managed by one entity in the geographic area where a FMD out break is hypothetically introduced in this study, only one level of animal identification for swine is assumed at the herd level in this research (i.e., 75 percent successful direct and indirect trace back).

This animal traceability study employs the bioeconomic methodology previously discussed. Specifically, NAADSM is integrated with the equilibrium displacement model. The results from the disease spread model and economic model are presented below.

Epidemiological Results

Results from the epidemiological model are expressed as means and standard deviations derived from 1,000 iterations from each simulation. Table 7 reports summary statistics for the number of animals destroyed for each animal ID level. As the level of tracing and surveillance was increased, the number of animals that were stamped-out decreased (Table 7). This finding is similar to that of Zhao, Wahl, and Marsh (2006). The number of cattle destroyed in feedlots at a low animal identification level is approximately 13% of the total cattle marketed from Kansas in 2005. As the level of surveillance was increased to medium and high animal identification levels, the percentage of animals destroyed in feedlots relative to the total number marketed decreased to about 10% and 5%, respectively. Because cow-calf operations are less intense in southwestern Kansas relative to feedlot operations, the percentage of farm-level cattle stamped-out at all identification levels are less (i.e., 0.9%, 0.5%, and 0.1% of the total Kansas calf crop at low, medium, and high identification levels, respectively). Although the identification levels of swine remained constant (i.e., 75% successful trace back), the higher the number of cattle herds that became infected with FMD increased the number of infected swine. Approximately 1.5% of the total hogs marketed from Kansas at low cattle trace back levels were destroyed while 0.8% and 0.3% were stamped-out at medium and high cattle identification levels.

The lengths of outbreak for the three trace back levels are listed in Table 8. The average length of outbreak for low animal identification was 109.4 days compared to 104.7 days for medium level and 97.9 days for high level ID. These outbreak lengths are a little longer than Schoenbaum and Disney's (2003) 30 to 109 days; however, they examined different mitigation strategies and used simulated data from different regions. This hypothetical outbreak is much shorter than the UK's actual outbreak in 2001 that lasted 221 days.

The mean duration of the outbreaks varied little between the three scenarios. Although Schoenbaum and Disney's duration varied by 60 days between the slow and fast spread categories, there was little change in the duration among the mitigation strategies with their slow-spread scenarios.

Table 7. Summary Statistics for the Number of Animals Depopulated for the Animal Traceability Study

	Mean	*Std. Dev.*	*Min.*	*Max.*
Total Destruction (head)				
Low Animal ID				
Cattle Feedlot	724,099	240,264	27,616	1,434,818
Cow Farm	14,164	5,454	679	29,634
Swine	49,619	60,577	0	610,662
Medium Animal ID				
Cattle Feedlot	519,442	219,602	20,000	1,231,300
Cow Farm	7,602	3,522	55	17,769
Swine	25,261	49,053	0	524,682
High Animal ID				
Cattle Feedlot	253,729	120,660	13,537	742,275
Cow Farm	2,084	1,162	0	6,904
Swine	9,244	18,262	0	195,750

Table 8. Summary Statistics for the Duration of the Outbreak for the Animal Traceability Study

	Mean	*Std. Dev.*	*Min.*	*Max.*
Length of Outbreak (Days)				
Low Animal ID	109.4	13.2	80	176
Medium Animal ID	104.7	12.3	76	176
High Animal ID	97.9	14.3	53	159

The NAADSM also tabulates accounting costs associated with epidemiological output variables (i.e., number of herds, number of animals destroyed, etc.). Assumptions regarding the cost accounting parameters were based on unpublished budgets developed by APHIS. Cost results are listed in Table 9. Recall, the accounting costs are comprised of appraisal, cleaning and disinfecting, euthanizing, indemnity payments, and disposal. Due to the results in Table 7 (number of depopulated animals); cost expenditures for low-level animal identification are higher compared to the medium and high-level identification systems.

Table 9.Summary Statistics for Cost Expenditures for the Animal Traceability Study

	Mean	*Std. Dev.*	*Min.*	*Max.*
Cost Expenditures				
Low Animal ID				
Feedlot	$559,904,788	$185,786,680	$21,385,871	$1,109,528,547
Farm	$10,997,448	$4,238,708	$525,575	$23,034,674
Swine	$38,353,840	$46,824,156	$0	$472,015,165
Medium Animal ID				
Feedlot	$401,940,914	$169,907,892	$15,478,708	$952,694,001
Farm	$6,028,625	$2,790,476	$44,286	$14,121,143
Swine	$19,527,457	$37,917,447	$0	$405,575,169
High Animal ID				
Feedlot	$196,332,835	$93,339,490	$10,503,369	$574,229,316
Farm	$1,649,471	$917,922	$0	$5,445,143
Swine	$7,146,814	$14,117,103	$0	$151,317,023

Economic Results

Elasticities

Elasticity estimates are an essential component in estimating an EDM. Although several elasticities have been estimated via econometric methods, most of the elasticities used have been obtained from prior research. Table 6 provides the parameter definitions and estimates.

Cattle Supply Elasticities for Kansas

Equation error terms across markets were hypothesized to be contemporaneously correlated due to close interactions across the marketing levels within the beef industry. The residual correlation matrix revealed a non-diagonal covariance matrix of errors, with a range of pair-wise correlations occurring. For example, the error correlation coefficient between feeder calf price and slaughter cattle supply was -0.60, and correlation between errors in feeder calf supply and slaughter cattle price equations was -0.02. Within market levels, error correlation between the feeder supply and price equations was 0.33 and between slaughter cattle supply and price the error correlation was 0.14.

In the initial estimation of the autoregressive distributed lag (ARDL) model, one- and two-period lags, (t-1) and (t-2), were specified on the slaughter supply (equation 96) and feeder supply (equation 98). Because economic theory offers little help in determining the appropriate ARDL lag length, the final lag structure was simplified through truncation (Brester and Marsh 1983; Marsh 1994, 2003). Because not all of the parameters were statistically significantly in the initial estimation, lagged parameters with the smallest *t*-values were dropped. Thus, in the final estimated ARDL model, the slaughter supply equation resulted in period (*t*-1) lags on the slaughter and feeder price, prime interest rate, and slaughter quantity and period (*t*) lag on corn price. The resulting lag lengths in the feeder supply equation were one period lags (*t*-1) for feeder and hay price while a one period lag was omitted (i.e., *t*-2 lags were used) for cull cow price and feeder quantity.

The autoregressive errors (within) equations and their contemporaneous correlation (across equations) are jointly estimated with the Iterative Three Stage Least Squares estimator. Tables 10 and 11 contain the I3SLS regression results for the slaughter cattle and feeder cattle system of inverse demand and supply equations, respectively.

Table 10. I3SLS Regression Results of Inverse Slaughter Demand and Supply

Slaughter Cattle Price:

$$\ln P_s^d = 3.7312 - 0.3555 * \ln Q_s^d + 0.3793 * \ln P_y + 0.2490 * \ln D_b - 0.21757 * \ln M$$

(3.472) (-5.7821) (7.5340) (3.7101) (-0.9014)

$R^2 = 0.9626$ D-W Statistic = 1.2440

Slaughter Cattle Supply:

$$\ln Q_s^s = 0.5852 + 0.22564 * \ln P_{s-1}^s - 0.3390 * \ln P_{f-1} + 0.0228 * \ln P_c - 0.0126 * \ln I_{-1}$$

(2.083) (2.3891) (-3.9455) (0.46545) (-0.2985)

$$+ 0.0178 * \ln T_s + 0.9391 * \ln Q_{s-1}^s$$

(0.1341) (11.721)

$R^2 = 0.9696$ D-W Statistic = 2.8110

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = 0.05$ significance level is 1.96 and at $\alpha = 0.10$ the critical value is 1.645.

Most coefficient estimates in the inverse slaughter cattle demand and supply equations are statistically significant at the 0.05 level, with the exception of the index of marketing costs (M), corn price (P_c), one-period lagged prime interest rate (I_{-1}), and feedlot technology (T_f). Coefficient signs on all of the statistically significant variables are consistent with theory.

Quantity of cattle slaughtered (Q_s^d) is a significant variable in affecting slaughter cattle price (the estimated coefficient is -0.356). This price flexibility is much lower than previous studies which examined the U.S. slaughter cattle (rather than Kansas slaughter cattle). For example, Buhr and Kim (1997) examined total U.S. slaughter cattle for the period 1970 to 1990 using quarterly data and found the price flexibility coefficient to be -0.61. Other reported price flexibilities are -3.646 and -0.688 (Holzer, 2005; Marsh, 2003). The expected positive impacts of by-product value (0.379) and retail beef demand (0.249) are statistically significant while marketing costs (-0.218) is statistically insignificant. The significantly positive effects of by-product value and retail beef demand implies as the price of beef by-product increases and consumer demand for retail beef increases, the price of slaughter cattle increase. The estimated price flexibility coefficient of beef by-product (0.379) is similar to Marsh (2004) of 0.382. The coefficient of retail beef demand (0.249) is smaller than the 0.604 and 0.689 elasticity coefficients reported by Marsh (2003) and Holzer (2005), respectively. Although marketing costs are insignificant, the negative sign implies as input costs increase, the price of slaughter cattle decrease.

Table 11. I3SLS Regression Results of Inverse Feeder Demand and Supply

Feeder Cattle Price:

$$\ln P_f^d = -7.1398 + 2.2810 * \ln P_s - 0.4425 * \ln P_c - 1.0913 * \ln Q_f^d + 0.0518 * \ln I$$

(-7.746) (14.205) (-6.1762) (-4.5026) (0.9185)

$$+ 0.7396 * T_s$$

(6.0636)

$R^2 = 0.8357$ D-W Statistic = 2.0004

Feeder Cattle Supply:

$$\ln Q_f^s = 1.2622 + 0.17866 * \ln P_{f-1}^s - 0.20699 * \ln P_{h-1} - 0.06534 * \ln P_{u-2}$$

(3.110) (4.2654) (-3.9140) (-2.8886)

$$- 0.70980 * T_f + 0.86785 * Q_{f-2}^s$$

(2.4264) (6.4069)

$R^2 = 0.7414$ D-W Statistic = 1.5968

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = 0.05$ significance level is 1.96 and at $\alpha = 0.10$ the critical value is 1.645.

