VALUE OF ANIMAL TRACEABILITY SYSTEMS IN MANAGING A FOOT-AND-MOUTH DISEASE OUTBREAK IN SOUTHWEST KANSAS

by

DUSTIN LESTER PENDELL

B.S., Illinois State University, 2000
M.S., Southern Illinois University, Carbondale, 2002

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

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Abstract

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.

In recent years, increasing numbers of economic analyses of animal diseases have integrated epidemiological models into economic frameworks. However, there are only a few studies that have used this integrated framework to analyze the effects of animal traceability on highly contagious animal diseases.

This study'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. 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 used in conjunction with an economic model to determine the changes in welfare of producers and consumers.

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 surveillance is increased, decreases in producer and consumer welfare are smaller. Furthermore, as surveillance is increased, decreases in producer and consumer surplus measures can be reduced by approximately 60 percent.

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Dedication

I dedicate this research to my wife, Kim. Not only has she has provided constant support and encouragement throughout this study, but she has been there for me throughout the entire PhD program. Without her by my side, none of this would have been possible. There is nothing I could possibly say that would express how much she means to me.

CHAPTER 1 - INTRODUCTION

Need for Study and Background Information

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.[1] 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.

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[1]The complete list of countries that currently have banned U.S. beef imports of as a result of BSE can be found at http://www.aphis.usda.gov/lpa/issues/bse/trade/bse_trade_ban_status.html.

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 1.1). 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.

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.

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).

The UK also experienced a severe FMD outbreak in 2001. On February 20, 2001 FMD was confirmed in Great Britain. The subsequent epidemiological analysis had shown that at least 57 premises were infected by the time the first case was identified. Evidence suggests initial spread of the disease was by two routes, movement of pigs from one farm to another and the second was a result of airborne spread to a nearby sheep farm and subsequent movement of those sheep to a large market (Scudamore, 2002). By September 30, 2001 when the outbreak was eradicated, some 221 days later, 2,026 cases of FMD had been confirmed; but not before over six million animals were destroyed and the disease spread to Ireland, France, and the Netherlands. As a result of FMD, Thompson et al. (2002) estimated losses in the UK at £5.8 to £6.3 billion ($10.7 to $11.7 billion U.S.).

One way to combat the spread of this highly contagious global disease is through animal identification. Being able to quickly identify the locations where the animal has been will affect the spread of the disease. Animal identification systems are rapidly developing throughout the world including the United States. To safeguard U.S. animal health, the U.S. Department of Agricultural (USDA) is implementing NAIS. This cooperative agreement between federal and state governments and the livestock industries is being developed through premise identification, animal identification, and animal tracking. This voluntary program had approximately 10 percent of the nation's premises registered by March 2006 and is scheduled to have 100 percent of premises registered, 100 percent of "new" animals identified, and 60 percent of animals less than one year of age to have complete animal movement data by January 2009 (USDA, APHIS, 2006).

Animal identification is critical in managing animal health. Animal ID allows for early detection of a disease and rapid animal tracing. Early detection of FMD and rapid animal tracing in the UK would have limited the spread in 2001. Because of a combination of movements of infected swine (i.e., the index case), airborne spread to a nearby sheep farm, and the lack of a trace back system, the FMD outbreak in the UK was intensified. Records indicate during a 10 day span (February 14 – February 23, 2001), at least 24,500 sheep entered the Longtown market and could have been exposed to the virus. By February 23rd, national animal movement controls were in place. Between February 20th (when the first case of FMD was confirmed) and February 23rd (the halt of animal movements), at least 62 farms had been infected as a result of infected animal movements (specifically, 57 farms were infected by February 20th and 119 farms were infected by February 23rd) (Scudamore, 2002). This highly contagious disease demonstrates why time is of the essence.

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, 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). Further, Kansas imported 4.58 million head of cattle in 2003 (approximately 88,000 head per week). 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 1.2). This region contained 1.99 million head of cattle and 650,000 head of hogs in late 2004/early 2005 (USDA, NASS).

Clearly, 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. One such tool that could help both public officials and private industry better handle and respond to such a crisis situation is animal traceability.

Objectives

Animal identification/trace-back systems have recently become a contentious issue, and will continue to generate debate in the coming years. 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 research is to determine the economic implications of different depths of animal ID/trace back systems in the event of a foot-and-mouth disease (FMD) outbreak in southwest Kansas. By different depths of animal ID/trace back systems; this research is referring to increased improvements of animal ID systems. The specific objectives of this research include:

- 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.

Organization of Thesis

The organization of this thesis is as follows. Chapter 2 begins by providing an overview of FMD and concludes with a review of past research that has modeled the spread of FMD. Chapter 3 discusses the epidemiological framework used to model the spread of FMD in southwest Kansas. Chapter 4 presents the theoretical and empirical economic framework used in this research. The final two chapters, Chapter 6 and Chapter 7, present the results, implications, and conclusions of this research.

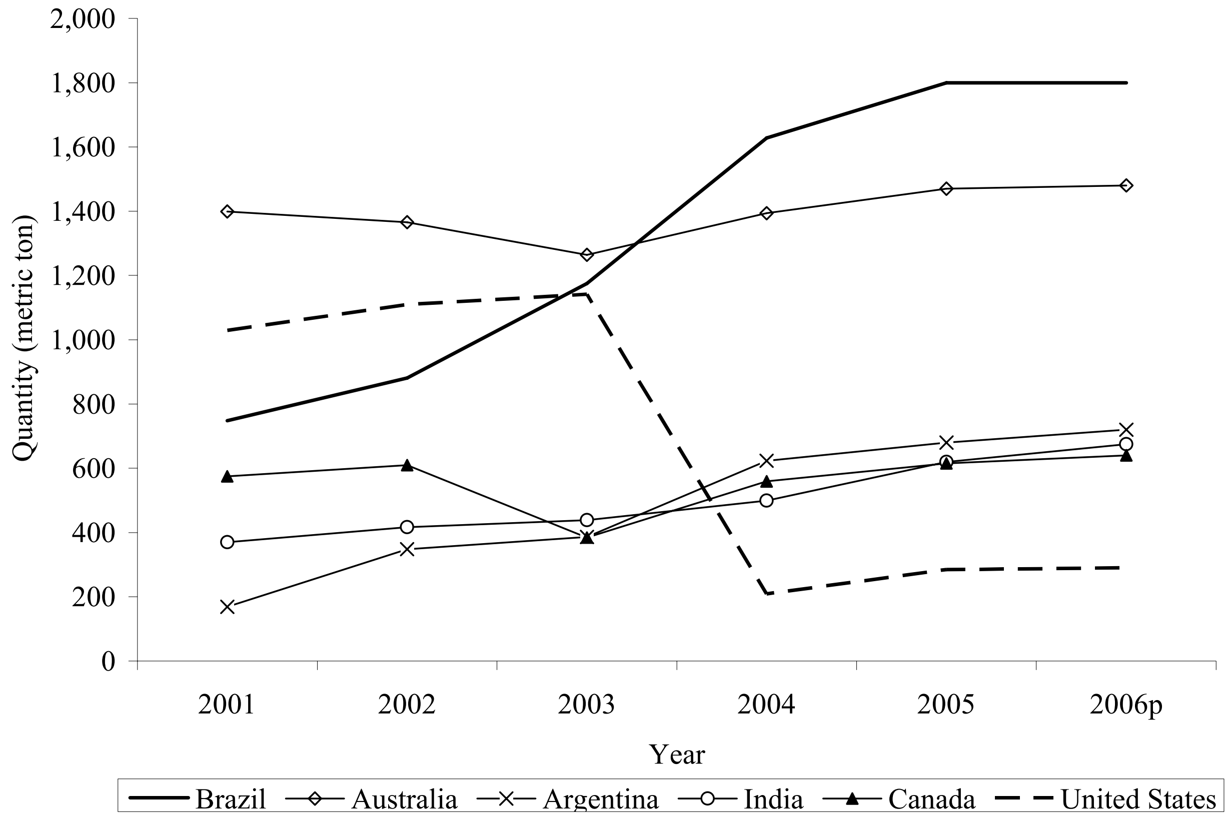

Figure 1.1 Beef and Veal Exports of Selected Leading Export Countries, 2001-2006 (1,000 Metric Tons)

Source: USDA, FAS USDA (February, 2006). Available at:
http://www.fas.usda.gov/dlp/circular/2005/05-11LP/beef_sum.pdf

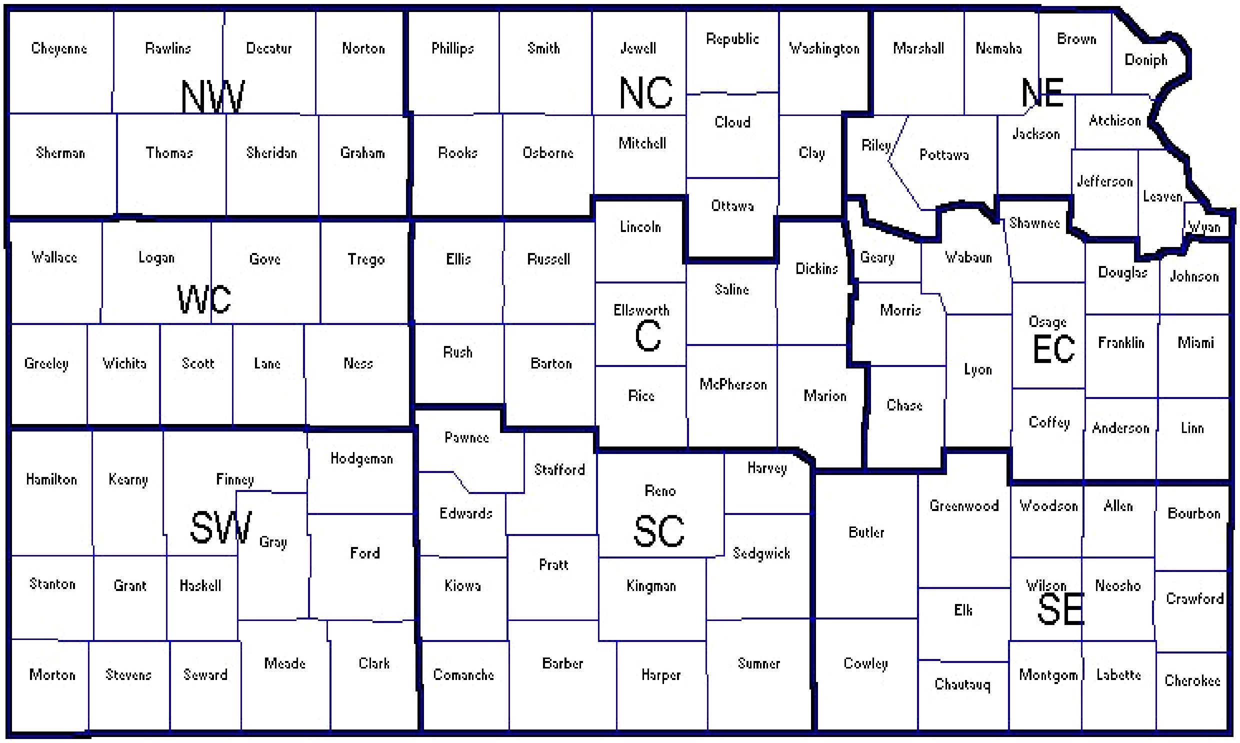

Figure 1.2 Map of Kansas Agricultural Statistics Districts

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

CHAPTER 2 - LITERATURE REVIEW

This literature review is divided into two sections. The first section describes a broad overview of FMD while the second section examines literature that has used epidemiological models to simulate both hypothetical and actual outbreaks of FMD.

Overview of Foot-and-Mouth Disease

Foot-and Mouth Disease (FMD) is a highly contagious viral disease of cloven-hoofed domestic and wild animals, such as cattle, bison, pigs, sheep, goats, and deer. Because FMD is highly contagious, it is arguably one of the most important, if not the most important, livestock diseases in terms of economic impact throughout the world.

The first case of FMD probably occurred in the early 1500's when a similar cattle disease in Italy was described. Nearly 400 years later, Loeffler and Frosch discovered the foot-and-mouth disease virus (FMDV). There are seven serotypes (or strains) of FMDV (O, A, C, Asia, South African 1, 2, and 3) and over 60 subtypes. The virus can survive for long periods in uncooked processed meats, frozen products (i.e., semen, meat, and bones), milk and dairy products (even when pasteurized), and fomites (i.e., clothing, shoes, hides, etc.). The FMDV can survive in the human respiratory tract for up to 28 hours.

Transmission of the FMDV primarily occurs via direct or indirect contact, animate vectors (e.g., humans), inanimate vectors (e.g., vehicles), and air (over land or across bodies of water). Sheep are considered 'maintenance' hosts of the virus because the diagnosis may take considerable time because it can exhibit very mild signs. Pigs act as 'amplifier' hosts for they produce 30 to 100 times the amount of virus compared to sheep or cattle. Cattle are termed ‘indicators’ of FMD because they typically show clinical signs of the disease earlier following infection than other species.

Animals with exposure to the virus will typically develop signs of FMD with in two to five days. FMD is characterized by development of a fever, vesicles (blisters), depression, excessive salivations, decreased milk production, lameness, and reluctance to move. FMD is typically not fatal in livestock, though mortality in animals less than one year of age is significantly more probable. In addition, pregnant livestock infected with FMD are at substantially greater risk of abortion. The main impact of FMD on infected livestock is reduced productivity. Loss of weight during the course of infection results in higher costs in feed and shelter. Typically, animals recover from FMD without any permanent effects; however, this is far from universal. McCauley (1979) compiled results from past cases of FMD and estimated the following impacts from livestock infected with FMD:

Dairy Cows – 10 percent of pregnant dairy cows abort resulting in milk losses estimated at 1,000 lbs./cow; 25 percent of dairy cows suffer a two-month delay in breeding; One-third of cows are either unable to lactate or are culled because of permanent damage due to mastitis; 6 percent of dairy cattle under 12 months die as a result of FMD; 50 percent of growing dairy cattle do not recover their normal appetite for one month resulting in an additional two months of finishing;

Beef Cows – 10 percent of pregnant beef cows abort; 6 percent of beef cattle under 12 months die as result of FMD; 50 percent of growing beef cattle do not recover their normal appetite for one month resulting in an additional two months of finishing;

Swine – Five percent of pregnant pigs affected with FMD abort; 50 percent of growing pigs do not recover their normal appetite for two weeks resulting in an additional two weeks of feed for finishing; 80 percent of pigs weighing less than 20 lbs. die.

The Office International des Epizooties (OIE), the most widely accepted world animal health organization, was established in 1924 to ensure transparency on the global incidence of animal diseases. A major role of the OIE is to serve as a clearinghouse of information on animal disease outbreaks. Other purposes of the OIE include analyzing and disseminating relevant veterinary information, providing scientific information on breakthroughs in disease control, and assisting countries with animal disease emergencies. The OIE also assists the World Trade Organization by preparing normative documents which form the basis for international sanitary rules used in governing international trade in animal products.

Because of the highly contagious nature and large economic impact of FMD throughout the world, "FMD is the first disease on the OIE List A and was the first disease for which the OIE established an official list of free countries and zones" (OIE website).[2] A country having FMD-free status has an enormous trade advantage. Countries that are FMD-free, as designated by the OIE, can restrict meat imports from countries that are not FMD-free, with trade limited to certain types of meat (e.g., processed meat). Sanitary restrictions on trade thus create a segmented market in which fresh meat exports from countries that are FMD-free sell at a price premium of between 50 to 60 percent (Ekboir et al., 2002). In addition, certain international markets, such as Japan and Korea, make a further distinction between FMD-free countries where vaccination is practiced and those that are FMD-free without vaccination because it is difficult to

[2] OIE List A is a "list of transmissible diseases which have the potential for very serious and rapid spread, irrespective of national borders, which are of serious socio-economic or public health consequence and which are of major importance in the international trade of animals and animal products." The List A can be found at: http://www.oie.int/eng/maladies/en_OldClassification.htm#ListeA.

distinguish the difference between meats from an infected animal versus one that has been vaccinated (Rich, 2005). This policy of "zero-risk" restricts meat imports in these markets from all but FMD-free without vaccination sources.

The OIE has designated several FMD status categories in which they classify a country. These categories, outlined in Chapter 2.2.10 of the Terrestrial Animal Health Code 2005, include:

1) FMD free where vaccination is not practiced (Article 2.2.10.2).

   To qualify for this status, a country should:

   - Have a record of regular and prompt animal disease reporting;
   - Send a declaration to the OIE stating:
     - There has been no outbreak of FMD during the past 12 months;
     - No evidence of FMDV infection has been during the past 12 months;
     - No vaccination against FMD has been carried out during the past 12 months;
   - Have not imported since the cessation of vaccination any animals vaccinated against FMD.

2) FMD free where vaccination is practiced (Article 2.2.10.3).

   To qualify for this status, a country should:

   - Have a record of regular and prompt animal disease reporting;
   - Send a declaration to the OIE that there has been no outbreak of FMD for the past two years and no evidence of FMDV for the past 12 months, with documented evidence that:
     - Surveillance for FMD and FMDV is in accordance with the OIE guidelines, and that regulatory measures for the prevention and control of FMD have been implemented;

- Routine vaccination is carried out for the purpose of the prevention of FMD;
- The vaccine used complies with the OIE standards.

If a country, that is FMD free where vaccination is practiced, wishes to change its status to FMD free where vaccination is not practiced, the country should wait for 12 months after vaccination has ceased and provide evidence showing that FMDV has not occurred during that time period.

3) FMD infected country or zone (Article 2.2.10.6)

A FMD infected country or zone occurs when neither (1) or (2) applies.

The OIE also recognizes the statuses of a FMD free zone where vaccination is not practiced and a FMD free zone where vaccination is practiced (Articles 2.2.10.5 and 2.2.10.6, respectively). These statuses occur when parts of a country are infected, but susceptible animals are separated for the rest of the country by a buffer zone. To obtain FMD free zone where vaccination is not practiced a country must follow the guidelines from (1) in addition to describing in detail:

- The regulatory measures for the prevention and control of both FMD and FMDV infection;
- The boundaries of the FMD free zone;
- The system for preventing the entry of the virus into the FMDV free zone.

A country also needs to supply documented evidence that these measures are properly implemented and supervised. To obtain FMD free zone where vaccination is practiced, a country must follow the guidelines from (2) in addition to declaring to the OIE that the country established a FMD free zone where vaccination is practiced.

The OIE has also established a number of other guidelines in regards to FMD. For example, Article 3.7.8 describes the guidelines for the surveillance of FMD, Article 2.2.10.7 explains how a country can regain FMD free status, and Article 3.8.6.5 lists four strategies that can be used to control FMD in a herd.

FMD is currently present in parts of South America, Europe, Asia, and Africa.[3] All the countries in North America and Australia have been recognized by the OIE as free of FMD without vaccination. North America has been FMD free since 1952 while Australia has been FMD-free since the late 19th century. Specifically in the U.S., FMD was first discovered in 1870. Since the initial outbreak, there have been eight additional outbreaks with the last being a mild epidemic in California in 1929. Prior to the 1929 epidemic, California had another outbreak in 1924 that resulted in destruction of 109,000 cattle, sheep, and swine. The 1924 outbreak also resulted in approximately 22,000 deer in the Stanislaus National Forest being destroyed after coming in contact with cattle. In 1914, the U.S. had its most devastating FMD outbreak, which began in Michigan and spread to the Chicago stockyards by 1915. Overall, FMD had spread to 22 states and 172,000 cattle, hogs, sheep, and goats were destroyed during the eradication program (McCauley, et al., 1979).

A more recent FMD epidemic occurred in 2001 in the UK and was widely publicized throughout the world. In Great Britain, a total of 2,026 cases of FMD were confirmed between February 20th and September 30th 2001 (Scudamore, 2002). According to Scudamore, the uniqueness of this disease spread was a combination of factors including: a delay in reporting suspicion of infected pigs (i.e., there was a delay in reporting the first premise to be infected with FMD), airborne infection of sheep on a nearby premise, movement of the infected sheep through

[3] The complete list of countries that currently have been certified by the OIE as FMD free where vaccination is not practiced can be found at http://www.oie.int/eng/info/en_fmd.htm.

the markets before the disease was diagnosed, the time of year when the climate favored the virus survival, and when large numbers of sheep were marketed and moved throughout the country.

Total losses from this UK outbreak were estimated to be £5.8-£6.3 billion (Thompson et al., 2002). Specifically, losses of £3.1 billion were attributed to agriculture and the food chain with a majority of these slaughter, disposal, and clean-up costs compensated by the government. Tourism was also largely affected. Based on survey data, businesses were estimated to have lost between £2.7 and £3.2 billion (i.e., approximately $4.7 to $5.6 million U.S.).

Previous Studies Modeling the Spread of FMD

Miller's (1979) study was one of the first to simulate the impact of a potential FMD outbreak in the U.S. using a state-transition model. In this model, there were four states (i.e., health conditions): i) susceptible; ii) infected; iii) immune; and iv) removed. Using FMD epidemic data from the 1967-1968 outbreak in the United Kingdom as a guideline for calibrating the model, Miller estimated that a FMD "runaway" situation could be reached in the U.S. within five weeks. Within 15 weeks, the FMD outbreak could peak with some 100,000 herds affected per week. The pandemic would significantly decline by the 30th week. His analysis suggested by then the disease would have affected a minimum of 60 percent of the animal population. This baseline situation was compared to simulations in which varying rates of "contact slaughter" were practiced (i.e., contact slaughter refers to destroying of herds before they become infectious). Miller found that if 19 percent of contact herds were destroyed, the incidence of disease at its peak would have been reduced by half.

Pech and McIlroy (1990) extended a non-spatial deterministic model that described the changes in the prevalence of infected and immune feral (wild) pigs in Australia, constructed by

Pech and Hone (1988) to include the movement of feral pigs. They used a three state-transition model (susceptible, latent/infective, and immune). Unlike most FMD studies, they did not analyze alternative control strategies. Rather, they focused on the "velocity" of a disease spread in the feral pig population in eastern Australia. They found FMD would spread at a rate of 2.8 km/day.

Berentsen, Dijkhuizen, and Oskam (1992) used a state-transition model combined with two economic models, a disease-control model (which calculated the direct losses for producers and government) and an export model (which calculated the indirect losses for producers, consumers, and government). The authors examined the potential impact that a FMD outbreak in Dutch cattle and pig herds would have as a result of export bans. The epidemiological spread model, which was similar to Miller (1979) and Dijkhuizen (1989), was used to simulate the following FMD control strategies: (i) annual vaccination of the cattle population; or (ii) no annual vaccination. Results from the disease spread model were used to calculate vaccination and eradiation costs. Those costs were then used in conjunction with the disease-control and export models revealing that strategies that included no annual vaccination were preferred to strategies where annual vaccinations were employed. This result occurred because control costs were lower and unvaccinated animals were able to obtain access to the FMD-free export markets.

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 (i.e., stamping-out implies slaughtering or destroying); 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. Unlike the three previously mentioned studies, the authors incorporated stochastic elements in their state-transition model. 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.

Horst (1998) developed a stochastic simulation model of FMD and Classical Swine Fever. This dynamic integrated model, called "VIRiS", (Virus Introduction Risk Simulation model) evaluates the entire "development path" of disease outbreaks, from an outbreak introduced from a neighboring county and a virus introduction within the Netherlands. Horst concluded that losses from a FMD outbreak would range from \$15.2 to \$127.1 million with an average of \$70.9 million.

Ekboir (1999) performed similar procedures as the previous studies 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 Miller (1979), Dijkhuizen (1989), Berentsen et al. (1992), and Garner and Lack (1995). Five health states used in this model include susceptible, latent (infected with the disease but not showing clinical signs), 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 (IMPLAN) 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.

Keeling et al. (2001) developed an individual stochastic farm-based model of the 2001 FMD epidemic in the UK. Similar to Miller (1979) and Berentsen, Dijkhuizen, and Oskam (1992), Keeling et al. used a state-transition model comprised of four states (susceptible, incubating, infectious, and slaughtered). Various control strategies, prompt culling, and vaccination were modeled to help with policy decisions. Vaccinating animals, in addition to prompt culling of infected animals, produced similar results to prompt culling of infected and neighboring herds. However, control strategies that involved vaccination need to occur from the start of the epidemic which is an optimistic assumption given the logistical constraints. The main result they found was the importance of rapid implementation of disease control strategies.

Morris et al. (2001) used a stochastic spatial simulation model (called InterSpread) to simulate the 2001 FMD outbreak in the UK using alternative control measures. The control strategies studied included varying the speed of stamping-out policies and the number of farms pre-emptively destroyed around each infected premise; increasing the time to destroying the infected premises; the use of vaccination only; and the effectiveness of a combination of vaccination and stamping-out. They concluded that an intensive stamping-out policy was the most effective strategy while using vaccination in conjunction with a stamping-out policy would result in a smaller epidemic. However, introducing vaccination would have been highly risky and resulted in unfavorable results in economic terms or reducing the scale and duration of the outbreak. As with Miller (1979), Pech and McIlroy (1990), and Keeling et al. (2001), no economic analysis was conducted.

Disney et al. (2001) analyzed the impact of improved animal identification systems through a simulated FMD outbreak in the U.S.[4] They considered several levels of potential animal identification systems:

<u>Cattle</u>

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.

<u>Swine</u>

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.

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[4] Documentation of this epidemiological spread model is discussed later in this section in Schoenbaum and Disney (2003).

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.[5]

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.

[5] For additional studies that examine animal identification systems and Classical Swine Fever see Saatkamp et al. (1995) and (1997).

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 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.

Contribution of this Research

There is an extensive literature estimating the economic impacts of hypothetical animal disease outbreaks. An increasing number of these studies are incorporating an epidemiological component. These epidemiological-economic frameworks have examined a number of different animal diseases using different economic models (i.e., partial equilibrium, Input-Output, computable general equilibrium, cost-benefit analysis, and linear programming). Most of this research has analyzed the effects of alternate mitigation strategies (i.e., vaccination, stamping-out, etc.).

This research is similar to the studies discussed above in several ways. For example, an epidemiological disease spread model is used to determine the severity of a hypothetical FMD outbreak using alternative mitigation strategies (i.e., different depths of animal identification). These results are then used in conjunction with an economic model to determine changes in welfare measures.

Although this research is similar to past work, it also differs in several important ways. First, this study uses a stochastic, state-transition, disease-spread model rather than a deterministic model. Second, this research uses actual U.S. regional herd-level data for multiple production types compared to simulated data or data for one production type. Third, the mitigation strategies evaluated here focus on different depths of animal identification and not vaccination or alternate stamping-out policies. Next, the partial equilibrium model used distinguishes between different marketing levels (i.e., retail, wholesale (processing), slaughter cattle (fed cattle), and farm (feeder cattle)) and allows for consumer substitutability of meats at the retail level (i.e., beef, pork, and poultry). Finally, the impacts of FMD on producer and consumer welfare changes are analyzed for the alternate commodities and marketing levels.

The results of this research will provide insight to numerous groups such as policy makers, government agencies (i.e., ERS), and researchers. Policy makers would have scientific evidence of the importance of trace back systems. Because the National Animal Identification System is currently being developed, this research would allow policy makers to make better informed decisions in finalizing the future guidelines for animal identification systems. This research would aid the ERS in making policy recommendations to Congress. Researchers would also be a beneficiary to this study. Because this project builds a methodology that links an epidemiological disease spread model with an EDM, this framework can be used for future research in better understanding the implications of a large number of alternative policy scenarios.

CHAPTER 3 - EPIDEMIOLOGICAL MODEL

Chapter 3 describes the epidemiological disease spread model. In this section, an overview of the input and output parameters are discussed. In addition, alternate levels of animal identification are defined and described.

Epidemiology deals with the incidence, distribution, and control of diseases in populations, such as animals, plants, or humans. As demonstrated in the previous section, infectious disease epidemics have been frequently studied and modeled. These epidemiological models vary in their level of complexity and typically are theoretical or empirical in nature. Theoretical epidemiological models, commonly referred to as mathematical epidemiological models, were primarily concerned with stochastic theories and probabilistic models (Anderson and May, 1991). Prior to the late 1980's, insights gained from sophisticated mathematical models were detached from an empirical base. Empirical epidemiological models are commonly used to assess potential disease outbreaks through simulations. One of these empirical models is the state-transition model. In state-transition models, a unit (i.e., animal or herd) is classified into one of several possible health states (i.e., susceptible, infected, immune, or removed). The transition (or pathways) between states depends on an array of factors with various vectors of disease transmissions (e.g., direct and indirect contacts) and probabilities associated with such transmissions. Most of these probabilities in a state-transition model are obtained from past outbreaks, field studies, and/or expert knowledge.

North American Animal Disease Spread Simulator

The epidemiological disease spread model used in this study is called the North American Animal Disease Spread Model (NAADSM). NAADSM was developed by U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) and has been used by Disney et al. (2001) and Schoenbaum and Disney (2003).

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. For example, the probability of detecting an infectious herd (is a function of time since the herd was infected) (Hill and Reeves, 2006).

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. The key disease parameter values are listed in Appendix A (Epidemiological Model).

Overview of 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.

Disease Manifestation

There are five health or disease states in which 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 FMDV, 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. Figure 3.1 depicts the health states a herd can attain and possible transitions among them.

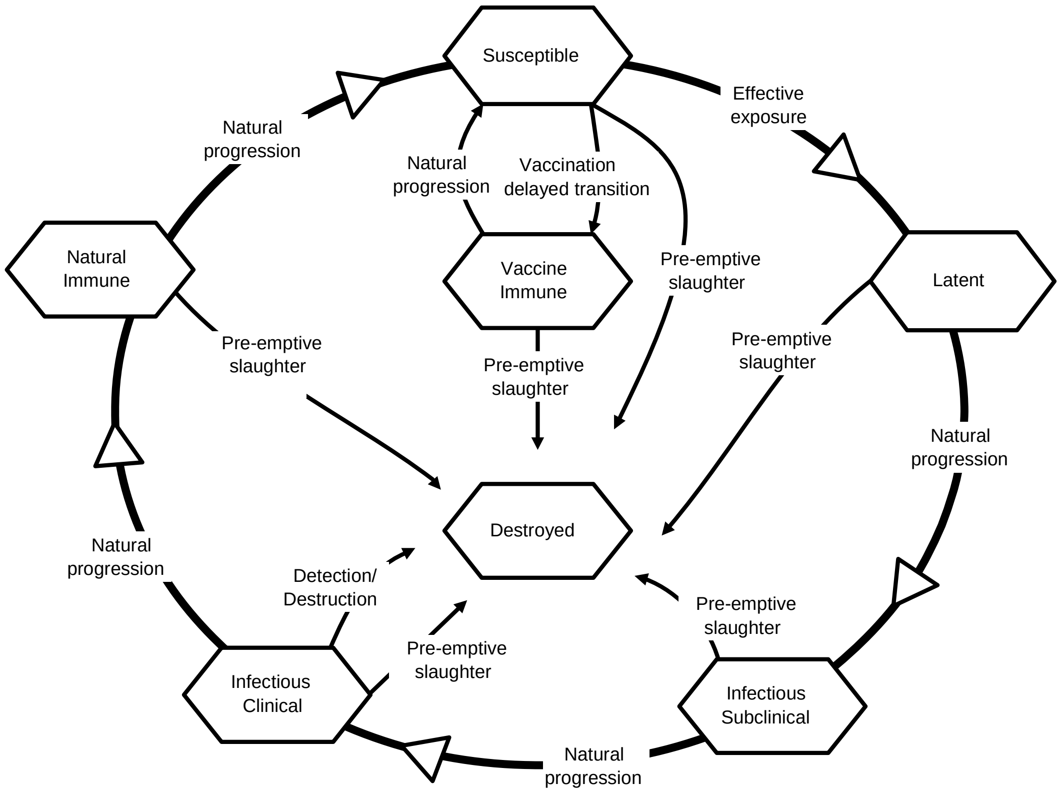

Figure 3.1 Health States and Possible Transitions Paths

Source: Hill and Reeves, 2006

Disease Transmission

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.

Disease Detection and Surveillance

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.

Disease Control

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. However, determining impacts of various vaccination programs is beyond the scope of this study. 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 will allow for pre-emptive destruction of those herds.

Direct Costs

The NAADSM calculates direct costs associated with a FMD outbreak. Specifically, destruction and vaccination costs are tabulated by the model. Because vaccination is not incorporated in this study, these costs are excluded. Destruction costs included in the model 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.

Overview of Output Parameters

The output statistics generated by the NAADSM fall into one of the two main categories, i) epidemiological outputs or ii) cost accounting outputs. A list of the epidemiological disease related outputs is found in Table 3.1 while the epidemiological cost related outputs are listed in Table 3.2.

Convergence

In addition to inputting herd level data and specifying the input parameters, the number of iterations needs to determined. The number of iterations is defined as the number of times that you want to run a particular scenario. Because this model is a stochastic model, each iteration will produce different results. The more iterations that are run, a more complete distribution of results will be obtained. The NAADSM produces a convergence plot for each variable. The convergence plots illustrate the effect that each new iteration has on the overall mean value. As more iterations are run, the convergence plot flattens out, indicating that additional iterations are decreasingly likely to have a notable influence on the distribution of results. These plots are used to provide an estimate of how many iterations are "enough" to obtain reliable results. The number of iterations used in this study is determined by running the initial simulation with 10 iterations. More iterations are continually added until the convergence plots indicate convergence on the mean value. As shown in Figure 3.2, the convergence plot for the mean of tscADest (i.e., total number of animal destroyed) from 10 iterations demonstrates the need for a higher number of iterations while Figure 3.3 illustrates 1,000 iterations are enough to obtain reliable results.

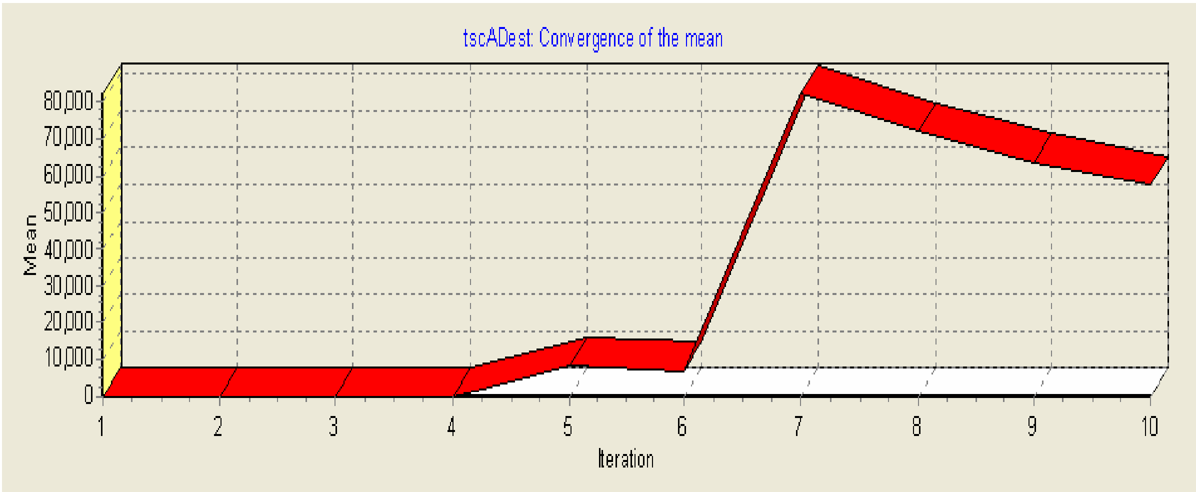

Figure 3.2 Convergence Plot of tscADest data from 10 iterations

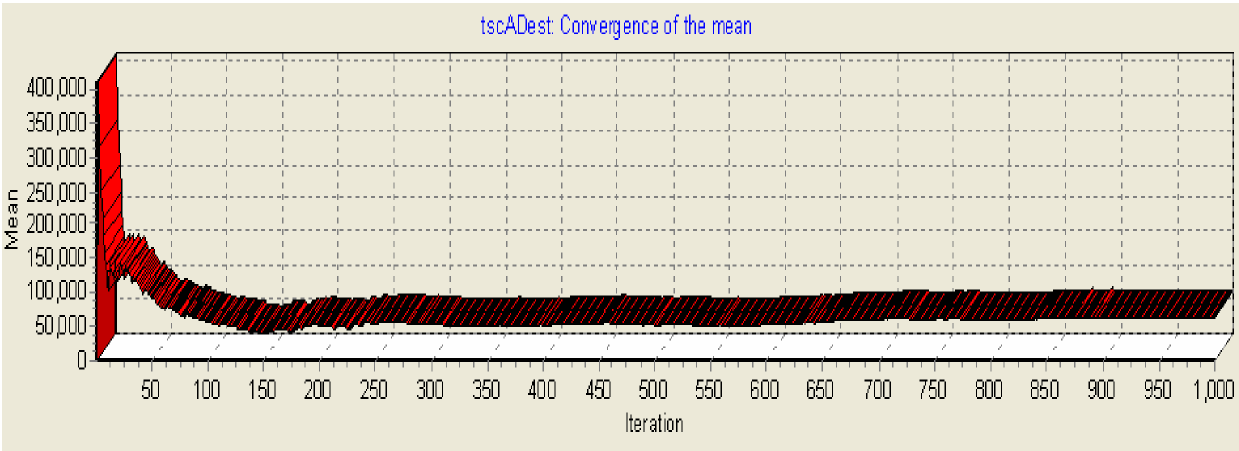

Figure 3.3 Convergence Plot of tscADest data from 1,000 iterations

Limitations

There are two assumptions made in the NAADSM that could lead to underestimated epidemiological results. The disease spread model assumes all animal trace backs occur within 24 hours of detection. This assumption regarding the length of time is much shorter than the proposed animal identification system by NAIS which is to enable a 48-hour trace back of the movements of any diseased or exposed animal. By allowing a longer trace back time period, the number of herd movements could increase and potentially spread FMD to a larger number of herds. However, tracking the movement of a diseased or exposed animal when the proposed animal identification system is in place could theoretically take less than 24 hours.

Another assumption made in the NAADSM also relates to herd trace back. Herd tracing only goes forward one level. In other words, herds that are recipients of direct or indirect contact from infected/detected herds would be identified. Identifying contacts that lead to the infection of infected/detected herds are not traced (see Figure 3.4). In Figure 3.4, when herd D is detected, it would be destroyed as would herds C and E (assuming D had direct or indirect contact with C and E). Although herds A and B could have had direct or indirect contact with D, A and B would not be destroyed because the model does not trace back. Further, herd F would not be destroyed if it had direct or indirect contact with herd C, unless herd C tested positive for FMD. This assumption could result in conservative epidemiological results.