Supply of slaughter cattle responds positively to slaughter price (0.226) and to slaughter supply from the previous time period (0.939). The coefficient values for corn price (0.023) and feedlot technology (0.018) were positive; however, both were statistically insignificant. Lagged feeder price (– 0.339) and lagged interest rate (– 0.013) both negatively affect slaughter supply; however, the lagged interest rate is not statistically significant. The negative result is consistent with the expectations that as the variable input price (price of feeder cattle) increases, the amount of fed cattle marketed to the processor declines. The estimated coefficients for slaughter price and lagged feeder price are similar to Marsh (2003) while lagged slaughter supply is larger (0.939) when compared to Marsh (2003), 0.555. The long-run elasticity estimate for slaughter supply (i.e., derived supply) is 3.71 {0.22564 / (1 – 0.9391)}.

All coefficients in the feeder cattle demand and supply equations are statistically significant at the 0.05 level, except for the interest rate. Signs of all estimated coefficients are consistent with theoretical expectations. In Table 10, feeder demand and supply equations, the slaughter price transmission coefficient of 2.281 is higher than previously reported values of 1.20, 1.36, and 1.48 by Marsh (2003), Shonkwiler and Hinckley (1985) and Buccola (1980), respectively. Feeder supply quantities and the price of corn have the expected negative impact on feeder cattle price of (–1.091) and (–0.443), respectively.

The feeder supply equation resulted in statistically significant coefficients on the first-order lag of feeder price (0.179). Estimations also resulted in a significant first order lag the price of hay (-0.207) and significant second-order lags on the price of cull cows (-0.065) and feeder cattle supply (0.868). The feeder cattle technology variable had a positive estimated coefficient of 0.710. The long-run elasticity estimate for feeder supply (i.e., primary supply) is 1.352 {0.17866 / (1 – 0.86785)}.

Quantity Transmission Elasticities

The quantity transmission elasticities were estimated using OLS with corrections for first-order auotcorrelated errors. Table 12 contains the regression results. The estimated transmission coefficients fall within the range of 0.93 to 1.02. The estimated retail-wholesale coefficient is 1.02. This implies that a 1% increase in the quantity of wholesale beef increases the quantity of retail beef by 1.02%. Quantity transmission elasticities are shown in Table 6.

Excess Supply Elasticities

The excess supply elasticities (i.e., import supply elasticities) were calculated using the standard excess supply trade elasticity. Because Canada's largest beef and pork export markets are the U.S., it is assumed that Canada exports beef and pork only to the U.S. To calculate import supply elasticities for wholesale beef and pork and fed cattle, quantities of Canadian production, consumption, and export of wholesale beef, wholesale pork, and fed cattle are required. In addition, Canadian supply and demand elasticities for wholesale beef, wholesale pork, and fed cattle are also needed. Feeder cattle import supply elasticities use the same information as fed cattle, except Mexican feeder cattle data are used instead of Canadian fed cattle data. Quantity data were obtained from several sources. These sources include the USDA's Foreign Agricultural Service (FAS), USDA's Economic Research Service (ERS), Agriculture and Agri-Food Canada, CanFax, Statistics Canada, and Rude, Carlberg and Fellow (2006). Supply and demand elasticities for wholesale beef and pork are assumed to be the same as the U.S. elasticities because of the lack of published results. The short- and long-run elasticities of supply and demand for U.S. wholesale beef and pork are listed in Table 6. Published supply and demand elasticity estimates for fed cattle are provided by Cranfield and Goddard (1999) and Rude, Carlberg and Fellow (2006), respectively. Canadian domestic supply elasticities for fed cattle for the short and long-run are 0.43 and 1.83, respectively (Cranfield and Goddard, 1999). Demand elasticity estimates are -0.6 (Rude, Carlberg, and Fellow, 2006). Because of the lack of studies regarding Mexican feeder cattle, supply and demand elasticities for Mexican feeder cattle are assumed to be the same as the U.S. elasticities estimates.

Table 12. OLS Regression Results of Quantity Transmission Elasticities

Quantity Transmission Elasticities for Beef:

$$\ln Q_B^r = -0.5558 + 1.0157 * \ln Q_B^w + 0.9704 * AR(1)$$
(-1.853) (33.510) (23.166)

$R^2 = 0.9821$ D-W Statistic = 1.5800

$$\ln Q_B^w = 0.9877 + 0.9403 * \ln Q_B^s + 0.9714 * AR(1)$$
(2.624) (26.083) (24.331)

$R^2 = 0.9843$ D-W Statistic = 1.611

$$\ln Q_B^s = 0.7264 + 0.9680 * \ln Q_B^f + 0.9679 * AR(1)$$
(3.782) (27.364) (21.968)

$R^2 = 0.9806$ D-W Statistic = 1.6301

Quantity Transmission Elasticities for Pork:

$$\ln Q_K^r = -0.1442 + 0.9880 * \ln Q_K^w + 0.7202 * AR(1)$$
(-1.171) (77.971) (5.873)

$R^2 = 0.9980$ D-W Statistic = 1.6112

$$\ln Q_K^w = 0.4186 + 0.9253 * \ln Q_K^s + 0.7601 * AR(1)$$
(0.739) (16.426) (6.291)

$R^2 = 0.9701$ D-W Statistic = 2.3476

Quantity Transmission Elasticities for Poultry:

$$\ln Q_Y^r = 0.5934 + 0.9250 * \ln Q_Y^w + 0.9521 * AR(1)$$
(0.881) (14.952) (15.530)

$R^2 = 0.9994$ D-W Statistic = 1.2457

Note: Asymptotic t-ratios are in parentheses below the estimated coefficients. Critical t-value at $\alpha = 0.05$ significance level is 1.96.

Shifts

The exogenous (percentage) changes as a result of FMD at each level of beef and pork industries were estimated. It is assumed there are no percentage changes in the poultry industry. Also, there are no percentage changes in costs at the retail levels for beef and pork industries. Table 13 reports the percentage changes used in the EDM that allows for trade and disaggregates Kansas from the Other States (i.e., the rest of the U.S.). Using 2005 average prices and quantities for each market level, the cost estimates, which were determined by the epidemiological model, represent increases in costs relative to total value of the marketing level. Percentage decrease in quantities, also determined by the epidemiological model, is for fed cattle, feeder cattle, and market hogs.

Simulation Results

Price and Quantity Effects

The impacts of the exogenous changes (listed in Table 13) were simulated for different depths of animal identification. Tables 14 – 19 contain the percentage changes for short- and long-run impacts on low-, medium-, and high-levels of animal identification for the EDM assuming: i) no effects on consumer demand for beef, pork and poultry; ii) 2% decrease in demand for beef and pork and a 1% increase in demand for poultry; and iii) all costs related to FMD are borne by the producer.[5] 95% confidence intervals reported are based upon distributions generated by the simulations.

The results for the percentage change in prices and quantities indicate as the depth or level of animal identification is increased, the smaller the change in price and quantity. This indicates as the level of surveillance is increased, the number of animals destroyed and related costs decrease, thus decreasing the percentage change in prices and quantities. Under the scenario, no change in demand, retail and wholesale poultry prices and quantities are not statistically significant at the 0.05 level. Further, as the level of animal identification is increased the number of insignificant percentage values increases.

The mean estimates for change in consumer and producer surplus for all three commodities at each marketing level are presented in Tables 20 – 23. In general, as the animal ID levels increases, changes in consumer and producer surplus become smaller. Change in beef producer surplus at the retail and fed cattle-levels in the short-run model with no change in demand are not statistically different from zero. Changes in pork and poultry producer surpluses are also not statistically different from zero, except for Kansas slaughter hogs. A FMD outbreak with low-level animal ID reduced total meat industry producer surplus by $191.87 million while high-level ID was reduced by $74 million (Table 20). Consumer surplus declines by $197.32 million for

[5] Past research has found that if meat products can be traced back to its origin, consumer willingness-to-pay for meat products increases. Although this study assumes small decreases in consumer demand as a result of a FMD outbreak, it is possible that consumer demand does indeed increase due to the increased surveillance levels. In the event of an increase in consumer demand, changes (i.e., reductions) in consumer and producer surplus will be smaller or possibly even positive surplus changes could occur.

low-level animal ID while medium and high-levels are reduced by $145.07 million and $78.01 million, respectively. Comparing the long-run model to the short-run model, changes in producer and consumer welfare measures in the long-run are much smaller. For example, long-run total beef industry producer surplus declines by $23.44 million with high-level animal ID while low-level animal ID declines by $266.34 million.

Table 22 indicates total beef industry producer surplus declines by $583.91 million for low-level surveillance while high-level surveillance is reduced by $405 million with all costs borne by the producers when consumers demand for beef and pork decreases by 2% and poultry demand increases by 1% in the short-run. Total retail consumer surplus is reduced by $270.98 million and $154.11 million for low and high surveillance levels. The change in total beef industry producer surplus is a negative $127.52 million and $87.51 million for low- and high-level ID, respectively, in the long-run model (Table 23). Table 23 also indicates total retail consumer surplus is reduced by $192.87 million under low-level animal ID and $192.32 million for high-level animal ID.

Table 13. Exogenous Changes Used in the EDM for the Animal Traceability Study, (%)

	Low Level Animal ID		Medium Level Animal ID		High Level Animal ID	
	Quantity	Cost	Quantity	Cost	Quantity	Cost
Beef Sector:						
Retail Level	0.0	0.0	0.0	0.0	0.0	0.0
Wholesale Level	0.0	0.151	0.0	0.151	0.0	0.151
Other States Slaughter (Fed Cattle) Level	0.0	0.607	0.0	0.436	0.0	0.213
Other States Farm (Feeder Cattle) Level	0.0	0.019	0.0	0.011	0.0	0.003
Kansas Slaughter (Fed Cattle) Level	-13.26	1.214	-9.515	0.872	-4.65	0.426
Kansas Farm (Feeder Cattle) Level	-0.944	0.038	-0.507	0.021	-0.14	0.006
Pork Sector:						
Retail Level	0.0	0.0	0.0	0.0	0.0	0.0
Wholesale Level	0.0	0.018	0.0	0.018	0.0	0.018
Other States Slaughter (Market Hog) Level	0.0	0.144	0.0	0.073	0.0	0.027
Kansas Slaughter (Market Hog) Level	-1.483	0.287	-0.254	0.146	-0.093	0.053
Poultry Sector:						
Retail Level	0.0	0.0	0.0	0.0	0.0	0.0
Wholesale Level	0.0	0.0	0.0	0.0	0.0	0.0

Table 14. Percentage Changes in the Endogenous Variables in the EDM with Low Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.932	(1.230, 2.634)	0.013	(0.008, 0.018)
Retail Beef Quantity	-1.007	(-1.501, -0.512)	-0.007	(-0.012, -0.002)
Wholesale Beef Price	1.162	(0.681, 1.643)	0.107	(0.081, 0.133)
Wholesale Beef Quantity	-2.213	(-2.637, -1.790)	-0.235	(-0.295, -0.175)
Import Wholesale Beef Price	1.162	(0.681, 1.643)	0.107	(0.081, 0.133)
Import Wholesale Beef Quantity	2.125	(0.781, 3.469)	1.092	(0.815, 1.369)
Other States Fed Cattle Price	1.218	(0.700, 1.736)	0.622	(0.573, 0.671)
Other States Fed Cattle Quantity	-0.892	(-1.329, -0.455)	1.137	(0.994, 1.279)
Kansas Fed Cattle Price	1.211	(0.695, 1.726)	0.619	(0.570, 0.667)
Kansas Fed Cattle Quantity	-14.286	(-14.79, -13.77)	-12.223	(-12.52, -11.92)
Import Fed Cattle Price	1.218	(0.700, 1.736)	0.622	(0.573, 0.671)
Import Fed Cattle Quantity	8.972	(2.599, 15.344)	11.310	(8.438, 14.182)
Other States Feeder Cattle Price	-2.077	(-2.678, -1.475)	-0.084	(-0.120, -0.049)
Other States Feeder Cattle Quantity	-0.475*	(-0.697, -0.253)	-0.257	(-0.357, -0.156)
Kansas Feeder Cattle Price	-2.043	(-2.635, -1.451)	-0.083	(-0.118, -0.048)
Kansas Feeder Cattle Quantity	-1.350	(-1.748, -0.952)	-1.094	(-1.144, -1.045)
Import Feeder Cattle Price	-2.077	(-2.678, -1.475)	-0.084	(-0.120, -0.049)
Import Feeder Cattle Quantity	-9.137	(-14.808, -3.466)	-1.679	(-2.432, -0.926)
Pork Sector:				
Retail Pork Price	0.294*	(-0.015, 0.604)	0.003	(0.002, 0.004)
Retail Pork Quantity	0.281*	(-0.173, 0.735)	0.001*	(-0.003, 0.005)
Wholesale Pork Price	0.297	(0.013, 0.582)	0.024	(0.018, 0.031)

Table 14. Percentage Changes in the Endogenous Variables in the EDM with Low Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Wholesale Pork Quantity	0.048*	(-0.185, 0.281)	-0.016	(-0.024, -0.008)
Import Wholesale Pork Price	0.297	(0.013, 0.582)	0.024	(0.018, 0.031)
Import Wholesale Pork Quantity	0.435	(0.012, 0.858)	0.099	(0.066, 0.131)
Other States Hog Price	0.268	(0.004, 0.531)	0.074	(0.067, 0.082)
Other States Hog Quantity	-0.034*	(-0.145, 0.078)	-0.010*	(-0.022, 0.002)
Kansas Hog Price	0.268	(0.004, 0.532)	0.074	(0.067, 0.082)
Kansas Hog Quantity	-1.660	(-1.771, -1.549)	-1.636	(-1.652, -1.621)
Import Hog Price	0.268	(0.004, 0.531)	0.074	(0.067, 0.082)
Import Hog Quantity	0.436	(0.004, 0.867)	0.306	(0.262, 0.350)
Poultry Sector:				
Retail Poultry Price	0.737*	(-0.787, 2.260)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.208*	(-0.219, 0.634)	0.003*	(-0.003, 0.009)
Wholesale Poultry Price	0.572*	(-0.608, 1.752)	0.000*	(0.000, 0.001)
Wholesale Poultry Quantity	0.080*	(-0.086, 0.246)	0.003*	(-0.003, 0.009)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 15. Percentage Changes in the Endogenous Variables in the EDM with Low Level Animal Identification and All Costs are Borne by the Producers, Change in Demand

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	0.408	(0.070, 0.745)	0.008*	(-0.090, 0.106)
Retail Beef Quantity	-2.303	(-2.503, -2.102)	-2.012	(-2.070, -1.955)
Wholesale Beef Price	0.111*	(-0.113, 0.335)	-0.001*	(-0.103, 0.100)
Wholesale Beef Quantity	-2.770	(-3.050, -2.490)	-2.308	(-2.772, -1.844)
Import Wholesale Beef Price	0.111	(-0.113, 0.335)	-0.001	(-0.103, 0.100)
Import Wholesale Beef Quantity	0.203*	(-0.219, 0.626)	-0.013*	(-1.053, 1.027)
Other States Fed Cattle Price	0.494	(0.209, 0.780)	0.350	(0.234, 0.465)
Other States Fed Cattle Quantity	-1.141	(-1.423, -0.859)	-0.744	(-1.301, -0.186)
Kansas Fed Cattle Price	-2.275	(-2.862, -1.688)	0.348	(0.232, 0.463)
Kansas Fed Cattle Quantity	-14.461	(-14.68, -14.24)	-13.375	(-13.81, -12.93)
Import Fed Cattle Price	0.494	(0.209, 0.780)	0.350	(0.234, 0.465)
Import Fed Cattle Quantity	3.639	(0.784, 6.494)	6.354	(3.822, 8.886)
Other States Feeder Cattle Price	-2.312	(-2.909, -1.715)	-0.460	(-0.626, -0.294)
Other States Feeder Cattle Quantity	-0.527	(-0.768, -0.286)	-1.316	(-1.781, -0.851)
Kansas Feeder Cattle Price	0.491	(0.208, 0.775)	-0.452	(-0.615, -0.289)
Kansas Feeder Cattle Quantity	-1.392	(-1.834, -0.949)	-1.594	(-1.830, -1.358)
Import Feeder Cattle Price	-2.312	(-2.909, -1.715)	-0.460	(-0.626, -0.294)
Import Feeder Cattle Quantity	-10.173	(-16.318, -4.027)	-9.156	(-12.596, -5.715)
Pork Sector:				
Retail Pork Price	-0.758	(-0.994, -0.522)	-0.083	(-0.163, -0.004)
Retail Pork Quantity	-1.296	(-1.561, -1.031)	-1.940	(-2.002, -1.879)
Wholesale Pork Price	-0.671	(-0.888, -0.455)	-0.220	(-0.383, -0.057)
Wholesale Pork Quantity	-0.737	(-0.922, -0.552)	-1.673	(-2.038, -1.307)
Import Wholesale Pork Price	-0.671	(-0.888, -0.455)	-0.220	(-0.383, -0.057)
Import Wholesale Pork Quantity	-0.982	(-1.339, -0.626)	-0.894	(-1.568, -0.220)
Other States Hog Price	-0.605	(-0.842, -0.369)	-0.615	(-0.773, -0.456)
Other States Hog Quantity	-0.391	(-0.498, -0.285)	-1.250	(-1.532, -0.967)
Kansas Hog Price	-0.606	(-0.843, -0.370)	-0.616	(-0.775, -0.457)
Kansas Hog Quantity	-2.019	(-2.136, -1.902)	-2.878	(-3.170, -2.587)
Import Hog Price	-0.605	(-0.842, -0.369)	-0.615	(-0.773, -0.456)
Import Hog Quantity	-0.985	(-1.378, -0.593)	-2.537	(-3.249, -1.824)

Table 15. Percentage Changes in the Endogenous Variables in the EDM with Low Level Animal Identification and All Costs are Borne by the Producers, Change in Demand, Cont.

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	1.693	(0.524, 2.862)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.478	(0.145, 0.811)	0.991	(0.959, 1.023)
Wholesale Poultry Price	1.318	(0.345, 2.290)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.184	(0.044, 0.325)	0.950	(0.767, 1.134)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 16. Percentage Changes in the Endogenous Variables in the EDM with Medium Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.424	(0.908, 1.941)	0.010	(0.006, 0.014)
Retail Beef Quantity	-0.743	(-1.106, -0.380)	-0.006	(-0.010, -0.001)
Wholesale Beef Price	0.856	(0.514, 1.198)	0.085	(0.067, 0.103)
Wholesale Beef Quantity	-1.633	(-1.941, -1.324)	-0.187	(-0.231, -0.143)
Import Wholesale Beef Price	0.856	(0.514, 1.198)	0.085	(0.067, 0.103)
Import Wholesale Beef Quantity	1.566	(0.569, 2.564)	0.869	(0.674, 1.063)
Other States Fed Cattle Price	0.834	(0.485, 1.183)	0.445	(0.410, 0.481)
Other States Fed Cattle Quantity	-0.647	(-0.970, -0.323)	0.811	(0.710, 0.911)
Kansas Fed Cattle Price	0.829	(0.482, 1.176)	0.443	(0.407, 0.478)
Kansas Fed Cattle Quantity	-10.257	(-10.612, -9.902)	-8.774	(-8.990, -8.557)
Import Fed Cattle Price	0.834	(0.485, 1.183)	0.445	(0.410, 0.481)
Import Fed Cattle Quantity	6.141	(1.906, 10.376)	8.097	(6.054, 10.139)
Other States Feeder Cattle Price	-1.508	(-1.946, -1.071)	-0.064	(-0.089, -0.039)
Other States Feeder Cattle Quantity	-0.342	(-0.507, -0.177)	-0.191	(-0.263, -0.119)
Kansas Feeder Cattle Price	-1.484	(-1.914, -1.053)	-0.063	(-0.088, -0.038)
Kansas Feeder Cattle Quantity	-0.795	(-1.085, -0.504)	-0.613	(-0.649, -0.577)
Import Feeder Cattle Price	-1.508	(-1.946, -1.071)	-0.064	(-0.089, -0.039)
Import Feeder Cattle Quantity	-6.635	(-10.734, -2.536)	-1.275	(-1.795, -0.755)
Pork Sector:				
Retail Pork Price	0.206*	(-0.014, 0.426)	0.002	(0.001, 0.003)
Retail Pork Quantity	0.215*	(-0.118, 0.547)	0.001*	(-0.002, 0.004)
Wholesale Pork Price	0.205*	(-0.003, 0.414)	0.016	(0.013, 0.020)
Wholesale Pork Quantity	0.053*	(-0.119, 0.225)	-0.010	(-0.015, -0.005)
Import Wholesale Pork Price	0.205*	(-0.003, 0.414)	0.016	(0.013, 0.020)
Import Wholesale Pork Quantity	0.301	(-0.009, 0.610)	0.067	(0.047, 0.086)
Other States Hog Price	0.169*	(-0.026, 0.365)	0.037	(0.033, 0.041)
Other States Hog Quantity	-0.004*	(-0.085, 0.078)	-0.006*	(-0.013, 0.001)
Kansas Hog Price	0.170*	(-0.026, 0.365)	0.037	(0.033, 0.041)
Kansas Hog Quantity	-0.831	(-0.914, -0.749)	-0.834	(-0.842, -0.826)
Import Hog Price	0.169*	(-0.026, 0.365)	0.037	(0.033, 0.041)
Import Hog Quantity	0.276*	(-0.045, 0.596)	0.154	(0.131, 0.176)