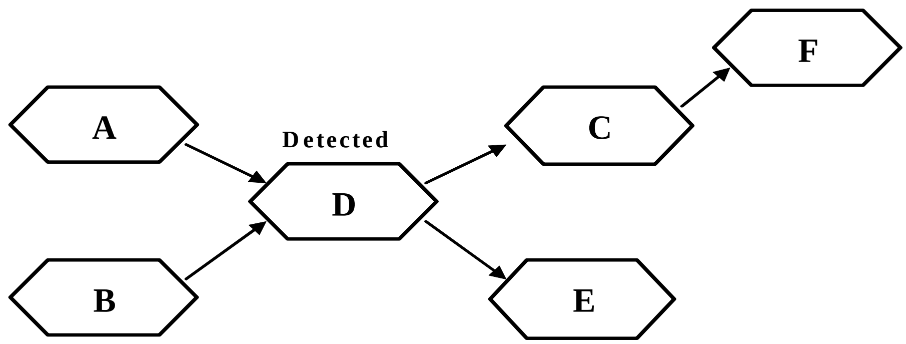

Figure 3.4 Trace-Out of Herds by NAADSM

There are additional limitations/assumptions in determining the spread of FMD in this research. This research does not include herd information outside the 14 counties studied, and so this research shall assume FMD does not spread outside these 14 counties. This will limit the spread of FMD, potentially lowering the number of infected animal and ultimately lowering changes in welfare measures. Also, although wildlife such as feral pigs and deer can contribute to FMD spread, wildlife movements are not incorporated into this study.

Animal Identification Levels

This 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).

The animal data needed in the epidemiological model are discussed in Chapter 5. The values for the parameters discussed above are presented in Appendix A. These values came from several sources (i.e., published papers, experts' opinions, and an unpublished report). The results from the disease spread model are discussed in Chapter 6.

Table 3.1 Epidemiological Disease Related Output Parameters and Definitions

Parameter	Definition
tscUSusc	Total number of units that were initially susceptible and those that became susceptible over the course of the iteration.
tscASusc	Total number of animals in units as described immediately above.
tscULat	Total number of units that were initially latent and those that became latent over the course of the iteration.
tscALat	Total number of animals in units as described immediately above.
tscUSubc	Total number of units that were initially subclinical and those that became subclinical over the course of the iteration.
tscASubc	Total number of animals in units as described immediately above.
tscUClin	Total number of units that were initially clinical and those that became clinical over the course of the iteration.
tscAClin	Total number of animals in units as described immediately above.
tscUNImm	Total number of units that were initially naturally immune and those that became naturally immune over the course of the iteration.
tscANImm	Total number of animals in units as described immediately above.
tscUVImm	Total number of units that were initially vaccine immune and those that became vaccine immune over the course of the iteration.
tscAVImm	Total number of animals in units as described immediately above.
tscUDest	Total number of units that were initially in the “destroyed” state and those that were destroyed during the course of the iteration.
tscADest	Total number of animals in units as described immediately above.
infcUIni	Total number of animals in units as described immediately above.
infcAIni	Number of animals in initially infected units at the beginning of the iteration.
infcUAir	Total of the number of units that became infected by airborne spread over the course of the iteration.

Table 3.1 Epidemiological Disease Related Output Parameters and Definitions, Cont.

Parameter	Definition
infcAAir	Total number of animals in units as described immediately above.
infcUDir	Total number of units that became infected by direct contact over the course of the iteration.
infcADir	Total number of animals in units as described immediately above.
infcUInd	Total number of units that became infected by indirect contact over the course of the iteration.
infcAInd	Total number of animals in units as described immediately above.
expcUDir	Total number of units directly exposed to any infected unit over the course of the iteration.
expcADir	Total number of animals in units as described immediately above.
expcUInd	Total number of units indirectly exposed to any infected unit over the course of the iteration.
expcAInd	Total number of animals in units as described immediately above.
trcUDir	Total number of units directly exposed and successfully traced over the course of the iteration.
trcADir	Total number of animals in units as described immediately above.
trcUInd	Total number of units indirectly exposed and successfully traced over the course of the iteration.
trcAInd	Total number of animals in units as described immediately above.
trcUDirp	Total number of units directly exposed that could possibly have been traced over the course of the iteration.
trcADirp	Total number of animals in units as described immediately above.
trcUIndp	Total number of units indirectly exposed that could possibly have been traced over the course of the iteration.

Table 3.1 Epidemiological Disease Related Output Parameters and Definitions, Cont.

Parameter	Definition
trcAIndp	Total number of animals in units as described immediately above.
detcUClin	Total number of clinical units detected over the course of the iteration.
detcAClin	Total number of animals in units as described immediately above.
descUIni	Total number of units in the "destroyed" state at the outset of the iteration
descAIni	Total number of animals in units as described immediately above.
descUDet	Total number of infected units destroyed because they were detected based on clinical signs over the course of the iteration.
descADet	Total number of animals in units as described immediately above.
descUDir	Total number of units destroyed because of direct contact with an infected unit over the course of the iteration.
descADir	Total number of animals in units as described immediately above.
descUInd	Total number of units destroyed because of indirect contact with an infected unit over the course of the iteration.
descAInd	Total number of animals in units as described immediately above.
descURing	Total number of units destroyed because they were within a destruction ring over the course of the iteration.
descARing	Total number of animals in units as described immediately above.
descUTotal	Total number of units that were destroyed for any reason over the course of the iteration.
descATotal	Total number of animals in units as described immediately above.
vaccUIni	Total number of units in the vaccine immune state at the outset of the iteration. (i.e., units vaccinated prior to the point in time when the simulation began).
vaccAIni	Total number of animals in units as described immediately above.

Table 3.1 Epidemiological Disease Related Output Parameters and Definitions, Cont.

Parameter	Definition
vaccURing	Total number of units vaccinated because they were within a vaccination ring over the course of the iteration.
vaccARing	Total number of animals in units as described immediately above.
firstDet	First detection day of first detection of an infected unit of the specified production type in the iteration.
firstVacc	First vaccination day of first vaccination of a unit of the specified production type in the iteration.
firstDestr	First destruction day of first destruction of a unit of the specified production type in the iteration.
outbreakLen	Length of the outbreak in the iteration.

Table 3.2 Epidemiological Cost Related Output Parameters and Definitions

Parameter	Definition
destrAppraisal	Total cost associated with unit appraisal over the course of the iteration.
destrCleaning	Total cost of cleaning and disinfection over the course of the iteration.
destrEuthanasia	Total cost of euthanasia over the course of the iteration.
destrIndemnification	Total cost of indemnification over the course of the iteration.
destrDisposal	Total cost of carcass disposal over the course of the iteration.
vaccSetup	Total cost associated with vaccination site setup over the course of the iteration.
vaccVaccination	Total cost of vaccinating animals over the course of the iteration.

CHAPTER 4 - ECONOMIC MODEL

This section describes in detail the economic analysis used in this study. This chapter 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, 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 Amosson et al. (1981), 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).

This study employs a partial equilibrium approach. Other studies that have used this approach to assess the impacts of animal disease include Amosson et al. (1981) which evaluated the impacts of brucellosis control programs on consumers and producers. Berentsen, Dijkhuizen, and Oskam (1992) used a single-sector model to examine alternate FMD control measures in the Netherlands. Although Mangen, Burell, and Mourits (2004) evaluated a single sector, their multi-level model was a vertically-integrated model of the entire Netherlands hog industry. Schoenbaum and Disney (2003) used the multi-sector model to compute welfare impacts of different FMD control scenarios in the U.S. Because of the importance of animal disease outbreaks, research is beginning to combine epidemiological models with economic analysis. Throughout the rest of this section, the specification of the multi-market and multi-level partial-equilibrium model of animal disease control is discussed.

Basic Modeling Strategy

Figure 4.1 illustrates the impact of FMD on prices and quantities for the U.S. beef industry in a multistage production system. To simplify this illustration, the U.S. beef marketing chain is separated into two marketing levels, retail and farm, and fixed input proportions are assumed. The top graph demonstrates the market for retail-level beef while the second graph illustrates the market for farm-level cattle. The primary demand and supply curves are denoted by $\mathbf{D^r}$ and $\mathbf{S^f}$, respectively. Derived demand at the farm-level is represented by $\mathbf{D^f}$ while derived supply at the retail-level is denoted by $\mathbf{S^r}$. Both graphs depict the initial equilibrium for retail beef and farm cattle at the intersection of the primary demand curve ($\mathbf{D^r}$) and derived supply curve ($\mathbf{S^r}$) and derived demand curve ($\mathbf{D^f}$) and primary supply curve ($\mathbf{S^f}$), respectively. At initial equilibrium, quantity of cattle produced at the farm level (on a retail weight equivalent basis) and beef sold to consumers at the retail level is $\mathbf{Q^0}$. Prices at the retail and farm level are $\mathbf{P_0^r}$ and $\mathbf{P_0^f}$, respectively.

In the event of a FMD outbreak, the effects of destroyed cattle quantities and increased costs associated with FMD are reflected by a decrease in primary supply ($\mathbf{S^{f'}}$) and derived supply ($\mathbf{S^{r'}}$). Although primary demand does not change ($\mathbf{D^{r}}$), a decrease in the derived demand for cattle occurs ($\mathbf{D^{f'}}$). This is due to an increase in costs of providing the final product (Tomek and Robinson, 2003). The new equilibrium prices increases to $\mathbf{P_1^r}$ and $\mathbf{P_1^f}$ at the retail-and farm-levels, respectively, while the new equilibrium quantity decreases to $\mathbf{Q^1}$. Although the farm-level price increases in Figure 4.1, it could be constructed such that the new farm level price decreases. Whether the new farm level price increases or decreases depends on the elasticities of the supply and demand curves. However, the new quantity ($\mathbf{Q^1}$) is less than the initial quantity ($\mathbf{Q^0}$).

Welfare effects arise from this stylized graph. Although the new farm-level price increases in Figure 4.1, this does not imply producers are better off. In this case (assuming consumer demand is held constant), the opposite is true because of the decline in farm level quantity ($\mathbf{Q^1}$). In the bottom graph, the hatched area $\mathbf{PS^0}$ represents the initial producer surplus while the double hatched area ($\mathbf{PS^1}$) represents the producer surplus after a FMD outbreak. Using Figure 4.1, the change in producer surplus is measured by using equation (1)

$$1)\quad \Delta PS_B^f = \left[1/2\left(P_1^f - \alpha_1\right)Q_1\right] - \left[1/2\left(P_0^f - \alpha_0\right)Q_0\right]$$

where α_0 and α_1 are the intercept terms before and after the shift, and ΔPS_B^f indicates the change in farm-level beef producer surplus. Consumer surplus is similar in this example. Assuming there is no change in consumer demand for retail beef, the change in consumer surplus is also negative. This is represented by the hatched area $\mathbf{CS^0}$ (initial consumer surplus) and the double hatched area $\mathbf{CS^1}$ (consumer surplus after a FMD outbreak). If we allow for the initial consumer demand to decrease (i.e., $\mathbf{D^r}$ shifts the left) as a result of FMD, this would reduce consumer welfare by less than described above.

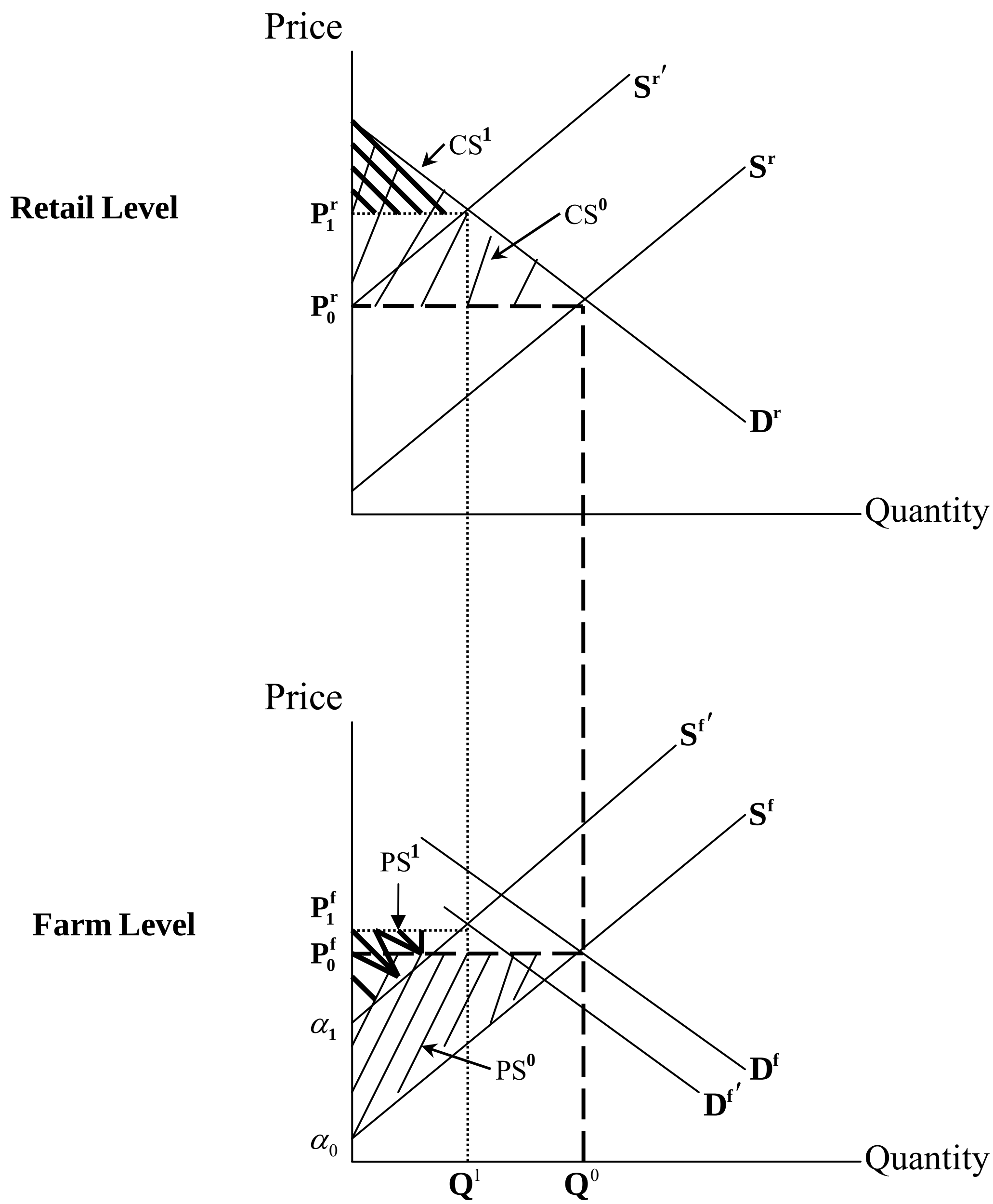

Figure 4.1 Effects of an FMD outbreak on Retail and Producer Levels.

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).

Although the following stylized three-commodity market model does not allow for international trade, it does provide the framework for how the equilibrium displacement model is developed and used. 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 thesis 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.

Similar to Brester, Marsh, and Atwood (2004), the structural demand and supply model for the U.S. beef, pork, and poultry industries are presented below.

Beef

Retail

2) Retail beef demand: $Q_B^r = f_1(P_B^r, P_K^r, P_Y^r, Z_B^r)$

3) Retail beef supply: $Q_B^r = f_2(P_B^r, Q_B^w, W_B^r)$

Wholesale

4) Wholesale beef demand: $Q_B^w = f_3(P_B^w, Q_B^r, Z_B^w)$

5) Wholesale beef supply: $Q_B^w = f_4(P_B^w, Q_B^s, W_B^w)$

Slaughter

6) Fed cattle demand: $Q_B^s = f_5(P_B^s, Q_B^w, Z_B^s)$

7) Fed cattle supply: $Q_B^s = f_6(P_B^s, Q_B^f, W_B^s, N_B^s)$

8) Fed cattle inventory: $N_B^s = f_7(F_B^s)$

Farm

9) Feeder cattle demand: $Q_B^f = f_7(P_B^f, Q_B^s, Z_B^f)$

10) Feeder cattle supply: $Q_B^f = f_8(P_B^f, W_B^f, N_B^f)$

11) Feeder cattle inventory: $N_B^f = f_{10}(F_B^f)$

Pork

Retail

12) Retail pork demand: $Q_K^r = f_{11}(P_B^r, P_K^r, P_Y^r, Z_K^r)$

13) Retail pork supply: $Q_K^r = f_{12}(P_K^r, Q_K^w, W_K^r)$

Wholesale

14) Wholesale pork demand: $Q_K^w = f_{13}(P_K^w, Q_K^r, Z_K^w)$

15) Wholesale pork supply: $Q_K^w = f_{14}(P_K^w, Q_K^s, W_K^w)$

Slaughter

16) Market hog demand: $Q_K^s = f_{15}(P_K^s, Q_K^w, Z_K^s)$

17) Market hog supply: $Q_K^s = f_{16}(P_K^s, Q_K^f, W_K^s, N_K^s)$

18) Market hog inventory: $N_K^s = f_{17}(F_K^s)$

Poultry

Retail

19) Retail poultry demand: $Q_Y^r = f_{18}(P_B^r, P_K^r, P_Y^r, Z_Y^r)$

20) Retail poultry supply: $Q_Y^r = f_{19}(P_Y^r, Q_Y^w, W_Y^r)$

Wholesale

21) Wholesale poultry demand: $Q_Y^w = f_{20}(P_Y^w, Q_Y^r, Z_Y^w)$

22) Wholesale poultry supply $Q_Y^w = f_{21}(P_Y^w, Q_Y^s, W_Y^w)$

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. 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.

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 (2002a), 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 (2) through (22) and converting to elasticity form results in the following equilibrium displacement of the U.S. beef, pork, and poultry markets from a FMD outbreak:

Beef

Retail Level

23) $EQ_B^r = \eta_{BB}^r EP_B^r + \eta_{BK}^r EP_K^r + \eta_{BY}^r EP_Y^r + Ez_B^r$

24) $EQ_B^r = \varepsilon_B^r EP_B^r + \tau_B^{rw} EQ_B^w$

Wholesale Level

25) $EQ_B^w = \eta_B^w EP_B^w + \tau_B^{wr} EQ_B^r$

26) $EQ_B^w = \varepsilon_B^w EP_B^w + \tau_B^{ws} EQ_B^s + Ew_B^w$

Slaughter Level

27) $EQ_B^s = \eta_B^s EP_B^s + \tau_B^{sw} EQ_B^w$

28) $EQ_B^s = \varepsilon_B^s P_B^s + \tau_B^{sf} EQ_B^f + EN_B^s + Ew_B^s$

29) $EN_B^s = EF_B^s$

Farm Level

30) $EQ_B^f = \eta_B^f EP_B^f + \tau_B^{fs} EQ_B^s$

31) $EQ_B^f = \varepsilon_B^f EP_B^f + EN_B^f + Ew_B^f$

32) $EN_B^f = EF_B^f$

Pork

Retail Level

33) $EQ_K^r = \eta_{KB}^r EP_B^r + \eta_{KK}^r EP_K^r + \eta_{KY}^r EP_Y^r + Ez_K^r$

34) $EQ_K^r = \varepsilon_K^r EP_K^r + \tau_K^{rw} EQ_K^w$

Wholesale Level

35) $EQ_K^w = \eta_K^w EP_K^w + \tau_K^{wr} EQ_K^r$

36) $EQ_K^w = \varepsilon_K^w EP_K^w + \tau_K^{ws} EQ_K^s + Ew_K^w$

Slaughter Level

37) $EQ_K^s = \eta_K^s EP_K^s + \tau_K^{sw} EQ_K^w$

38) $EQ_K^s = \varepsilon_K^s EP_K^s + EN_K^s + Ew_K^s$

39) $EN_K^s = EF_K^s$

Poultry

Retail Level

40) $EQ_Y^r = \eta_{YB}^r EP_B^r + \eta_{YK}^r EP_K^r + \eta_{YY}^r P_Y^r + Ez_Y^r$

41) $EQ_Y^r = \varepsilon_Y^r EP_Y^r + \tau_Y^{wr} EQ_Y^w$

Wholesale Level

42) $EQ_Y^w = \eta_Y^w EP_Y^w + \tau_Y^{rw} EQ_Y^r$

43) $EQ_Y^w = \varepsilon_Y^w EP_Y^w$

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 elasticities which are defined in Table 4.1.

In addition to providing a basic version of how FMD is incorporated throughout the marketing levels, the simplified three-sector model also provides the framework how the EDM is constructed. However, the three-sector commodity model does not account for international trade of beef at the farm, slaughter, and wholesale-levels and of pork at slaughter and wholesale-levels in response to a FMD outbreak. Trade is also integrated into the structural model below 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. This animal movement ban and border closing is also 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 thesis). 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

44) U.S. retail beef demand: $Q_B^r = f_1(P_{BUS}^r, P_{KUS}^r, P_{YUS}^r, Z_{BUS}^r)$

45) U.S. retail beef supply: $Q_B^r = f_2(P_{BUS}^r, Q_B^w, W_{BUS}^r)$

Wholesale

46) U.S. wholesale beef demand: $Q^{wd}_{BUS} = f_3(P^w_{BUS}, Q^r_B, Z^w_{BUS})$

47) Export wholesale beef demand: $Q^w_{BE} = f_4(P^w_{BE}, Z^w_{BE})$

48) U.S. wholesale beef supply: $Q^{ws}_{BUS} = f_5(P^w_{BUS}, Q^s_B, W^w_{BUS})$

49) Import wholesale beef supply: $Q^w_{BI} = f_6(P^w_{BI}, W^w_{BI})$

50) Total wholesale beef demand: $Q^w_B = Q^{wd}_{BUS} + Q^w_{BE}$

51) Total wholesale beef supply $Q^w_B = Q^{ws}_{BUS} + Q^w_{BI}$

Slaughter

52) Total fed cattle demand: $Q^s_B = f_7(P^s_{BUS}, Q^w_B, Z^s_{BUS})$

53) KS fed cattle supply: $Q^s_{BKS} = f_8(P^s_{BKS}, Q^f_B, W^s_{BKS}, N^s_B)$

54) Other States fed cattle supply: $Q^s_{BO} = f_9(P^s_{BUS}, Q^f_B, W^s_{BO})$

55) Total U.S. fed cattle supply: $Q^s_{BUS} = Q^s_{BKS} + Q^s_{BO}$

56) Import fed cattle supply: $Q^s_{BI} = f_{10}(P^s_{BI}, W^s_{BI})$

57) Total fed cattle supply: $Q^s_B = Q^s_{BUS} + Q^s_{BI}$

58) KS fed cattle inventory: $N^s_B = f_{11}(F^s_B)$

Farm

59) Total feeder cattle demand: $Q^f_B = f_{12}(P^f_{BUS}, Q^s_B, Z^f_B)$

60) KS feeder cattle supply: $Q^f_{BKS} = f_{13}(P^f_{BKS}, W^f_{BKS}, N^f_B)$

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

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

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

64) Total feeder cattle supply: $Q^f_B = Q^f_{BKS} + Q^f_{BO}$

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

Price Relationships

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

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

Pork Sector:

Retail

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

69) U.S. retail pork supply: $Q^r_K = f_{18}(P^r_{KUS}, Q^w_K, W^r_{KUS})$

Wholesale

70) U.S. wholesale pork demand: $Q_{KUS}^{wd} = f_{19}(P_{KUS}^{w}, Q_{K}^{r}, Z_{KUS}^{w})$

71) Export wholesale pork demand: $Q_{KE}^{w} = f_{20}(P_{KE,}^{w} Z_{KE}^{w})$

72) U.S. wholesale pork supply: $Q_{KUS}^{ws} = f_{21}(P_{KUS}^{w}, Q_{K}^{s}, W_{KUS}^{w})$

73) Import wholesale pork supply: $Q_{KI}^{w} = f_{22}(P_{KI}^{w}, W_{KI}^{w})$

74) Total wholesale pork demand: $Q_{K}^{w} = Q_{KUS}^{wd} + Q_{KE}^{w}$

75) Total wholesale pork supply: $Q_{K}^{w} = Q_{KUS}^{ws} + Q_{KI}^{w}$

Slaughter

76) Total market hog demand: $Q_{K}^{s} = f_{23}(P_{KUS}^{s}, Q_{K}^{w}, Z_{KUS}^{s})$

77) KS market hog supply: $Q_{KKS}^{s} = f_{24}(P_{KKS}^{s}, W_{KKS}^{s})$

78) Other States market hog supply: $Q_{KO}^{s} = f_{25}(P_{KUS}^{s}, W_{KO}^{s}, N_{K}^{s})$

79) Total U.S. market hog supply: $Q_{KUS}^{s} = Q_{KKS}^{s} + Q_{KO}^{s}$

80) Import market hog supply: $Q_{KI}^{s} = f_{26}(P_{KI}^{s}, W_{KI}^{s})$

81) Total supply of market hog: $Q_{K}^{s} = Q_{KUS}^{s} + Q_{KI}^{s}$

82) KS market hog inventory: $N_{K}^{s} = f_{27}(F_{K}^{s})$

Price Relationships

83) Kansas and Other States slaughter prices: $P_{KKS}^{s} = P_{KO}^{s} + S_{K}^{s}$

Poultry Sector:

Retail

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

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

Wholesale

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

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

where the variables, subscripts, and superscripts defined above remain. New subscripts include *US*, *O*, *KS*, *I*, and *E* which denote U.S., Other States, Kansas, Imports, and Export, 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*). 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 50-51, 57, 67, 74-75, and 81 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 finds 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 had some producers concerned. 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 (forthcoming) 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 66 and 67 are included to show the relationship between Other States and Kansas prices for cattle at the slaughter and farm-levels, respectively, while equation 83 shows the relationship between Other States and Kansas prices for slaughter hogs.

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 58, 65, and 82 while equations 48, 53, 54, 60, 61, 72, 77, and 78 use the cost information provided by NAADSM. Chapter 6 contains the percentage shifts in the EDM while Appendix B contains calculations and assumptions used in determining these estimates.

The following EDM model corresponds to the above structural model:

Beef Sector:

Retail Level

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

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

Wholesale Level

90) $EQ_{BUS}^{wd} = \eta_{BUS}^w EP_{BUS}^w + \tau_B^{wr} EQ_B^r$

91) $EQ_{BE}^w = \eta_{BE}^w EP_{BE}^w$

92) $EQ_{BUS}^{ws} = \varepsilon_{BUS}^w EP_{BUS}^w + \tau_B^{ws} EQ_B^s + Ew_{BUS}^w$

93) $EQ_{BI}^w = \varepsilon_{BI}^w EP_{BI}^w$

94) $EQ_{B}^{w} = \left(Q_{BUS}^{w} / Q_{B}^{w}\right) EQ_{BUS}^{wd} + \left(Q_{BE}^{w} / Q_{B}^{w}\right) EQ_{BE}^{w}$

95) $EQ_{B}^{w} = \left(Q_{BUS}^{w} / Q_{B}^{w}\right) EQ_{BUS}^{ws} + \left(Q_{BI}^{w} / Q_{B}^{w}\right) EQ_{BI}^{w}$

Slaughter Level

96) $EQ_{B}^{s} = \eta_{BUS}^{s} EP_{BUS}^{s} + \tau_{B}^{sw} EQ_{B}^{w}$

97) $EQ_{BKS}^{s} = \varepsilon_{BKS}^{s} EP_{BKS}^{s} + \tau_{B}^{sf} \left(Q_{BKS}^{f} / Q_{BUS}^{f}\right) EQ_{B}^{f} + EN_{B}^{s} + Ew_{BKS}^{s}$

98) $EQ_{BO}^{s} = \varepsilon_{BUS}^{s} EP_{BUS}^{s} + \tau_{B}^{sf} \left(Q_{BO}^{f} / Q_{BUS}^{f}\right) EQ_{B}^{f} + Ew_{BO}^{s}$

99) $EQ_{BUS}^{s} = \left(Q_{BKS}^{s} / Q_{BUS}^{s}\right) EQ_{BKS}^{s} + \left(Q_{BO}^{s} / Q_{BUS}^{s}\right) EQ_{BO}^{s}$

100) $EQ_{BI}^{s} = \varepsilon_{BI}^{s} P_{BI}^{s}$

101) $EQ_{B}^{s} = \left(Q_{BUS}^{s} / Q_{B}^{s}\right) EQ_{BUS}^{s} + \left(Q_{BI}^{s} / Q_{B}^{s}\right) EQ_{BI}^{s}$

102) $EN_{B}^{s} = EF_{B}^{s}$

Farm Level

103) $EQ_{B}^{f} = \eta_{BUS}^{f} EP_{BUS}^{f} + \tau_{B}^{fs} EQ_{B}^{s}$

104) $EQ_{BKS}^{f} = \varepsilon_{BKS}^{f} EP_{BKS}^{f} + EN_{B}^{f} + Ew_{BKS}^{f}$

105) $EQ_{BO}^{f} = \varepsilon_{BUS}^{f} EP_{BUS}^{f} + Ew_{BO}^{f}$

106) $EQ_{BUS}^{f} = \left(Q_{BKS}^{f} / Q_{BUS}^{f}\right) EQ_{BKS}^{f} + \left(Q_{BO}^{f} / Q_{BUS}^{f}\right) EQ_{BO}^{f}$

107) $EQ_{BI}^{f} = \varepsilon_{BI}^{f} EP_{BI}^{f}$

108) $EQ_{B}^{f} = \left(Q_{BUS}^{f} / Q_{B}^{f}\right) EQ_{BUS}^{f} + \left(Q_{BI}^{f} / Q_{BO}^{f}\right) EQ_{BI}^{f}$

109) $EN_{B}^{f} = EF_{B}^{f}$

Price Relationships

110) $EP_{BKS}^{s} = \left(P_{BUS}^{s} / P_{BKS}^{s}\right) EP_{BUS}^{s}$

111) $EP_{BKS}^{f} = \left(P_{BUS}^{f} / P_{BKS}^{f}\right) EP_{BUS}^{f}$

<u>Pork:</u>

Retail Level

112) $EQ_{K}^{r} = \eta_{KB}^{r} EP_{BUS}^{r} + \eta_{KK}^{r} EP_{KUS}^{r} + \eta_{KY}^{r} EP_{YUS}^{r} + Ez_{KUS}^{r}$

113) $EQ_K^r = \varepsilon_K^r EP_{KUS}^r + \tau_K^{rw} EQ_K^w$

Wholesale Level

114) $EQ_{KUS}^{wd} = \eta_{KUS}^w EP_{KUS}^w + \tau_K^{wr} EQ_K^r$

115) $EQ_{KE}^w = \eta_{KE}^w EP_{KE}^w$

116) $EQ_{KUS}^{ws} = \varepsilon_{KUS}^w EP_{KUS}^w + \tau_K^{ws} EQ_K^s + Ew_{KUS}^w$

117) $EQ_{KI}^w = \varepsilon_{KI}^w EP_{KI}^w$

118) $EQ_K^w = \left(Q_{KUS}^w / Q_K^w\right) EQ_{KUS}^{wd} + \left(Q_{KE}^w / Q_K^w\right) EQ_{KE}^w$

119) $EQ_K^w = \left(Q_{KUS}^w / Q_K^w\right) EQ_{KUS}^{ws} + \left(Q_{KI}^w / Q_K^w\right) EQ_{KI}^w$

Slaughter Level

120) $EQ_K^s = \eta_{KUS}^s EP_{KUS}^s + \tau_K^{sw} EQ_K^w$

121) $EQ_{KKS}^s = \varepsilon_{KKS}^s EP_{KKS}^s + EN_K^s + Ew_{KKS}^s$

122) $EQ_{KO}^s = \varepsilon_{KUS}^s EP_{KUS}^s + Ew_{KO}^s$

123) $EQ_{KUS}^s = \left(Q_{KKS}^s / Q_{KUS}^s\right) EQ_{KKS}^s + \left(Q_{KO}^s / Q_{KUS}^s\right) EQ_{KO}^s$

124) $EQ_{KI}^s = \varepsilon_{KI}^s EP_{KI}^s$

125) $EQ_K^s = \left(Q_{KUS}^s / Q_K^s\right) EQ_{KUS}^s + \left(Q_{KI}^s / Q_K^s\right) EQ_{KI}^s$

126) $EN_K^s = EF_K^s$

Price Relationships

127) $EP_{KKS}^s = \left(P_{KUS}^s / P_{KKS}^s\right) EP_{KUS}^s$

<u>Poultry:</u>

Retail Level

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

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

Wholesale Level

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

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

The definitions of the parameters for the above EDM are listed in Table 4.1.

Once the elasticity values have been determined for the above system of equations (equations 88 – 131), matrix algebra methods can be used to solve for the percentage changes in the endogenous variables (prices and quantities) resulting from exogenous shocks. In matrix form, the EDM can be written as:

132) $\mathbf{M*Y = X}$

where **Y** is a vector of changes in the endogenous price and quantity variables, **X** is a vector of percentage changes in the exogenous supply and demand shift variables, and **M** is a matrix of elasticity values. The percentage changes in the endogenous variables can be determined by solving for **Y** in equation (131). The solution vector is:

133) $\mathbf{Y = M^{-1}*X}$.

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).

Although change in producer surplus can be measured through equation (1), the intercept terms (α_0 and α_1) are not a direct result of the EDM. Therefore, the intercept terms needs to be calculated first. For calculation of the intercept terms see Appendix B. Another issue regarding measuring changes in producer surplus deals with the exogenous percentage changes in costs and quantities. Because costs shifts are a vertical shift in the supply curve and quantity shifts (i.e., stamped-out cattle) are a horizontal shift, the quantity shifts need to be converted to a vertical shift which will allow both types of shifts to be added together. See Appendix B for these calculations.

Calculation of the change in consumer surplus in this study follows the approach taken by many studies. As discussed earlier, the system of equations is a local approximation of the unknown supply and demand curves. The EDM is a linear approximation in the relative changes and elasticities and as result the curves shift parallel due to the exogenous factors (Alston, Norton, and Pardey, 1995). Given these assumptions and using the relative changes in prices and quantities (*EP* and *EQ*), initial equilibrium price and quantity values (P^0 and Q^0), and demand shocks to the system of equations (*z*), Alston, Norton, and Pardey show the change in consumer welfare is expressed as follows:

$$134)\quad \Delta CS = -P^0 Q^0 (EP - z)(1 + 0.5EQ).$$

Elasticities

To determine the percentage changes in the endogenous variables (**Y**), 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), Cranefield (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 supply and demand equations which examines the feeder and slaughter cattle sectors in Kansas. As noted by Marsh (1994 and 2003), statistical problems related to estimating this model arise from the potential simultaneity between feeder and slaughter cattle price and quantity variables, and to the correlation among the error terms. Competition throughout the beef industry is assumed in this study because studies by Azzam and Schroeter (1995) and Morrison Paul (2001) have found little evidence for market power in the beef processing industry. Because of the competition assumption, exogenous increases in demand at the retail-level increase derived demands (Wohlgenant, 1989). Further, this study assumes demand at the retail-level is exogenous.

Similar to Marsh (2003), the structural demand and supply model for Kansas slaughter and feeder cattle markets are as follows:

Slaughter:

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

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

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

Feeder:

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

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

140) 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 (135) and (136) 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).[6] 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 (137) and (138), 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

[6] The calculations of the beef demand index can be found in Appendix B.

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.

Statistical Problems

Estimating the slaughter/feeder cattle model as a system of equations with time-series data can involve several statistical problems. These problems include: i) non-stationarity and cointegration; ii) joint dependency (simultaneity); and iii) autoregressive and contemporaneously correlated error terms (Holzer, 2005).

Non-Stationarity and Cointegration

Many economic time series demonstrate characteristics of a random walk, a non-stationary process. The presence of non-stationarity (also referred to as unit roots) in variables does not allow for estimation in level form. The Dickey-Fuller or augmented Dickey-Fuller (ADF) unit root tests are common procedures used in testing for stationarity. If the null hypothesis of a unit root is not rejected by the ADF test, then the data can be differenced and the estimation can occur. This preserves the statistical properties of ordinary least squares (OLS). Once one has determined the data series are non-stationary in the levels but stationary in first differences, I (1), we can proceed to determine if the data series are cointegrated (i.e., the data series drift together at roughly the same rate). If the unit root data are cointegrated, OLS can be used to estimate the parameters in level form. Another related technique that can be used in estimating cointegrated equations is the error correction model (Greene, 2003).

To determine if a relationship exists between data, the Engle-Granger methodology can be applied. This commonly applied testing procedure begins by pre-testing the data series for their order of integration. Assuming the data are I (1), an OLS regression is performed. An ADF test is performed on the estimated OLS residuals. If the null hypothesis of unit root is rejected, then the residual sequence is stationary and the data series are cointegrated. If the data series are cointegrated, an OLS regression can be estimated and produce “super-consistent” parameter estimates. If data are cointegrated, the estimated residuals from the OLS regression can be used to estimate an error-correction model which will produce seed-of-adjustment parameters (Enders, 2004)

Johnston and DiNardo (1997) show that with simultaneity in model equations, consideration of cointegration problems in the estimation procedure is typically not considered. Hence, the system of equations can be estimated in level form.

Simultaneity

Price-quantity relationships in the livestock-meat markets may be subject to simultaneity. If simultaneity is present in a model, OLS will produce an inconsistent estimator. However, one can estimate the system with a Two-Stage Least Squares (2SLS) estimator, Limited Information Maximum Likelihood estimator, Three-State Least Squares (3SLS) estimator, Full Information Maximum Likelihood estimator, or a Generalized Methods of Moments estimator which corrects for simultaneity and produces consistent parameter estimates (Greene, 2003).

Autoregressive and Contemporaneously Correlated Error Terms

In a classical linear regression model, the error terms are assumed to have a zero mean, are independently distributed (uncorrelated), and have a finite variance. However, time series data often display serially correlation (autocorrelation) of the error terms across periods.

Autocorrelation affects the estimation and inference of the OLS estimators. OLS estimates are inefficient and the inference is adversely affected. Commonly used tests for serial correlation are the Lagrange Multiplier test, the Durbin-Watson test, and Durbin-h test (lagged dependent variable).

When estimating a model by a system with time series regressions, one needs to take caution because of the possibility of contemporaneously correlated errors (i.e., nondiagonal covariance error matrix). Stochastic processes that are closely related in the supply and demand equations may exhibit a non-diagonal covariance matrix of errors. For example, errors in the demand for slaughter cattle might be expected to be related to errors in feeder cattle demand (Marsh, 2003). Further, misspecifications to the demand and supply equations could also result in cross-correlated errors (Johnson and DiNardo, 1997).

Econometric Estimation

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 2SLS (limited information system) estimator corrects for simultaneity, but does not correct for a non-diagonal error matrix. Therefore, a full-information system (I3SLS) estimator is required to restore both asymptotic efficiency and consistency in the slaughter/feeder cattle model (Greene, 2003).