Table 16. Percentage Changes in the Endogenous Variables in the EDM with Medium Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	0.542*	(-0.607, 1.692)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.153*	(-0.172, 0.478)	0.002*	(-0.002, 0.007)
Wholesale Poultry Price	0.422*	(-0.479, 1.323)	0.000*	(0.000, 0.001)
Wholesale Poultry Quantity	0.059*	(-0.067, 0.185)	0.002*	(-0.002, 0.007)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 17. Percentage Changes in the Endogenous Variables in the EDM with Medium Level Animal Identification and All Costs are Borne by the Producers, Change in Demand

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	-0.093*	(-0.348, 0.162)	0.005*	(-0.093, 0.103)
Retail Beef Quantity	-2.033	(-2.181, -1.885)	-2.011	(-2.068, -1.954)
Wholesale Beef Price	-0.189	(-0.369, -0.009)	-0.023*	(-0.121, 0.075)
Wholesale Beef Quantity	-2.187	(-2.385, -1.990)	-2.260	(-2.720, -1.800)
Import Wholesale Beef Price	-0.189	(-0.369, -0.009)	-0.023*	(-0.121, 0.075)
Import Wholesale Beef Quantity	-0.346*	(-0.725, 0.033)	-0.236*	(-1.236, 0.764)
Other States Fed Cattle Price	0.115*	(-0.094, 0.323)	0.173	(0.063, 0.283)
Other States Fed Cattle Quantity	-0.895	(-1.073, -0.717)	-1.069	(-1.620, -0.519)
Kansas Fed Cattle Price	0.114*	(-0.094, 0.321)	0.172	(0.063, 0.281)
Kansas Fed Cattle Quantity	-10.432	(-10.50, -10.35)	-9.924	(-10.33, -9.51)
Import Fed Cattle Price	0.115*	(-0.094, 0.323)	0.173	(0.063, 0.283)
Import Fed Cattle Quantity	0.842	(-0.750, 2.433)	3.140	(1.046, 5.233)
Other States Feeder Cattle Price	-1.743	(-2.184, -1.301)	-0.440	(-0.600, -0.279)
Other States Feeder Cattle Quantity	-0.393	(-0.573, -0.213)	-1.250	(-1.699, -0.801)
Kansas Feeder Cattle Price	-1.715	(-2.149, -1.280)	-0.432	(-0.590, -0.275)
Kansas Feeder Cattle Quantity	-0.837	(-1.171, -0.502)	-1.112	(-1.340, -0.885)
Import Feeder Cattle Price	-1.743*	(-2.184, -1.301)	-0.440	(-0.600, -0.279)
Import Feeder Cattle Quantity	-7.671	(-12.305, -3.036)	-8.753	(-12.076, -5.431)
Pork Sector:				
Retail Pork Price	-0.846	(-1.079, -0.612)	-0.084	(-0.164, -0.004)
Retail Pork Quantity	-1.361	(-1.610, -1.113)	-1.940	(-2.002, -1.879)
Wholesale Pork Price	-0.762	(-0.981, -0.544)	-0.228	(-0.389, -0.068)
Wholesale Pork Quantity	-0.732	(-0.925, -0.538)	-1.667	(-2.033, -1.302)
Import Wholesale Pork Price	-0.762	(-0.981, -0.544)	-0.228	(-0.389, -0.068)
Import Wholesale Pork Quantity	-1.115	(-1.486, -0.745)	-0.927	(-1.593, -0.260)
Other States Hog Price	-0.703	(-0.958, -0.448)	-0.652	(-0.811, -0.492)
Other States Hog Quantity	-0.361	(-0.477, -0.245)	-1.246	(-1.530, -0.962)
Kansas Hog Price	-0.705	(-0.960, -0.449)	-0.653	(-0.813, -0.493)
Kansas Hog Quantity	-1.190	(-1.319, -1.061)	-2.076	(-2.371, -1.781)
Import Hog Price	-0.703	(-0.958, -0.448)	-0.652	(-0.811, -0.492)
Import Hog Quantity	-1.145	(-1.571, -0.719)	-2.689	(-3.413, -1.966)

Table 17. Percentage Changes in the Endogenous Variables in the EDM with Medium Level Animal Identification and All Costs are Borne by the Producers, Change in Demand, Cont.

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	1.500	(0.476, 2.525)	0.008*	(-0.016, 0.033)
Retail Poultry Quantity	0.423	(0.132, 0.715)	0.991	(0.958, 1.023)
Wholesale Poultry Price	1.168	(0.316, 2.019)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.163	(0.039, 0.287)	0.950	(0.766, 1.133)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 18. Percentage Changes in the Endogenous Variables in the EDM with High Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	0.770	(0.498, 1.041)	0.007	(0.004, 0.009)
Retail Beef Quantity	-0.403	(-0.595, -0.210)	-0.004	(-0.006, -0.001)
Wholesale Beef Price	0.462	(0.281, 0.644)	0.057	(0.048, 0.066)
Wholesale Beef Quantity	-0.883	(-1.032, -0.735)	-0.125	(-0.148, -0.101)
Import Wholesale Beef Price	0.462	(0.281, 0.644)	0.057	(0.048, 0.066)
Import Wholesale Beef Quantity	0.846	(0.311, 1.381)	0.580	(0.478, 0.681)
Other States Fed Cattle Price	0.340	(0.168, 0.511)	0.216	(0.198, 0.234)
Other States Fed Cattle Quantity	-0.335	(-0.477, -0.192)	0.387	(0.338, 0.437)
Kansas Fed Cattle Price	0.338	(0.167, 0.508)	0.215	(0.197, 0.232)
Kansas Fed Cattle Quantity	-5.026	(-5.173, -4.879)	-4.292	(-4.397, -4.187)
Import Fed Cattle Price	0.340	(0.168, 0.511)	0.216	(0.198, 0.234)
Import Fed Cattle Quantity	2.500	(0.641, 4.359)	3.927	(2.936, 4.918)
Other States Feeder Cattle Price	-0.762	(-0.975, -0.549)	-0.035	(-0.048, -0.022)
Other States Feeder Cattle Quantity	-0.170	(-0.253, -0.088)	-0.101	(-0.137, -0.065)
Kansas Feeder Cattle Price	-0.750	(-0.960, -0.540)	-0.034	(-0.047, -0.022)
Kansas Feeder Cattle Quantity	-0.280	(-0.426, -0.133)	-0.191	(-0.209, -0.173)
Import Feeder Cattle Price	-0.762	(-0.975, -0.549)	-0.035	(-0.048, -0.022)
Import Feeder Cattle Quantity	-3.354	(-5.408, -1.299)	-0.693	(-0.957, -0.429)
Pork Sector:				
Retail Pork Price	0.102*	(-0.017, 0.220)	0.001	(0.001, 0.001)
Retail Pork Quantity	0.122*	(-0.057, 0.301)	0.001*	(-0.001, 0.003)
Wholesale Pork Price	0.099*	(-0.013, 0.211)	0.009	(0.008, 0.009)
Wholesale Pork Quantity	0.044*	(-0.048, 0.136)	-0.005	(-0.007, -0.003)
Import Wholesale Pork Price	0.099*	(-0.013, 0.211)	0.009	(0.008, 0.009)
Import Wholesale Pork Quantity	0.145*	(-0.021, 0.311)	0.035	(0.028, 0.043)
Other States Hog Price	0.058*	(-0.045, 0.161)	0.001	(0.000, 0.002)
Other States Hog Quantity	0.021*	(-0.022, 0.063)	-0.001*	(-0.003, 0.001)
Kansas Hog Price	0.058*	(-0.045, 0.161)	0.001	(0.000, 0.002)
Kansas Hog Quantity	-0.075	(-0.118, -0.032)	-0.097	(-0.098, -0.095)
Import Hog Price	0.058*	(-0.045, 0.161)	0.001	(0.000, 0.002)
Import Hog Quantity	0.094*	(-0.075, 0.263)	0.004	(0.000, 0.008)

Table 18. Percentage Changes in the Endogenous Variables in the EDM with High Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	0.292*	(-0.328, 0.911)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.082*	(-0.093, 0.258)	0.002*	(-0.001, 0.005)
Wholesale Poultry Price	0.227*	(-0.259, 0.713)	0.000*	(0.000, 0.000)
Wholesale Poultry Quantity	0.032*	(-0.036, 0.100)	0.002*	(-0.001, 0.004)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 19. Percentage Changes in the Endogenous Variables in the EDM with High Level Animal Identification and All Costs are Borne by the Producers, Change in Demand

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	-0.738	(-1.056, -0.421)	0.002*	(-0.096, 0.099)
Retail Beef Quantity	-1.684	(-1.903, -1.466)	-2.009	(-2.066, -1.952)
Wholesale Beef Price	-0.576	(-0.808, -0.344)	-0.051*	(-0.145, 0.042)
Wholesale Beef Quantity	-1.434	(-1.617, -1.251)	-2.198	(-2.653, -1.743)
Import Wholesale Beef Price	-0.576	(-0.808, -0.344)	-0.051*	(-0.145, 0.042)
Import Wholesale Beef Quantity	-1.055	(-1.738, -0.371)	-0.525*	(-1.478, 0.428)
Other States Fed Cattle Price	-0.375	(-0.602, -0.149)	-0.057*	(-0.161, 0.048)
Other States Fed Cattle Quantity	-0.581	(-0.745, -0.418)	-1.493	(-2.039, -0.947)
Kansas Fed Cattle Price	-0.373	(-0.598, -0.148)	-0.056*	(-0.160, 0.047)
Kansas Fed Cattle Quantity	-5.200	(-5.363, -5.037)	-5.442	(-5.832, -5.053)
Import Fed Cattle Price	-0.375	(-0.602, -0.149)	-0.057*	(-0.161, 0.048)
Import Fed Cattle Quantity	-2.767	(-5.083, -0.451)	-1.030*	(-2.957, 0.897)
Other States Feeder Cattle Price	-0.995	(-1.267, -0.724)	-0.410	(-0.564, -0.257)
Other States Feeder Cattle Quantity	-0.221	(-0.326, -0.117)	-1.160	(-1.590, -0.730)
Kansas Feeder Cattle Price	-0.979	(-1.246, -0.712)	-0.404	(-0.555, -0.253)
Kansas Feeder Cattle Quantity	-0.321	(-0.512, -0.130)	-0.690	(-0.907, -0.474)
Import Feeder Cattle Price	-0.995	(-1.267, -0.724)	-0.410	(-0.564, -0.257)
Import Feeder Cattle Quantity	-4.379	(-7.056, -1.702)	-8.171	(-11.349, -4.993)
Pork Sector:				
Retail Pork Price	-0.948	(-1.211, -0.685)	-0.085	(-0.165, -0.005)
Retail Pork Quantity	-1.452	(-1.752, -1.152)	-1.941	(-2.002, -1.879)
Wholesale Pork Price	-0.868	(-1.121, -0.616)	-0.236	(-0.394, -0.077)
Wholesale Pork Quantity	-0.740	(-0.968, -0.513)	-1.662	(-2.027, -1.297)
Import Wholesale Pork Price	-0.868	(-1.121, -0.616)	-0.236	(-0.394, -0.077)
Import Wholesale Pork Quantity	-1.270	(-1.700, -0.840)	-0.958	(-1.618, -0.298)
Other States Hog Price	-0.814	(-1.114, -0.514)	-0.688	(-0.849, -0.527)
Other States Hog Quantity	-0.336	(-0.473, -0.200)	-1.241	(-1.527, -0.955)
Kansas Hog Price	-0.816	(-1.116, -0.515)	-0.689	(-0.850, -0.528)
Kansas Hog Quantity	-0.433	(-0.584, -0.282)	-1.339	(-1.636, -1.041)
Import Hog Price	-0.814	(-1.114, -0.514)	-0.688	(-0.849, -0.527)
Import Hog Quantity	-1.325	(-1.828, -0.822)	-2.839	(-3.573, -2.104)

Table 19. Percentage Changes in the Endogenous Variables in the EDM with High Level Animal Identification and All Costs are Borne by the Producers, No Change in Demand, Cont.

	2% Decrease Beef and Pork & 1% Increase Poultry in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	1.254	(0.204, 2.304)	0.008*	(-0.016, 0.033)
Retail Poultry Quantity	0.354	(0.057, 0.651)	0.990	(0.958, 1.022)
Wholesale Poultry Price	0.976	(0.120, 1.831)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.137	(0.013, 0.260)	0.949	(0.766, 1.132)

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 20. Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the EDM with All Costs Borne by the Producer, No Change in Demand - Short Run, ($ Millions)

	No Change in Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-35.53*	-26.17*	-14.15*
Wholesale Level	-80.12	-57.41	-28.15
Other States Slaughter (Fed Cattle) Level	-31.57*	-23.92*	-14.49*
Kansas Slaughter (Fed Cattle) Level	-58.60*	-39.63*	-18.09*
Other States Farm (Feeder Cattle) Level	-58.03	-42.05	-21.19
Kansas Farm (Feeder Cattle) Level	-2.50	-1.79	-0.89
Total Beef Industry Producer Surplus	-266.34	-190.99	-96.96
Pork Producer Surplus:			
Retail Level	14.21*	10.46*	5.63*
Wholesale Level	3.01*	2.42*	1.50*
Other States Slaughter (Hog) Level	1.45*	1.16*	0.71*
Kansas Slaughter (Hog) Level	-0.48	-0.23	0.02
Total Pork Industry Producer Surplus	18.18	13.81	0.73
Poultry Producer Surplus:			
Retail Level	41.96*	30.83*	16.57*
Wholesale Level	14.34*	10.53*	5.66*
Total Poultry Industry Producer Surplus	56.29	41.36	22.23
Total Meat Industry Producer Surplus	*-191.87*	*-135.82*	*-74.00*
Retail Consumer Surplus:			
Retail Beef	-152.51	-112.57	-60.92
Retail Pork	-12.29	-8.60	-4.25
Retail Poultry	-32.52*	-23.90*	-12.84*
Total Retail Consumer Surplus	-197.32	-145.07	-78.01

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 21. Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the EDM with All Costs Borne by the Producer, No Change in Demand - Long Run, ($ Millions)

	No Change in Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	0.46*	0.36*	0.24*
Wholesale Level	0.48	0.18*	-0.22*
Other States Slaughter (Fed Cattle) Level	11.18	7.96	3.79
Kansas Slaughter (Fed Cattle) Level	-68.66	-50.92	-25.93
Other States Farm (Feeder Cattle) Level	-2.59	-1.91	-1.00
Kansas Farm (Feeder Cattle) Level	-2.01	-1.10	-0.32
Total Beef Industry Producer Surplus	-61.13	-45.44	-23.44
Pork Producer Surplus:			
Retail Level	0.06*	0.05*	0.03*
Wholesale Level	-0.03*	-0.07	-0.11
Other States Slaughter (Hog) Level	0.03*	0.01*	-0.01*
Kansas Slaughter (Hog) Level	-0.89	-0.46	-0.15
Total Pork Industry Producer Surplus	-0.82	-0.47	-0.24
Poultry Producer Surplus:			
Retail Level	0.006*	0.004*	0.003*
Wholesale Level	0.007*	0.006*	0.004*
Total Poultry Industry Producer Surplus	0.01	0.01	0.01
Total Meat Industry Producer Surplus	*-61.95*	*-45.90*	*-23.68*
Retail Consumer Surplus:			
Retail Beef	-1.03	-0.82	-0.55
Retail Pork	-0.12	-0.08	-0.04
Retail Poultry	0.00*	0.00*	0.00*
Total Retail Consumer Surplus	-1.15	-0.90	-0.59

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 22. Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the EDM with All Costs Borne by the Producer, Change in Demand - Short Run, ($ Millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-238.72	-228.29	-214.89
Wholesale Level	-144.76	-121.79	-92.18
Other States Slaughter (Fed Cattle) Level	-65.46	-57.69	-48.10
Kansas Slaughter (Fed Cattle) Level	-69.27	-43.51	-22.21
Other States Farm (Feeder Cattle) Level	-64.51	-48.51	-27.62
Kansas Farm (Feeder Cattle) Level	-1.18	-2.06	-1.16
Total Beef Industry Producer Surplus	-583.91	-501.85	-405.00
Pork Producer Surplus:			
Retail Level	-52.77	-56.43	-61.13
Wholesale Level	-16.87	-17.43	-18.33
Other States Slaughter (Hog) Level	-9.88	-10.16	-10.60
Kansas Slaughter (Hog) Level	-0.81	-0.56	-0.31
Total Pork Industry Producer Surplus	-80.33	-84.58	-90.05
Poultry Producer Surplus:			
Retail Level	96.36	85.40	71.36
Wholesale Level	32.93	29.19	24.40
Total Poultry Industry Producer Surplus	129.29	114.59	95.76
Total Meat Industry Producer Surplus	*-534.95*	*-471.83*	*-399.29*
Retail Consumer Surplus:			
Retail Beef	-188.79	-149.73	-99.21
Retail Pork	-51.52	-47.88	-43.59
Retail Poultry	-30.68*	-22.18*	-11.30*
Total Retail Consumer Surplus	-270.98	-219.80	-154.11

*Indicates the value is not statistically different from zero at the 0.05 level.

Table 23. Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the EDM with All Costs Borne by the Producer, Change in Demand - Long Run, ($ Millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-16.98	-17.07	-17.19
Wholesale Level	-15.20	-15.50	-15.89
Other States Slaughter (Fed Cattle) Level	-6.01	-9.19	-13.30
Kansas Slaughter (Fed Cattle) Level	-74.02	-55.38	-29.07
Other States Farm (Feeder Cattle) Level	-12.88	-12.21	-11.30
Kansas Farm (Feeder Cattle) Level	-2.44	-1.53	-0.75
Total Beef Industry Producer Surplus	-127.52	-110.88	-87.51
Pork Producer Surplus:			
Retail Level	-12.17	-12.19	-12.21
Wholesale Level	-7.94	-7.98	-8.02
Other States Slaughter (Hog) Level	-8.86	-8.88	-8.89
Kansas Slaughter (Hog) Level	-1.14	-0.71	-0.41
Total Pork Industry Producer Surplus	-30.11	-29.76	-29.53
Poultry Producer Surplus:			
Retail Level	1.86	1.86	1.86
Wholesale Level	2.39	2.39	2.38
Total Poultry Industry Producer Surplus	4.251	4.248	4.244
Total Meat Industry Producer Surplus	*-153.56*	*-136.55*	*-112.92*
Retail Consumer Surplus:			
Retail Beef	-157.65	-157.45	-157.18
Retail Pork	-79.25	-79.21	-79.17
Retail Poultry	44.03	44.03	44.03
Total Retail Consumer Surplus	-192.87	-192.63	-192.32

*Indicates the value is not statistically different from zero at the 0.05 level.

Conclusions & Summary of Animal Traceability Study

After September 11th 2001, America's vulnerability to terrorist attacks became much more apparent. One area of vulnerability exposed to bioterrorism is U.S. agriculture. Additional concerns regarding U.S. agriculture is the management of animal diseases. With the 2003 discovery of BSE in the U.S. and more recent cases in 2005 and 2006, the need for having the ability to rapidly trace animal movements has become apparent. In the event of a contagious animal disease, say FMD, tracking animal movement in a timely manner is essential to disease containment. Animal identification will help limit the spread of the disease which will reduce costs and minimize trade losses. To help combat spread of contagious animal diseases, the USDA has recently launched the National Animal Identification System with intent to trace movement of an infected animal within 48 hours.

Welfare results were different among the alternative scenarios. When demand was held constant, producers from the beef industry had declines in welfare which ranged from $226.34 million with low-level ID to $96.96 million with high-level ID. Allowing demand to change for beef, pork and poultry, producer surplus declined by $583.91 million and $405 million for low- and high-level surveillance systems, respectively. Overall, the decline in producer surplus at different marketing levels implies the amount of money producers can allocate to fixed costs and investments decline.