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:

$$141)\quad \ln P_s^d = a(0) + a(1)*\ln Q_s^d + a(2)*\ln P_y + a(3)*\ln D_b + a(4)*\ln M$$

Slaughter Supply:

$$142)\quad \begin{aligned} \ln Q_s^s = {} & b(0) + b(1)*\ln P_s^s + b(2)*\ln P_{s-1}^s + b(3)*\ln P_f + b(4)*\ln P_{f-1} + b(5)*\ln P_c \\ & + b(6)*\ln P_{c\text{-}1} + b(7)*\ln I + b(8)*\ln I_{-1} + b(9)*\ln T_s + b(10)*\ln Q_{s\text{-}1}^s \end{aligned}$$

Feeder Demand Price:

$$143)\quad \ln P_f^d = c(0) + c(1)*\ln P_s + c(2)*\ln P_c + c(3)*\ln Q_f^d + c(4)*\ln I + c(5)*T_s$$

Feeder Supply:

$$\text{144)}\quad \begin{aligned} \ln Q_f^s &= d(0) + d(1)*\ln P_{f-1}^s + d(2)*\ln P_{f-2}^s + d(3)*\ln P_{h-1} + d(4)*\ln P_{h-2} \\ &+ d(5)*\ln P_{u-1} + d(6)*\ln P_{u-2} + d(7)*T_f + d(8)*Q_{f-1}^s + d(9)*Q_{f-2}^s \end{aligned}$$

When estimating a 3SLS iteratively, the initial estimation is performed to estimate the initial parameters. Next, a new set of residuals is generated and used to calculate a new variance-covariance matrix. The new variance-covariance matrix is used to construct a new set of parameters. This procedure is continued until the coefficients and weights of the error covariance matrix converge (i.e., the jointly dependent or endogenous price and quantity variables are corrected by using an I3SLS).

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:

145) $\ln Q_B^r = a(0) + a(1) * \ln Q_B^w$

146) $\ln Q_B^w = a(0) + a(1) * \ln Q_B^s$

147) $\ln Q_B^s = a(0) + a(1) * \ln Q_B^f$

Quantity Transmission Elasticities for Pork:

148) $\ln Q_K^r = a(0) + a(1) * \ln Q_k^w$

149) $\ln Q_K^w = a(0) + a(1) * \ln Q_k^s$

Quantity Transmission Elasticities for Poultry:

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

The calculated values (i.e., a(1)) obtained from the above equations give the percentage change in the left hand side variable given a one percent change in the right hand side variable. Take equation (145) for example, the coefficient a(1) represents the percentage change in retail beef quantity given a one percent change in wholesale beef quantity.

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:

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

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*, 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. See Appendix B for calculations and assumptions of the excess supply elasticities.

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 study 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 study provides means, Chebychev 95% confidence intervals, and *p*-values for the results generated from the empirical distributions.

The data used in estimating the economic models discussed above and the elasticities used can be found in Chapter 5. Results of the simulated endogenous changes and welfare measures are provided in Chapter 6.

Table 4.1 Parameters and Definitions Used in Equilibrium Displacement Model

Parameter	Definition
η^{r}_{BB}	Own-price elasticity of retail beef demand
η^{r}_{BK}	Cross-price elasticity of retail beef demand w.r.t. pork price
η^{r}_{BY}	Cross-price elasticity of retail beef demand w.r.t. poultry price
η^{r}_{KB}	Cross-price elasticity of retail pork demand w.r.t. beef price
η^{r}_{KK}	Own-price elasticity of retail pork demand
η^{r}_{KY}	Cross-price elasticity of retail pork demand w.r.t poultry price
η^{r}_{YB}	Cross-price elasticity of retail poultry demand w.r.t to beef price
η^{r}_{YK}	Cross-price elasticity of retail poultry demand w.r.t to beef price
η^{r}_{YY}	Own-price elasticity of retail poultry demand
η^{w}_{BUS}	Wholesale beef own-price derived demand elasticity
η^{s}_{BUS}	Slaughter cattle Other States own-price derived demand elasticity
η^{f}_{BUS}	Farm-level Other States own-price derived demand elasticity
η^{w}_{KUS}	Wholesale pork own-price derived demand elasticity
η^{s}_{KUS}	Slaughter hogs Other States own-price derived demand elasticity
η^{w}_{YUS}	Wholesale poultry own-price derived demand elasticity
η^{s}_{KUS}	Own-price derived retail beef supply elasticity

Table 4.1 Parameters and Definitions Used in Equilibrium Displacement Model, Cont.

Parameter	Definition
η_{KUS}^{s}	Own-price derived retail beef supply elasticity
η_{BUS}^{w}	Own-price derived wholesale beef supply elasticity
ε_{BUS}^{s}	Own-price derived Other States slaughter cattle supply elasticity
ε_{BUS}^{f}	Own-price derived Other States farm supply elasticity
ε_{BKS}^{s}	Own-price derived Kansas slaughter cattle supply elasticity
ε_{BKS}^{f}	Own-price derived Kansas farm beef supply elasticity
ε_{K}^{r}	Own-price derived retail pork supply elasticity
ε_{KUS}^{w}	Own-price derived wholesale pork supply elasticity
ε_{KUS}^{s}	Own-price derived Other States slaughter pork supply elasticity
ε_{KKS}^{s}	Own-price derived Kansas slaughter pork supply elasticity
ε_{YUS}^{r}	Own-price derived retail poultry supply elasticity
ε_{YUS}^{w}	Own-price derived wholesale poultry supply elasticity
ε_{BI}^{w}	Import supply elasticities for beef at wholesale level
ε_{BI}^{s}	Import supply elasticities for cattle at slaughter level
ε_{BI}^{f}	Import supply elasticities for cattle at farm level

Table 4.1 Parameters and Definitions Used in Equilibrium Displacement Model, Cont.

Parameter	Definition
ε_{KI}^{s}	Import supply elasticities for pork at slaughter level
τ_{B}^{wr}	% change in wholesale beef quantity given a 1% change in retail beef quantity
τ_{B}^{sw}	% change in fed cattle quantity given a 1% change in wholesale beef quantity
τ_{B}^{fs}	% change in feeder cattle quantity given a 1% change in fed cattle quantity
τ_{K}^{wr}	% change in wholesale pork quantity given a 1% change in retail pork quantity
τ_{K}^{sw}	% change in slaughter hog quantity given a 1% change in wholesale pork quantity
τ_{Y}^{rw}	% change in wholesale poultry quantity given a 1% change in retail poultry quantity
τ_{B}^{rw}	% change in retail beef quantity given a 1% change in wholesale beef quantity
τ_{B}^{ws}	% change in wholesale beef quantity given a 1% change in fed beef quantity
τ_{B}^{sf}	% change in fed cattle quantity given a 1% change in feeder cattle quantity
τ_{K}^{rw}	% change in retail pork quantity given a 1% change in wholesale pork quantity
τ_{K}^{ws}	% change in wholesale pork quantity given a 1% change in slaughter hog quantity
τ_{Y}^{rw}	% change in retail poultry quantity given a 1% change in wholesale quantity

CHAPTER 5 - DATA

This chapter contains the descriptions, sources, and derivations of data used in this thesis. Chapter 5 is divided in two major sections, epidemiological model 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 in this study (from KDHE) 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 5.1 contains summary statistics of the data obtained from KDHE.

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).[7] 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 5.1.

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. 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

[7] 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+.

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 production is obtained from USDA's *Livestock Slaughter* reports. Table 5.2 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 5.3 contains summary statistics for the data used in estimating the OLS models.

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 5.4 lists quantity data and supply and demand elasticities used in estimating the excess supply elasticities.

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's *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's *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's *Red Meat Yearbook*. Quantities of domestic fed cattle and market hogs are total lbs. marketed and are obtained from NASS's *Meat Animals Production, Disposition, and Income*. Quantities of domestic feeder cattle and imported fed cattle, feeder cattle, and market hogs are obtained from 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.[8] 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's 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's 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 5.5. 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 5.6 provides model parameters, definitions, and sources.

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

Table 5.1 Summary Statistics of Herd and Animal Data used in the Epidemiological Model

Species	Count[a]	Mean[b]	Min.[b]	Max.[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.

Table 5.2 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)	1,136.44	1,890	5,495	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 5.3 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

Table 5.4 Variable Definitions and Values Used in Estimating Excess Supply Elasticities

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

Table 5.4 Variable Definitions and Values Used in Estimating Excess Supply Elasticities, Cont.

Variable	Definition	Quantity
$\varepsilon^{s}_{BCanada}$	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.

Table 5.5 Baseline Price and Quantities Used in Analysis

	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 5.6 Parameter Definitions, Values, and Sources Used in Analysis

Parameter	Definition	Value (Short Run / 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

Table 5.6 Parameter Definitions, Values, and Sources Used in Analysis, Cont.

Parameter	Definition	Value Short Run	Value Long Run
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

Table 5.6 Parameter Definitions, Values, and Sources Used in Analysis, Cont.

Parameter	Definition	Value Short Run	Value Long Run
ε_{BI}^{f}	Import supply elasticities for cattle at farm level[h]	4.40	19.92
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	

Table 5.6 Parameter Definitions, Values, and Sources Used in Analysis, Cont.

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Definition</th><th colspan="2">Value</th></tr>
<tr><th>Short</th><th>Long</th></tr>
<tr><th>Run</th><th>Run</th></tr>
<tr><td>τ_K^{ws}</td><td>% change in wholesale pork quantity given a 1% change in slaughter hog quantity[h]</td><td colspan="2">0.923</td></tr>
<tr><td>τ_Y^{rw}</td><td>% change in retail poultry quantity given a 1% change in wholesale quantity[h]</td><td colspan="2">0.93</td></tr>
</table>

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).

CHAPTER 6 - RESULTS

The results of this study are presented below. This chapter is divided into two sections. The first section contains results from the epidemiological disease spread model while the second presents findings from the economic framework discussed in Chapter 4.

Epidemiological Results

Results from the epidemiological model are expressed as means and standard deviations derived from 1,000 iterations from each simulation. Table 6.1 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 6.1). 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 6.2. 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.

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. For more details on these parameters see Appendix A. Cost results are listed in Table 6.3. Recall from Chapter 3 the accounting costs are comprised of appraisal, cleaning and disinfecting, euthanizing, indemnity payments, and disposal. Due to the results in Table 6.1 (number of depopulated animals); cost expenditures for low-level animal identification are higher compared to the medium and high-level identification systems.

Bates, Carpenter, and Thurmond (2003a) and Ekboir (1999) analyzed costs in hypothetical FMD outbreaks in California. These studies, discussed in Chapter 2, have a large range in costs. Bates, Carpenter, and Thurmond (2003a) estimated total costs for slaughter, indemnity, cleaning and disinfection from \$56.3 to \$92.4 million while Ekboir calculated total costs of \$476 to \$1,462 million to clean and disinfect, depopulate, and quarantine. A couple of the major differences between these studies include size of area studied (i.e., animal population) and inclusion of quarantine costs and costs associated with cleaning and disinfecting processing plants. As seen in Table 6.3, this study estimates total costs in the range of $205.1 to $609.3 million.

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 5.5 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 pairwise 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 AGDL model, one- and two-period lags, (t-1) and (t-2), were specified on the slaughter supply (equation 136) and feeder supply (equation 138). Because economic theory offers little help in determining the appropriate AGDL 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 AGDL 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 in Shazam. Tables 6.4 and 6.5 contain the I3SLS regression results for the slaughter cattle and feeder cattle system of inverse demand and supply equations, respectively.

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.

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 6.6, 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 6.3 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 6.6.

Excess Supply Elasticities

The excess supply elasticities (i.e., import supply elasticities) were calculated using the standard excess supply trade elasticity found in Chapter 4. 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 5.5. 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.

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 6.7 contains the percentage decreases in costs and quantities for the aggregated EDM that does not allow for trade and does not disaggregate Kansas from the rest of the U.S. Table 6.8 reports the percentage changes used in the disaggregated 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. All calculations for the percentage changes can be found in Appendix B.

Simulation Results

Price and Quantity Effects

Using equation (132), impacts of the exogenous changes (listed in Tables 6.7 and 6.8) were simulated for different depths of animal identification. Tables 6.9 – 6.14 contain the percentage changes for short- and long-run impacts on low-, medium-, and high-levels of animal identification for the aggregated 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.[9] Tables 6.15 – 6.20 are similar to Tables 6.9 – 6.14 except all costs are not borne by the producer. In these scenarios, it is assumed 50% of the FMD related costs are borne by the producers and the remaining is borne by the Government. Endogenous changes in prices and quantities in the disaggregated model are presented in Tables 6.21 through 6.32. In both the aggregated and disaggregated equilibrium displacement models, 95% confidence intervals reported are based upon distributions generated by the simulations.

Both the aggregated and disaggregated equilibrium displacement models produce similar results. 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

[9] 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.

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. When comparing all costs borne by producers vs. 50% of costs are borne by producers, the percentage change in prices and quantities are smaller when the producers only bear half of the costs.

The mean estimates for change in consumer and producer surplus for all three commodities at each marketing level are presented in Tables 6.33 – 6.48. In general, as the surveillance increases, changes in consumer and producer surplus become smaller. The simulation models indicate change in beef producer surplus at the retail-level and pork and poultry producer surplus at all levels is statistically insignificant for the aggregated EDM in the short-run with no change in demand. The simulation model indicated an increase in the retail and wholesale-levels producer surplus for pork. However, this result is impossible given there is no change in consumer demand. This increase was attributed to highly inelastic supply elasticities which attributed to the linear supply functions having negative price intercepts. Continuing with the aggregated EDM in the short-run with no change in demand, producer surplus for the meat industry declines by $321.14 million (low-level identification) while high-level animal ID declines by $116.43 million. Across all meat sectors, change in retail-level consumer surplus declines by $354.43 million for low-level animal identification and $134.46 million for high-level identification. Consumer surplus for retail poultry is not statistically different from zero at the 0.05 level for any level of identification.

The long-run results for the aggregated EDM with no change in consumer demand follow a similar pattern as the short-run results, but the magnitude of the measures is much smaller.

Producer surplus losses for the meat industry become smaller with increased identification systems. Similar to the short-run model, producer surplus at the retail and wholesale-levels and consumer surplus for poultry are statistically insignificant.

Tables 6.35 and 6.36 report changes in producer surplus for each market level and consumer surplus at the retail-level for the aggregated EDM with a 2% decrease in beef and pork demand and a 1% increase in poultry demand and all costs are borne by the producers for the short- and long-run, respectively. Change in total meat industry producer surplus for low-level identification in the short-run declines by $626.70 million while medium- and high-levels of animal trace back decline by $543.86 million and $422.58 million, respectively. All values are statistically significant except consumer surplus for poultry at the retail-level. Long-run results indicate little change between identification levels for producer surplus in the meat industry. The range for change in producer surplus is a negative $158.55 million to a negative $117.49 million. Consumer surplus has a decrease between low and high trace back systems, $194.81 million to $195.47 million, respectively. Results for the aggregated EDM with 50% of costs borne by the producer are similar to the model where all costs are borne by the producer except producer and consumer surplus measures are lower. However, when comparing the long-run aggregated EDM with all costs vs. 50% of costs borne by the producer, the differences between the change in producer and consumer surpluses for the two models are less than 50%. This occurs because costs are only one of the components that shift the supply curve to the left. The other component is the destruction of cattle which shifts the supply curve more than the increase in costs.

Table 6.41 – Table 6.48 contain the results for changes in consumer and producer surplus for the disaggregated EDM. These results follow similar patterns to the aggregated EDM. For example, as animal identification levels are increased the decline in producer surplus becomes

smaller. One major difference between aggregated and disaggregated models is the changes in consumer and producer surplus measures are smaller in the disaggregated models. The consumer and producer surplus measures are smaller in the disaggregated models for a couple reasons. When Kansas and Other States are disaggregated, the respective elasticities and quantities used in estimating the endogenous percentage changes in prices and quantities are different. In addition, imports are incorporated into the disaggregated model.

Change in beef producer surplus at the retail and fed cattle-levels in the short-run disaggregated models 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 6.41). Consumer surplus declines by $197.32 million for 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 6.34 indicates total beef industry producer surplus declines by $583.91 million for low-level surveillance while high-level surveillance is reduced by $405 million under in the disaggregated EDM 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 6.44). Table 6.44 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.

Tables 6.45 – 6.48 contain the results for the disaggregated EDM with 50% of the costs borne by the producer. The results are similar to the models where all costs are borne by the producers. Although the changes in surpluses are smaller when 50% of the costs are borne by the producers, the difference between the results in the two models (when 100% of the costs are borne by the producers vs. 50% are borne by the producer) are small. For example, producer surplus for the total meat industry is reduced by $191.87 million when all costs are borne by the producer compared to $151.97 million when the producers bear only 50% of the costs (Table 6.41 and Table 6.45, respectively). The differences between the two models in the long-run are minimal.

The critical results discussed above and presented in the tables below demonstrate the importance animal identification can have on a FMD outbreak in southwest Kansas. As the depth or level of animal identification increases, the percentage change in prices and quantities decrease. As animal traceability increases, these changes in prices and quantities result in smaller changes in consumer and producer surplus measures.

Table 6.1 Summary Statistics for the Number of Animals Depopulated

	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 6.2 Summary Statistics for the Duration of the Outbreak

	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

Table 6.3 Summary Statistics for Cost Expenditures

	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

Table 6.4 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 α = 0.05 significance level is 1.96 and at α = 0.10 the critical value is 1.645.

Table 6.5 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.

Table 6.6 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.

Table 6.7 Exogenous Changes Used in Aggregated EDM (%)

	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
Slaughter (Fed Cattle) Level	-1.653	1.214	-1.186	0.872	-0.579	0.426
Farm (Feeder Cattle) Level	-0.037	0.038	-0.027	0.021	-0.007	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
Slaughter (Market Hog) Level	-0.498	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 6.8 Exogenous Changes Used in Disaggregated EDM (%)

	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 6.9 Percentage Changes in the Endogenous Variables in the Aggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	3.382	(2.163, 4.601)	-0.017	(-0.026, -0.007)
Retail Beef Quantity	-1.739	(-2.480, -0.997)	0.011	(0.003, 0.019)
Wholesale Beef Price	1.895	(0.985, 2.804)	-0.132	(-0.198, -0.066)
Wholesale Beef Quantity	-2.886	(-3.428, -2.343)	0.086	(0.038, 0.135)
Fed Cattle Price	0.704	(0.149, 1.260)	0.976	(0.861, 1.091)
Fed Cattle Quantity	-3.436	(-3.870, -3.003)	0.732	(0.484, 0.980)
Feeder Cattle Price	-3.151	(-4.017, -2.286)	0.188	(0.123, 0.253)
Feeder Cattle Quantity	-0.768	(-1.126, -0.411)	0.454	(0.273, 0.636)
Pork Sector:				
Retail Pork Price	0.717	(0.174, 1.260)	0.015	(0.008, 0.023)
Retail Pork Quantity	0.354	(-0.448, 1.156)	0.007*	(-0.002, 0.016)
Wholesale Pork Price	0.750	(0.177, 1.322)	0.085	(0.052, 0.117)
Wholesale Pork Quantity	-0.170*	(-0.626, 0.287)	-0.053	(-0.077, -0.030)
Hog Price	0.668	(0.146, 1.191)	0.317	(0.288, 0.346)
Hog Quantity	-0.511	(-0.733, -0.289)	-0.215	(-0.261, -0.168)
Poultry Sector:				
Retail Poultry Price	1.323*	(-1.413, 4.059)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.373*	(-0.401, 1.148)	-0.002*	(-0.011, 0.006)
Wholesale Poultry Price	1.030*	(-1.117, 3.176)	0.000*	(-0.001, 0.001)
Wholesale Poultry Quantity	0.144*	(-0.156, 0.444)	-0.002*	(-0.010, 0.006)

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

Table 6.10 Percentage Changes in the Endogenous Variables in Aggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers

	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	1.675	(0.916, 2.435)	0.007*	(-0.097, 0.110)
Retail Beef Quantity	-2.851	(-3.301, -2.400)	-2.007	(-2.066, -1.948)
Wholesale Beef Price	0.716	(0.172, 1.260)	-0.107*	(-0.248, 0.035)
Wholesale Beef Quantity	-3.373	(-3.789, -2.957)	-2.006	(-2.425, -1.586)
Fed Cattle Price	0.193*	(-0.226, 0.612)	0.703	(0.560, 0.846)
Fed Cattle Quantity	-3.602	(-3.976, -3.228)	-1.583	(-2.252, -0.913)
Feeder Cattle Price	-3.308	(-4.186, -2.430)	-0.337	(-0.504, -0.170)
Feeder Cattle Quantity	-0.803	(-1.175, -0.431)	-1.025	(-1.494, -0.556)
Pork Sector:				
Retail Pork Price	-0.340	(-0.657, -0.023)	-0.034*	(-0.135, 0.067)
Retail Pork Quantity	-1.265	(-1.720, -0.810)	-2.022	(-2.098, -1.947)
Wholesale Pork Price	-0.373	(-0.709, -0.038)	-0.183*	(-0.435, 0.070)
Wholesale Pork Quantity	-1.026	(-1.288, -0.765)	-1.913	(-2.220, -1.607)
Hog Price	-0.274*	(-0.575, 0.026)	-0.489	(-0.720, -0.257)
Hog Quantity	-0.897	(-1.024, -0.771)	-1.664	(-2.079, -1.250)
Poultry Sector:				
Retail Poultry Price	2.213	(0.281, 4.145)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.625	(0.076, 1.173)	0.996	(0.965, 1.026)
Wholesale Poultry Price	1.722	(0.157, 3.287)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.241	(0.018, 0.464)	0.955	(0.769, 1.141)

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

Table 6.11 Percentage Changes in the Endogenous Variables in Aggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	2.474	(1.588, 3.360)	-0.010	(-0.017, -0.003)
Retail Beef Quantity	-1.279	(-1.820, -0.739)	0.007	(0.001, 0.012)
Wholesale Beef Price	1.385	(0.722, 2.048)	-0.082	(-0.130, -0.033)
Wholesale Beef Quantity	-2.118	(-2.507, -1.729)	0.053	(0.019, 0.088)
Fed Cattle Price	0.450	(0.051, 0.849)	0.699	(0.618, 0.779)
Fed Cattle Quantity	-2.478	(-2.782, -2.174)	0.516	(0.337, 0.695)
Feeder Cattle Price	-2.281	(-2.903, -1.658)	0.131	(0.084, 0.177)
Feeder Cattle Quantity	-0.549	(-0.807, -0.291)	0.321	(0.191, 0.451)
Pork Sector:				
Retail Pork Price	0.457	(0.066, 0.848)	0.009	(0.005, 0.012)
Retail Pork Quantity	0.305*	(-0.277, 0.888)	0.004*	(-0.002, 0.009)
Wholesale Pork Price	0.479	(0.066, 0.892)	0.047	(0.031, 0.064)
Wholesale Pork Quantity	-0.028*	(-0.354, 0.298)	-0.030	(-0.042, -0.018)
Hog Price	0.405	(0.036, 0.774)	0.160	(0.145, 0.175)
Hog Quantity	-0.234	(-0.389, -0.079)	-0.112	(-0.136, -0.088)
Poultry Sector:				
Retail Poultry Price	0.957*	(-1.038, 2.953)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.270*	(-0.294, 0.835)	-0.001*	(-0.007, 0.004)
Wholesale Poultry Price	0.745*	(-0.820, 2.310)	-0.000*	(-0.001, 0.000)
Wholesale Poultry Quantity	0.104*	(-0.114, 0.323)	-0.001*	(-0.006, 0.004)

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

Table 6.12 Percentage Changes in the Endogenous Variables in Aggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers

	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	0.767	(0.292, 1.243)	0.013*	(-0.091, 0.118)
Retail Beef Quantity	-2.391	(-2.669, -2.114)	-2.011	(-2.071, -1.951)
Wholesale Beef Price	0.206*	(-0.135, 0.548)	-0.057*	(-0.203, 0.089)
Wholesale Beef Quantity	-2.605	(-2.896, -2.314)	-2.038	(-2.460, -1.617)
Fed Cattle Price	-0.061*	(-0.356, 0.234)	0.426	(0.283, 0.569)
Fed Cattle Quantity	-2.644	(-2.917, -2.372)	-1.799	(-2.463, -1.135)
Feeder Cattle Price	-2.437	(-3.084, -1.790)	-0.394	(-0.564, -0.223)
Feeder Cattle Quantity	-0.584	(-0.858, -0.310)	-1.158	(-1.635, -0.681)
Pork Sector:				
Retail Pork Price	-0.600	(-0.844, -0.356)	-0.041*	(-0.141, 0.059)
Retail Pork Quantity	-1.314	(-1.614, -1.015)	-2.026	(-2.101, -1.950)
Wholesale Pork Price	-0.644	(-0.901, -0.387)	-0.220*	(-0.462, 0.022)
Wholesale Pork Quantity	-0.885	(-1.093, -0.677)	-1.890	(-2.195, -1.586)
Hog Price	-0.538	(-0.796, -0.280)	-0.645	(-0.878, -0.413)
Hog Quantity	-0.620	(-0.737, -0.503)	-1.561	(-1.975, -1.147)
Poultry Sector:				
Retail Poultry Price	1.85	(0.486, 3.208)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.52	(0.135, 0.908)	0.996	(0.965, 1.028)
Wholesale Poultry Price	1.44	(0.318, 2.558)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.20	(0.040, 0.362)	0.955	(0.769, 1.142)

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

Table 6.13 Percentage Changes in the Endogenous Variables in Aggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.304	(0.844, 1.763)	-0.002*	(-0.005, 0.001)
Retail Beef Quantity	-0.676	(-0.959, -0.394)	0.002	(0.000, 0.004)
Wholesale Beef Price	0.730	(0.384, 1.075)	-0.017*	(-0.040, 0.006)
Wholesale Beef Quantity	-1.118	(-1.312, -0.924)	0.011*	(-0.004, 0.027)
Fed Cattle Price	0.123	(-0.077, 0.323)	0.339	(0.300, 0.377)
Fed Cattle Quantity	-1.233	(-1.373, -1.093)	0.235	(0.149, 0.322)
Feeder Cattle Price	-1.147	(-1.455, -0.839)	0.057	(0.035, 0.079)
Feeder Cattle Quantity	-0.265	(-0.395, -0.136)	0.148	(0.086, 0.210)
Pork Sector:				
Retail Pork Price	0.221	(0.017, 0.425)	0.004	(0.003, 0.006)
Retail Pork Quantity	0.174*	(-0.131, 0.479)	0.002	(0.000, 0.004)
Wholesale Pork Price	0.232	(0.017, 0.448)	0.023	(0.017, 0.029)
Wholesale Pork Quantity	0.013*	(-0.156, 0.183)	-0.014	(-0.019, -0.009)
Hog Price	0.174*	(-0.017, 0.364)	0.057	(0.052, 0.063)
Hog Quantity	-0.075*	(-0.155, 0.004)	-0.043	(-0.052, -0.034)
Poultry Sector:				
Retail Poultry Price	0.502*	(-0.547, 1.550)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.142*	(-0.155, 0.438)	0.000*	(-0.002, 0.001)
Wholesale Poultry Price	0.390*	(-0.432, 1.213)	0.000*	(0.000, 0.000)
Wholesale Poultry Quantity	0.055*	(-0.060, 0.169)	0.000*	(-0.002, 0.001)

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

Table 6.14 Percentage Changes in the Endogenous Variables in Aggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers

	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	-0.403	(-0.719, -0.086)	0.021*	(-0.085, 0.127)
Retail Beef Quantity	-1.788	(-1.971, -1.606)	-2.016	(-2.077, -1.955)
Wholesale Beef Price	-0.449	(-0.704, -0.194)	0.008*	(-0.147, 0.162)
Wholesale Beef Quantity	-1.605	(-1.806, -1.404)	-2.080	(-2.505, -1.656)
Fed Cattle Price	-0.389	(-0.602, -0.175)	0.066*	(-0.088, 0.220)
Fed Cattle Quantity	-1.399	(-1.599, -1.198)	-2.080	(-2.747, -1.412)
Feeder Cattle Price	-1.304	(-1.676, -0.932)	-0.467	(-0.644, -0.290)
Feeder Cattle Quantity	-0.300	(-0.449, -0.150)	-1.331	(-1.827, -0.835)
Pork Sector:				
Retail Pork Price	-0.836	(-1.092, -0.580)	-0.045*	(-0.145, 0.055)
Retail Pork Quantity	-1.445	(-1.716, -1.174)	-2.027	(-2.103, -1.951)
Wholesale Pork Price	-0.891	(-1.159, -0.623)	-0.244	(-0.479, -0.010)
Wholesale Pork Quantity	-0.844	(-1.075, -0.612)	-1.874	(-2.177, -1.571)
Hog Price	-0.769	(-1.071, -0.467)	-0.748	(-0.981, -0.515)
Hog Quantity	-0.461	(-0.603, -0.320)	-1.493	(-1.907, -1.079)
Poultry Sector:				
Retail Poultry Price	1.391	(0.373, 2.410)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.393	(0.104, 0.681)	0.998	(0.965, 1.031)
Wholesale Poultry Price	1.083	(0.243, 1.923)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.152	(0.030, 0.273)	0.957	(0.770, 1.143)

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

Table 6.15 Percentage Changes in the Endogenous Variables in Aggregated EDM with Low Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	2.610	(1.663, 3.558)	-0.015	(-0.023, -0.006)
Retail Beef Quantity	-1.335	(-1.909, -0.760)	0.010	(0.003, 0.017)
Wholesale Beef Price	1.463	(0.758, 2.169)	-0.116	(-0.171, -0.062)
Wholesale Beef Quantity	-2.220	(-2.647, -1.793)	0.076	(0.036, 0.117)
Fed Cattle Price	0.610	(0.173, 1.046)	0.770	(0.681, 0.860)
Fed Cattle Quantity	-2.688	(-3.039, -2.338)	0.586	(0.388, 0.785)
Feeder Cattle Price	-2.469	(-3.151, -1.786)	0.149	(0.098, 0.201)
Feeder Cattle Quantity	-0.599	(-0.880, -0.319)	0.364	(0.219, 0.510)
Pork Sector:				
Retail Pork Price	0.623	(0.196, 1.050)	0.015	(0.008, 0.022)
Retail Pork Quantity	0.226*	(-0.398, 0.850)	0.007*	(-0.001, 0.015)
Wholesale Pork Price	0.650	(0.201, 1.099)	0.080	(0.048, 0.112)
Wholesale Pork Quantity	-0.230*	(-0.591, 0.132)	-0.050	(-0.073, -0.028)
Hog Price	0.602	(0.184, 1.020)	0.318	(0.289, 0.347)
Hog Quantity	-0.538	(-0.717, -0.359)	-0.212	(-0.259, -0.166)
Poultry Sector:				
Retail Poultry Price	1.032*	(-1.087, 3.151)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.291*	(-0.308, 0.891)	-0.002*	(-0.009, 0.006)
Wholesale Poultry Price	0.803*	(-0.860, 2.466)	0.000*	(-0.001, 0.001)
Wholesale Poultry Quantity	0.112*	(-0.120, 0.345)	-0.002*	(-0.009, 0.005)

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

Table 6.16 Percentage Changes in the Endogenous Variables in Aggregated EDM with Low Level Animal Identification and 50% of Costs Borne by the Producers

	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	0.904	(0.385, 1.423)	0.009*	(-0.095, 0.113)
Retail Beef Quantity	-2.447	(-2.749, -2.145)	-2.008	(-2.067, -1.948)
Wholesale Beef Price	0.285*	(-0.085, 0.654)	-0.092*	(-0.235, 0.052)
Wholesale Beef Quantity	-2.707	(-3.021, -2.394)	-2.016	(-2.436, -1.595)
Fed Cattle Price	0.098*	(-0.216, 0.413)	0.497	(0.356, 0.639)
Fed Cattle Quantity	-2.854	(-3.147, -2.561)	-1.729	(-2.390, -1.067)
Feeder Cattle Price	-2.625	(-3.321, -1.929)	-0.375	(-0.544, -0.207)
Feeder Cattle Quantity	-0.634	(-0.929, -0.339)	-1.115	(-1.587, -0.642)
Pork Sector:				
Retail Pork Price	-0.434	(-0.671, -0.197)	-0.035*	(-0.136, 0.066)
Retail Pork Quantity	-1.393	(-1.703, -1.083)	-2.023	(-2.098, -1.947)
Wholesale Pork Price	-0.473	(-0.725, -0.221)	-0.187*	(-0.439, 0.065)
Wholesale Pork Quantity	-1.086	(-1.290, -0.883)	-1.910	(-2.217, -1.604)
Hog Price	-0.340	(-0.586, -0.095)	-0.487	(-0.719, -0.256)
Hog Quantity	-0.925	(-1.031, -0.818)	-1.662	(-2.076, -1.248)
Poultry Sector:				
Retail Poultry Price	1.922	(0.481, 3.362)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.542	(0.133, 0.952)	0.996	(0.965, 1.027)
Wholesale Poultry Price	1.495	(0.312, 2.679)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.209	(0.039, 0.379)	0.955	(0.769, 1.141)

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

Table 6.17 Percentage Changes in the Endogenous Variables in Aggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.891	(1.208, 2.574)	-0.010	(-0.016, -0.004)
Retail Beef Quantity	-0.977	(-1.392, -0.562)	0.006	(0.001, 0.011)
Wholesale Beef Price	1.059	(0.550, 1.568)	-0.077	(-0.116, -0.039)
Wholesale Beef Quantity	-1.618	(-1.924, -1.313)	0.050	(0.022, 0.079)
Fed Cattle Price	0.408	(0.096, 0.720)	0.552	(0.488, 0.616)
Fed Cattle Quantity	-1.936	(-2.182, -1.689)	0.416	(0.274, 0.557)
Feeder Cattle Price	-1.781	(-2.271, -1.291)	0.105	(0.068, 0.142)
Feeder Cattle Quantity	-0.429	(-0.631, -0.227)	0.259	(0.155, 0.362)
Pork Sector:				
Retail Pork Price	0.354	(0.054, 0.653)	0.006	(0.003, 0.010)
Retail Pork Quantity	0.230*	(-0.216, 0.676)	0.002*	(-0.002, 0.007)
Wholesale Pork Price	0.371	(0.055, 0.687)	0.036	(0.022, 0.049)
Wholesale Pork Quantity	-0.028*	(-0.278, 0.222)	-0.023	(-0.033, -0.013)
Hog Price	0.325	(0.041, 0.609)	0.131	(0.119, 0.144)
Hog Quantity	-0.194	(-0.313, -0.074)	-0.090	(-0.110, -0.071)
Poultry Sector:				
Retail Poultry Price	0.733*	(-0.794, 2.259)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.207*	(-0.225, 0.639)	-0.002*	(-0.006, 0.003)
Wholesale Poultry Price	0.570*	(-0.627, 1.768)	0.000*	(-0.001, 0.000)
Wholesale Poultry Quantity	0.080*	(-0.088, 0.247)	-0.001*	(-0.006, 0.003)

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

Table 6.18 Percentage Changes in the Endogenous Variables in Aggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers

	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	0.184*	(-0.158, 0.527)	0.014*	(-0.091, 0.118)
Retail Beef Quantity	-2.089	(-2.285, -1.894)	-2.011	(-2.071, -1.951)
Wholesale Beef Price	-0.120*	(-0.375, 0.135)	-0.052*	(-0.200, 0.096)
Wholesale Beef Quantity	-2.106	(-2.334, -1.877)	-2.042	(-2.464, -1.620)
Fed Cattle Price	-0.103*	(-0.337, 0.130)	0.279	(0.134, 0.424)
Fed Cattle Quantity	-2.102	(-2.321, -1.883)	-1.899	(-2.561, -1.238)
Feeder Cattle Price	-1.938	(-2.453, -1.422)	-0.419	(-0.591, -0.248)
Feeder Cattle Quantity	-0.464	(-0.682, -0.246)	-1.220	(-1.702, -0.739)
Pork Sector:				
Retail Pork Price	-0.703	(-0.932, -0.474)	-0.043*	(-0.143, 0.057)
Retail Pork Quantity	-1.389	(-1.636, -1.142)	-2.027	(-2.103, -1.951)
Wholesale Pork Price	-0.752	(-0.992, -0.512)	-0.231*	(-0.471, 0.008)
Wholesale Pork Quantity	-0.885	(-1.088, -0.682)	-1.883	(-2.188, -1.579)
Hog Price	-0.618	(-0.878, -0.358)	-0.674	(-0.906, -0.442)
Hog Quantity	-0.580	(-0.701, -0.459)	-1.540	(-1.953, -1.126)
Poultry Sector:				
Retail Poultry Price	1.623	(0.517, 2.728)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.458	(0.144, 0.772)	0.996	(0.964, 1.028)
Wholesale Poultry Price	1.263	(0.345, 2.181)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.177	(0.043, 0.310)	0.955	(0.769, 1.142)

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

Table 6.19 Percentage Changes in the Endogenous Variables in Aggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	0.968	(0.623, 1.313)	-0.003	(-0.006, -0.001)
Retail Beef Quantity	-0.502	(-0.713, -0.291)	0.002	(0.000, 0.004)
Wholesale Beef Price	0.542	(0.283, 0.801)	-0.026	(-0.045, -0.008)
Wholesale Beef Quantity	-0.831	(-0.980, -0.681)	0.017	(0.004, 0.030)
Fed Cattle Price	0.150*	(-0.004, 0.304)	0.268	(0.237, 0.299)
Fed Cattle Quantity	-0.954	(-1.069, -0.840)	0.195	(0.126, 0.263)
Feeder Cattle Price	-0.888	(-1.129, -0.647)	0.047	(0.029, 0.065)
Feeder Cattle Quantity	-0.206	(-0.306, -0.105)	0.122	(0.073, 0.172)
Pork Sector:				
Retail Pork Price	0.165	(0.013, 0.317)	0.003	(0.002, 0.004)
Retail Pork Quantity	0.129*	(-0.099, 0.356)	0.001	(0.000, 0.003)
Wholesale Pork Price	0.174	(0.013, 0.334)	0.016	(0.011, 0.021)
Wholesale Pork Quantity	0.008*	(-0.118, 0.135)	-0.010	(-0.014, -0.006)
Hog Price	0.139*	(-0.003, 0.282)	0.047	(0.043, 0.052)
Hog Quantity	-0.062	(-0.122, -0.003)	-0.034	(-0.041, -0.027)
Poultry Sector:				
Retail Poultry Price	0.373*	(-0.407, 1.152)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.105*	(-0.115, 0.326)	0.000*	(-0.002, 0.001)
Wholesale Poultry Price	0.290*	(-0.321, 0.902)	0.000*	(0.000, 0.000)
Wholesale Poultry Quantity	0.041*	(-0.045, 0.126)	0.000*	(-0.002, 0.001)

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

Table 6.20 Percentage Changes in the Endogenous Variables in Aggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers

	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	(-1.089, -0.387)	0.020*	(-0.086, 0.126)
Retail Beef Quantity	-1.614	(-1.823, -1.406)	-2.015	(-2.076, -1.955)
Wholesale Beef Price	-0.637	(-0.926, -0.347)	-0.001*	(-0.157, 0.154)
Wholesale Beef Quantity	-1.318	(-1.508, -1.127)	-2.075	(-2.499, -1.650)
Fed Cattle Price	-0.361	(-0.566, -0.157)	-0.005	(-0.161, 0.151)
Fed Cattle Quantity	-1.120	(-1.296, -0.945)	-2.120	(-2.788, -1.453)
Feeder Cattle Price	-1.044	(-1.350, -0.739)	-0.477	(-0.655, -0.299)
Feeder Cattle Quantity	-0.240	(-0.361, -0.119)	-1.357	(-1.855, -0.858)
Pork Sector:				
Retail Pork Price	-0.892	(-1.172, -0.611)	-0.047*	(-0.146, 0.053)
Retail Pork Quantity	-1.490	(-1.799, -1.182)	-2.028	(-2.104, -1.952)
Wholesale Pork Price	-0.949	(-1.243, -0.656)	-0.251	(-0.485, -0.018)
Wholesale Pork Quantity	-0.848	(-1.102, -0.595)	-1.870	(-2.174, -1.567)
Hog Price	-0.803	(-1.129, -0.477)	-0.758	(-0.991, -0.525)
Hog Quantity	-0.449	(-0.601, -0.297)	-1.484	(-1.898, -1.070)
Poultry Sector:				
Retail Poultry Price	1.263	(0.200, 2.326)	0.009*	(-0.016, 0.033)
Retail Poultry Quantity	0.356	(0.056, 0.657)	0.997	(0.964, 1.030)
Wholesale Poultry Price	0.983	(0.117, 1.848)	0.096	(0.077, 0.114)
Wholesale Poultry Quantity	0.138	(0.013, 0.263)	0.956	(0.769, 1.143)

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

Table 6.21 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers

	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)
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)

Table 6.21 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
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 6.22 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers

	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 6.22 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and All Costs are Borne by the Producers, 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 6.23 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers

	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 6.23 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers, 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 6.24 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers

	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 6.24 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and All Costs are Borne by the Producers

	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 6.25 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers

	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 6.25 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers, 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 6.26 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers

	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 6.26 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and All Costs are Borne by the Producers, 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 6.27 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.599	(0.990, 2.207)	0.010	(0.006, 0.014)
Retail Beef Quantity	-0.835	(-1.234, -0.436)	-0.005	(-0.009, -0.001)
Wholesale Beef Price	0.960	(0.578, 1.343)	0.081	(0.060, 0.102)
Wholesale Beef Quantity	-1.833	(-2.203, -1.463)	-0.178	(-0.228, -0.127)
Import Wholesale Beef Price	0.960	(0.578, 1.343)	0.081	(0.060, 0.102)
Import Wholesale Beef Quantity	1.757	(0.653, 2.860)	0.826	(0.601, 1.051)
Other States Fed Cattle Price	1.086	(0.667, 1.506)	0.533	(0.491, 0.576)
Other States Fed Cattle Quantity	-0.531	(-0.937, -0.126)	1.195	(1.076, 1.315)
Kansas Fed Cattle Price	1.080	(0.663, 1.497)	0.530	(0.488, 0.573)
Kansas Fed Cattle Quantity	-13.695	(-14.15, -13.23)	-11.939	(-12.19, -11.68)
Import Fed Cattle Price	1.086	(0.667, 1.506)	0.533	(0.491, 0.576)
Import Fed Cattle Quantity	8.000	(2.574, 13.425)	9.696	(7.250, 12.142)
Other States Feeder Cattle Price	-1.764	(-2.297, -1.232)	-0.071	(-0.101, -0.041)
Other States Feeder Cattle Quantity	-0.397	(-0.595, -0.199)	-0.210	(-0.294, -0.127)
Kansas Feeder Cattle Price	-1.736	(-2.260, -1.212)	-0.070	(-0.099, -0.041)
Kansas Feeder Cattle Quantity	-1.275	(-1.608, -0.942)	-1.058	(-1.100, -1.016)
Import Feeder Cattle Price	-1.764	(-2.297, -1.232)	-0.071	(-0.101, -0.041)
Import Feeder Cattle Quantity	-7.763	(-12.630, -2.895)	-1.419	(-2.026, -0.811)
Pork Sector:				
Retail Pork Price	0.226*	(-0.029, 0.481)	0.002	(0.001, 0.002)
Retail Pork Quantity	0.244*	(-0.133, 0.621)	0.001*	(-0.002, 0.004)
Wholesale Pork Price	0.224*	(-0.012, 0.460)	0.014	(0.010, 0.018)
Wholesale Pork Quantity	0.067*	(-0.124, 0.259)	-0.009	(-0.013, -0.004)
Import Wholesale Pork Price	0.224*	(-0.012, 0.460)	0.014	(0.010, 0.018)
Import Wholesale Pork Quantity	0.328*	(-0.020, 0.675)	0.057	(0.038, 0.076)
Other States Hog Price	0.205*	(-0.013, 0.424)	0.046	(0.041, 0.050)
Other States Hog Quantity	0.012*	(-0.078, 0.103)	0.010	(0.003, 0.018)
Kansas Hog Price	0.206*	(-0.013, 0.424)	0.046	(0.041, 0.050)
Kansas Hog Quantity	-1.542	(-1.635, -1.449)	-1.544	(-1.554, -1.535)
Import Hog Price	0.205*	(-0.013, 0.424)	0.046	(0.041, 0.050)
Import Hog Quantity	0.334*	(-0.021, 0.689)	0.188	(0.162, 0.215)

Table 6.27 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Low Level Animal Identification and 50% of Costs Borne by the Producers, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	0.606*	(-0.645, 1.856)	0.000	(0.000, 0.000)
Retail Poultry Quantity	0.171*	(-0.179, 0.521)	0.002	(-0.002, 0.007)
Wholesale Poultry Price	0.471*	(-0.512, 1.455)	0.000	(0.000, 0.001)
Wholesale Poultry Quantity	0.066*	(-0.071, 0.203)	0.002	(-0.002, 0.006)

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

Table 6.28 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers

	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	0.079*	(-0.199, 0.356)	0.005*	(-0.093, 0.102)
Retail Beef Quantity	-2.126	(-2.288, -1.965)	-2.011	(-2.068, -1.953)
Wholesale Beef Price	-0.086*	(-0.278, 0.106)	-0.027*	(-0.127, 0.072)
Wholesale Beef Quantity	-2.388	(-2.627, -2.149)	-2.251	(-2.712, -1.790)
Import Wholesale Beef Price	-0.086*	(-0.278, 0.106)	-0.027*	(-0.127, 0.072)
Import Wholesale Beef Quantity	-0.158*	(-0.521, 0.205)	-0.279*	(-1.293, 0.736)
Other States Fed Cattle Price	0.366	(0.125, 0.606)	0.261	(0.149, 0.373)
Other States Fed Cattle Quantity	-0.779	(-1.018, -0.540)	-0.685	(-1.237, -0.133)
Kansas Fed Cattle Price	0.364	(0.125, 0.603)	0.259	(0.148, 0.371)
Kansas Fed Cattle Quantity	-13.870	(-14.03, -13.70)	-13.089	(-13.50, -12.67)
Import Fed Cattle Price	0.366	(0.125, 0.606)	0.261	(0.149, 0.373)
Import Fed Cattle Quantity	2.691	(0.396, 4.987)	4.739	(2.458, 7.020)
Other States Feeder Cattle Price	-1.999	(-2.503, -1.494)	-0.447	(-0.609, -0.284)
Other States Feeder Cattle Quantity	-0.449	(-0.660, -0.238)	-1.270	(-1.725, -0.814)
Kansas Feeder Cattle Price	-1.966	(-2.462, -1.470)	-0.440	(-0.599, -0.280)
Kansas Feeder Cattle Quantity	-1.317	(-1.690, -0.943)	-1.558	(-1.788, -1.327)
Import Feeder Cattle Price	-1.999	(-2.503, -1.494)	-0.447	(-0.609, -0.284)
Import Feeder Cattle Quantity	-8.793	(-14.105, -3.481)	-8.897	(-12.265, -5.529)
Pork Sector:				
Retail Pork Price	-0.826	(-1.055, -0.596)	-0.084	(-0.164, -0.005)
Retail Pork Quantity	-1.332	(-1.584, -1.081)	-1.940	(-2.002, -1.879)
Wholesale Pork Price	-0.744	(-0.965, -0.523)	-0.230	(-0.391, -0.070)
Wholesale Pork Quantity	-0.718	(-0.908, -0.527)	-1.666	(-2.031, -1.300)
Import Wholesale Pork Price	-0.744	(-0.965, -0.523)	-0.230	(-0.391, -0.070)
Import Wholesale Pork Quantity	-1.089	(-1.458, -0.720)	-0.936	(-1.604, -0.268)
Other States Hog Price	-0.667	(-0.920, -0.414)	-0.643	(-0.803, -0.483)
Other States Hog Quantity	-0.345	(-0.459, -0.231)	-1.229	(-1.513, -0.945)
Kansas Hog Price	-0.669	(-0.922, -0.415)	-0.644	(-0.804, -0.484)
Kansas Hog Quantity	-1.901	(-2.024, -1.778)	-2.786	(-3.080, -2.492)
Import Hog Price	-0.667	(-0.920, -0.414)	-0.643	(-0.803, -0.483)
Import Hog Quantity	-1.086	(-1.501, -0.672)	-2.654	(-3.375, -1.933)

Table 6.28 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers, 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	1.566	(0.499, 2.633)	0.008*	(-0.016, 0.033)
Retail Poultry Quantity	0.442	(0.144, 0.739)	0.990	(0.958, 1.023)
Wholesale Poultry Price	1.218	(0.347, 2.089)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.170	(0.044, 0.297)	0.950	(0.766, 1.133)

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

Table 6.29 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	1.165	(0.724, 1.605)	0.008	(0.005, 0.011)
Retail Beef Quantity	-0.609	(-0.899, -0.320)	-0.004	(-0.007, -0.001)
Wholesale Beef Price	0.700	(0.423, 0.976)	0.062	(0.047, 0.077)
Wholesale Beef Quantity	-1.336	(-1.600, -1.073)	-0.137	(-0.173, -0.100)
Import Wholesale Beef Price	0.700	(0.423, 0.976)	0.062	(0.047, 0.077)
Import Wholesale Beef Quantity	1.280	(0.478, 2.081)	0.635	(0.472, 0.798)
Other States Fed Cattle Price	0.759	(0.459, 1.058)	0.382	(0.351, 0.413)
Other States Fed Cattle Quantity	-0.383	(-0.669, -0.096)	0.855	(0.769, 0.941)
Kansas Fed Cattle Price	0.754	(0.456, 1.052)	0.380	(0.349, 0.410)
Kansas Fed Cattle Quantity	-9.829	(-10.149, -9.509)	-8.567	(-8.752, -8.381)
Import Fed Cattle Price	0.759	(0.459, 1.058)	0.382	(0.351, 0.413)
Import Fed Cattle Quantity	5.587	(1.772, 9.402)	6.945	(5.193, 8.697)
Other States Feeder Cattle Price	-1.277	(-1.659, -0.895)	-0.054	(-0.075, -0.032)
Other States Feeder Cattle Quantity	-0.286	(-0.429, -0.143)	-0.157	(-0.217, -0.096)
Kansas Feeder Cattle Price	-1.256	(-1.632, -0.881)	-0.053	(-0.074, -0.032)
Kansas Feeder Cattle Quantity	-0.743	(-0.984, -0.502)	-0.589	(-0.619, -0.558)
Import Feeder Cattle Price	-1.277	(-1.659, -0.895)	-0.054	(-0.075, -0.032)
Import Feeder Cattle Quantity	-5.619	(-9.133, -2.104)	-1.071	(-1.510, -0.632)
Pork Sector:				
Retail Pork Price	0.158*	(-0.027, 0.344)	0.001	(0.001, 0.002)
Retail Pork Quantity	0.182*	(-0.092, 0.457)	0.001*	(-0.001, 0.003)
Wholesale Pork Price	0.155*	(-0.017, 0.326)	0.009	(0.007, 0.011)
Wholesale Pork Quantity	0.059*	(-0.080, 0.199)	-0.005	(-0.008, -0.002)
Import Wholesale Pork Price	0.155*	(-0.017, 0.326)	0.009	(0.007, 0.011)
Import Wholesale Pork Quantity	0.226*	(-0.026, 0.479)	0.037	(0.026, 0.048)
Other States Hog Price	0.133*	(-0.024, 0.291)	0.023	(0.021, 0.025)
Other States Hog Quantity	0.018*	(-0.047, 0.083)	0.005	(0.001, 0.009)
Kansas Hog Price	0.134*	(-0.024, 0.292)	0.023	(0.021, 0.026)
Kansas Hog Quantity	-0.773	(-0.840, -0.706)	-0.786	(-0.792, -0.781)
Import Hog Price	0.133*	(-0.024, 0.291)	0.023	(0.021, 0.025)
Import Hog Quantity	0.217*	(-0.039, 0.473)	0.095	(0.081, 0.109)

Table 6.29 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	0.440*	(-0.470, 1.351)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.124*	(-0.131, 0.379)	0.002*	(-0.002, 0.005)
Wholesale Poultry Price	0.343*	(-0.373, 1.059)	0.000*	(0.000, 0.000)
Wholesale Poultry Quantity	0.048*	(-0.052, 0.148)	0.002*	(-0.002, 0.005)

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

Table 6.30 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers

	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	-0.349	(-0.597, -0.102)	0.002*	(-0.095, 0.100)
Retail Beef Quantity	-1.895	(-2.053, -1.737)	-2.009	(-2.066, -1.952)
Wholesale Beef Price	-0.343	(-0.527, -0.159)	-0.046*	(-0.142, 0.050)
Wholesale Beef Quantity	-1.889	(-2.067, -1.711)	-2.210	(-2.668, -1.752)
Import Wholesale Beef Price	-0.343	(-0.527, -0.159)	-0.046*	(-0.142, 0.050)
Import Wholesale Beef Quantity	-0.627	(-1.087, -0.168)	-0.470*	(-1.451, 0.512)
Other States Fed Cattle Price	0.041*	(-0.156, 0.238)	0.109	(0.002, 0.217)
Other States Fed Cattle Quantity	-0.630	(-0.785, -0.474)	-1.025	(-1.572, -0.478)
Kansas Fed Cattle Price	0.041*	(-0.155, 0.236)	0.109	(0.002, 0.216)
Kansas Fed Cattle Quantity	-10.003	(-10.056, -9.951)	-9.717	(-10.115, -9.320)
Import Fed Cattle Price	0.041*	(-0.156, 0.238)	0.109	(0.002, 0.217)
Import Fed Cattle Quantity	0.300*	(-1.167, 1.766)	1.988*	(0.000, 3.976)
Other States Feeder Cattle Price	-1.510	(-1.880, -1.141)	-0.429	(-0.587, -0.272)
Other States Feeder Cattle Quantity	-0.337	(-0.495, -0.179)	-1.216	(-1.658, -0.774)
Kansas Feeder Cattle Price	-1.486	(-1.850, -1.122)	-0.422	(-0.577, -0.267)
Kansas Feeder Cattle Quantity	-0.784	(-1.066, -0.502)	-1.088	(-1.312, -0.865)
Import Feeder Cattle Price	-1.510	(-1.880, -1.141)	-0.429	(-0.587, -0.272)
Import Feeder Cattle Quantity	-6.645	(-10.637, -2.653)	-8.549	(-11.818, -5.280)
Pork Sector:				
Retail Pork Price	-0.893	(-1.139, -0.647)	-0.085	(-0.165, -0.005)
Retail Pork Quantity	-1.393	(-1.661, -1.125)	-1.940	(-2.002, -1.879)
Wholesale Pork Price	-0.813	(-1.050, -0.576)	-0.235	(-0.395, -0.076)
Wholesale Pork Quantity	-0.725	(-0.930, -0.520)	-1.662	(-2.028, -1.297)
Import Wholesale Pork Price	-0.813	(-1.050, -0.576)	-0.235	(-0.395, -0.076)
Import Wholesale Pork Quantity	-1.189	(-1.585, -0.794)	-0.956	(-1.620, -0.292)
Other States Hog Price	-0.739	(-1.013, -0.465)	-0.666	(-0.826, -0.505)
Other States Hog Quantity	-0.339	(-0.463, -0.215)	-1.235	(-1.520, -0.950)
Kansas Hog Price	-0.740	(-1.015, -0.466)	-0.667	(-0.828, -0.506)
Kansas Hog Quantity	-1.132	(-1.266, -0.997)	-2.029	(-2.324, -1.733)
Import Hog Price	-0.739	(-1.013, -0.465)	-0.666	(-0.826, -0.505)
Import Hog Quantity	-1.203	(-1.651, -0.755)	-2.748	(-3.476, -2.020)

Table 6.30 Percentage Changes in the Endogenous Variables in Disaggregated EDM with Medium Level Animal Identification and 50% of Costs Borne by the Producers, 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	1.403	(0.382, 2.425)	0.008*	(-0.016, 0.033)
Retail Poultry Quantity	0.396	(0.108, 0.683)	0.990	(0.958, 1.022)
Wholesale Poultry Price	1.091	(0.263, 1.919)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.153	(0.032, 0.274)	0.949	(0.766, 1.133)

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

Table 6.31 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Beef Sector:				
Retail Beef Price	0.605	(0.381, 0.830)	0.005	(0.003, 0.006)
Retail Beef Quantity	-0.317	(-0.465, -0.168)	-0.003	(-0.004, -0.001)
Wholesale Beef Price	0.364	(0.222, 0.505)	0.038	(0.030, 0.045)
Wholesale Beef Quantity	-0.695	(-0.821, -0.568)	-0.083	(-0.102, -0.065)
Import Wholesale Beef Price	0.364	(0.222, 0.505)	0.038	(0.030, 0.045)
Import Wholesale Beef Quantity	0.665	(0.252, 1.079)	0.388	(0.305, 0.470)
Other States Fed Cattle Price	0.336	(0.191, 0.481)	0.186	(0.171, 0.201)
Other States Fed Cattle Quantity	-0.195	(-0.327, -0.063)	0.413	(0.371, 0.455)
Kansas Fed Cattle Price	0.334	(0.190, 0.478)	0.185	(0.170, 0.200)
Kansas Fed Cattle Quantity	-4.809	(-4.952, -4.666)	-4.188	(-4.278, -4.098)
Import Fed Cattle Price	0.336	(0.191, 0.481)	0.186	(0.171, 0.201)
Import Fed Cattle Quantity	2.476	(0.733, 4.219)	3.377	(2.525, 4.229)
Other States Feeder Cattle Price	-0.638	(-0.824, -0.452)	-0.029	(-0.039, -0.018)
Other States Feeder Cattle Quantity	-0.142	(-0.212, -0.071)	-0.082	(-0.112, -0.052)
Kansas Feeder Cattle Price	-0.628	(-0.810, -0.445)	-0.028	(-0.039, -0.018)
Kansas Feeder Cattle Quantity	-0.255	(-0.375, -0.135)	-0.180	(-0.195, -0.165)
Import Feeder Cattle Price	-0.638	(-0.824, -0.452)	-0.029	(-0.039, -0.018)
Import Feeder Cattle Quantity	-2.806	(-4.550, -1.063)	-0.569	(-0.789, -0.349)
Pork Sector:				
Retail Pork Price	0.082*	(-0.014, 0.179)	0.001	(0.000, 0.001)
Retail Pork Quantity	0.095*	(-0.048, 0.237)	0.001*	(-0.001, 0.002)
Wholesale Pork Price	0.080*	(-0.009, 0.169)	0.006	(0.005, 0.007)
Wholesale Pork Quantity	0.031*	(-0.041, 0.103)	-0.004	(-0.005, -0.002)
Import Wholesale Pork Price	0.080*	(-0.009, 0.169)	0.006	(0.005, 0.007)
Import Wholesale Pork Quantity	0.118*	(-0.013, 0.249)	0.024	(0.018, 0.030)
Other States Hog Price	0.060*	(-0.021, 0.141)	0.008	(0.007, 0.009)
Other States Hog Quantity	0.011*	(-0.022, 0.045)	0.001*	(-0.001, 0.003)
Kansas Hog Price	0.060*	(-0.021, 0.142)	0.008	(0.007, 0.009)
Kansas Hog Quantity	-0.278	(-0.313, -0.244)	-0.289	(-0.291, -0.286)
Import Hog Price	0.060*	(-0.021, 0.141)	0.008	(0.007, 0.009)
Import Hog Quantity	0.098*	(-0.035, 0.230)	0.033	(0.028, 0.039)

Table 6.31 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers, Cont.

	No Change in Demand			
Endogenous Variables	Short Run	Confidence Interval	Long Run	Confidence Interval
Poultry Sector:				
Retail Poultry Price	0.229*	(-0.244, 0.702)	0.000*	(0.000, 0.000)
Retail Poultry Quantity	0.064*	(-0.068, 0.197)	0.001*	(-0.001, 0.003)
Wholesale Poultry Price	0.178*	(-0.194, 0.550)	0.000*	(0.000, 0.000)
Wholesale Poultry Quantity	0.025*	(-0.027, 0.077)	0.001*	(-0.001, 0.003)

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

Table 6.32 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers

	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	-0.901	(-1.247, -0.554)	-0.001*	(-0.098, 0.096)
Retail Beef Quantity	-1.596	(-1.836, -1.356)	-2.008	(-2.065, -1.951)
Wholesale Beef Price	-0.674	(-0.921, -0.426)	-0.070*	(-0.163, 0.022)
Wholesale Beef Quantity	-1.244	(-1.424, -1.065)	-2.157	(-2.611, -1.702)
Import Wholesale Beef Price	-0.674	(-0.921, -0.426)	-0.070*	(-0.163, 0.022)
Import Wholesale Beef Quantity	-1.232	(-1.989, -0.475)	-0.717*	(-1.660, 0.226)
Other States Fed Cattle Price	-0.378	(-0.614, -0.142)	-0.087*	(-0.190, 0.017)
Other States Fed Cattle Quantity	-0.441	(-0.594, -0.287)	-1.467	(-2.011, -0.923)
Kansas Fed Cattle Price	-0.376	(-0.610, -0.141)	-0.086*	(-0.189, 0.017)
Kansas Fed Cattle Quantity	-4.982	(-5.150, -4.815)	-5.338	(-5.727, -4.950)
Import Fed Cattle Price	-0.378	(-0.614, -0.142)	-0.087*	(-0.190, 0.017)
Import Fed Cattle Quantity	-2.784	(-5.164, -0.404)	-1.580*	(-3.520, 0.361)
Other States Feeder Cattle Price	-0.870	(-1.096, -0.644)	-0.404	(-0.556, -0.252)
Other States Feeder Cattle Quantity	-0.193	(-0.284, -0.101)	-1.141	(-1.567, -0.715)
Kansas Feeder Cattle Price	-0.856	(-1.078, -0.634)	-0.398	(-0.547, -0.248)
Kansas Feeder Cattle Quantity	-0.296	(-0.459, -0.132)	-0.679	(-0.894, -0.465)
Import Feeder Cattle Price	-0.870	(-1.096, -0.644)	-0.404	(-0.556, -0.252)
Import Feeder Cattle Quantity	-3.828	(-6.149, -1.507)	-8.047	(-11.195, -4.899)
Pork Sector:				
Retail Pork Price	-0.968	(-1.257, -0.679)	-0.085	(-0.165, -0.006)
Retail Pork Quantity	-1.479	(-1.814, -1.145)	-1.941	(-2.003, -1.879)
Wholesale Pork Price	-0.886	(-1.163, -0.610)	-0.239	(-0.397, -0.080)
Wholesale Pork Quantity	-0.753	(-0.989, -0.516)	-1.661	(-2.026, -1.296)
Import Wholesale Pork Price	-0.886	(-1.163, -0.610)	-0.239	(-0.397, -0.080)
Import Wholesale Pork Quantity	-1.297	(-1.749, -0.845)	-0.969	(-1.630, -0.308)
Other States Hog Price	-0.811	(-1.123, -0.500)	-0.681	(-0.842, -0.520)
Other States Hog Quantity	-0.346	(-0.486, -0.205)	-1.239	(-1.525, -0.953)
Kansas Hog Price	-0.813	(-1.126, -0.501)	-0.682	(-0.843, -0.521)
Kansas Hog Quantity	-0.636	(-0.789, -0.484)	-1.531	(-1.828, -1.233)
Import Hog Price	-0.811	(-1.123, -0.500)	-0.681	(-0.842, -0.520)
Import Hog Quantity	-1.321	(-1.830, -0.811)	-2.810	(-3.542, -2.077)

Table 6.32 Percentage Changes in the Endogenous Variables in Disaggregated EDM with High Level Animal Identification and 50% of Costs Borne by the Producers, 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	1.195	(0.081, 2.309)	0.008*	(-0.016, 0.033)
Retail Poultry Quantity	0.337	(0.021, 0.654)	0.989	(0.957, 1.022)
Wholesale Poultry Price	0.929	(0.040, 1.819)	0.095	(0.077, 0.113)
Wholesale Poultry Quantity	0.130	(0.001, 0.259)	0.948	(0.765, 1.132)

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

Table 6.33 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with All Costs Borne by the Producer ($ millions)

	No Change in Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-60.60*	-45.53*	-23.52*
Wholesale Level	-141.24	-108.52	-50.75
Slaughter (Fed Cattle) Level	-153.01	-107.46	-58.79
Farm (Feeder Cattle) Level	-92.14	-71.90	-33.40
Total Beef Industry Producer Surplus	-446.98	-333.41	-166.46
Pork Producer Surplus:			
Retail Level	25.19*	19.52*	9.62*
Wholesale Level	2.68*	3.06*	1.96*
Slaughter (Hog) Level	-3.15*	-0.75*	0.07*
Total Pork Industry Producer Surplus	24.71	21.84	11.65
Poultry Producer Surplus:			
Retail Level	75.37*	58.74*	28.58*
Wholesale Level	25.77*	20.09*	9.79*
Total Poultry Industry Producer Surplus	101.14	78.83	38.37
Total Meat Industry Producer Surplus	*-321.14*	*-232.74*	*-116.43*
Retail Consumer Surplus:			
Retail Beef	-265.94	-194.98	-103.06
Retail Pork	-30.00	-19.11	-9.25
Retail Poultry	-58.49*	-42.31*	-22.15*
Total Retail Consumer Surplus	-354.43	-256.41	-134.46

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

Table 6.34 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with All Costs Borne by the Producer ($ millions)

	No Change in Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-0.56	-0.35	-0.07*
Wholesale Level	-6.61	-5.91	-4.99
Slaughter (Fed Cattle) Level	-64.85	-46.52	-22.83
Farm (Feeder Cattle) Level	3.05	2.67	1.34
Total Beef Industry Producer Surplus	-68.97	-50.11	-26.55
Pork Producer Surplus:			
Retail Level	0.36	0.20	0.10
Wholesale Level	0.13*	-0.05*	-0.17
Slaughter (Hog) Level	-0.30	-0.17	-0.08
Total Pork Industry Producer Surplus	0.19	-0.02	-0.14
Poultry Producer Surplus:			
Retail Level	-0.004*	-0.003*	0.000*
Wholesale Level	-0.005*	-0.003*	0.000*
Total Poultry Industry Producer Surplus	-0.01	-0.01	0.00
Total Meat Industry Producer Surplus	*-68.78*	*-50.13*	*-26.69*
Retail Consumer Surplus:			
Retail Beef	1.31	0.82	0.171
Retail Pork	-0.64	-0.36	-0.174
Retail Poultry	0.00*	0.00*	0.00*
Total Retail Consumer Surplus	0.67	0.46	0.00

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

Table 6.35 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with All Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-250.63	-235.49	-213.29
Wholesale Level	-191.46	-158.86	-101.21
Slaughter (Fed Cattle) Level	-178.69	-133.29	-85.11
Farm (Feeder Cattle) Level	-96.62	-76.39	-37.90
Total Beef Industry Producer Surplus	-717.40	-604.03	-437.52
Pork Producer Surplus:			
Retail Level	-43.26	-48.87	-58.62
Wholesale Level	-19.49	-21.20	-20.19
Slaughter (Hog) Level	-15.70	-16.58	-12.50
Total Pork Industry Producer Surplus	-78.46	-86.65	-91.31
Poultry Producer Surplus:			
Retail Level	126.06	109.41	79.16
Wholesale Level	43.10	37.42	27.09
Total Poultry Industry Producer Surplus	169.16	146.83	106.25
Total Meat Industry Producer Surplus	*-626.70*	*-543.86*	*-422.58*
Retail Consumer Surplus:			
Retail Beef	-287.39	-216.89	-125.55
Retail Pork	-68.89	-16.60	-48.27
Retail Poultry	-53.77*	-37.58*	-17.40*
Total Retail Consumer Surplus	-410.04	-271.06	-191.22

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

Table 6.36 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with All Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-16.97	-16.76	-16.49
Wholesale Level	-16.66	-15.98	-15.09
Slaughter (Fed Cattle) Level	-85.90	-68.01	-44.90
Farm (Feeder Cattle) Level	-11.99	-12.37	-13.67
Total Beef Industry Producer Surplus	-131.53	-113.13	-90.15
Pork Producer Surplus:			
Retail Level	-11.61	-11.77	-11.86
Wholesale Level	-8.70	-8.87	-8.99
Slaughter (Hog) Level	-10.99	-10.86	-10.77
Total Pork Industry Producer Surplus	-31.29	-31.50	-31.62
Poultry Producer Surplus:			
Retail Level	1.870	1.872	1.874
Wholesale Level	2.399	2.401	2.404
Total Poultry Industry Producer Surplus	4.269	4.272	4.278
Total Meat Industry Producer Surplus	*-158.55*	*-140.35*	*-117.49*
Retail Consumer Surplus:			
Retail Beef	-157.59	-158.08	-158.72
Retail Pork	-81.25	-80.97	-80.78
Retail Poultry	44.03	44.03	44.03
Total Retail Consumer Surplus	-194.81	-195.02	-195.47

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

Table 6.37 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	No Change in Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-45.53*	-33.94*	-17.39*
Wholesale Level	-108.52	-77.85	-37.56
Slaughter (Fed Cattle) Level	-107.46	-78.09	-39.91
Farm (Feeder Cattle) Level	-71.90	-52.22	-25.84
Total Beef Industry Producer Surplus	-333.41	-242.10	-120.71
Pork Producer Surplus:			
Retail Level	19.52*	14.00*	7.15*
Wholesale Level	0.95*	2.27*	1.45*
Slaughter (Hog) Level	-4.04*	-0.75*	0.00*
Total Pork Industry Producer Surplus	16.44	15.52	8.60
Pork Poultry Surplus:			
Retail Level	58.74*	41.75*	21.24*
Wholesale Level	20.09*	14.29*	7.27*
Total Poultry Industry Producer Surplus	78.83	56.04	28.51
Total Meat Industry Producer Surplus	*-238.14*	*-170.54*	*-83.60*
Retail Consumer Surplus:			
Retail Beef	-205.66	-149.23	-76.64
Retail Pork	-26.03	-14.79	-6.91
Retail Poultry	-45.48*	-32.27*	-16.39*
Total Retail Consumer Surplus	-277.17	-196.30	-99.93

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

Table 6.38 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	No Change in Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-0.50	-0.33	-0.11
Wholesale Level	-5.46	-4.91	-4.19
Slaughter (Fed Cattle) Level	-60.82	-43.61	-21.34
Farm (Feeder Cattle) Level	2.59	2.07	1.09
Total Beef Industry Producer Surplus	-64.19	-46.78	-24.55
Pork Producer Surplus:			
Retail Level	0.34	0.15	0.07
Wholesale Level	0.15*	-0.07	-0.17
Slaughter (Hog) Level	-0.28	-0.06*	-0.03
Total Pork Industry Producer Surplus	0.20	0.01	-0.14
Poultry Producer Surplus:			
Retail Level	-0.004*	-0.003*	-0.000*
Wholesale Level	-0.004*	-0.004*	-0.001*
Total Poultry Industry Producer Surplus	-0.01	-0.01	0.00
Total Meat Industry Producer Surplus	*-63.99*	*-46.77*	*-24.69*
Retail Consumer Surplus:			
Retail Beef	1.16	0.77	0.26
Retail Pork	-0.61	-0.27	-0.12
Retail Poultry	0.00*	0.00*	0.00*
Total Retail Consumer Surplus	0.56	0.50	0.14

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

Table 6.39 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-235.49	-223.76	-207.15
Wholesale Level	-158.86	-128.25	-88.10
Slaughter (Fed Cattle) Level	-133.29	-73.45	-66.20
Farm (Feeder Cattle) Level	-76.39	-55.69	-28.46
Total Beef Industry Producer Surplus	-604.03	-481.15	-389.90
Pork Producer Surplus:			
Retail Level	-48.87	-54.29	-61.06
Wholesale Level	-21.20	-19.88	-20.69
Slaughter (Hog) Level	-16.58	-13.19	-12.37
Total Pork Industry Producer Surplus	-86.65	-87.37	-94.13
Poultry Producer Surplus:			
Retail Level	109.41	92.34	71.81
Wholesale Level	37.42	31.59	24.58
Total Poultry Industry Producer Surplus	146.83	123.93	96.39
Total Meat Industry Producer Surplus	*-543.86*	*-444.59*	*-387.64*
Retail Consumer Surplus:			
Retail Beef	-227.48	-171.42	-99.25
Retail Pork	-64.92	-53.77	-45.92
Retail Poultry	-40.68*	-27.47*	-11.59*
Total Retail Consumer Surplus	-333.09	-252.66	-156.76

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

Table 6.40 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Aggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-16.91	-16.74	-16.53
Wholesale Level	-15.54	-15.01	-14.30
Slaughter (Fed Cattle) Level	-81.98	-65.18	-43.45
Farm (Feeder Cattle) Level	-12.44	-12.95	-13.92
Total Beef Industry Producer Surplus	-126.87	-109.88	-88.20
Pork Producer Surplus:			
Retail Level	-11.63	-11.82	-11.89
Wholesale Level	-8.68	-8.90	-8.99
Slaughter (Hog) Level	-10.97	-10.75	-10.72
Total Pork Industry Producer Surplus	-31.28	-31.47	-31.61
Poultry Producer Surplus:			
Retail Level	1.87	1.87	1.87
Wholesale Level	2.40	2.40	2.40
Total Poultry Industry Producer Surplus	4.271	4.272	4.276
Total Meat Industry Producer Surplus	*-153.88*	*-137.08*	*-115.53*
Retail Consumer Surplus:			
Retail Beef	-157.74	-158.12	-158.62
Retail Pork	-81.21	-80.88	-80.73
Retail Poultry	44.03	44.03	44.03
Total Retail Consumer Surplus	-194.92	-194.97	-195.32

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

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Table 6.41 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with All Costs Borne by the Producer ($ 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 6.42 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with All Costs Borne by the Producer ($ millions)

	No Change in Demand - Long Run		
	Low Level	Medium Level	High Level
Beef Producer Surplus:			
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 6.43 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with All Costs Borne by the Producer ($ 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 6.44 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with All Costs Borne by the Producer ($ 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.

Table 6.45 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	No Change in Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-29.50*	-21.46*	-11.09*
Wholesale Level	-66.79	-47.35	-22.27
Other States Slaughter (Fed Cattle) Level	-14.20*	-10.67*	-6.51*
Kansas Slaughter (Fed Cattle) Level	-54.46*	-36.58*	-16.41*
Other States Farm (Feeder Cattle) Level	-49.06	-35.47	-17.69
Kansas Farm (Feeder Cattle) Level	-2.12	-1.51	-0.74
Total Beef Industry Producer Surplus	-214.01	-151.53	-73.97
Pork Producer Surplus:			
Retail Level	11.72*	8.53*	4.43*
Wholesale Level	2.78*	2.15*	1.15*
Other States Slaughter (Hog) Level	1.65*	1.21*	0.59*
Kansas Slaughter (Hog) Level	-0.45	-0.21	-0.07
Total Pork Industry Producer Surplus	15.70	11.68	6.10
Poultry Producer Surplus:			
Retail Level	34.54*	25.10*	13.04*
Wholesale Level	11.80*	8.58*	4.46*
Total Poultry Industry Producer Surplus	46.34	33.67	17.50
Total Meat Industry Producer Surplus	*-151.97*	*-106.17*	*-50.37*
Retail Consumer Surplus:			
Retail Beef	-126.25	-92.07	-47.93
Retail Pork	-9.44*	-6.60	-3.43
Retail Poultry	-26.78*	-19.46	-10.11
Total Retail Consumer Surplus	-162.47	-118.13	-61.47

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

Table 6.46 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	No Change in Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	0.34*	0.26*	0.16
Wholesale Level	-0.81	-1.08	-1.42
Other States Slaughter (Fed Cattle) Level	14.01	10.00	4.83
Kansas Slaughter (Fed Cattle) Level	-70.01	-51.88	-26.40
Other States Farm (Feeder Cattle) Level	-2.10	-1.56	-0.81
Kansas Farm (Feeder Cattle) Level	-1.99	-1.09	-0.32
Total Beef Industry Producer Surplus	-60.56	-45.34	-23.95
Pork Producer Surplus:			
Retail Level	0.04*	0.03*	0.02
Wholesale Level	-0.11*	-0.14	-0.15
Other States Slaughter (Hog) Level	0.13	0.06	0.02
Kansas Slaughter (Hog) Level	-0.90	-0.46	-0.17
Total Pork Industry Producer Surplus	-0.84	-0.51	-0.29
Poultry Producer Surplus:			
Retail Level	0.00*	0.00*	0.00*
Wholesale Level	0.01*	0.00*	0.00*
Total Poultry Industry Producer Surplus	0.01	0.01	0.00
Total Meat Industry Producer Surplus	*-61.39*	*-45.84*	*-24.23*
Retail Consumer Surplus:			
Retail Beef	-0.78	-0.60	-0.37
Retail Pork	-0.07	-0.05	-0.03
Retail Poultry	0.00*	0.00*	0.00*
Total Retail Consumer Surplus	-0.85	-0.65	-0.40

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

Table 6.47 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Short Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-231.96	-223.02	-211.48
Wholesale Level	-131.27	-111.61	-86.24
Other States Slaughter (Fed Cattle) Level	-48.06	-44.41	-40.09
Kansas Slaughter (Fed Cattle) Level	-58.15	-40.45	-20.53
Other States Farm (Feeder Cattle) Level	-55.53	-41.92	-24.11
Kansas Farm (Feeder Cattle) Level	-2.38	-1.78	-1.01
Total Beef Industry Producer Surplus	-527.36	-463.18	-383.46
Pork Producer Surplus:			
Retail Level	-55.19	-58.30	-62.29
Wholesale Level	-17.08	-17.69	-18.67
Other States Slaughter (Hog) Level	-9.67	-10.10	-10.72
Kansas Slaughter (Hog) Level	-0.77	-0.54	-0.40
Total Pork Industry Producer Surplus	-82.72	-86.63	-92.08
Poultry Producer Surplus:			
Retail Level	89.04	79.75	67.88
Wholesale Level	30.44	27.27	23.21
Total Poultry Industry Producer Surplus	119.48	107.01	91.09
Total Meat Industry Producer Surplus	*-490.60*	*-442.80*	*-384.44*
Retail Consumer Surplus:			
Retail Beef	-163.11	-129.68	-86.50
Retail Pork	-48.71	-45.91	-42.78
Retail Poultry	-25.02*	-17.82*	-8.62*
Total Retail Consumer Surplus	-236.84	-193.41	-137.89

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

Table 6.48 Changes in Producer Surplus for Each Market level and Consumer Surplus at the Retail Level for the Disaggregated EDM with 50% of Costs Borne by the Producer ($ millions)

	2% Decrease Beef and Pork & 1% Increase in Poultry Demand - Long Run		
Beef Producer Surplus:	Low Level	Medium Level	High Level
Retail Level	-17.09	-17.17	-17.27
Wholesale Level	-12.82	-13.08	-13.41
Other States Slaughter (Fed Cattle) Level	-3.22	-7.17	-12.27
Kansas Slaughter (Fed Cattle) Level	-70.83	-52.96	-27.80
Other States Farm (Feeder Cattle) Level	-12.39	-11.86	-11.12
Kansas Farm (Feeder Cattle) Level	-2.41	-1.51	-0.74
Total Beef Industry Producer Surplus	-118.76	-103.74	-82.61
Pork Producer Surplus:			
Retail Level	-12.20	-12.21	-12.22
Wholesale Level	-8.02	-8.05	-8.06
Other States Slaughter (Hog) Level	-8.76	-8.82	-8.87
Kansas Slaughter (Hog) Level	-1.15	-0.71	-0.43
Total Pork Industry Producer Surplus	-30.13	-29.80	-29.58
Poultry Producer Surplus:			
Retail Level	1.86	1.86	1.86
Wholesale Level	2.39	2.39	2.38
Total Poultry Industry Producer Surplus	4.247	4.245	4.242
Total Meat Industry Producer Surplus	*-144.64*	*-129.29*	*-107.95*
Retail Consumer Surplus:			
Retail Beef	-157.41	-157.23	-157.00
Retail Pork	-79.20	-79.17	-79.16
Retail Poultry	44.03	44.03	44.03
Total Retail Consumer Surplus	-192.57	-192.37	-192.13

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

CHAPTER 7 - CONCLUSIONS & SUMMARY

Summary

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.