Improved animal trace back systems result in reduced producer and consumer surplus measures in the event of FMD. That is, as the depth of animal identification is increased, the welfare losses become smaller. This occurs mainly because the number of animals destroyed in a high-level identification system is lower when compared to a low-level identification system. These results imply time is crucial when eradicating a contagious animal disease such as FMD. Not only does a high-level surveillance system reduce the number of destroyed animals which reduces changes to producer and consumer surpluses, it also reduces the amount of time to fully eradiate the disease. Increased trace back systems could also lead to increases in food safety and thus improved consumer confidence in U.S. meat products, increasing consumer demand for red meats as found by Dickinson, Hobbs, and Bailey (2003). Additional benefits from animal identification include improved supply chain management, increased farm profits, and potential access to closed international markets.

Regional Economic Impacts of a Foot-and-Mouth Disease Outbreak Study

The objective of this second study is to determine the economic implications of a hypothetical FMD outbreak in a specific local region in southwest Kansas under three different disease introduction scenarios. These scenarios include disease introduction at a single cow-calf operation, introduction at a single medium-sized feedlot (feedlot with between 10,000-20,000 head of cattle one-time feeding capacity), and introduction simultaneously at five large feedlots (feedlots with greater than 40,000 head one-time feeding capacity). The first two scenarios would be indicative of a likely small-scale outbreak (though there is some probability of the outbreak being large). Whereas, the latter scenario represents what could characterize a purposeful simultaneous introduction of the disease and would have a much greater probability of a larger outbreak. The simultaneous introduction into five large feedlots could ultimately result in larger consequences due to the number of cattle that would be destroyed and the number of animate (e.g., humans) and inanimate (e.g., vehicles) vectors entering a large feedlot on a daily basis.

Similar to the animal traceability study, NAADSM is used to determine the probable spread of a hypothetical FMD outbreak in southwest Kansas, an area selected because of its relatively high concentration of large cattle feeding operations as well as other livestock enterprises and a large beef processing presence. Results from the disease spread model are integrated into an economic framework to determine the regional economic impacts. Results from this study can be used to assess what economic impacts would be if such an event occurred in a local region and in implementing future invasive species and foreign animal disease management policies.

The description of the epidemiological disease spread model was previously discussed. The difference in the disease spread model between this regional economic impact study and the animal traceability study is the incidence of the introduction of FMD. In addition, this study considered only 30% animal traceability level for cattle in the analysis.

This study employs both partial equilibrium analysis (i.e., equilibrium displacement model) and input-output approaches. The EDM framework and associated elasticities used in this regional analysis are the same as the animal traceability study and are described above.

The input-output (I-O) model constructed for this analysis is a multiregional model (Miller and Blair, 1985; Miller, 1998). Given the concentration of cattle production and processing in the southwest Kansas region, much of near-term impact will be concentrated within the region. However, the overall control strategy will affect the entire state of Kansas as livestock will not be permitted to move in either direction across state borders.

The I-O construction followed procedures generally employed in standard core-periphery models (e.g., Holland and Hughes, 1992; Kilkenny, 1993, 1995; Kilkenny and Rose, 1995). With the regions specified as the 14-county southwestern Kansas economy, and the 91-county rest of Kansas economy, separate I-O models were built for each region plus the combined region using the IMPLAN modeling system (MIG, 1999). One general enhancement incorporated into this research was the use of IMPLAN's new national trade flow model (Lindall, Olson and Alward, 2005) to estimate the inter-regional trade flows in this fully-developed social accounting matrix (SAM) framework.

The derivation of the SAM multiplier model follows Alward (1996). Having the economic multipliers for our 14-county southwestern Kansas region and our 91-county rest of Kansas region, we look to the partial equilibrium results for the direct economic impacts. The sectors most likely directly impacted in the event of a disease outbreak would be cattle ranching and farming (including feedlot production), other animal production – except poultry and cattle (i.e., swine production), animal slaughtering, grain farming, and transportation. The task was to translate the values from partial equilibrium analysis into direct impacts to the I-O model.

The Kansas farm and slaughter levels of producer surplus represent the value of lost cattle and swine production. Similarly, the wholesale levels of beef and pork producer surplus are the value of lost animal slaughtering. These are the values available to be distributed to all of the impacted sectors both in southwestern Kansas and the rest of Kansas.

The value of cattle and swine production is first distributed to southwestern Kansas and the rest of Kansas using Kansas agricultural statistics. One of the primary inputs into cattle and swine production is the value of feed. Thus, some portion of the value of livestock production needed to be deducted from Kansas farm and slaughter sectors and applied to grain production as an estimate of the loss of demand for grain inputs. The total value attributed to grain farming was estimated by multiplying the number of cattle destroyed by a per head added cost to the grain industry for hauling grain an additional 200 miles that otherwise would have been used in the southwest KS feedlots.

Similarly, the wholesale level of producer surplus represents the increment of value generated in the processing and packing activities occurring there. Some proportion of that value can be attributed to the transportation services needed to move inputs and outputs associated with this activity. Here it is assumed that about one-half percent of the total value of livestock processing is attributable to transportation inputs. These then serve as the values derived from the partial equilibrium model and distributed to affected sectors in the I-O model to estimate the total economic impacts to southwestern Kansas and the state.

Epidemiological Results

Results from the epidemiological model are expressed as means and standard deviations derived from 1,000 iterations from each simulation. The expected number and standard deviation of animals that would be destroyed if a FMD outbreak occurs differs substantially by scenario at each level (Table 24). As the size of the index herd was increased, the number of animals that were stamped-out increased. Two things, 1) number of animals infected and 2) length of disease outbreak, are among the most important epidemiological outputs. For example, if the index case for a FMD outbreak that begins within a cow-calf herd, an expected 92,612 head of livestock in feedlots are destroyed and the disease outbreak would last 29 days in length. If the index case for a FMD outbreak begins within a medium-sized feedlot, the expected number of livestock in feedlots destroyed would be 292,425 head and the disease would endure for 39 days. For FMD that is simultaneously introduced at five large feedlots, an expected 1.20 million head of cattle in feedlots would be destroyed in southwest Kansas and the outbreak would last 89 days.

The standard deviation of the number of animals destroyed is relatively large. These large values are because in a number of simulations the number of animals destroyed was near zero and in others most of livestock in the region is destroyed because of wide-spread disease outbreak. We focus our regional economic analysis on the average number of animals destroyed. However, with the large standard deviations, analyzing the economic implications of distributions of disease impact and spread deserve additional research.

Table 24. Summary Statistics for the Number of Animals Depopulated for the Regional Economic Impacts Study

	Mean	*Std. Dev.*
Total Destruction (head)		
Five Large Feedlot Herds		
Feedlot	1,200,427	1,134,904
Farm	26,113	24,870
Swine	387,415	384,553
One Feedlot Herd		
Feedlot	292,425	760,049
Farm	6,304	16,520
Swine	92,041	246,576
One Cow-Calf Herd		
Feedlot	92,612	445,760
Farm	2,018	9,884
Swine	26,343	134,644
Length of Outbreak (Days)		
Five Large Feedlot Herds	89	47.76
One Feedlot Herd	39	38.94
One Cow-Calf Herd	29	26.28

Economic Results

Mean estimates for changes in producer surplus associated with the different scenarios at each market level are presented in Table 25. In addition, the 95% confidence intervals for changes in producer surplus are presented in Table 25. In general, as the number of animals present at the premises of the index case increases, producer surplus losses associated with a FMD outbreak become larger. Total producer surplus (retail, wholesale, slaughter, and farm) for the beef industry declines by $43.2 million when the index case is a single cow-calf herd. When the initial case of FMD occurs in a medium-sized feedlot, total producer surplus losses for the beef industry are $166.5 million. Total producer surplus declines by $728.5 million if FMD is introduced in five large feedlots.

The regional impacts of various outbreak scenarios are shown in Tables 26 and 27. Presentation of the results follows the standard information available in IMPLAN SAM models. The top one-third of the tables show the value of productive activity (output) using a 14-sector aggregation scheme. While most sectors are highly aggregated, those assumed most impacted by a disease outbreak (grain farming, cattle ranching and farming, animal production-except cattle and poultry (i.e., swine

Table 25. Changes in Producer Surplus for Each Market Level Associated with Three Different Hypothetical FMD Incidence Scenarios, ($ Millions)

	Hypothetical FMD Incidence Scenario		
	Five Large Feedlot Herds	One Medium-Size Feedlot Herd	One Cow-Calf Herd
Beef Producer Surplus:			
Retail Level	-63.57	-17.39	-6.97
	(-138.25, 48.82)[a]	(-50.30, 15.14)	(-32.23, 9.97)
Wholesale Level	-134.87	-33.08	-10.90
	(-154.35, -50.57)	(-50.12, -16.83)	(-29.09, -9.43)
Other States Slaughter (Fed Cattle) Level	-50.15	-16.82	-9.34
	(-132.51, 110.81)	(-54.28, 25.50)	(-39.93, 8.81)
Kansas Slaughter (Fed Cattle) Level	-374.93	-72.97	-6.99
	(-7,162.79, 6,381.24)	(-1,291.76, 1,131.37)	(-20.16, -7.86)
Other States Farm (Feeder Cattle) Level	-73.20	-24.20	-8.67
	(-94.94, -51.45)	(-31.75, -17.80)	(-18.50, -10.59)
Kansas Farm (Feeder Cattle) Level	-9.51	-2.01	-0.37
	(-16.28, -0.83)	(-1.37, -0.75)	(-0.87, -0.46)
Total Beef Industry Producer Surplus	-706.23	-166.47	-43.24
Pork Producer Surplus:			
Retail Level	22.64	6.34	2.84
	(-6.30, 42.22)	(-2.17, 14.97)	(-1.39, 9.69)
Wholesale Level	3.90	1.11	0.61
	(-4.16, 10.53)	(-1.44, 3.75)	(-1.19, 2.20)
Other States Slaughter (Hog) Level	4.88	1.14	0.22
	(0.41, 9.40)	(-0.35, 2.78)	(-0.22, 1.85)
Kansas Slaughter (Hog) Level	-5.10	-1.12	0.00
	(-6.23, -3.87)	(-1.32, -0.99)	(-1.28, -0.96)
Total Pork Industry Producer Surplus	26.32	7.47	3.67
Poultry Producer Surplus:			
Retail Level	66.87	18.74	8.40
	(-56.66, 162.74)	(-19.48, 57.22)	(-12.50, 37.12)
Wholesale Level	22.86	6.41	2.87
	(-19.83, 56.15)	(-6.83, 19.76)	(-4.39, 12.82)
Total Poultry Industry Producer Surplus	89.74	25.15	11.27
Total Meat Industry Producer Surplus	-590.18	-133.86	-28.30

[a]Indicates the 95% confidence interval.

production), meatpacking, and truck transportation) are broken out in detail. The middle third of the table shows three value-added (income) categories, and the lower third shows households by income group.

In I-O analysis, the direct economic impacts are the immediate changes in the value of total final demand. Subsequent impacts to value added or household income arise as the indirect or backward-linked sectors and institutions are affected by the direct change in final demand. Thus, in an immediate (direct) sense, all that is changing is the value of production. Impacts to labor, households and interlinked industry sectors do not appear until the total impacts are computed. The value of the direct impacts for cattle, hogs, and meatpacking are taken directly from the partial equilibrium analysis as described earlier. Estimates associated with grain farming and truck transportation were estimated based on a consensus of experts knowledgeable with both the region and the overall value of production in the livestock and meatpacking sectors.

The vector of direct impacts assumed to accrue to southwestern Kansas is shown for the three FMD incidence scenarios in Table 26. In the large feedlot outbreak scenario, the output impacts to the region prior to recovery were estimated to be over $685 million with approximately 64 and 16 percent of the impacts coming from cattle ranching and farming and animal slaughtering, respectively (Table 26). As seen in Table 27, the total output impacts to the rest of Kansas for the same scenario were estimated to be about an additional $260 million. In the rest of the state, cattle ranching and farming bears the largest brunt of the FMD outbreak with $110.9 million (Table 27). Other sectors that are significantly impacted include animal slaughtering, rest of manufacturing, finance, insurance, real estate, and services.

The combined overall impact for the State of Kansas can be obtained by summing the values in Tables 26 and 27. When considering the combined output impacts for all 105 counties in Kansas, the total estimated economic impact would reach nearly $1 billion in productive activity in the five large feedlot outbreak scenario.

SAM accounts also permit the estimation of impacts accruing to value-added (all types of income associated with production) and to households (primarily labor income). Continuing with the five large feedlots scenario, nearly $150 million in total value-added would be lost to southwestern Kansas with an additional $76 million loss to the rest of Kansas. Residents of the region would see a direct decline of approximately $110 million in household income. As the impacts emanate throughout the rest of Kansas, the total impact to value-added reaches about $220 million and total household income declines by about $175 million.

Corresponding impacts in the other scenarios are substantially smaller, but not trivial. A FMD outbreak in a single medium-sized feedlot could result in approximately $200 million decline in total economic activity. Even a relatively small outbreak in a single cow-calf herd would tally about $35 million in lost output to Kansas.

Table 26. Estimated Direct and Total Impact to Southwest Kansas Region Associated with Alternative Hypothetical FMD Outbreak Scenarios, (2004$ Millions)

Region	Description	Direct Impact: Five Large Feedlot Herds	Direct Impact: One Feedlot Herd	Direct Impact: One Cow-Calf Herd	Total Impact: Five Large Feedlot Herds	Total Impact: One Feedlot Herd	Total Impact: One Cow-Calf Herd
14-County Southwest Kansas (Region A)	Grain Farming	-4.330	-1.055	-0.334	-5.202	-1.231	-0.359
	Cattle Ranching and Farming	-346.000	-65.874	-6.324	-435.920	-85.170	-10.446
	Animal Production - except cattle and poultry	-4.590	-1.008	0.000	-5.624	-1.261	-0.082
	Rest of Agriculture	0.000	0.000	0.000	-1.563	-0.314	-0.043
	Mining	0.000	0.000	0.000	-0.023	-0.005	-0.001
	Construction	0.000	0.000	0.000	-1.610	-0.322	-0.045
	Animal - except poultry - slaughtering	-105.740	-25.935	-8.547	-107.966	-26.456	-8.697
	Rest of Manufacturing	0.000	0.000	0.000	-15.736	-3.101	-0.378
	Truck Transportation	-2.040	-0.424	-0.072	-8.175	-1.696	-0.297
	Rest of TCPU	0.000	0.000	0.000	-17.242	-3.487	-0.535
	Wholesale and Retail Trade	0.000	0.000	0.000	-23.568	-4.826	-0.801
	Finance Insurance Real Estate	0.000	0.000	0.000	-25.642	-5.201	-0.816
	Services	0.000	0.000	0.000	-33.724	-6.879	-1.117
	Government	0.000	0.000	0.000	-3.660	-0.734	-0.107
	SUM	-462.700	-94.296	-15.277	-685.655	-140.682	-23.724
	Employee Compensation	0.000	0.000	0.000	-75.897	-15.700	-2.733
	Proprietor Income	0.000	0.000	0.000	-13.502	-2.731	-0.416
	Other Property Type Income	0.000	0.000	0.000	-56.589	-11.372	-1.715
	SUM	0.000	0.000	0.000	-145.988	-29.802	-4.864
	Households LT10k	0.000	0.000	0.000	-1.046	-0.214	-0.035
	Households 10-15k	0.000	0.000	0.000	-1.780	-0.364	-0.060
	Households 15-25k	0.000	0.000	0.000	-7.783	-1.593	-0.263
	Households 25-35k	0.000	0.000	0.000	-11.082	-2.268	-0.374
	Households 35-50k	0.000	0.000	0.000	-20.638	-4.224	-0.698
	Households 50-75k	0.000	0.000	0.000	-32.515	-6.654	-1.098
	Households 75-100k	0.000	0.000	0.000	-16.115	-3.297	-0.544
	Households 100-150k	0.000	0.000	0.000	-11.050	-2.261	-0.373
	Households 150k+	0.000	0.000	0.000	-8.142	-1.666	-0.275
	SUM	0.000	0.000	0.000	-110.151	-22.542	-3.721

Table 27. Estimated Direct and Total Impact to Rest of Kansas Associated with Alternative Hypothetical FMD Outbreak Scenarios, (2004$ Millions)

		Direct Impact			Total Impact		
	Description	Five Large Feedlot Herds	One Feedlot Herd	One Cow-Calf Herd	Five Large Feedlot Herds	One Feedlot Herd	One Cow-Calf Herd
91-County Rest of Kansas (Region B)	Grain Farming	-4.330	-1.055	-0.334	-6.900	-1.582	-0.410
	Cattle Ranching and Farming	-38.440	-9.106	-1.035	-110.883	-25.350	-4.749
	Animal Production - except cattle and poultry	-0.510	-0.112	0.000	-4.719	-1.141	-0.334
	Rest of Agriculture	0.000	0.000	0.000	-4.574	-0.941	-0.137
	Mining	0.000	0.000	0.000	-0.220	-0.046	-0.008
	Construction	0.000	0.000	0.000	-0.740	-0.166	-0.032
	Animal - except poultry - slaughtering	-26.430	-6.484	-2.137	-26.673	-6.541	-2.153
	Rest of Manufacturing	0.000	0.000	0.000	-23.924	-5.086	-0.846
	Truck Transportation	-0.510	-0.106	-0.018	-3.171	-0.699	-0.139
	Rest of TCPU	0.000	0.000	0.000	-11.314	-2.508	-0.484
	Wholesale and Retail Trade	0.000	0.000	0.000	-13.650	-3.062	-0.618
	Finance Insurance Real Estate	0.000	0.000	0.000	-23.065	-5.177	-1.029
	Services	0.000	0.000	0.000	-28.711	-6.404	-1.269
	Government	0.000	0.000	0.000	-1.550	-0.349	-0.069
	SUM	-70.220	-16.863	-3.524	-260.095	-59.053	-12.277
	Employee Compensation	0.000	0.000	0.000	-36.248	-8.143	-1.670
	Proprietor Income	0.000	0.000	0.000	-5.795	-1.285	-0.255
	Other Property Type Income	0.000	0.000	0.000	-33.719	-7.569	-1.498
	SUM	0.000	0.000	0.000	-75.762	-16.998	-3.423
	Households LT10k	0.000	0.000	0.000	-0.539	-0.121	-0.024
	Households 10-15k	0.000	0.000	0.000	-1.007	-0.226	-0.046
	Households 15-25k	0.000	0.000	0.000	-3.438	-0.771	-0.155
	Households 25-35k	0.000	0.000	0.000	-5.250	-1.178	-0.237
	Households 35-50k	0.000	0.000	0.000	-9.587	-2.151	-0.434
	Households 50-75k	0.000	0.000	0.000	-17.824	-3.998	-0.806
	Households 75-100k	0.000	0.000	0.000	-10.888	-2.442	-0.492
	Households 100-150k	0.000	0.000	0.000	-9.534	-2.139	-0.431
	Households 150k+	0.000	0.000	0.000	-7.054	-1.582	-0.319
	SUM	0.000	0.000	0.000	-65.121	-14.609	-2.945

Conclusions & Summary of Regional Economic Impacts Study

Most previous research on FMD has drawn the same general conclusion; a FMD outbreak has severe economic implications. This study estimated the economic impact of a FMD outbreak in southwestern Kansas under three different disease introduction scenarios. The scenarios included introduction of FMD at a cow-calf operation, a medium-sized feedlot, and simultaneously at five large feedlots. The different scenarios were used to demonstrate how the incidence of such a disease would have widely different epidemiological and economic implications. As such, diligence in managing, having contingency plans in place, investment in disease control strategies, and for ways to deal with the disease if it were to occur are much different depending upon the nature of the disease incidence or outbreak.

If the disease was introduced in a single cow herd, with rapid detection and ability to arrest the disease quickly and restore normal cattle and meat movement in the region in a relatively short time frame, local economic damages would be modest. That is, total economic impact (production activity, value-added, and household income) on the local southwest Kansas economy would be a loss of about $35 million. However, in contrast, if the disease were introduced in five large feedlots, the total economic impact in the area would approach a $1 billion loss.

Clearly, if the disease hit several large feedlots at once, the economic loss would very substantial for the local community. This indicates that diligent animal health surveillance programs and policies and industry management strategies to ensure against FMD introduction in large feedlots is critical. Given the amount of traffic into large feedlots every day and the number of cattle coming into such facilities for finishing on a regular basis, introduction and spread of a contagious disease to other premises is not only easier, but probable. The aggressiveness and amount of resources that would be worth committing to a FMD incident if it were to occur in this region depends on the nature of the incident. If the incident occurred in large feedlots, a considerable amount of resource commitment to control the disease appears to be a prudent investment.