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 marketings in the U.S. and therefore, introduction of a contagious disease such as FMD in this region would significantly affect U.S. and world livestock and meat markets. Therefore, to better understand the effects of a FMD outbreak in the U.S., this study estimated 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.

Most previous research on FMD has drawn the same general conclusion; contain and eradicate FMD as soon as possible. A recent study by Zhao, Wahl, and Marsh (2006) concluded that increased surveillance helps curtail the spread of the disease, and thus, limits welfare loses. Disney et al. (2001) found that benefits of animal identification systems in cattle outweigh added costs in a hypothetical FMD outbreak. Given these findings, an epidemiological model using actual feedlot and farm data was developed for southwest Kansas to study the effects of a hypothetical FMD outbreak. An equilibrium displacement model consisting of four sectors in the beef marketing chain, three sectors in the pork marketing chain, and two sectors in the poultry marketing chain was constructed. The EDM was then shocked to reflect the imposition of a FMD outbreak in southwest Kansas.

This study contributes to the animal disease economic literature in several important ways. This study employs a stochastic, state-transition, disease-spread model to evaluate the impacts of a FMD outbreak. Actual U.S. regional herd-level data with latitude and longitude coordinates were obtained from Kansas Department of Health and Environment for multiple production types. The control strategies evaluated here focus on different depths of animal identification and not vaccination or alternate stamping-out policies. The output produced from the epidemiological disease spread model was then used in conjunction with an economic framework that allowed for horizontally linked beef, pork, and poultry demands at the retail-level as well as vertical linkages between producers, processors, and retail sectors.

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 surveillance increases, the shifts in the supply curves become incrementally smaller.

Although there are criticisms regarding consumer and producer surplus measures, it is a commonly used approach in analyzing welfare effects in a partial equilibrium analysis and is used in this study to measure welfare effects. Welfare results were different among the alternative scenarios. In the aggregated models, declines in producer surplus for the beef industry when demand was held constant ranged from \$446.98 million with low-level ID to \$166.46 million with high-level ID.[10] Results indicate a much larger decline in producer surplus for beef when demand for beef and pork decrease by 2% and demand for poultry increases by 1%. Producers in the beef industry had a reduction in welfare by \$717.70 million for low-level ID compared to \$437.52 million decline with high-level ID. Results for the disaggregated models followed the same patterns as the aggregated models; except the changes in welfare measures were smaller in magnitude. 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

[10] Recall producer surplus for a firm is the difference between the market price of the good and the marginal costs of production summed over all units produced.

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.

As demonstrated in Chapter 6, 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.

The value of this research lies in its ability to quantify the impact of alternative levels of animal traceability in the event of a regional FMD outbreak. The results of this research will provide insight to numerous groups such as policy makers, government agencies (i.e., ERS and APHIS), and researchers. This study provides policy makers with scientific evidence of the importance of alternate surveillance 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. 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.

Limitations

While the study presented here is an improvement over existing studies, limitations still exist. The results from the epidemiological model may be understated for two reasons. First, the current version of the disease spread model only traces forward one level. Second, FMD was only allowed to spread within the 14 counties in southwest Kansas. Other limitations of this research regarding the economic model include the lack of a dynamic component to the EDM and the lack of supply and demand elasticities for Canadian wholesale beef and pork and Mexican feeder cattle which are used to estimate import elasticities. Additionally, by using previously published elasticity estimates, variances for these elasticities which are used in the simulations are typically not published.

Future Research

Although limitations in this research do exist, some of these limitations can be addressed. To address the possible understatement of the epidemiological model, additional animal data can be obtained for the remaining 91 counties in Kansas. This would allow the disease to potentially spread throughout Kansas, rather than containing it southwest Kansas. Also, if one can obtain similar animal data for the surrounding states this can easily be incorporated into the disease spread model. At this point the epidemiological model only traces forward one level. With APHIS continually updating and improving the disease spread model, a future version of the disease spread could be used that would allow for more than one level forward tracing. The mitigation strategies analyzed in this study are different levels of traceability. Further research could examine additional mitigation strategies, such as vaccination programs and alternate ring destruction programs. Several other interesting studies that could be examined with the use of the epidemiological spread model would be: i) to examine the regional economic impacts of a FMD outbreak with the use of an Input-Output or computable general equilibrium model; ii) to examine the economic value of APHIS having immediate access to animal identification/trace back data given a FMD outbreak; and iii) to examine the economic value of varying levels of producer adoption of animal identification/trace-back systems with a FMD outbreak. Another interesting study would be to use the economic framework described above to analyze the impacts of traceability costs on producer and consumer surplus. Those results could then be compared to the results presented in this research which would not only evaluate the impacts of a FMD outbreak with alternate surveillance levels, but also the impacts of introducing animal ID and the associated costs.

Overall, this research increases our understanding of the economic impacts of increased animal traceability in the event of a FMD outbreak. An aggregated and disaggregated EDM model was used in conjunction with an epidemiological model in order to quantify these effects. Findings show as the level of animal trace back systems are increased; changes in welfare losses are smaller. Although there are some limitations in this study, this methodology provides a good indication of the impacts of animal identification given a regional FMD outbreak. Furthermore, its potential in estimating the impacts of additional contagious animal disease outbreak makes it particularly attractive.

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Appendix A - Epidemiological Model

Model

The epidemiological model used in this research is the North American Animal Disease Spread Model (NAADSM). The version of the NAADSM used is version 3.0.80 Build 060705-Cheyenne. It is assumed that FMD began in two small-to-medium sized cattle feedlots in the central part of the area studied in this research.

Input Parameters

The key *disease* parameters for the model are as follows:

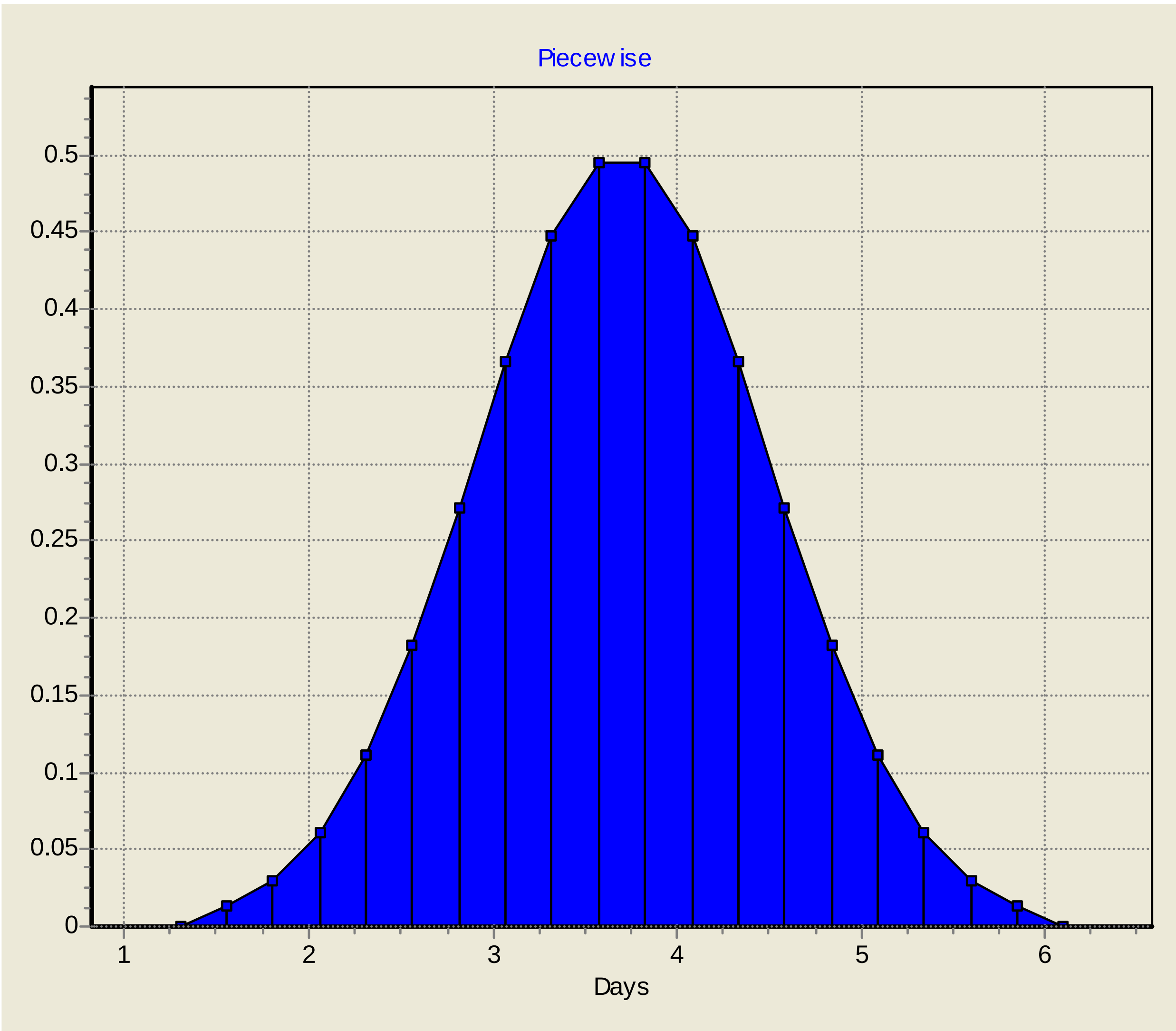

Figure A.1 PDF Defining the Duration of the *Latent* Period for Cattle

(Source: Ashley Hill, Jan. 2006)

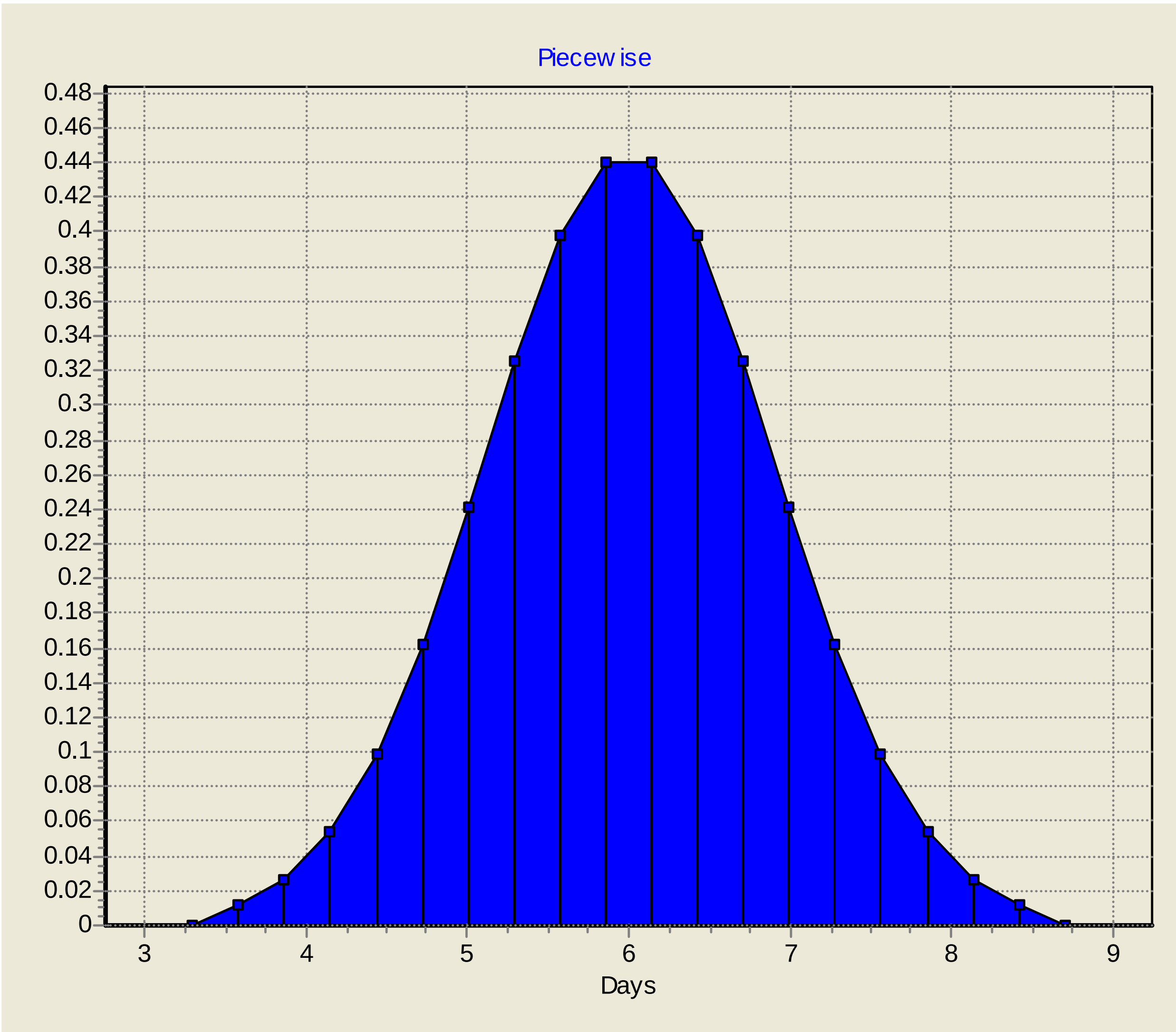

Figure A.2 PDF Defining the Duration of the *Latent* Period for Swine

(Source: Ashley Hill, Jan. 2006)

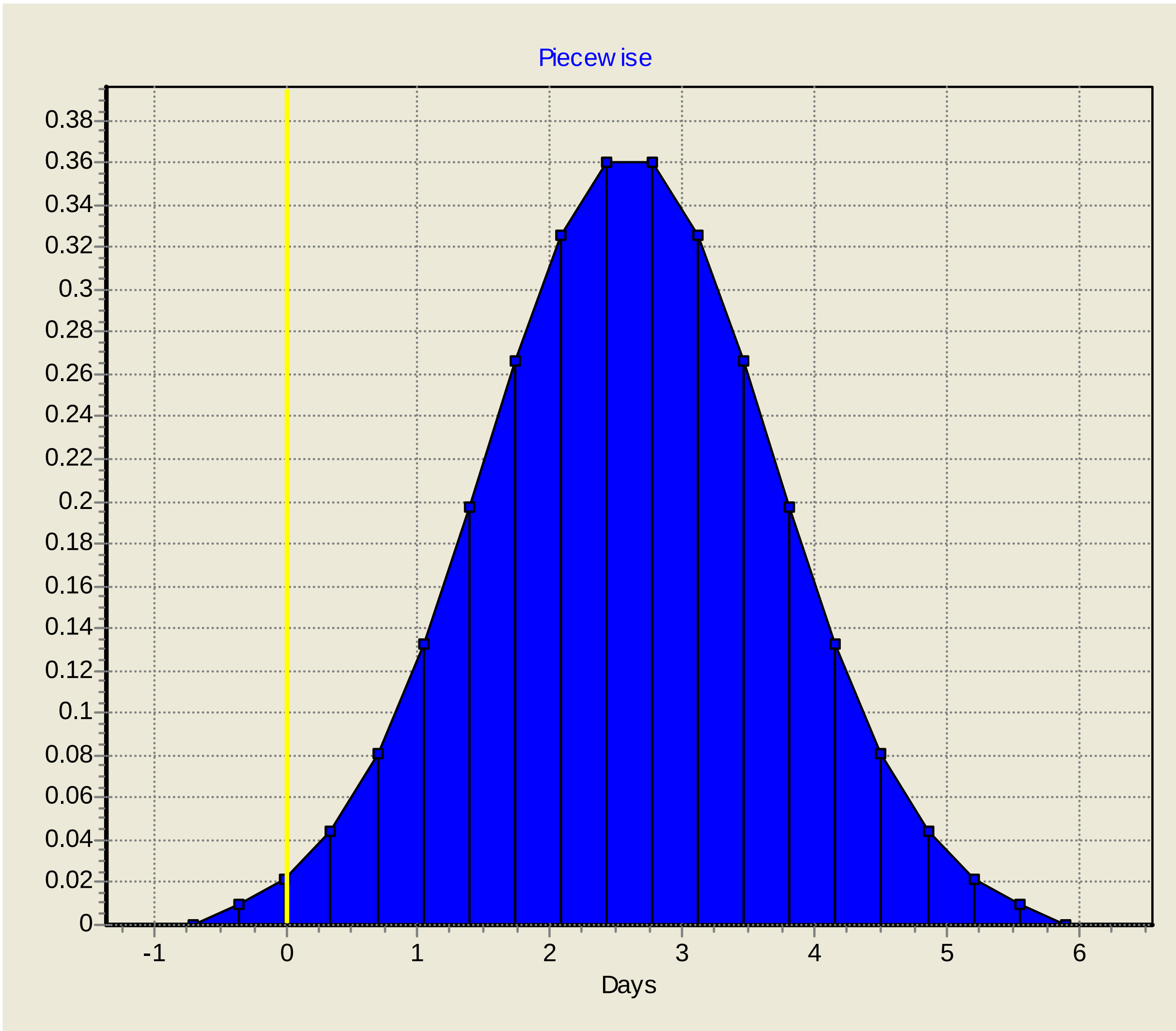

Figure A.3 PDF Defining the Duration of the *Infectious Subclinical* Period for Cattle

(Source: Ashley Hill, Jan. 2006)

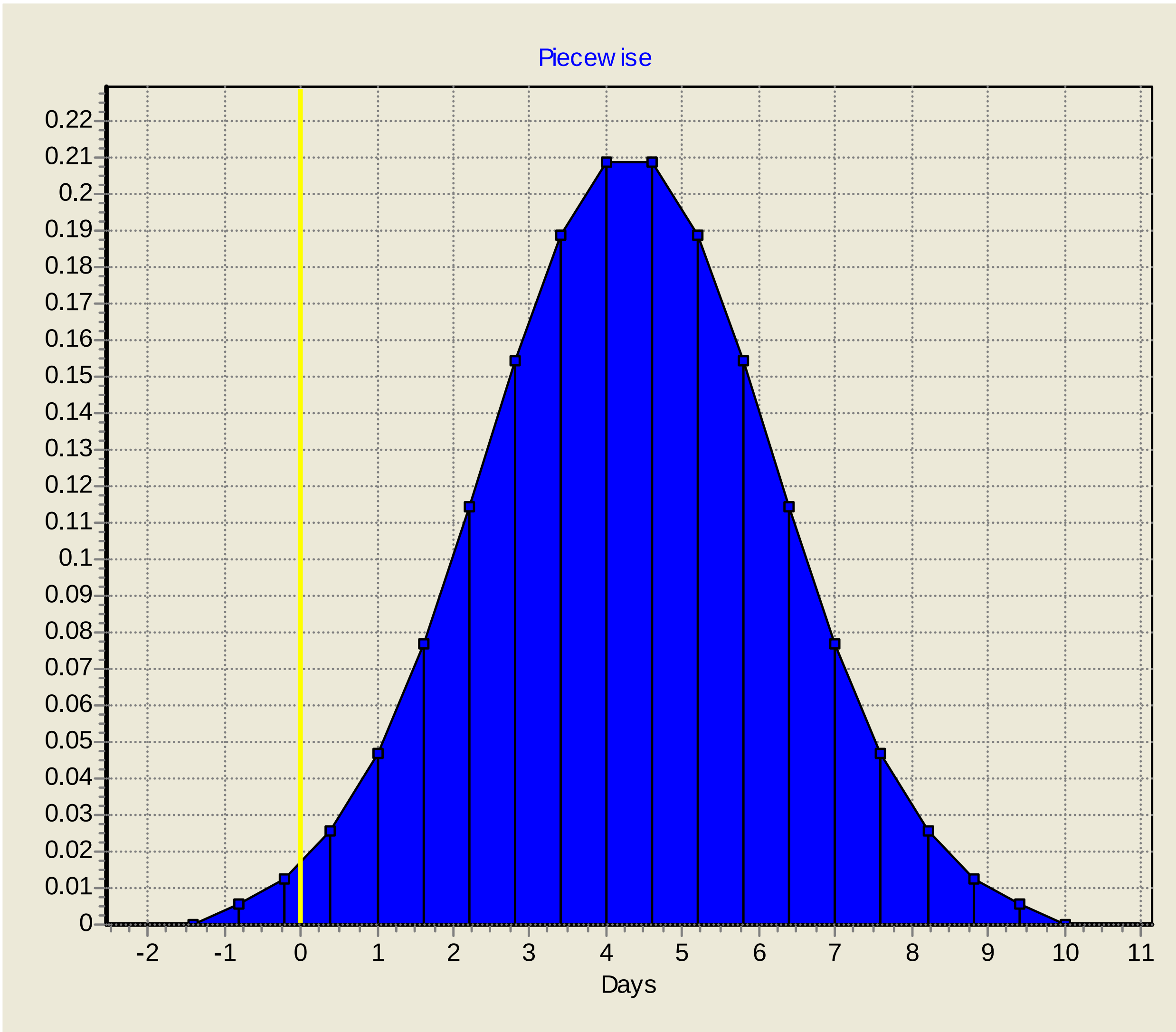

Figure A.4 PDF Defining the Duration of the *Infectious Subclinical* Period for Swine

(Source: Ashley Hill, Jan. 2006)

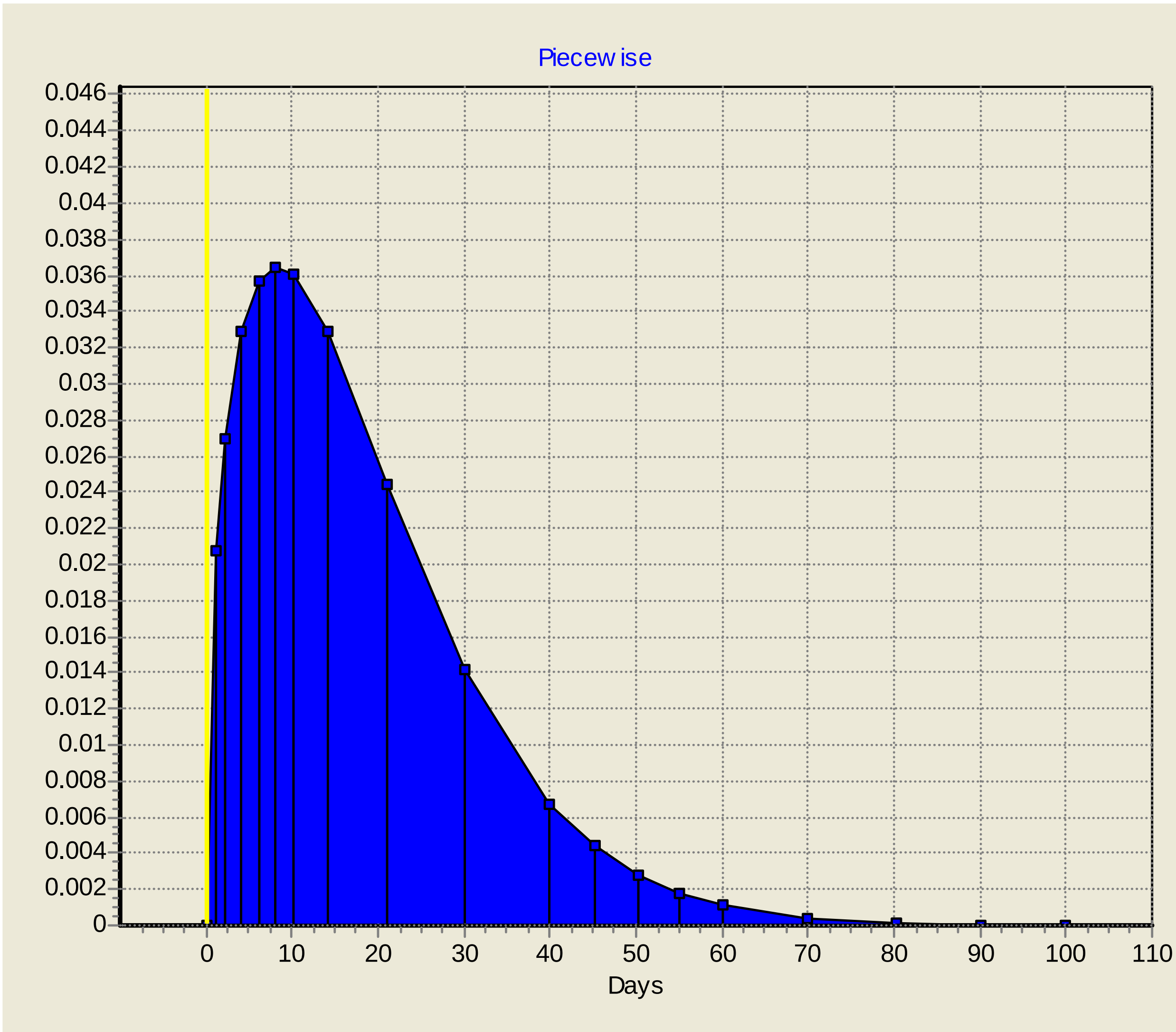

Figure A.5 PDF Defining the Duration of the *Infectious Clinical* Period for Cattle

(Source: Ashley Hill, Jan. 2006)

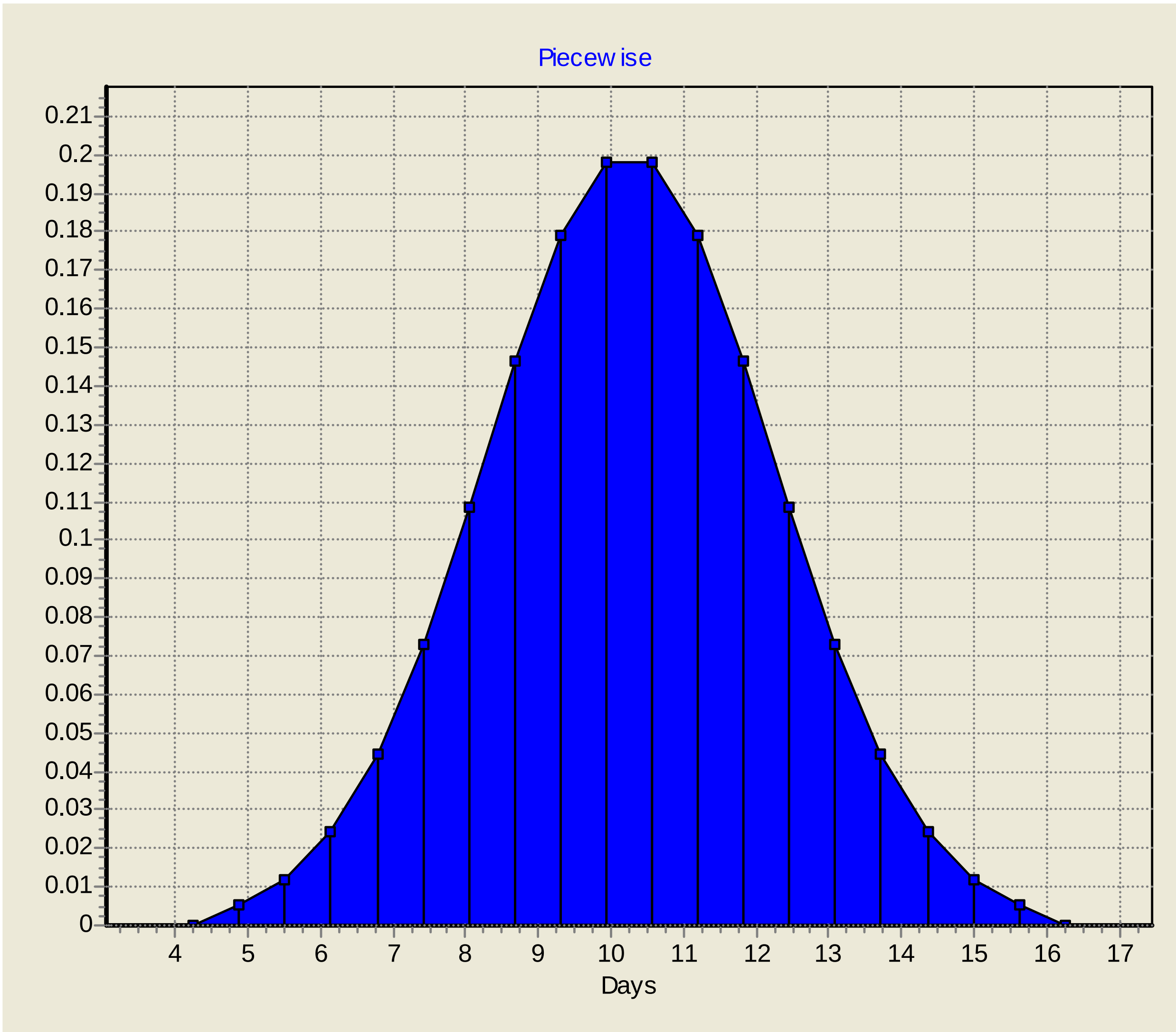

Figure A.6 PDF Defining the Duration of the *Infectious Clinical* Period for Swine

(Source: Ashley Hill, Jan. 2006)

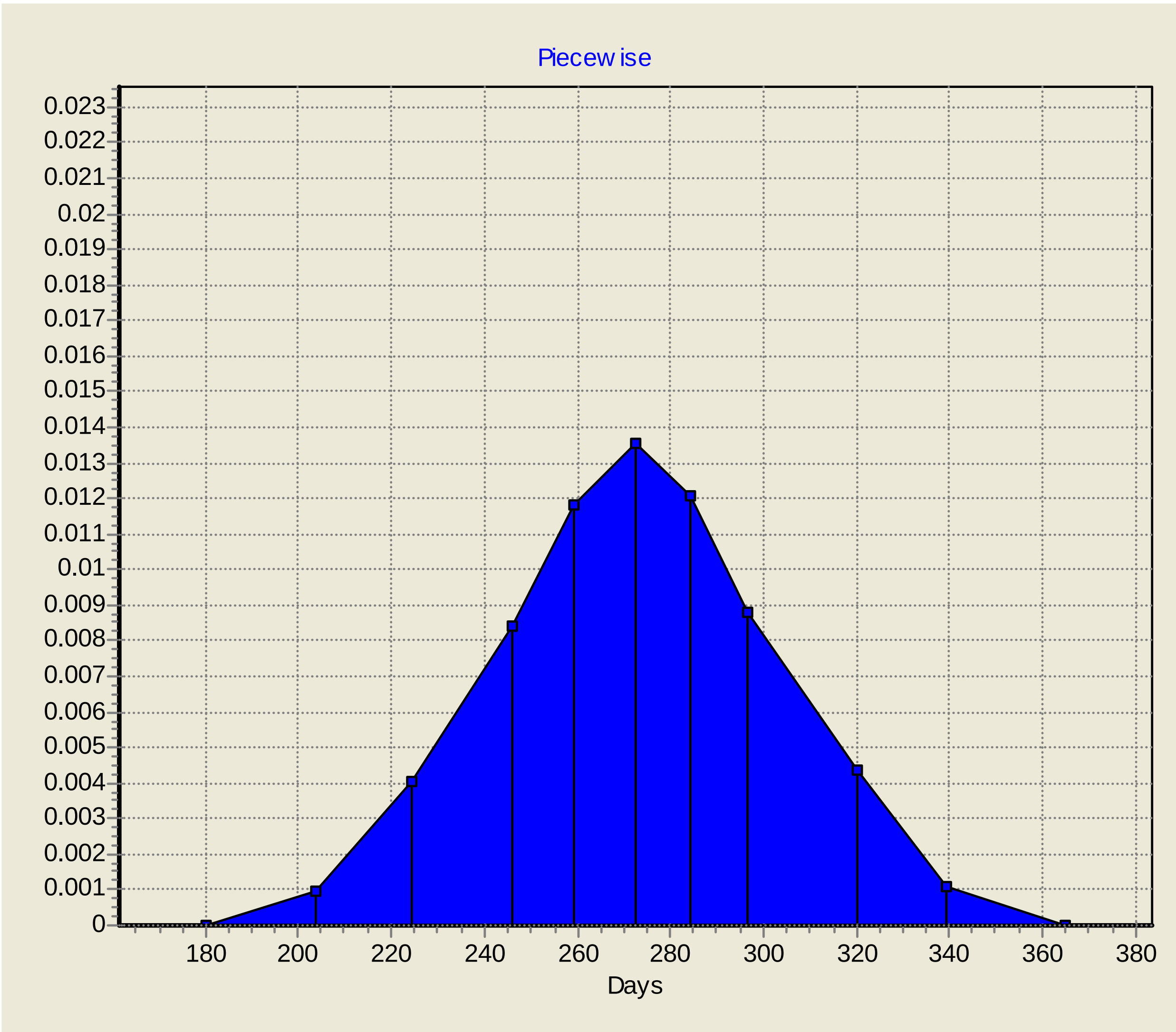

Figure A.7 PDF Defining the Duration of the *Immune* Period for Cattle and Swine

(Source: Ashley Hill, Jan. 2006)

The key *disease spread* parameters for the model are as follows:

Table A.7.1 Production-Type Combinations (i.e., FMD can spread between these production types)

Feedlot to Feedlot
Feedlot to Cow-Calf
Feedlot to Swine
Feedlot to Dairy
Cow-Calf to Feedlot
Cow-Calf to Cow-Calf
Cow-Calf to Swine
Cow-Calf to Dairy
Swine to Feedlot
Swine to Cow-Calf
Swine to Swine
Swine to Dairy
Dairy to Feedlot
Dairy to Cow-Calf
Dairy to Swine
Dairy to Dairy

(Source: Ashley Hill, Jan. 2006)

Table A.7.2 Contact Disease Spread

Production Type	Latent units can spread disease	Subclinical units can spread disease	Use fix contact rate	Mean contact rate (recipient units/unit/day)*	Probability of infection transfer
Feedlot to Feedlot	Yes	Yes	No	0.08	0.89
Feedlot to Cow-Calf	Yes	Yes	No	0.56	0.89
Feedlot to Swine	Yes	Yes	No	0.00	0.91
Feedlot to Dairy	Yes	Yes	No	0.28	0.89
Cow-Calf to Feedlot	Yes	Yes	No	0.56	0.89
Cow-Calf to Cow-Calf	Yes	Yes	No	0.03	0.89
Cow-Calf to Swine	Yes	Yes	No	0.00	0.91
Cow-Calf to Dairy	Yes	Yes	No	0.00	0.89
Swine to Feedlot	Yes	Yes	No	0.00	0.89
Swine to Cow-Calf	Yes	Yes	No	0.00	0.89
Swine to Swine	Yes	Yes	No	0.33	0.95
Swine to Dairy	Yes	Yes	No	0.00	0.89
Dairy to Feedlot	Yes	Yes	No	0.28	0.89
Dairy to Cow-Calf	Yes	Yes	No	0.00	0.89
Dairy to Swine	Yes	Yes	No	0.00	0.91
Dairy to Dairy	Yes	Yes	No	0.57	0.89

*Direct contact disease spread between these production-type combinations.