Conclusions & Summary

Concerns regarding foreign animal diseases have escalated substantially in recent years. Terrorist attacks on the United States in September 2001 greatly increased awareness of vulnerability of U.S. agriculture to bioterrorism. In addition to heightened bioterrorism concerns, increased globalization and world travel make transmission of foreign animal diseases more probable. With the 2003 discovery of BSE in the U.S. and more recent cases in 2005 and 2006, the ability to identify, arrest, and eradicate a highly contagious foreign animal disease has become apparent.

In the event of a contagious animal disease, say FMD, tracking animal movement in a timely manner is essential to disease containment. Animal identification will help limit the spread of the disease which will reduce costs and minimize trade losses. To help combat spread of contagious animal diseases, the USDA has recently launched the National Animal Identification System with intent to trace movement of an infected animal within 48 hours.

In 2005, producers in Kansas marketed the largest number of fed cattle in the nation at 5.3 million head. Kansas and neighboring states represent roughly 80% of fed cattle marketing's in the U.S. and therefore, introduction of a contagious disease such as FMD in this region would not only significantly affect this local region in Kansas and the state of Kansas, but the entire U.S. and world livestock and meat markets. Therefore, to better understand the effects of a FMD outbreak in the U.S., one study in this report estimates the effects of a hypothetical outbreak of FMD in southwest Kansas. Specifically, the objectives of this study were to:

- Determine the impact of a hypothetical outbreak of foot-and-mouth disease in southwest Kansas via an epidemiological disease spread model,
- Determine how a hypothetical outbreak of foot-and-mouth disease with different levels of animal ID/trace back systems will affect the welfare of producers and consumers.

In addition to increased costs at the respective sectors within the marketing chains, a FMD outbreak would decrease supply of wholesale beef, fed cattle, feeder cattle, wholesale pork, and market hogs. Assuming no change in consumer demand for beef, pork, and poultry, this leftward shift of the supply curves leads to increased prices and ultimately reductions in total consumer and producer surplus. However, as the level of animal identification was increased, the number of animals stamped-out decreased as did the costs associated with FMD. These decreases resulted in smaller leftward shifts of the supply curves and smaller welfare losses. With decreases in demand for beef and pork and an increase in demand for poultry, this resulted in larger backward shifts of the supply curves for beef and pork sectors. However, as traceability increases, the shifts in the supply curves become incrementally smaller.

Welfare results for the animal traceability study were different among the alternative scenarios. When demand was held constant, producers from the beef industry had declines in welfare which ranged from $226.34 million with low-level ID to $96.96 million with high-level ID. Allowing demand to change for beef, pork and poultry, producer surplus declined by $583.91 million and $405 million for low- and high-level trace back systems, respectively. Overall, the decline in producer surplus at different marketing levels implies the amount of money producers can allocate to fixed costs and investments decline.

Improved animal trace back systems result in reduced producer and consumer surplus measures in the event of FMD. That is, as the depth of animal identification is increased, the welfare losses become smaller. This occurs mainly because the number of animals destroyed in a high-level identification system is lower when compared to a low-level identification system. These results imply time is crucial when eradicating a contagious animal disease such as FMD. Not only does a high-level surveillance system reduce the number of destroyed animals which reduces changes to producer and consumer surpluses, it also reduces the amount of time necessary to fully eradicate the disease. Increased trace back systems could also lead to increases in food safety and thus improved consumer confidence in U.S. meat products, increasing consumer demand for red meats as found by Dickinson, Hobbs, and Bailey (2003). Additional benefits from animal identification include improved supply chain management, increased farm profits, and potential access to closed international markets.

To better understand the regional effects of a FMD outbreak in the U.S., the second study in this report determined economic impacts of a hypothetical FMD outbreak in a specific local region in southwest Kansas under three different disease introduction scenarios. This region was selected because of its relatively high concentration of large cattle feeding operations as well as other livestock enterprises and a large beef processing presence. As a result, the local economy is highly dependent on the livestock industry which amplifies the importance of such a disease outbreak.

Total impacts estimated to accrue to southwestern Kansas associated with a FMD outbreak originating in a cow-calf, medium-size feedlot, and five large feedlots scenarios were estimated to be $32 million, $193 million, and $942 million, respectively. The combined overall impact for the State of Kansas for the cow-calf, medium-size feedlot, and five large feedlots scenarios were estimated to be losses of $51 million, $284 million, and $1.3 billion, respectively.

Results from this study demonstrate how widely different the epidemiological and economic implications could be with such a disease. As such, disease surveillance, management strategies, mitigation investment, and ways to deal with the disease, if it were to occur, are much different depending upon the nature of the disease incidence.

The value of this report lies in its ability to quantify the impacts of alternative levels of animal traceability and different disease introduction scenarios in the event of a regional FMD outbreak. The results of these studies will provide insight to numerous groups such as policy makers, government agencies (i.e., ERS and APHIS), and researchers. The animal traceability study provides policy makers with scientific evidence of the importance of alternate animal ID systems. Because the National Animal Identification System is currently being developed, this research allows policy makers to make better informed decisions in finalizing the future guidelines for animal identification systems and invasive species management policies. The regional economic impact study also provides policy makers with information regarding how aggressive and the amount of resources that would be worth committing to a FMD incident. This research aids the ERS and APHIS in making policy recommendations to Congress. Researchers can use this methodology that links an epidemiological disease spread model with an EDM for future research in better understanding the implications of a large number of alternative policy scenarios.

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Appendix A – Output to Date from PREISM Project

Dissertation

Dustin L. Pendell. *Value of Animal Traceability Systems in Managing a Foot-and-Mouth Disease Outbreak in Southwest Kansas*. PhD Dissertation. Kansas State University Manhattan, KS. September 2006.

Publications

Pendell, D.L, J. Leatherman, T.C. Schroeder, and G.S. Alward. "The Economic Impacts of a Foot-And-Mouth Disease Outbreak: A Regional Analysis." *Journal of Agricultural and Applied Economics*: Forthcoming.

Pendell, D.L, T.C. Schroeder, J. Leatherman, and G.S. Alward. "Summary of a Regional Economic Impact of a Hypothetical Foot-And-Mouth Disease Outbreak in Southwest Kansas." In Livestock and Wildlife Disease Report (LWDR 07–01), Colorado State University Cooperative Extension. September 2007.

Pendell, D., and T. Schroeder. "Value of animal traceability systems in managing a foot-and-mouth disease outbreak in southwest Kansas." In 2007 Beef Cattle Research, Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Report of Progress. Available at: http://www.oznet.ksu.edu/library/lvstk2/SRP978.pdf.

Presentations

Pendell, D., and T. Schroeder. "Value of Animal Traceability Systems in Managing a FMD Outbreak." USDA PREISM Workshop, Washington DC, October 19, 2007.

Pendell, D.L. "Considerations for Economic Modeling." Presented at USDA, APHIS Introduction to Epidemiologic Simulation Modeling course. Fort Collins, Colorado, August 2007.

Pendell, D.L, J. Leatherman, T.C. Schroeder, and G.S. Alward. "The Economic Impacts of a Foot-And-Mouth Disease Outbreak: A Regional Analysis." Presented at the 2007 Western Agricultural Economics Association annual meetings. Portland, Oregon, July 2007.

Pendell, D., T. Schroeder, and A.E. Hill. "Value of Animal Traceability Systems in Managing a FMD Outbreak." USDA PREISM Workshop, Washington DC, October 20, 2006.

Pendell, D.L. "The Economic Value of Traceability Systems in the Event of a FMD Outbreak." Presented at Colorado State University. Fort Collins, Colorado, January 2006.

Pendell, D.L. "The Economic Value of Traceability Systems in the Event of a FMD Outbreak." Presented at University of Florida. Gainesville, Florida, February 2006.

Pendell, D.L. "The Economic Value of Traceability Systems in the Event of a FMD Outbreak." Presented at Oklahoma State University. Stillwater, Oklahoma, March 2006.

Schroeder, T. and D. Pendell. "Economic Impacts of a Contagious Animal Disease: Research Proposal." USDA PREISM Workshop, Washington DC, October 19, 2005.

Work in Progress

Pendell, D.L, and T.C. Schroeder. "Value of Animal Traceability Systems in Managing Contagious Animal Diseases." Presentation at Annual Professional Meetings.

Pendell, D.L, and T.C. Schroeder. "Value of Animal Traceability Systems in Managing Contagious Animal Diseases." Working paper being prepared for submission to a peer-reviewed journal.

Stroade, J., D.L. Pendell, and T.C. Schroeder. "Brazilian Beef Industry." Working paper.

Appendix B – Current Bioeconomic Modeling Research Projects

This funded project has created leverage and a foundation for future research extending the contribution of this project well beyond just the publications that emanate directly from this work. The bioeconomic modeling framework developed in this study is of particular value in future projects that are now on-going. Specifically, the partial equilibrium modeling framework integrated with an epidemiological disease spread model allows for broader estimation of economic impacts of many potential contagious livestock disease outbreaks and associated management strategies to curtail diseases. Currently, there are three new research projects underway that leverage the framework developed from this project.

Project 1: Surveillance Zones

The first project is titled "Evaluation of Alternative Surveillance and Control Zone Options in NAADSM." This project will evaluate the recently developed "zones" option in NAADSM. Zones are defined as areas of differing surveillance and control policies during disease outbreaks. The basic form of a zone is a circle around a unit. Evaluation of the zone capability within NAADSM is considered particularly important to advising formulation of emergency response plans for an outbreak of contagious animal diseases.

Project 2: Probability Distributions

The second project in progress that will use this bioeconomic model is titled "Efficient Management Strategies for a Contagious Animal Disease Outbreak: Probability Distributions of Economic Impacts from Foot-and-Mouth Disease." The overarching purpose of this project is to determine the *probability distribution*s of expected economic impacts associated with various emergency management strategies in the event of a highly contagious foreign animal disease, foot-and-mouth disease (FMD), outbreak in the U.S. In the presence of risk and uncertainty, understanding probabilities of possible outcomes is integral before enacting a disease mitigation strategy.

Project 3: National Animal Identification System

The third project, "Benefit Cost Analysis of the National Animal Identification System," will also incorporate the methodology described in this report. This project is designed to assess the economic benefits and costs of a National Animal Identification System in the U.S. including premise registration; animal identification systems; and animal movement reporting for number of species at different marketing levels.