*Values are determined by using Bates, Thurmond, Carpenter, 2001. Monthly values are divided by 30 to arrive at a unit/day value.
Source: Personal communications with Dale Blasi, Mike Tokach, Chris Reinhardt March 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

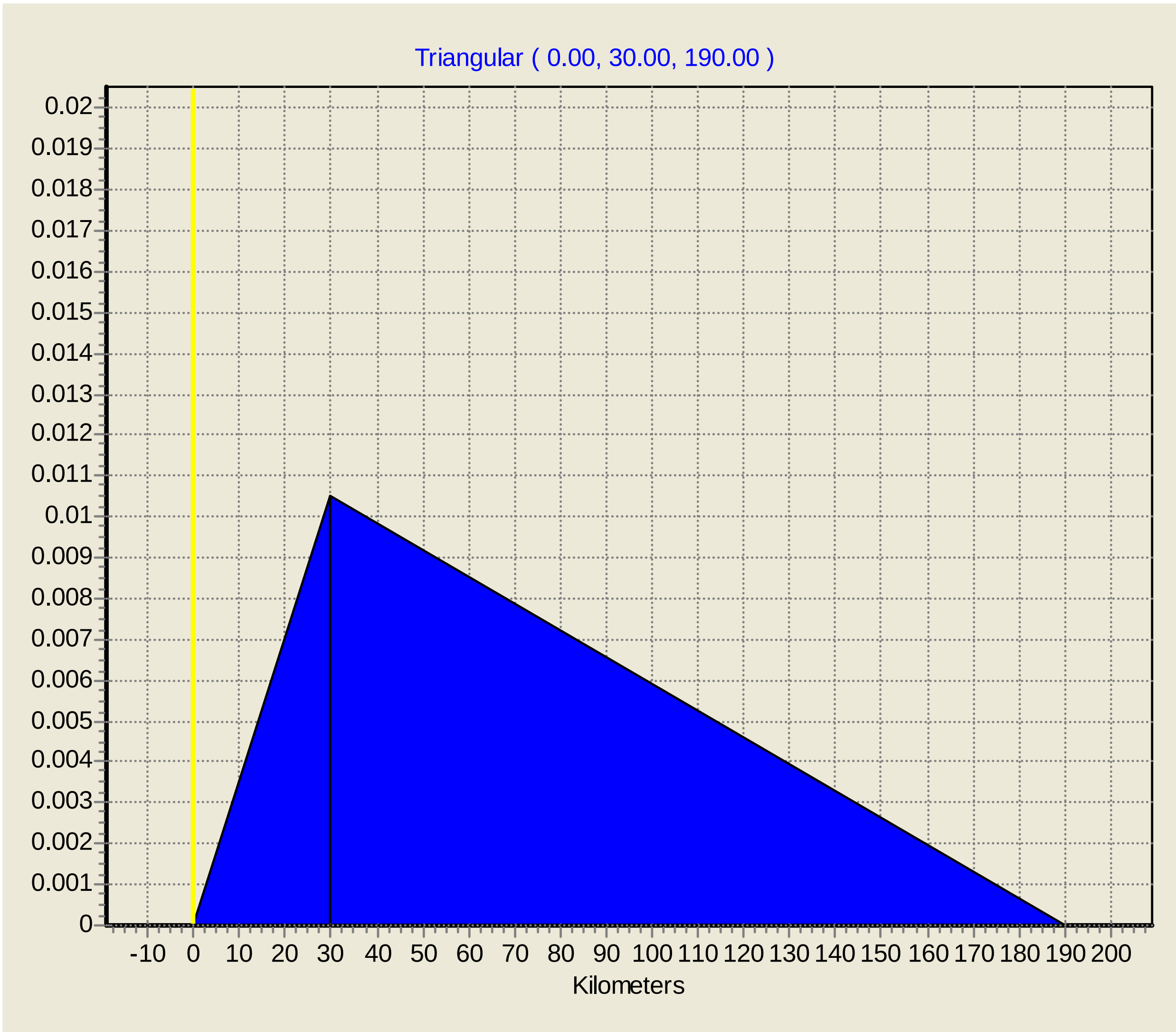

Figure A.8 Distance Distribution of Recipient Units (Feedlot to Feedlot)

Source: Personal communication with Chris Reinhardt, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

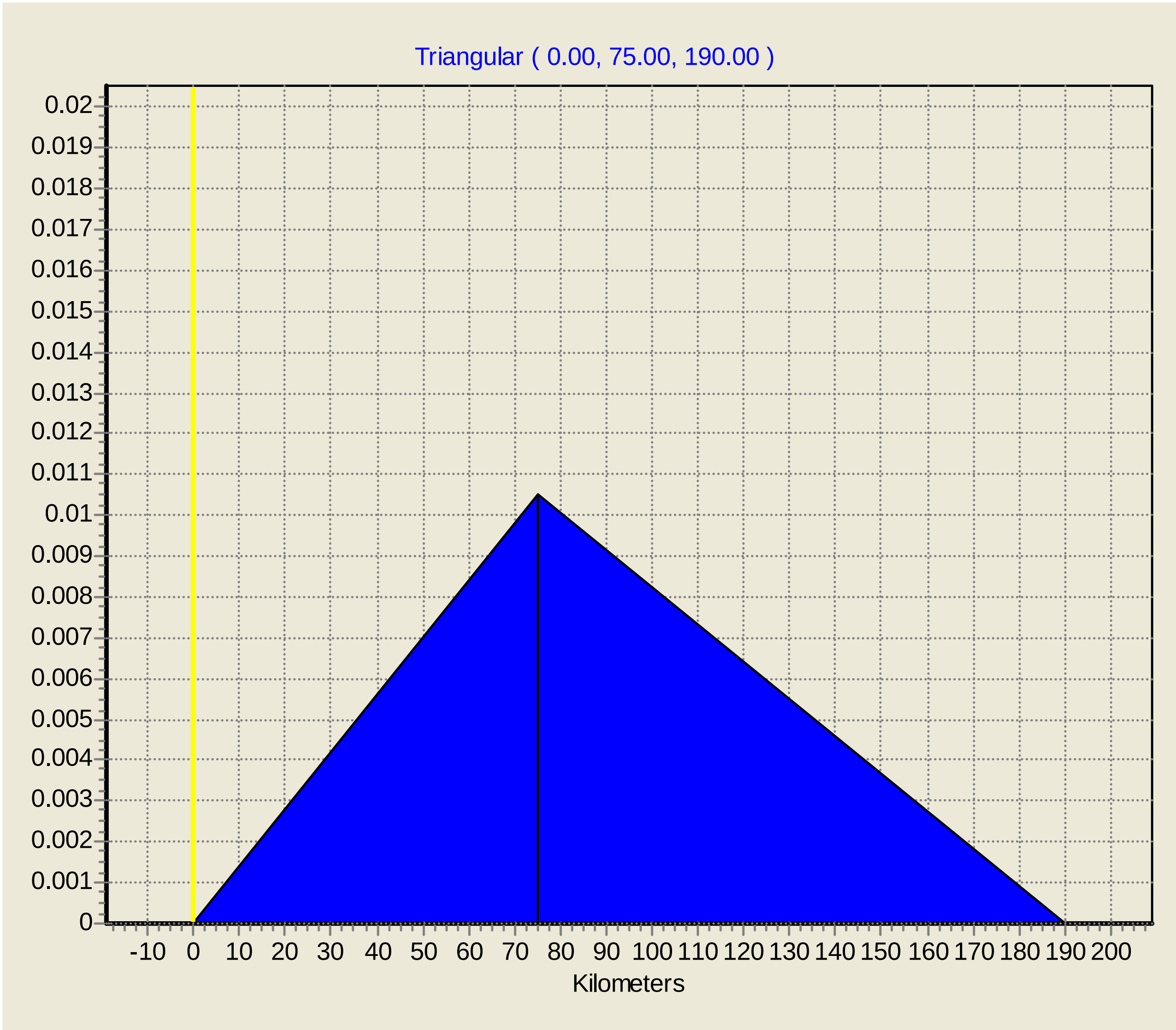

Figure A.9 Distance Distribution of Recipient Units (Feedlot to Cow-Calf)

Source: Personal communications with Dale Blasi and Chris Reinhardt, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

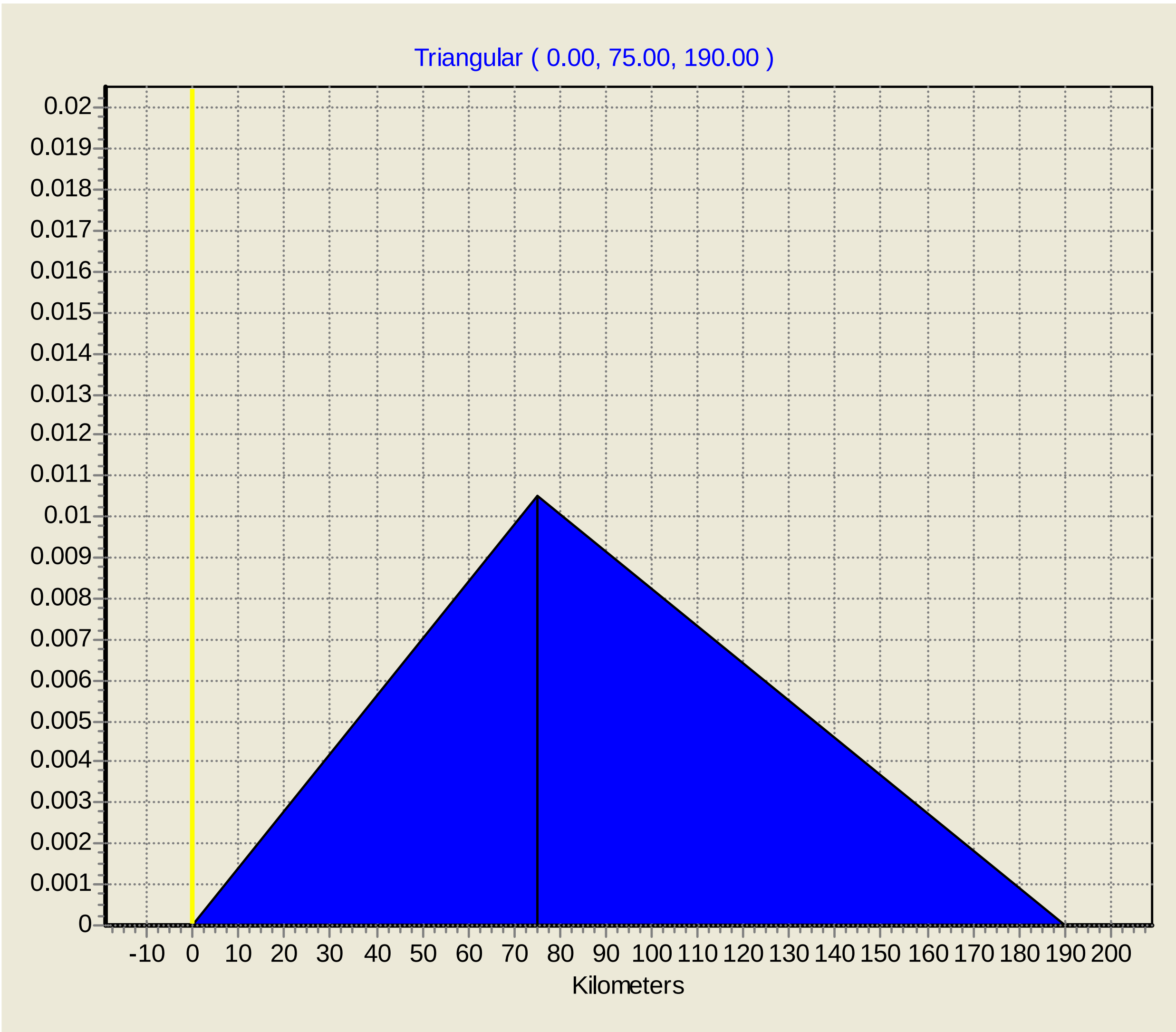

Figure A.10 Distance Distribution of Recipient Units (Feedlot to Dairy)

Source: Personal communication with Chris Reinhardt, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipient units (feedlot to swine) – Direct Contact
    - Distribution is a Fixed Value and is zero.

Source: Personal communication with Chris Reinhardt and Mike Tokach, 2006

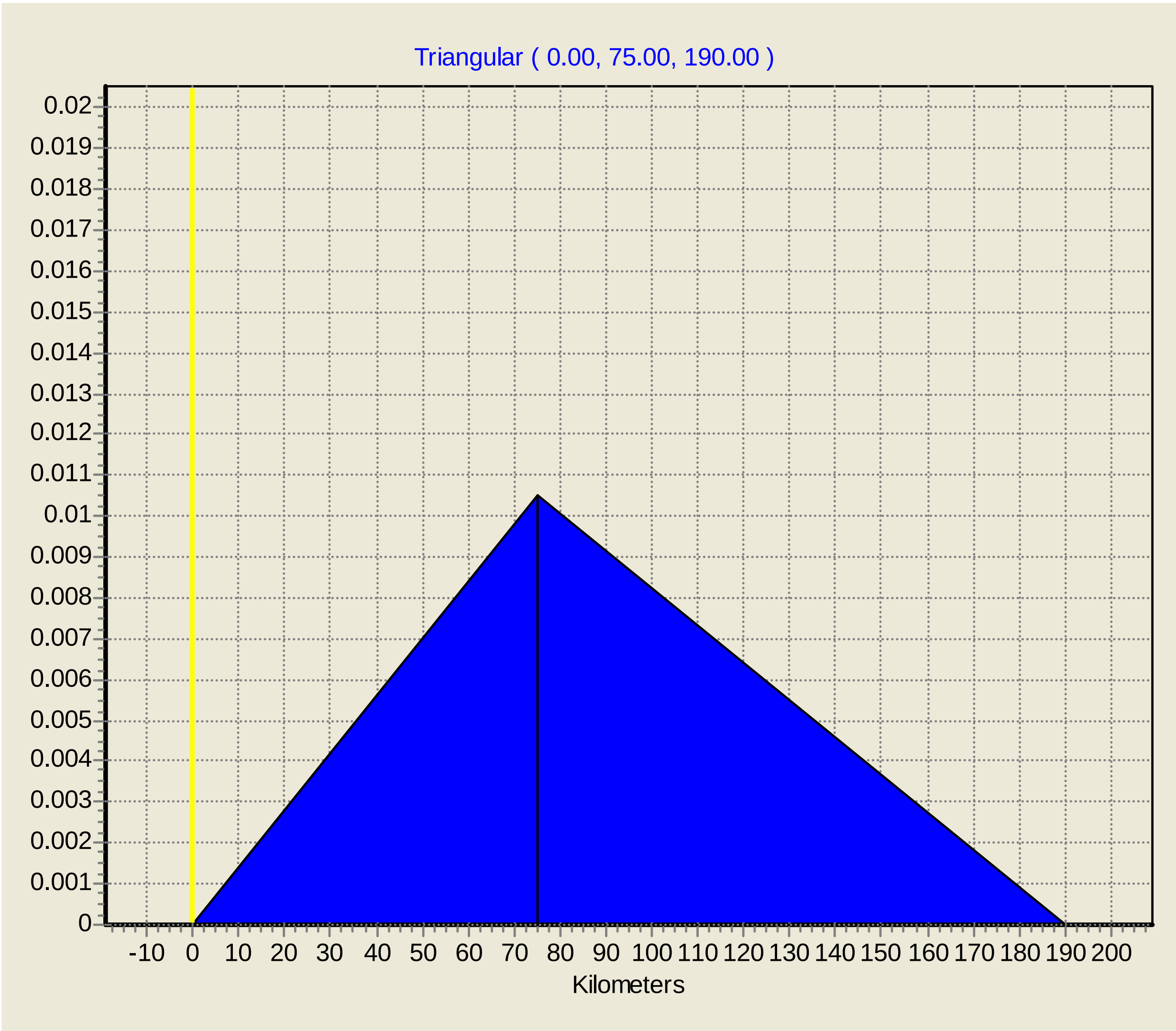

Figure A.11 Distance Distribution of Recipient Units (Cow-Calf to Feedlot)

Source: Personal communications with Chris Reinhardt and Dale Blasi, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

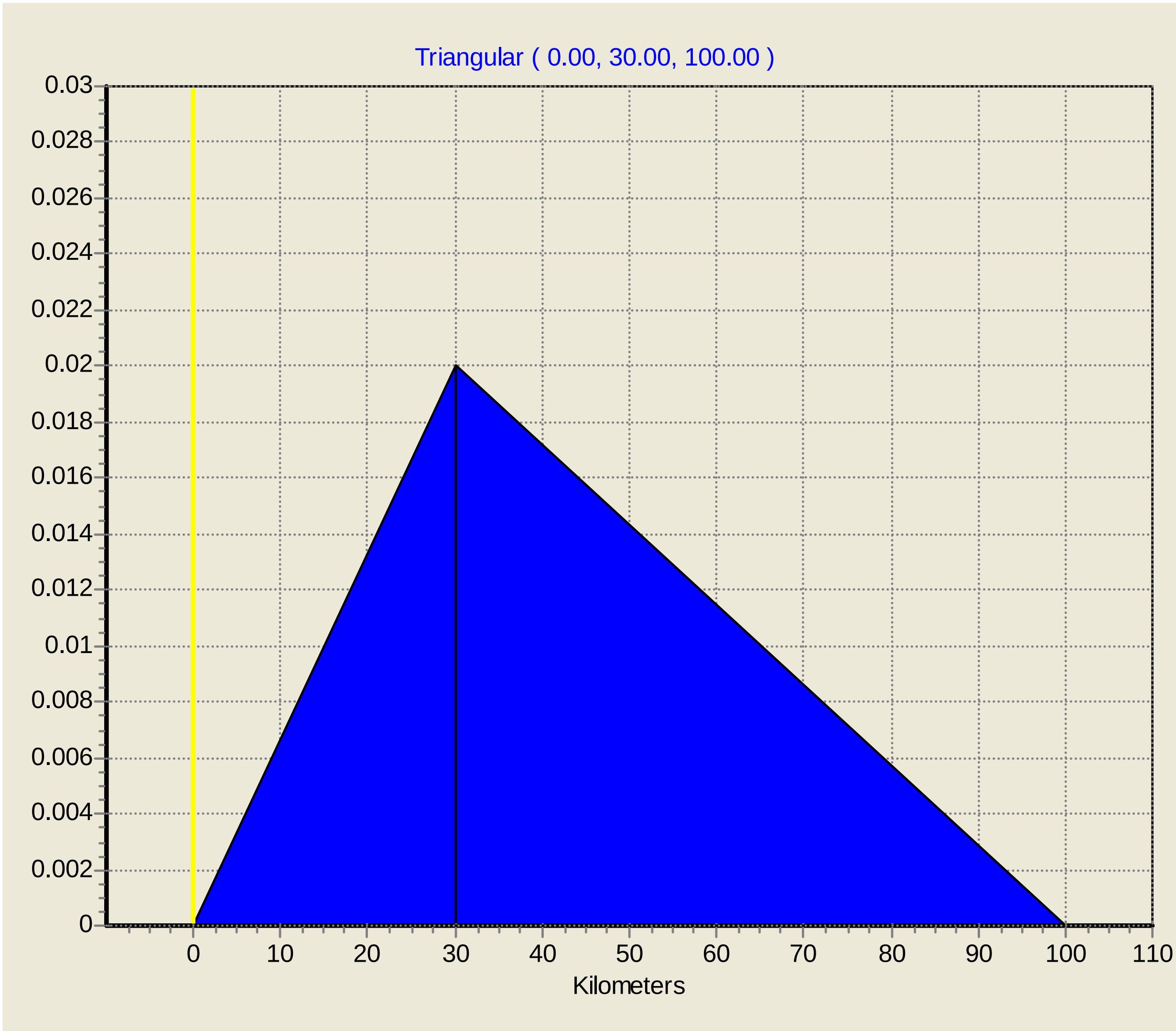

Figure A.12 Distance Distribution of Recipient Units (Cow-Calf to Cow-Calf)

Source: Personal communication with Dale Blasi, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

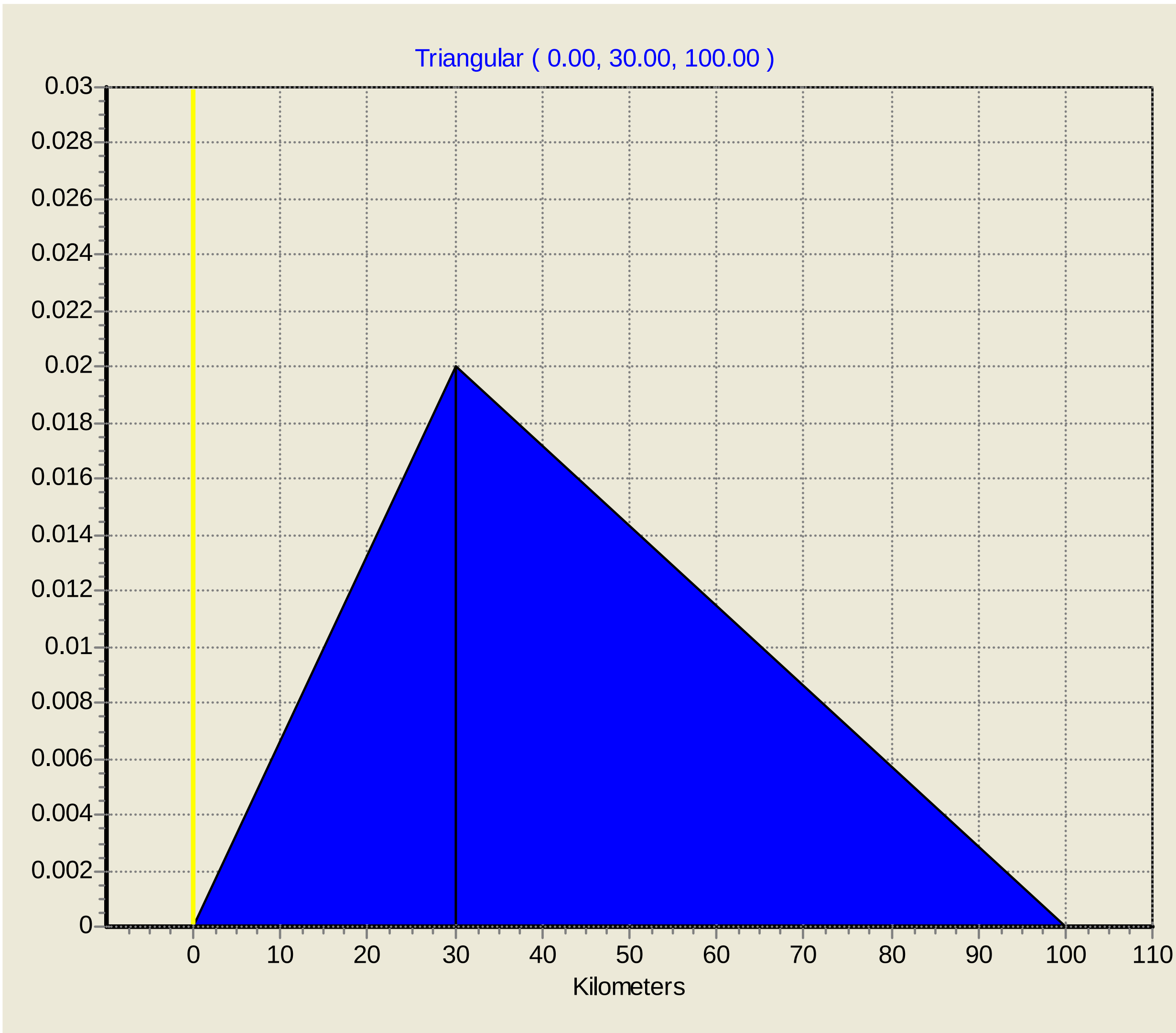

Figure A.13 Distance Distribution of Recipient Units (Cow-Calf to Dairy)

Source: Personal communication with Dale Blasi, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipient units (cow-calf to swine) – Direct Contact
    - Distribution is a Fixed Value and is zero.

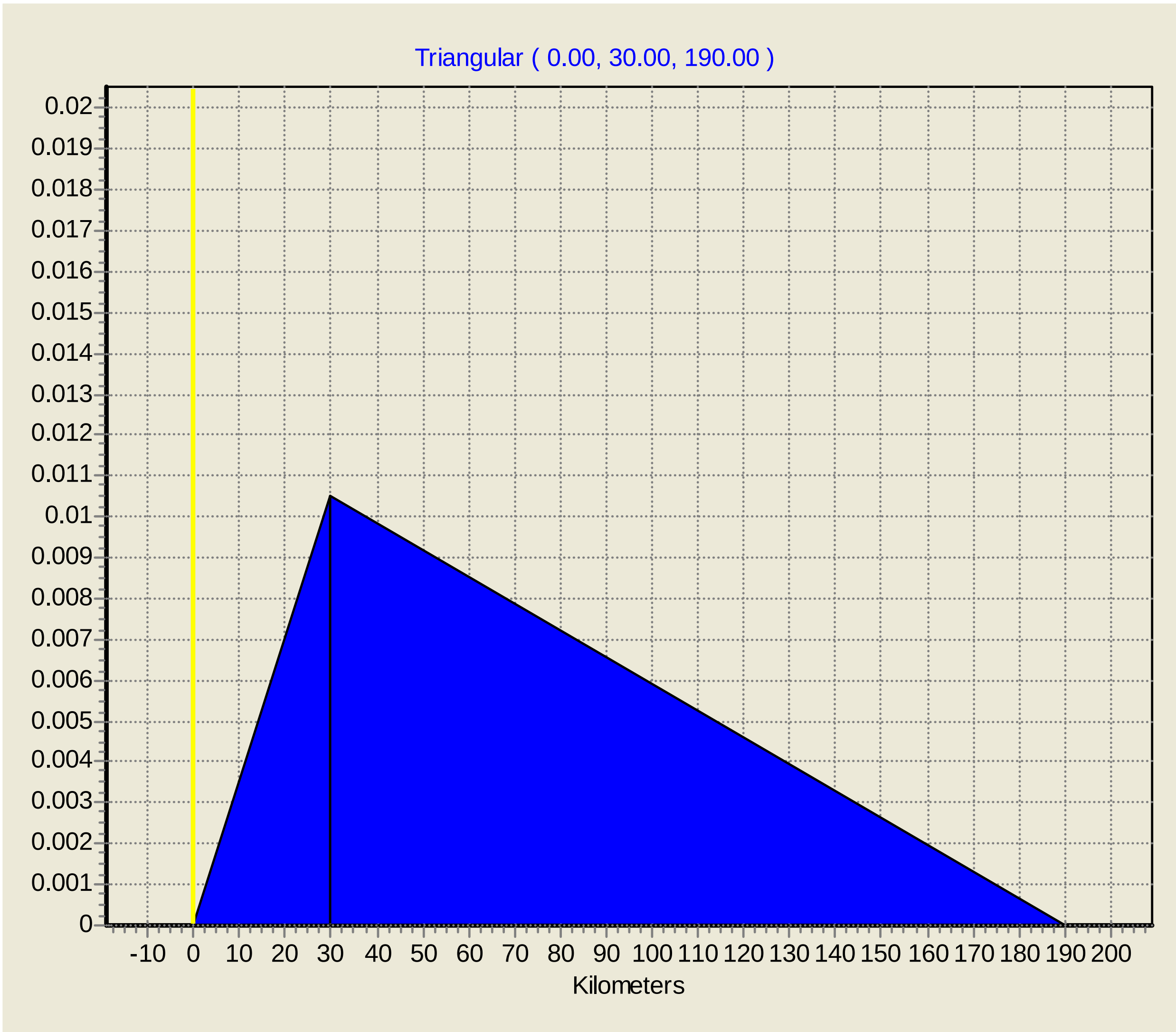

Figure A.14 Distance Distribution of Recipient Units (Dairy to Feedlot)

Source: Personal communication with Chris Reinhardt, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

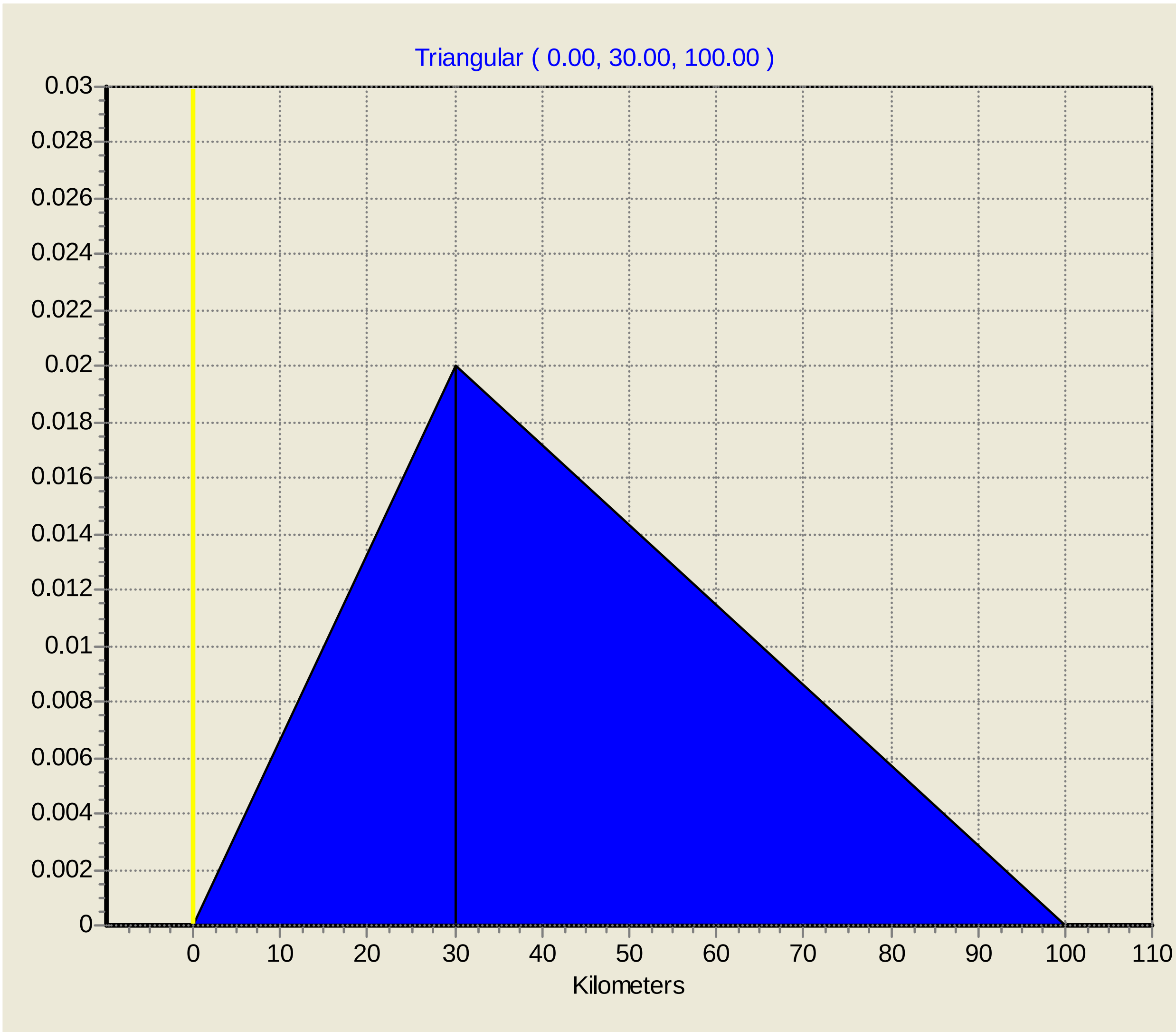

Figure A.15 Distance Distribution of Recipient Units (Dairy to Cow-Calf)

Source: Personal communication with Dale Blasi, 2006;
Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

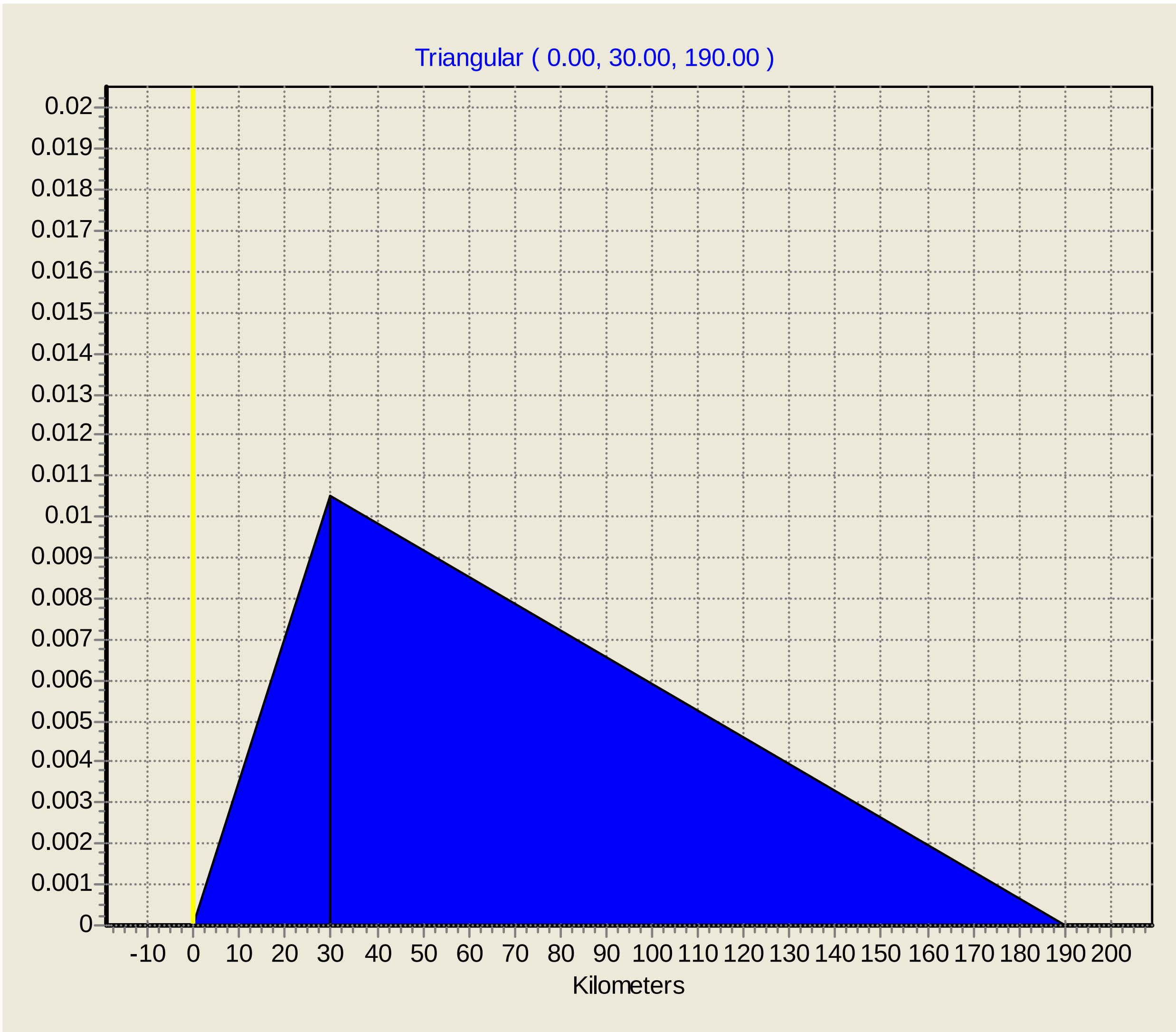

Figure A.16 Distance Distribution of Recipient Units (Dairy to Dairy)

Source: Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipients units (swine to feedlot) – Direct Contact
  - Distribution is a Fixed Value and is zero.

- Distance distribution of recipients units (swine to cow-calf) – Direct Contact
    - Distribution is a Fixed Value and is zero.

- Distance distribution of recipients units (swine to dairy) – Direct Contact
    - Distribution is a Fixed Value and is zero.

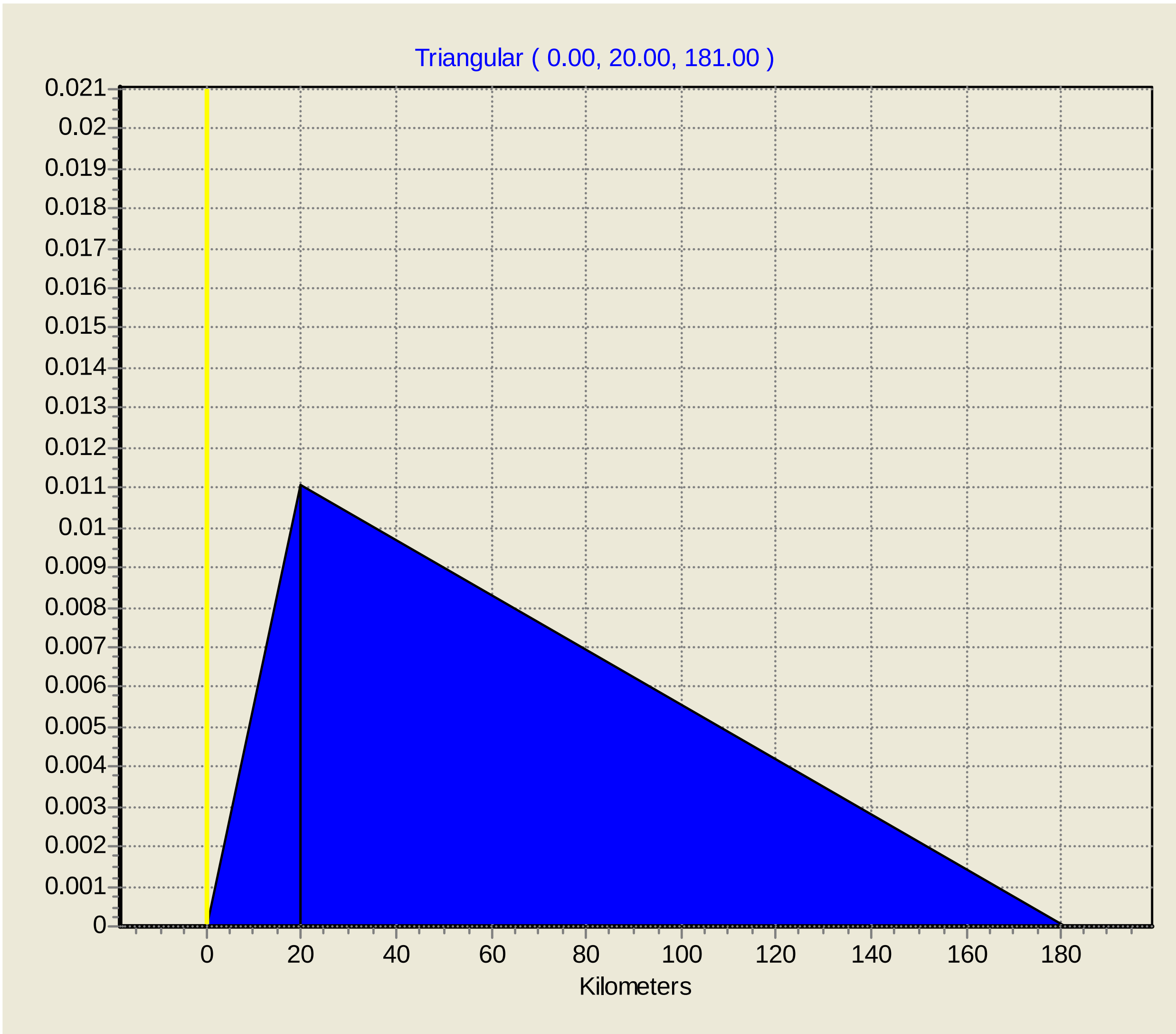

Figure A.17 Distance Distribution of Recipient Units (Swine to Swine)

Source: Personal communications with Mike Tokach; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

– Shipping delay (for all possible production type combinations):

  The distribution for shipping delay is the same for all production type combinations. The distribution is a single point and the value is zero.

  Source: Barbara A. Corso, Feb. 2006

Table A.7.3 Contact Disease Spread

Production Type	Latent units can spread disease	Subclinical units can spread disease	Use fix contact rate	Mean contact rate (recipient units/unit/day)*	Probability of infection transfer
Feedlot to Feedlot	Yes	Yes	No	6.53	0.10
Feedlot to Cow-Calf	Yes	Yes	No	0.10	0.10
Feedlot to Swine	Yes	Yes	No	0.00	0.15
Feedlot to Dairy	Yes	Yes	No	0.75	0.10
Cow-Calf to Feedlot	Yes	Yes	No	0.10	0.10
Cow-Calf to Cow-Calf	Yes	Yes	No	0.93	0.10
Cow-Calf to Swine	Yes	Yes	No	0.00	0.15
Cow-Calf to Dairy	Yes	Yes	No	0.10	0.10
Swine to Feedlot	Yes	Yes	No	0.00	0.10
Swine to Cow-Calf	Yes	Yes	No	0.00	0.10
Swine to Swine	Yes	Yes	No	5.30	0.20
Swine to Dairy	Yes	Yes	No	0.00	0.10
Dairy to Feedlot	Yes	Yes	No	0.75	0.10
Dairy to Cow-Calf	Yes	Yes	No	0.10	0.10
Dairy to Swine	Yes	Yes	No	0.00	0.15
Dairy to Dairy	Yes	Yes	No	24.76	0.10

* *Indirect* contact disease spread between these production-type combinations

*Values are determined by using Bates, Thurmond, Carpenter, 2001. Monthly values are divided by 30 to arrive at a unit/day value.

Source: Personal communications with Dale Blasi, Mike Tokach, Chris Reinhardt (March 2006); Schoenbaum and Disney; Bates, Thurmond, and Carpenter, 2001 and 2003b.

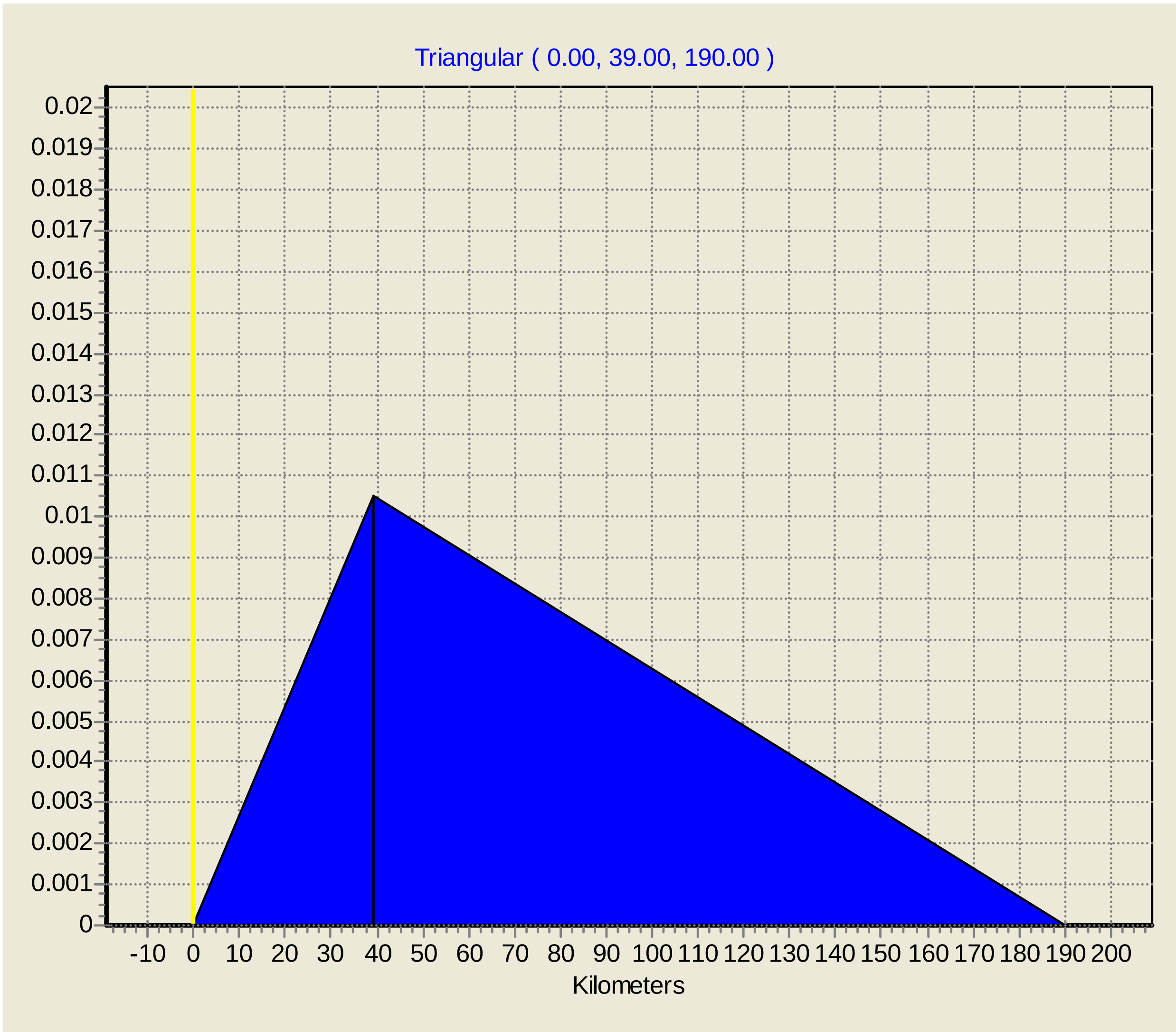

Figure A.18 Distance Distribution of Recipient Units (Feedlot to Feedlot)

Source: Personal communication with Chris Reinhardt, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

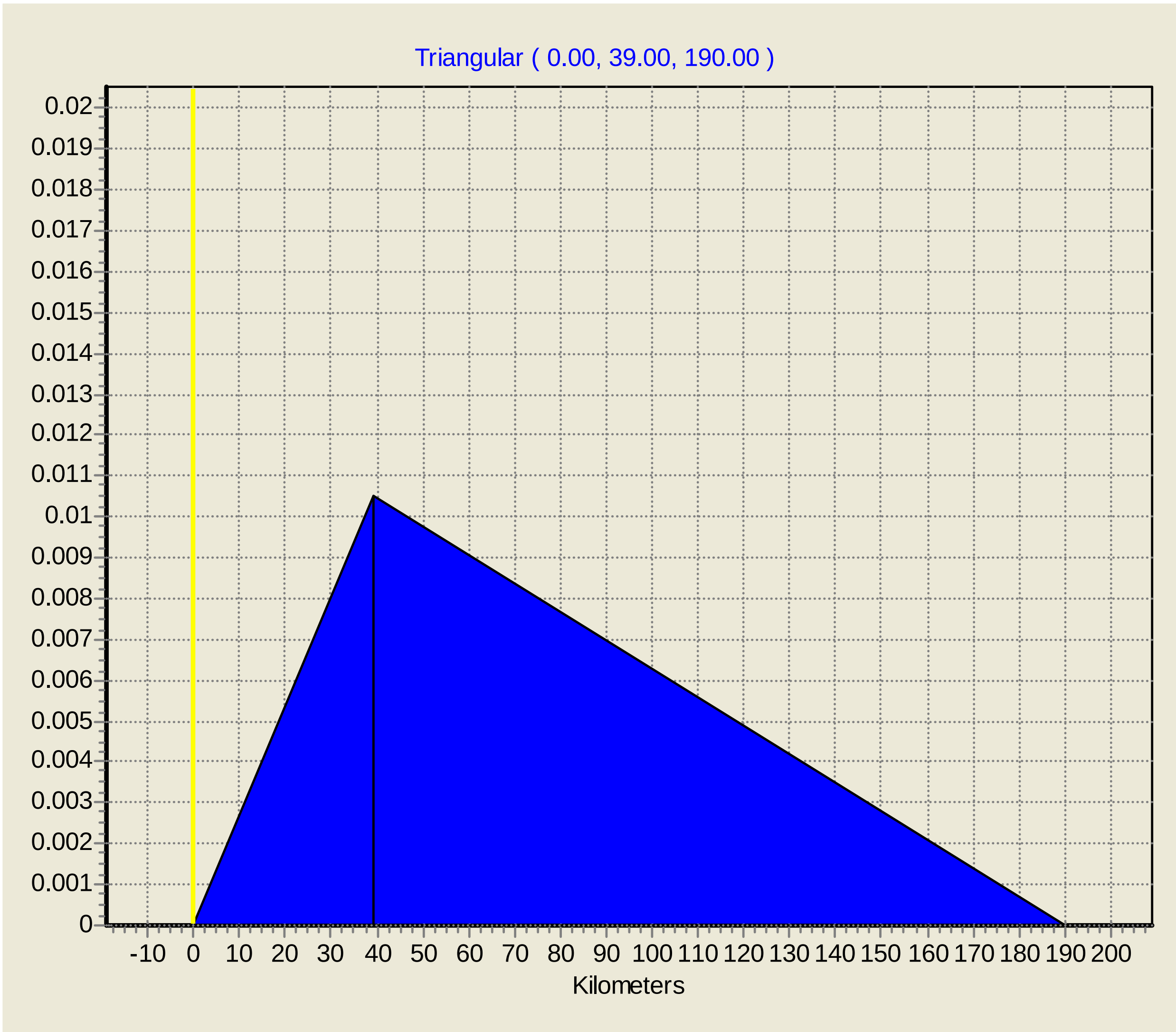

Figure A.19 Distance Distribution of Recipient Units (Feedlot to Cow-Calf)

Source: Personal communications with Chris Reinhardt and Dale Blasi, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

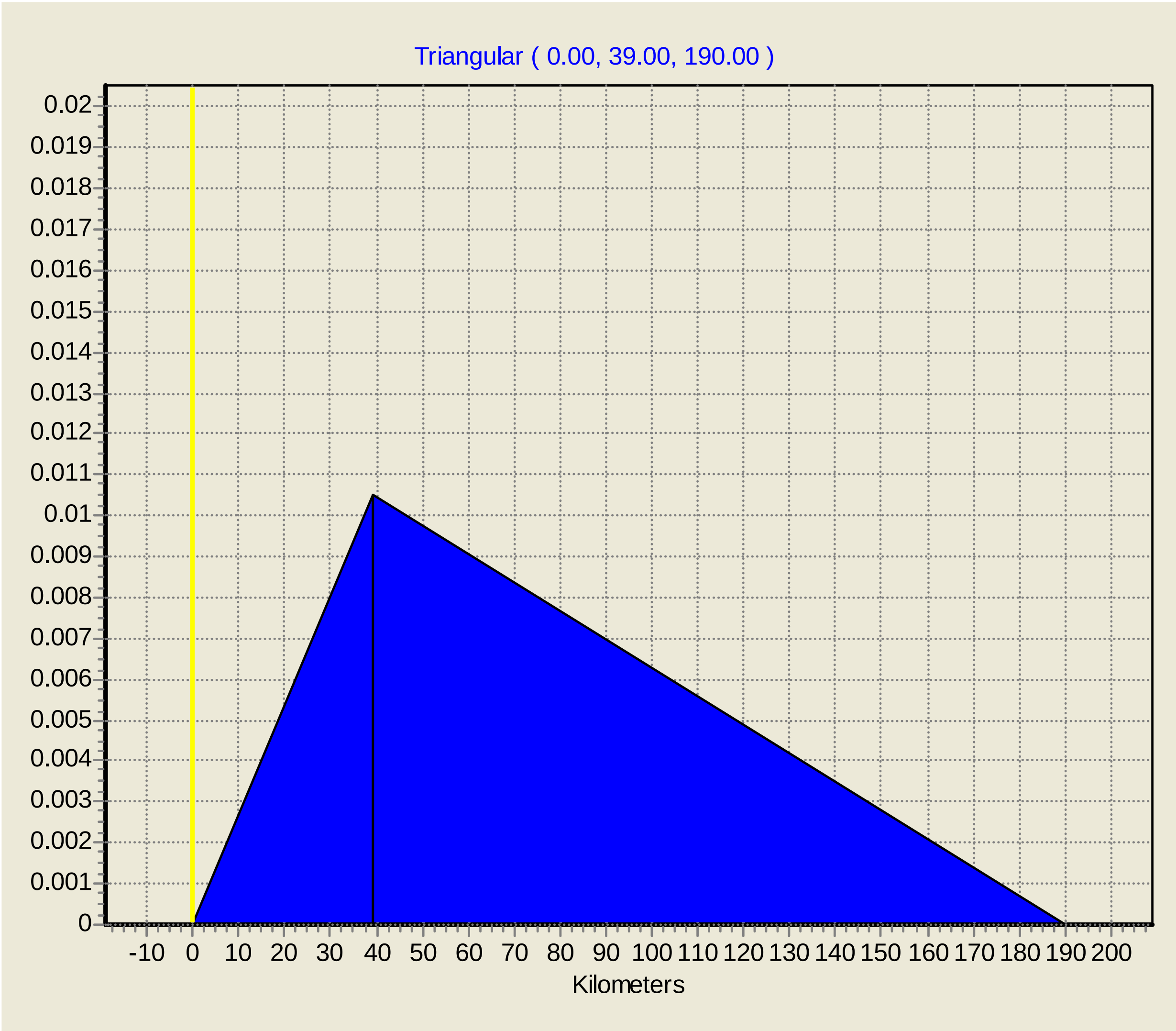

Figure A.20 Distance Distribution of Recipient Units (Feedlot to Dairy)

Source: Personal communication with Chris Reinhardt, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipient units (feedlot to swine) – Indirect Contact
    - Distribution is a Fixed Value and is zero.

Source: Personal communication with Mike Tokach, 2006

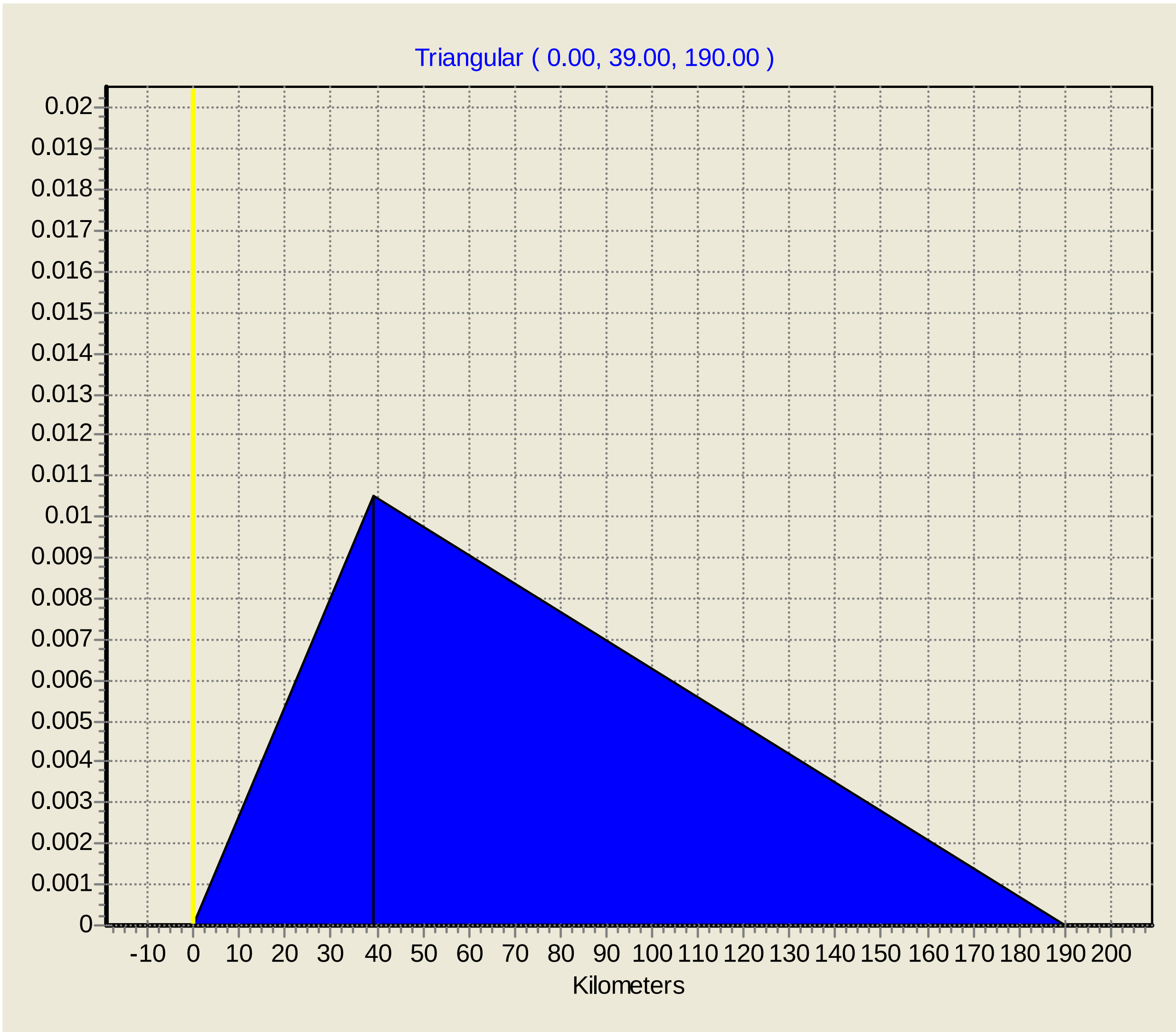

Figure A.21 Distance Distribution of Recipient Units (Cow-Calf to Feedlot)

Source: Personal communications with Chris Reinhardt and Dale Blasi, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

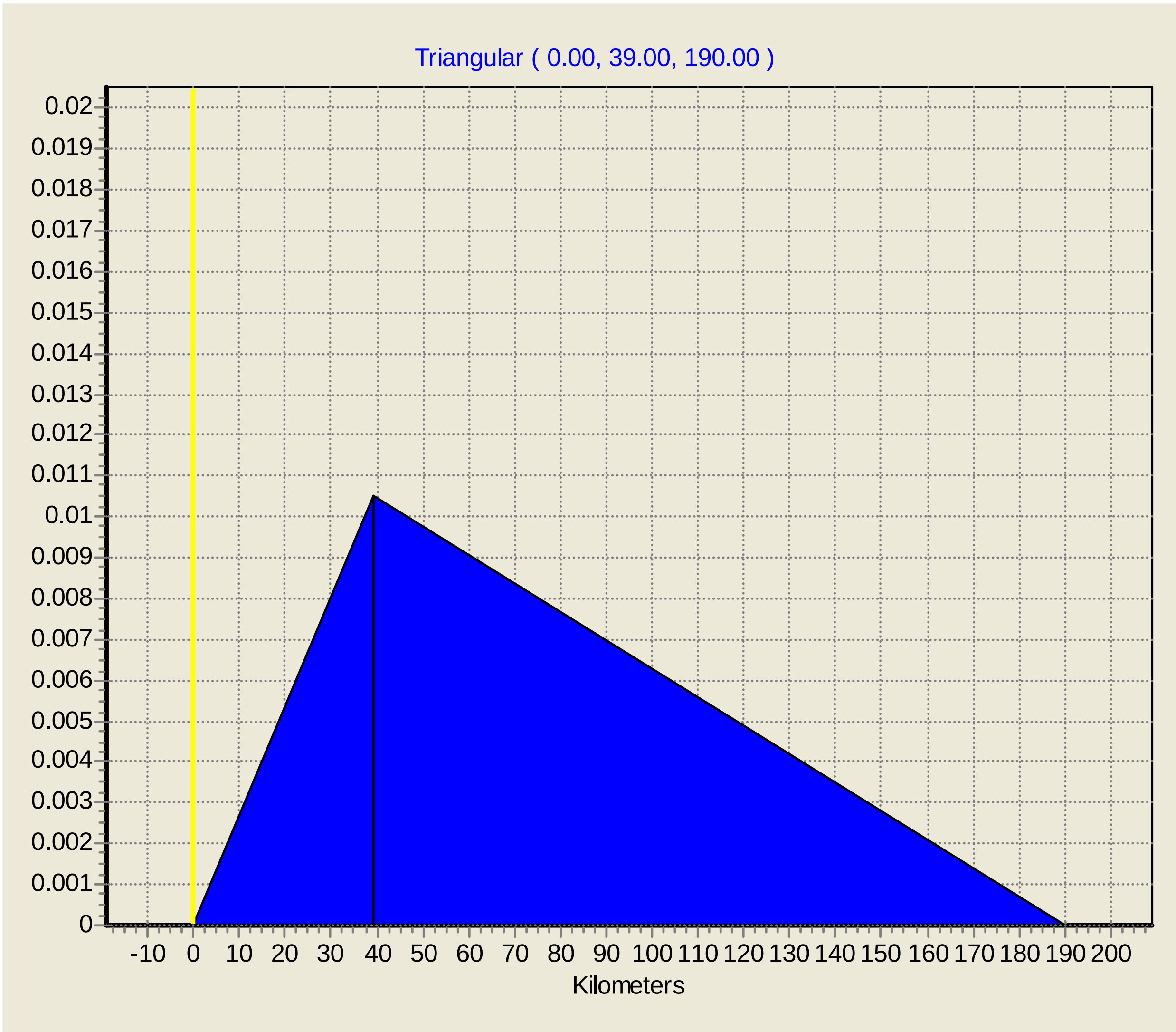

Figure A.22 Distance Distribution of Recipient Units (Cow-Calf to Cow-Calf)

Source: Personal communication with Dale Blasi, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

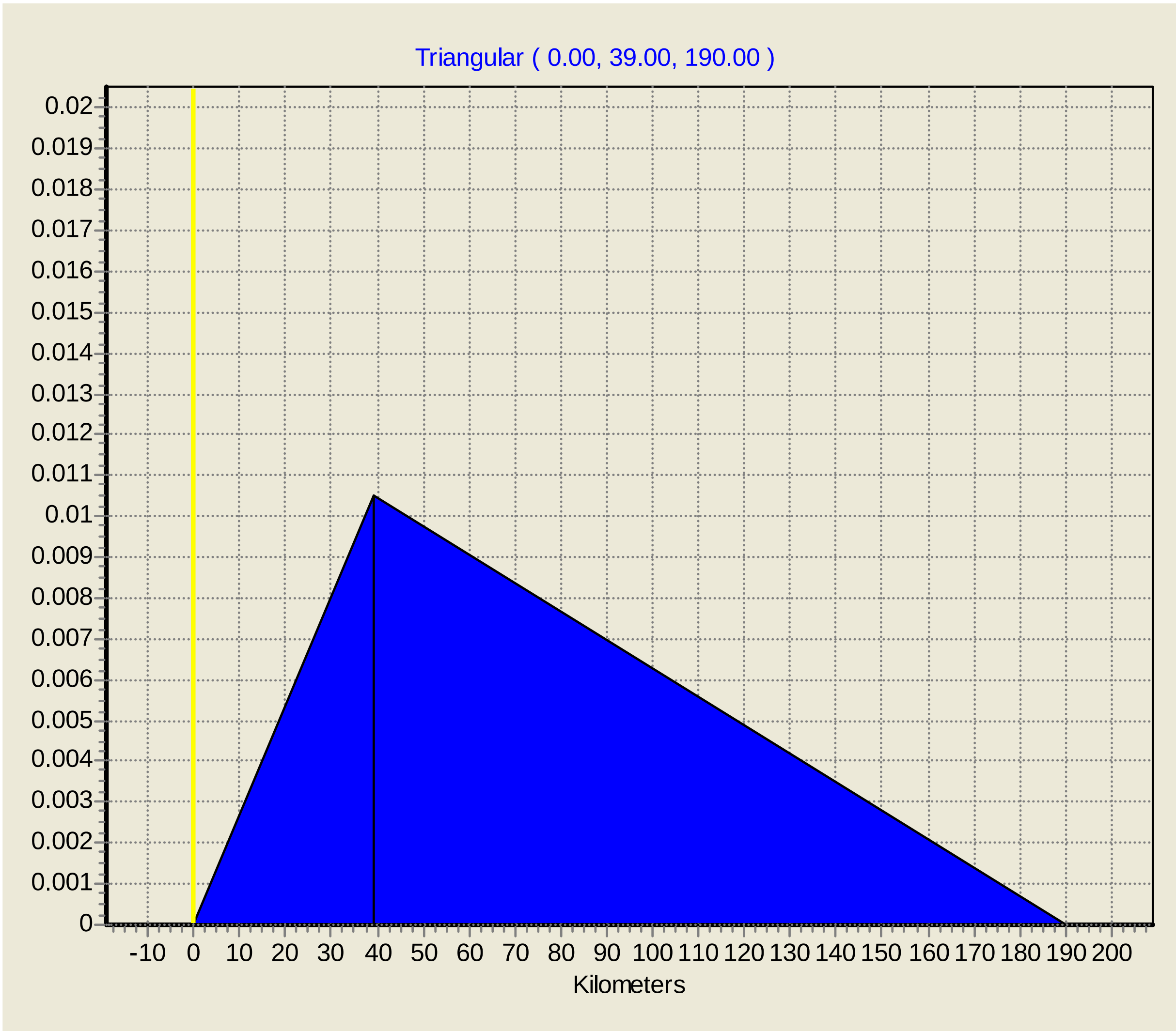

Figure A.23 Distance Distribution of Recipient Units (Cow-Calf to Dairy)

Source: Personal communication with Dale Blasi, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipient units (cow-calf to swine) – Indirect Contact
  - Distribution is a Fixed Value and is zero.

Source: Personal communication with Mike Tokach, 2006

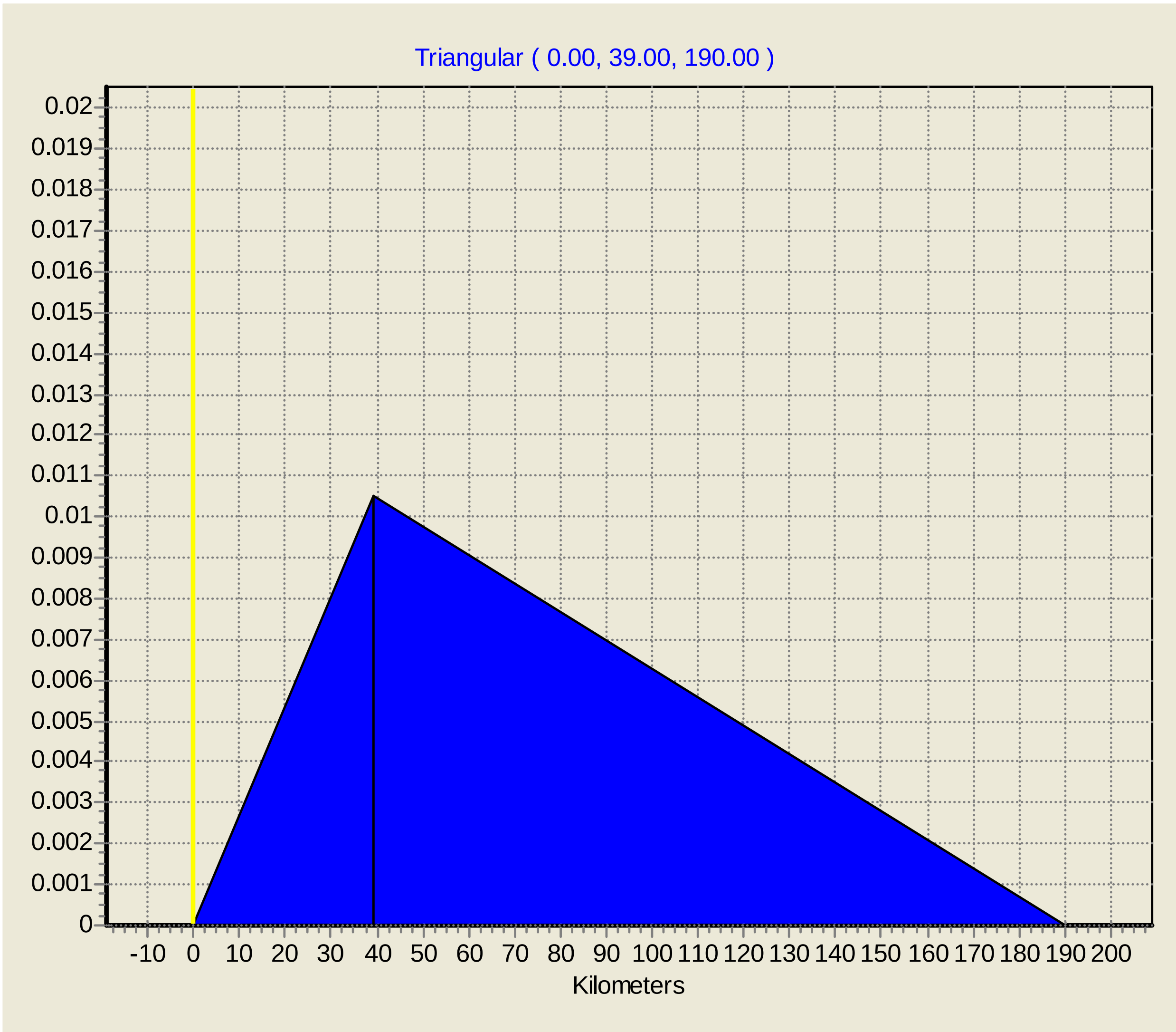

Figure A.24 Distance Distribution of Recipient Units (Dairy to Feedlot)

Source: Personal communication with Chris Reinhardt, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

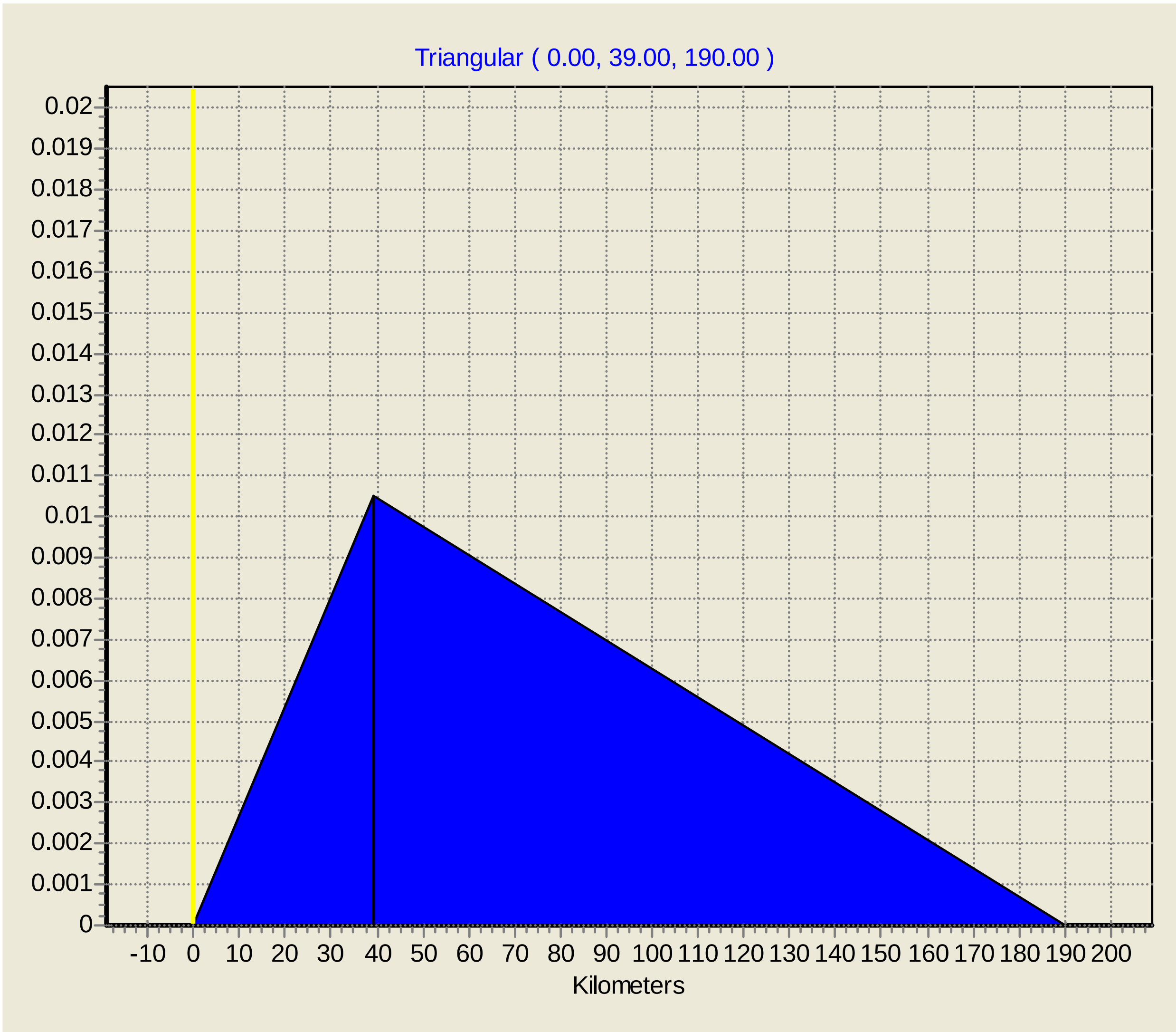

Figure A.25 Distance Distribution of Recipient Units (Cow-Calf to Dairy)

Source: Personal communication with Dale Blasi, 2006; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

– Distance distribution of recipient units (dairy to dairy) – Indirect Contact

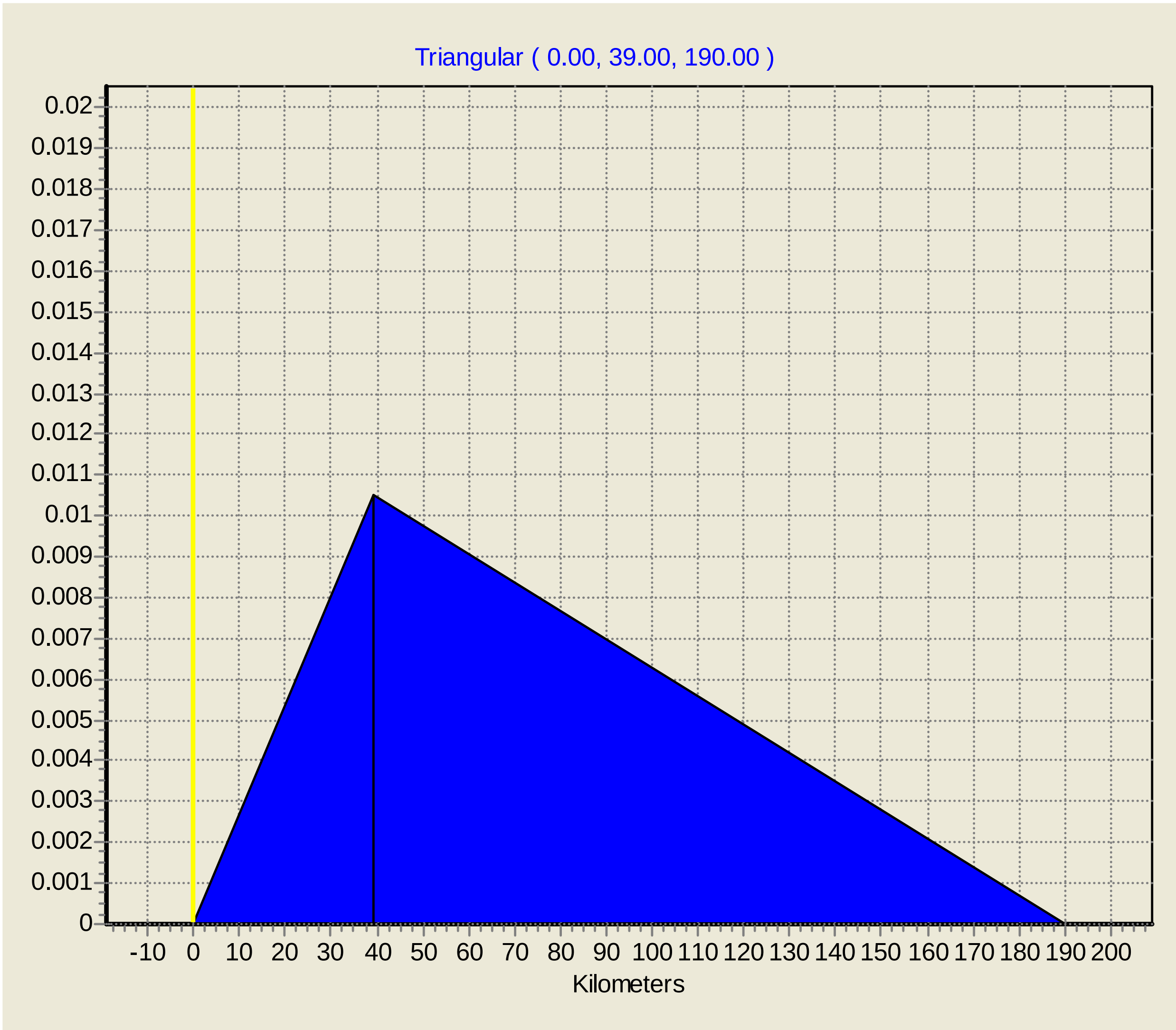

Figure A.26 Distance Distribution of Recipient Units (Dairy to Dairy)

Source: Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

- Distance distribution of recipients units (swine to feedlot) – Indirect Contact
  - Distribution is a Fixed Value and is zero.

Source: Personal communication with Mike Tokach, 2006

- Distance distribution of recipients units (swine to cow-calf) – Indirect Contact
  - Distribution is a Fixed Value and is zero.

Source: Personal communication with Mike Tokach, 2006

- Distance distribution of recipients units (swine to dairy) – Indirect Contact
  - Distribution is a Fixed Value and is zero.

Source: Personal communication with Mike Tokach, 2006

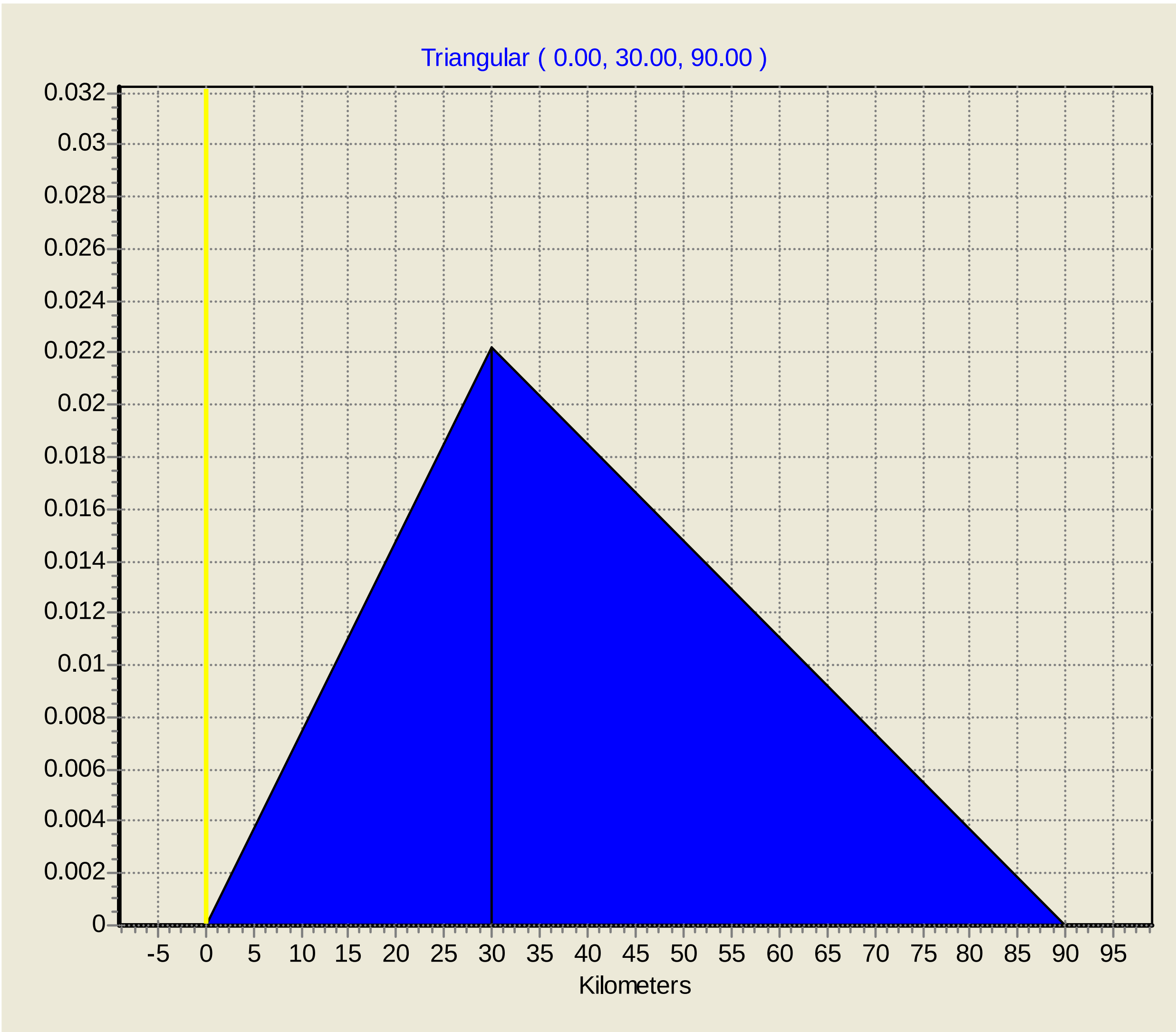

Figure A.27 Distance Distribution of Recipient Units (Swine to Swine)

Source: Personal communications with Mike Tokach; Schoenbaum and Disney, 2003; Bates, Thurmond, and Carpenter, 2001 and 2003b.

Table A.7.4 Airborne Disease Spread

Production Type	Probability spread/contagious day, at 1 km, average unit sizes	Maximum distance spread under these conditions (in km)
Feedlot to Feedlot	0.02	3
Feedlot to Cow-Calf	0.02	3
Feedlot to Swine	0.02	3
Feedlot to Dairy	0.02	3
Cow-Calf to Feedlot	0.02	3
Cow-Calf to Cow-Calf	0.02	3
Cow-Calf to Swine	0.02	3
Cow-Calf to Dairy	0.02	3
Swine to Feedlot	0.02	3
Swine to Cow-Calf	0.02	3
Swine to Swine	0.02	3
Swine to Dairy	0.02	3
Dairy to Feedlot	0.02	3
Dairy to Cow-Calf	0.02	3
Dairy to Swine	0.02	3
Dairy to Dairy	0.02	3

(Source: Ashley Hill and Dustin Pendell, Jan. 2006; Schoenbaum and Disney, 2003)

– Rate of disease transfer declines exponentially from source

– Wind direction

Range of wind direction is described by degrees. Specifically, the range of the wind direction is 0 to 359 degrees (i.e., the direction in which FMD can spread by air is directionless).

Source: Personal communications with Kansas State Climatologist's Office, Jan. 2006

- **DISEASE DETECTION**
  - Disease detection was included in this simulation.

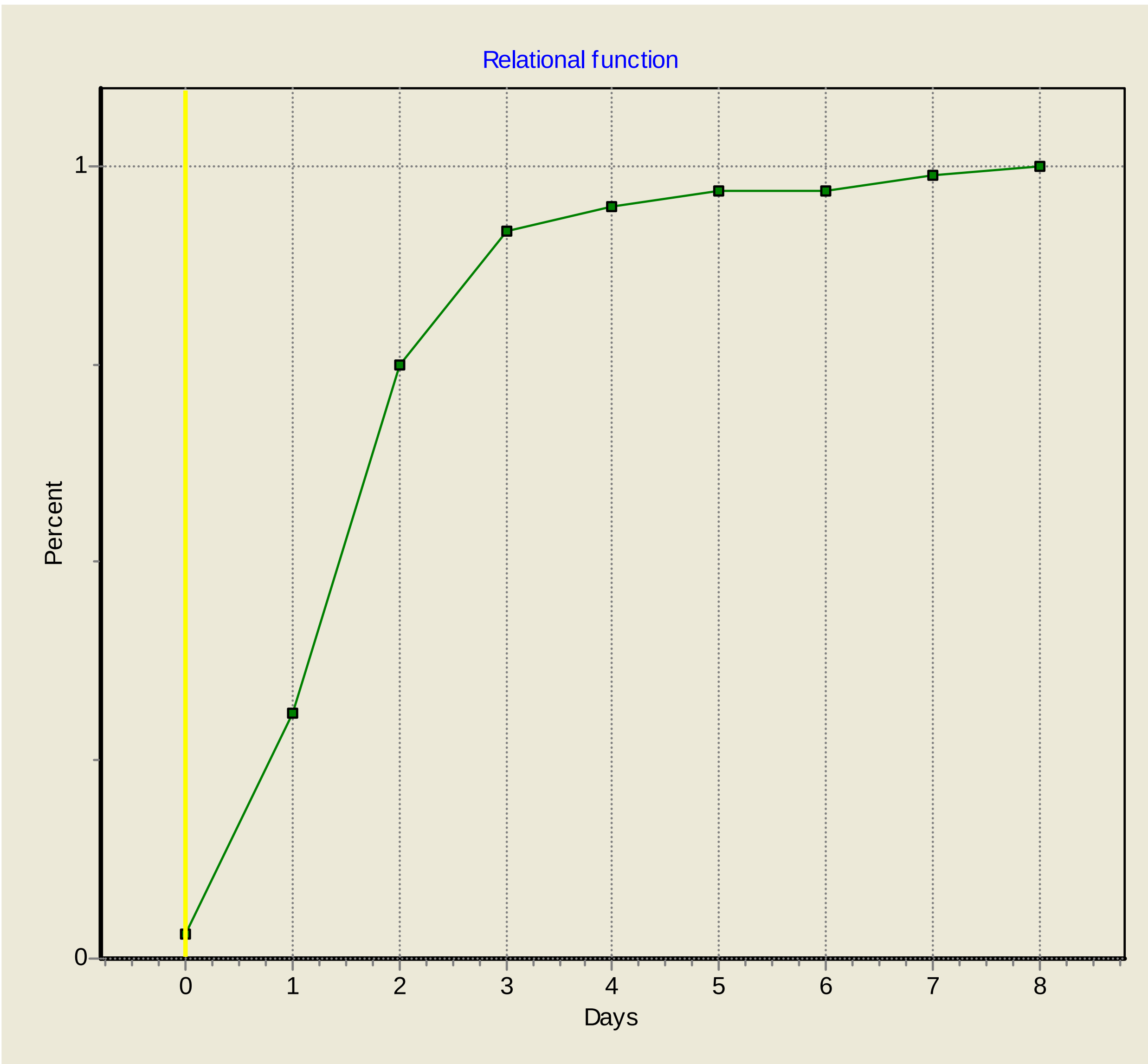

Figure A.28 Probability of Reporting, Given the Number of Days that a Unit was Infectious (Cattle)

(Source: Ashley Hill, Jan. 2006)

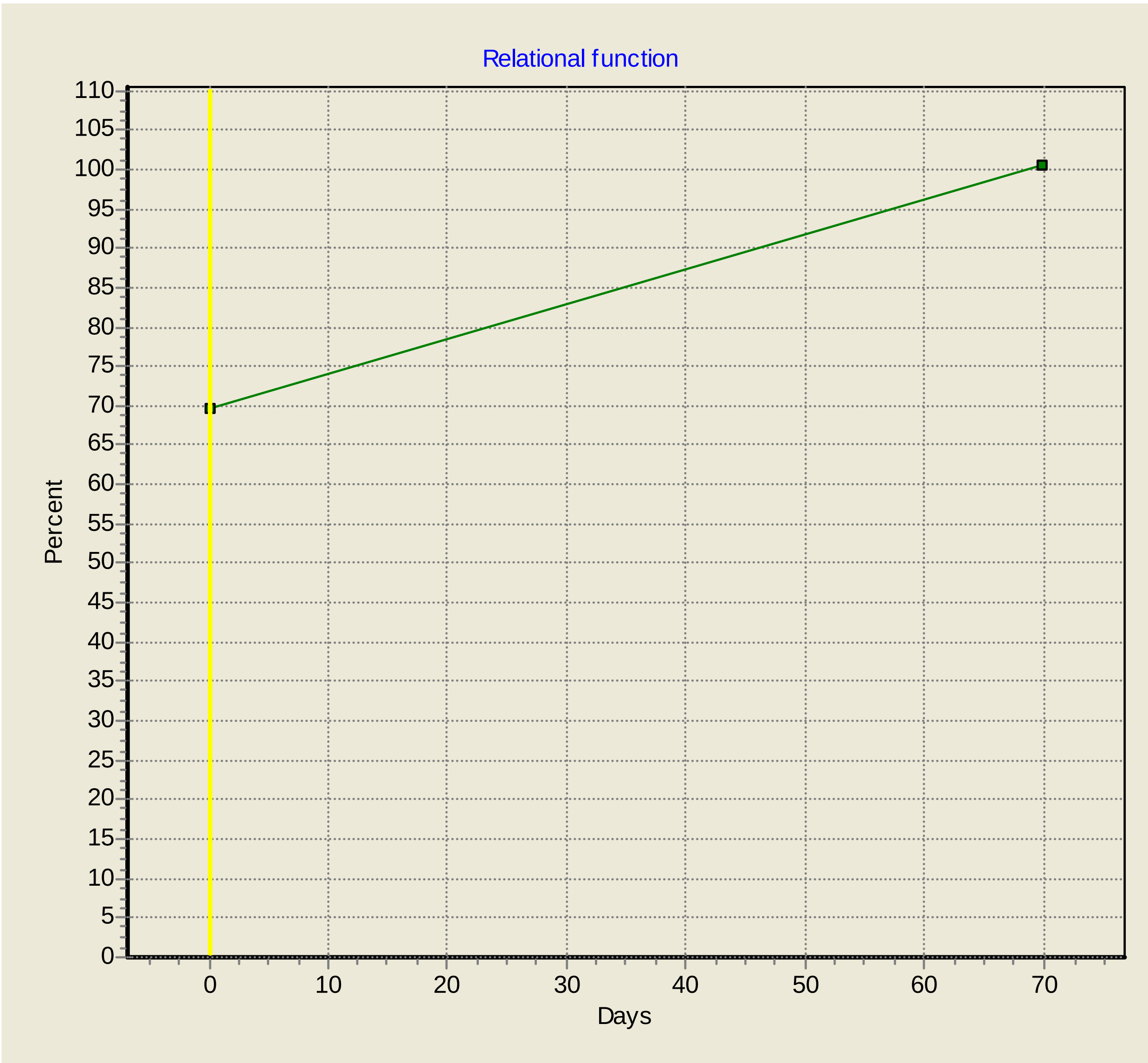

Figure A.29 Probability of Reporting, Given the Day since the Disease was First Detected (Cattle)

(Source: U.S. Midwestern EPI example (APHIS), July 2006)

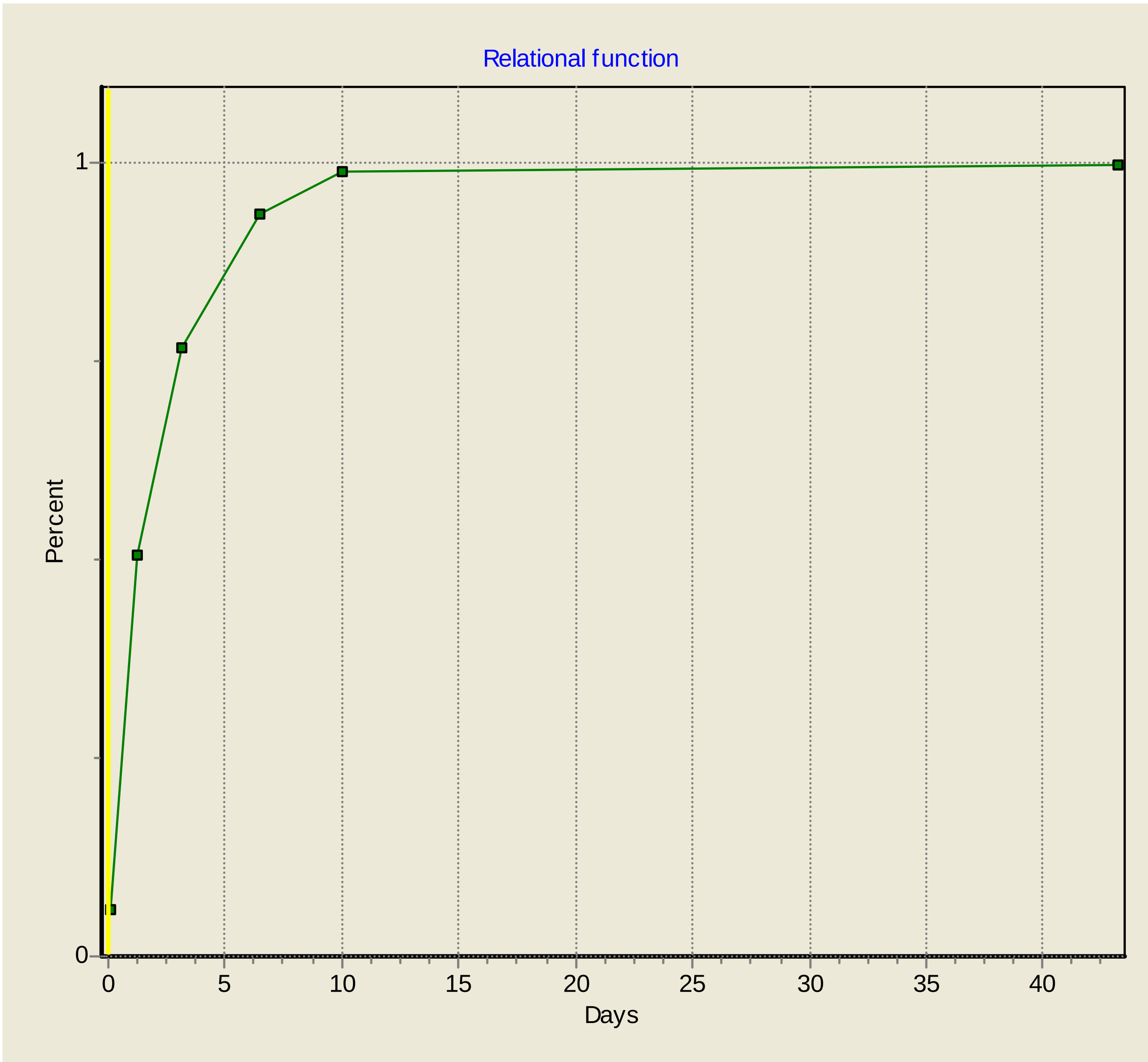

Figure A.30 Probability of Reporting, Given the Day since the Disease was Infectious (Swine)

(Source: Ashley Hill, Jan. 2006)

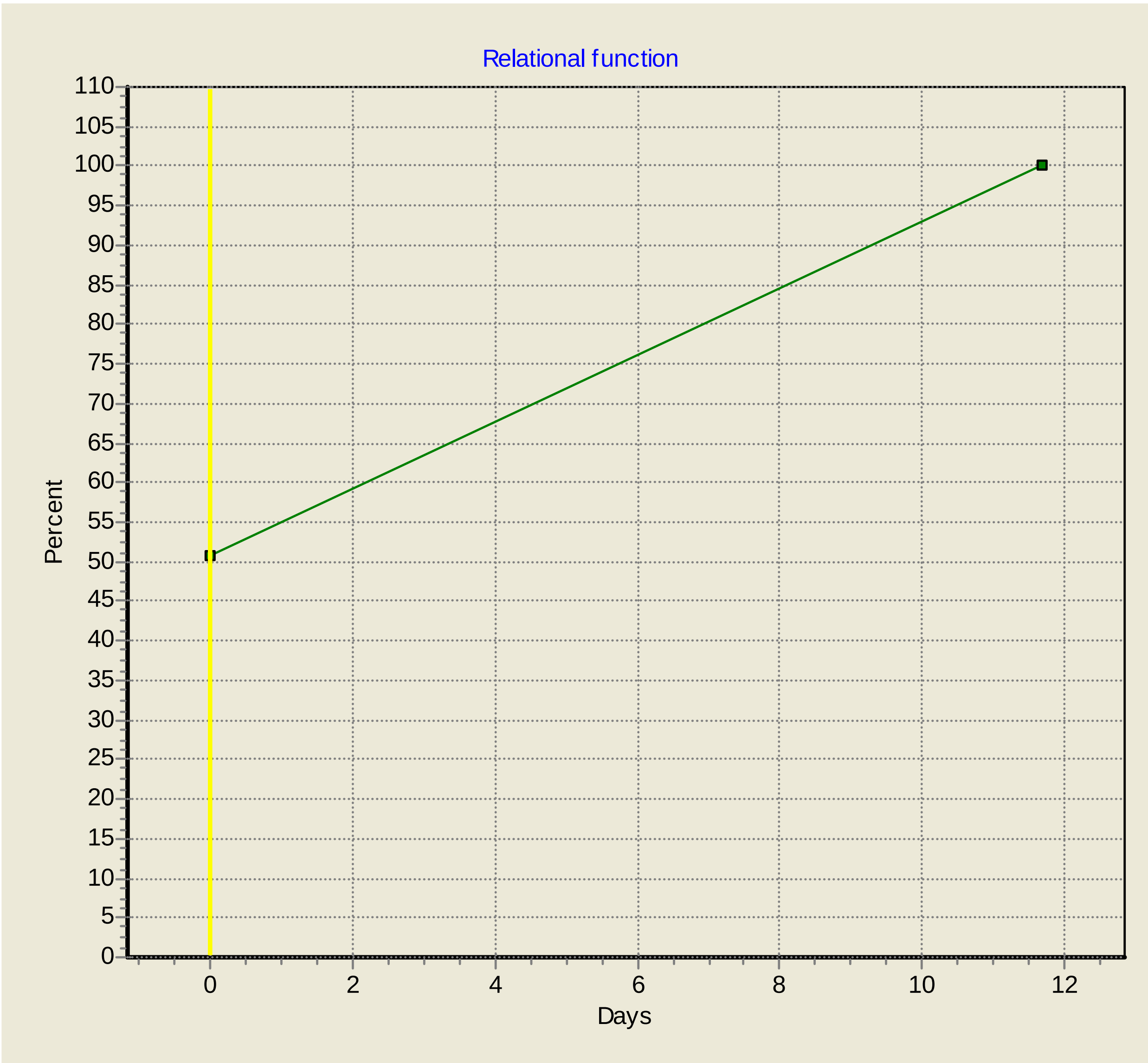

Figure A.31 Probability of Reporting, Given the Day since the Disease was First Detected (Swine)

(Source: U.S. Midwestern EPI example (APHIS), July 2006)

SURVEILLANCE

- Surveillance was included in this simulation.

Table A.7.5 Surveillance Parameters and Values Used Analysis

	Trace direct contacts		Trace indirect contacts	
Production Type	Contact days before detection	Probability of trace success	Contact days before detection	Probability of trace success
Feedlot	14	0.3; 0.6; 0.9	14	0.3; 0.6; 0.9
Cow-Calf	14	0.3; 0.6; 0.9	14	0.3; 0.6; 0.9
Dairy	14	0.3; 0.6; 0.9	14	0.3; 0.6; 0.9
Swine	14	0.75	14	0.75

(Source: Barbarba Corso, Feb. 2006; Dustin Pendell and Ted Schroeder, July 2006)

- **DESTRUCTION**

  – Delay before implementing destruction program (days): 3 days
  (Source: Barbarba Corso, Feb. 2006)

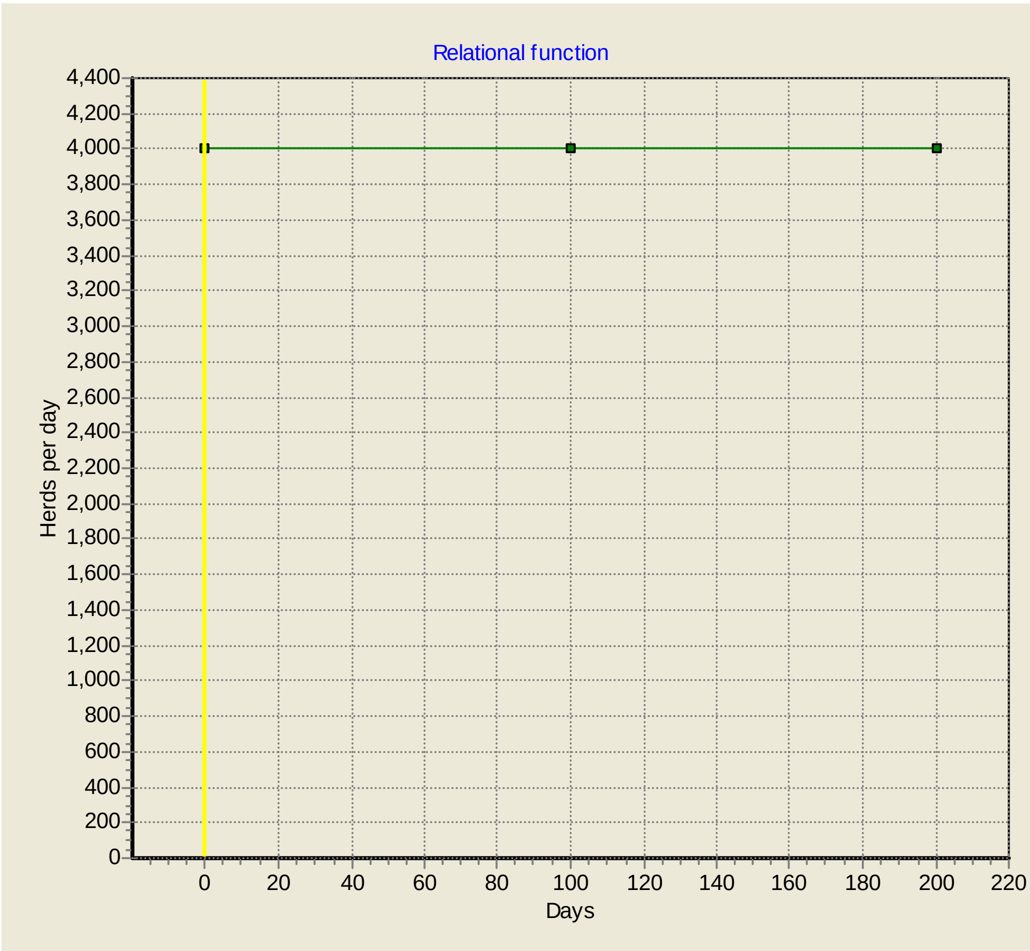

Figure A.32 Destruction Capacity

Source: Ann Seitzigner, July 2006

Table A.7.6 Destruction Priorities

Primary Reason	Secondary Reason
Reason for destruction	Detected
Production type	Direct contact
Days holding	Circle/ring
	Indirect contact

Source: Barbarba Corso, Feb. 2006

- **DESTRUCTION**
  - Applies to all four production types: feedlot, cow-calf, swine, and dairy
    - Destroy detected disease units of this production type
    - Trigger ring destruction around detected units of this production type
      - Ring radius (km): 2.42
    - Pre-emptively destroy units of this production type
      - Destroy units of this production type that have had DIRECT contact with a detected unit as identified by trace surveillance
      - Destroy units of this production type that have had INDIRECT contact with a detected unit as identified by trace surveillance
      - Destroy units of this production type within the specified ring surrounding a detected unit

Source: Personal communications with Barbarba Corso, Feb. 2006; Kansas Emergency Plan, Jan. 2006

- **VACCINATION**
  - Vaccination was not included in this simulation.

Output Parameters

Table A.7.7 Direct Costs

Types of Costs	Costs ($)
Feedlot	
Cost of appraisal (per herd)	$210.00
Cost of cleaning and disinfection (per herd)	$9,844.00
Indemnification (per animal)	$766.00
Euthanasia (per animal)	$5.10
Carcass disposal (per animal)	$1.83
Cow-Calf	
Cost of appraisal (per herd)	$84.00
Cost of cleaning and disinfection (per herd)	$1,565.00
Indemnification (per animal)	$766.00
Euthanasia (per animal)	$24.59
Carcass disposal (per animal)	$13.19
Swine	
Cost of appraisal (per herd)	$84.00
Cost of cleaning and disinfection (per herdt)	1,127.50
Indemnification (per animal)	$92.00
Euthanasia (per animal)	$3.61
Carcass disposal (per animal)	$2.55
Dairy	
Cost of appraisal (per herd)	$84.00
Cost of cleaning and disinfection (per herd)	$3,315.00
Indemnification (per animal)	$1,583
Euthanasia (per animal)	$5.02
Carcass disposal (per animal)	$1.97

(Source: Ann Seitzinger and Dustin Pendell, May 2006)

Appendix B - Economic Model

Shifts

The percentage shifters were estimated for the different levels of the beef and pork industries. There are quantity and cost shifts that will occur in this study. Quantity shifts include feeder cattle, fed cattle, and market hogs while costs shifts will occur at the farm, slaughter and wholesale levels for beef and slaughter and wholesale levels in pork. This study assumes no supply side shifts at the retail level for all three commodities as well as at the wholesale level for poultry.

The following text and calculations describe how the percentage shifts were determined. To begin this description let's assume we are using the aggregated EDM (i.e., no trade and Kansas is not disaggregated; similar to Brester, Marsh, and Atwood, 2004). Quantity shifts were estimated by dividing the total number of animals destroyed (which is determined by the epidemiological model) by the total number of animals in the U.S. For example, under a low level animal identification system at the slaughter level for the beef industry the number of fed cattle destroyed is approximately 725 head. This number is divided by the total number of fed cattle in the U.S. to arrive at the quantity shift for low level animal identification at the slaughter level. The same holds true for medium and high levels of animal identification. The same calculations are performed for slaughter hogs and farm-level beef. Table B.1 contain the percentage changes in the U.S. and Kansas animal populations due to animals being stamped-out or depopulated because of FMD.

The next set of derivations is the percentage change in costs. Through the epidemiological model we are able to calculate direct costs. The direct costs are comprised of: i) appraisal costs; ii) cleaning and disinfecting; iii) indemnity payments; iv) euthanasia costs; v) disposal costs. This study assumes the producer would pay 100% of these costs tabulated by the spread model. In addition, we will calculate the welfare measures if the U.S. Government were to pay for 50% of these costs. To estimate these percentage changes, take low level animal identification at the slaughter level for the beef industry for example. Total expenditures for would be approximately $560 million (Table 6.3). To translate this cost estimate to a percentage cost shift, divide the total costs from FMD by the total value of the industry at the specific marketing level. Table B.2 provides the percentage cost shifts.

The costs at the wholesale level for beef and pork are also estimated (Table B.4). Let's begin with beef. This research assumes there are five beef processors in Kansas (i.e., Tyson – Emporia and Holcomb, National Beef Processing – Liberal and Dodge City, and Cargill Meat Solutions – Dodge City). The capacity for each plant is:

Tyson – Emporia, KS –	4,000 head/day
Tyson – Holcomb, KS –	6,000 head/day
National – Liberal, KS –	6,000 head/day
National – Dodge City, KS –	4,000 head/day
Cargill – Dodge City, KS –	6,000 head/day.

Fixed costs for beef processing plants this size range from $62-$70 per head (Duewer, L.A., and K.E. Nelson, 1992). This study assumes fixed costs of $65/head. Assuming the processing plant shuts down for 10 day, the plant would lose [fixed costs*capacity*10 days for shut down]. In addition, we also assume one day's worth of processed meat and by-products would be destroyed. Take Cargill's plant in Dodge City for example:

Assumptions:
$65/head fixed costs

6,000 head capacity/day
Operate at 98% capacity
Average live weight for cattle – 1,260 lbs (LMIC)
Average dressed weight for steers and heifers – 783.63 lbs (LMIC)
Box-beef price (average for choice 6-9 and select 6-9) – $141.14/cwt (LMIC)
By-product price – $8.15/cwt (NASS)
Plant closes for 10 days
1 day's worth of meat & by-products would be destroyed

Calculation:
(6,000*$65*10) = $3,900,000 (Costs due to closed processing plant)

(6,000*98%*783.63*$1.41*1) + ($0.0815*1,260*6,000*98%) = $7,107,187.65 (Costs due to disposal of processed meat and by-products)

Total Costs = $7,107,187.65 + $3,900,000 = $11,007,187.65

Total value of U.S. beef processing = $36,009,775,679 (Quantity*Price)

Total cost increase to U.S. wholesale beef industry = $11,007,187.65 / $36,009,775,679 = 0.000305 or 0.031%.

The same calculations and assumptions hold for the four remaining beef processing plants. The total cost increase for the entire U.S. beef industry at the wholesale level is 0.132%.

The percentage change in cost at the slaughter level for pork is calculated in a somewhat different manner because there are no pork processing plants in Kansas. However, a FMD outbreak in southwest Kansas would affect the pork processing industry because a significant amount of southwest Kansas swine are slaughter in a nearby processing plant in Guymon, Oklahoma. The hog slaughtering facility is owned by Seaboard Corporation which also owns approximately 90 to 95% of swine in southwest Kansas (Tokach, 2006). Although Seaboard owns a significant portion of swine in Kansas, Seaboard also owns swine operations in Oklahoma, Texas, and Colorado. Because no data are available regarding the number of hogs slaughtered at the Guymon location from each state, this study assumes the only costs incurred by the processing plant is the destruction of one day's processed meat and by-products. The costs are estimated as follows:

Assumptions:

15,000 head capacity/day (Meyer, 1996)
Operate at 98% capacity
Average live weight for market hogs – 269.08 lbs (LMIC)
Average dressed weight for steers and heifers – 216.79 lbs (LMIC)
Pork Carcass Cut-Out Value, 51-52% Lean - $69.88/cwt (LMIC)
By-product price – $11.12/cwt (NASS)
1 day's worth of meat & by-products would be destroyed

Calculation:
(15,000*98%* 216.79*$0.6988*1) + ($0.1112*269.08*15,000*98%) = $2,666,793.86
(Costs due to disposal of processed meat and by-products)

Total Costs = $2,666,793.86

Total value to U.S. pork processing = $14,453,604,373 (Quantity*Price)

Total cost increase to U.S. wholesale pork industry = $2,666,793.86 / $14,453,604,373 = 0.000185 or 0.0185%.

The total cost increase for the entire pork industry at the wholesale level is 0.0185%.

Excess Supply Elasticities

The following are the derivations for excess supply elasticities at the wholesale beef, wholesale pork, slaughter cattle, slaughter hogs, and farm-level cattle.

Wholesale beef – U.S.'s imports the largest amount of beef from Canada, so the excess supply elasticity for Canada's wholesale beef as follows:

0.28*(3.252 billion lbs. / 1.219 billion lbs.) + 0.57*(2.326 billion lbs. / 1.219 billion lbs.)

= 1.83 (excess supply elasticity for SR)
= 10.24 (excess supply elasticity for LR)

$\varepsilon^{w}_{BCanada}$ = 0.28 (Canadian own-price derived wholesale beef supply elasticity, assumed to be the same as the U.S. own-price derived wholesale supply elasticity) – SR; (3.43 – LR)

$\eta^{w}_{BCanada}$ = -0.57 (Canadian own-price derived wholesale beef demand elasticity, assumed to be the same as the U.S. own-price derived wholesale demand elasticity)

$Q^{ws}_{BCanada}$ = 3.252 billion lbs. (source: USDA, FAS) s = Supply

$Q^{wd}_{BCanada}$ = 2.326 billion lbs.; Assumed demand for wholesale beef was Supply + Imports – Exports (source: USDA, FAS) d = Demand

$Q^{wx}_{BCanada}$ = 1.219 billion lbs. (source: USDA, FAS) x = Export

Wholesale pork – U.S.'s imports the largest amount of pork from Canada, so the excess supply elasticity for Canada's wholesale pork as follows:

0.44*(4.222 billion lbs. / 2.388 billion lbs.) + 0.71*(2.141billion lbs. / 2.388 billion lbs.)

= 1.41 (excess supply elasticity for SR)
= 4.07 (excess supply elasticity for LR)

$\varepsilon^{w}_{BCanada}$ = 0.44 (Canadian own-price derived wholesale pork supply elasticity, assumed to be the same as the U.S. own-price derived wholesale supply elasticity) – SR; (1.94 – LR)

$\eta^{w}_{BCanada}$ = -0.71 (Canadian own-price derived wholesale pork demand elasticity, assumed to be the same as the U.S. own-price derived wholesale demand elasticity),

$Q^{ws}_{BCanada}$ = 4.222 billion lbs. (source: USDA, FAS) s = Supply

$Q^{wd}_{BCanada}$ = 2.141 billion lbs.; Assumed demand for wholesale pork was Supply + Imports – Exports (source: USDA, FAS) d = Demand

$Q^{wx}_{BCanada}$ = 2.388 billion lbs. (source: USDA, FAS) x = Export

Slaughter cattle – U.S.'s imports the largest amount of fed cattle from Canada, so this research assumed the U.S. only imports fed cattle from Canada. That begin said, the excess supply elasticity for Canada's fed cattle as follows:

0.44*(3.552 mil. head / 0.460 mil. head) + 0.6*(3.112 mil. head / 0.460 mil. head)

= 7.38 (excess supply elasticity – SR)
= 18.19 (excess supply elasticity – LR)

$\varepsilon^{w}_{BCanada}$ = 0.43 (Canadian own-price derived fed cattle supply elasticity) – SR; (1.83 – LR)

$\eta^{w}_{BCanada}$ = -0.6 (Canadian own-price derived fed cattle demand elasticity)

$Q^{ws}_{BCanada}$ = 3.552 million head of Canadian Fed Cattle Production (source: Canfax)
s = Supply

$Q^{wd}_{BCanada}$ = 3.112 million head; Assumed demand for Canadian fed cattle was production + import - export (source: Canfax, ERS) d = Demand

$Q^{wx}_{BCanada}$ = 0.460 million head (source: USDA, ERS) x = Export

Feeder cattle – U.S.'s imports the largest amount of feeder cattle from Mexico, so this thesis assumed the U.S. only imports feeder cattle from Mexico. That begin said, the excess supply elasticity for Mexico's feeder cattle as follows:

0.22*(7.5 mil. head / 1.26 mil. head) + 0.62*(6.26 mil. head / 1.26 mil. head)

= 4.40 (excess supply elasticity)
= 19.92 (excess supply elasticity)

$\varepsilon^{w}_{BCanada}$ = 0.22 (Mexico's own-price derived feeder cattle supply elasticity; Assumed to be the same as the U.S.'s own-price derived feeder cattle supply elasticity) – SR; (2.82 – LR)

$\eta^{w}_{BCanada}$ = -0.62 (Mexico's own-price derived feeder cattle demand elasticity; Assumed to be the same as the U.S.'s own-price derived feeder cattle demand elasticity))

$Q^{ws}_{BCanada}$ = 7.5 million head of Mexico's 2005 calf crop (source: USDA, FAS) *s* = Supply

$Q^{wd}_{BCanada}$ = 6.26 million head; Assumed demand for Mexico's feeder cattle was production + import – export (i.e., imports were 1,003) *d* = Demand

$Q^{wx}_{BCanada}$ = 1.26 million head exported (source: ERS) *x* = Export

Retail Beef Demand Index

The retail beef demand index was originally calculated by the 1998 Beef Demand Study Group using 1980 = 100.0 as the base year. Later it was updated by Marsh (2003) using an earlier base year of 1970 = 100.0. The beef demand index measures annual shifts in retail beef demand. The index is based on differences between the observed retail price and estimated retail price in percentage terms (holding demand constant). The following calculations and example can be found in Marsh (2003, p. 903):

(B5) $$\frac{Q_t - Q_{t-1}}{Q_{t-1}} = \%\Delta Q$$

(B6) $$\frac{\%\Delta Q}{\eta_d} = \%\Delta Q$$

(B7) $$P_{t-1} + \%\Delta P * P_{t-1} = P$$

(B8) $$\frac{P_t - P}{P} = D'$$

where *Q* and *P* are the retail beef quantity and price. *D'* represent the difference between the actual retail price in year *t* and its constant demand price expressed as a percentage of the constant demand price.

Using the above equations, the beef demand index is calculated for 1971 (recall the base year for the beef demand index is 1970). Per capita beef consumption (*Q*) in 1970 and 1971 is 84.6 and 83.9 lbs., respectively. Choice retail beef prices (P) (deflated by the CPI) for 1970 and 1971 are \$2.57 and \$2.62, respectively. Assume the demand elasticity is constant at -0.67. Using equations (B5) through (B8), prices, quantities and elasticities mentioned above, the result will be the 0.8 percent shift in retail beef demand. For example, (B9) $\dfrac{83.9-84.6}{84.6}=-0.008$

(B10) $\dfrac{-0.008}{-0.67}=0.012$

(B11) 2.57 + 0.012*(2.57) = $2.60/lb.

(B12) $\dfrac{2.62-2.60}{2.60}=0.008$

Now adding the 0.8 percent shift in retail beef demand to the previous year's index (in this case 1970 is the base year) the result is 1971's beef demand index of 100.8. For more details regarding the beef demand index see (Marsh, 2003).

Welfare Measures

To calculate the change in producer surplus equation (1) can be used. However, the EDM does not provide intercept terms. The following example will demonstrate how to calculate the intercept term. First, we note the following:

Baseline price and quantity, percentage change in price and quantity after the exogenous shock (and hence the new price and quantity), and farm-level supply elasticity.

Given the above information, the slope of the supply curve can be calculated as follows:

$$\frac{\partial Q}{\partial P}\frac{P}{Q}=\varepsilon \longrightarrow \frac{\partial Q}{\partial P}=\frac{\varepsilon Q}{P} \longrightarrow \frac{\partial P}{\partial Q}=\frac{P}{\varepsilon Q}=\text{b (slope)} \longrightarrow$$

$$P=\alpha+\text{b}Q \longrightarrow P-\frac{\text{P}}{\varepsilon Q}Q=\alpha \text{ (original intercept)}$$

Now that the original intercept has been calculated, the shifts are done by changing the intercept. Assuming a vertical shift and using percentage changes, the following equation will estimate the new intercept, $(\alpha + (\alpha * x))$, where x is the percentage change (i.e., a 5% increase is 0.05).

Figure B.1 Changes in U.S. and Kansas Animal Population Relative to Total Animal Population in the U.S. and Kansas due to Stamping-Out, respectively (%)

Low Animal ID		*Medium Animal ID*		*High Animal ID*	
United States					
Fed Cattle	5.268	Fed Cattle	3.779	Fed Cattle	1.846
Feeder Cattle	0.051	Feeder Cattle	0.027	Feeder Cattle	0.008
Market Hogs	0.498	Market Hogs	0.254	Market Hogs	0.093
Kansas					
Fed Cattle	13.264	Fed Cattle	9.515	Fed Cattle	4.686
Feeder Cattle	0.944	Feeder Cattle	0.507	Feeder Cattle	0.139
Market Hogs	1.483	Market Hogs	0.755	Market Hogs	0.276

Figure B.2 Percentage Change in Costs at the Slaughter and Farm Levels

	50% of Costs Borne by Producers	All Costs Borne by Producers
Low Animal ID	(%)	(%)
Fed Cattle	1.1951*	2.3901
Feeder Cattle	0.0393	0.0785
Market Hogs	0.1411	0.2822
Medium Animal ID		
Fed Cattle	0.8579	1.7158
Feeder Cattle	0.0215	0.0430
Market Hogs	0.0718	0.1437
High Animal ID		
Fed Cattle	0.4191	0.8381
Feeder Cattle	0.0059	0.0118
Market Hogs	0.0263	0.0526

*This value (1.1951%) was determined as follows:
Total expenditures / Total value of fed cattle industry.