THESIS

ECONOMIC IMPACT OF FERAL SWINE TRANSMITTING FOOT-AND-MOUTH DISEASE TO LIVESTOCK IN KANSAS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY TYLER WILLIAM COZZENS ENTITLED ECONOMIC IMPACT OF FERAL SWINE TRANSMITTING FOOT-AND-MOUTH DISEASE TO LIVESTOCK IN KANSAS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

ECONOMIC IMPACT OF FERAL SWINE TRANSMITTING FOOT-AND-MOUTH DISEASE TO LIVESTOCK IN KANSAS

In the United States, concern has arisen regarding the potential introduction of foot-and-mouth disease (FMD), a foreign animal disease, and its subsequent spread by feral swine populations into domestic livestock. Feral swine are ideal candidates to potentially spread FMD, because they are free ranging with sizeable home ranges, frequently contact domestic livestock, have high fecundity and populations are expanding geographically throughout the United States. Feral swine surveillance is becoming a solution to safeguard and mitigate the potential for feral swine to transmit FMD to domestic livestock (e.g., cattle, pigs, and sheep).

The potentially devastating economic impacts were evidenced by the economic impact of FMD in the UK and Taiwan (FAO, 2009; Yang et al., 1999). It has been estimated that if FMD were to enter the U.S. the economic losses would be $14 billion (Paarlberg et al., 2002). Such large potential losses are an example of the important economic contribution that livestock production makes to the larger U.S. economy.

The objective of this research is to analyze the farm level impacts of alternate surveillance systems in feral swine in the event of a FMD outbreak in Kansas. Specifically, a disease spread model is used to model and evaluate the spread of FMD in

Kansas. Output from the disease spread model is incorporated into a partial equilibrium model to determine the changes in prices. The change in prices for grains and livestock are then used to evaluate the farm level impacts in Kansas using whole farm budgets.

Results obtained from the disease spread model indicate that under no surveillance the largest amount of animals are destroyed, 2,599,419, with a duration of 193 days. Under twice per month surveillance, 2,555,768 animals are destroyed and the outbreak lasts 189 days. Once per week surveillance shows that 2,585,666 animals are destroyed and the duration lasts 192 days. The NAADSM results for Kansas show that the states livestock industry could potentially face large livestock losses from feral swine transmitting FMD.

The impacts to the average farms in Kansas show that producers with a large amount of livestock, in particular swine, see the biggest percentage changes in net income levels. This would be expected as pig and hog prices decrease once the FMD outbreak occurs and return to base levels in quarter four showing that there is a loss in swine prices from a FMD outbreak. Cattle prices initially decrease once the FMD outbreak occurs but then increase above base levels showing that average farms have the potential to regain lost revenues. The whole farm income results indicate that a producer not in the quarantine zone has the potential to capitalize on increasing livestock prices once the trade restrictions are lifted after quarter three.

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Table of Contents

List of Figures

List of Tables

CHAPTER 1 - INTRODUCTION

A new and potentially devastating threat faces the United States livestock production in the form of invasive feral swine spreading foreign animal diseases like foot-and-mouth disease (FMD). Invasive feral swine have been reproductively successful and environmentally devastating in the U.S. due to the fact that they are highly mobile, have high fecundity, operate in ecologically naïve environments, and serve as a reservoir for a host of zoonotic diseases. Because they can spread many diseases, including FMD, to domestic livestock (e.g., cattle, swine and sheep), surveillance of feral swine is a potential solution to mitigate disease spread.

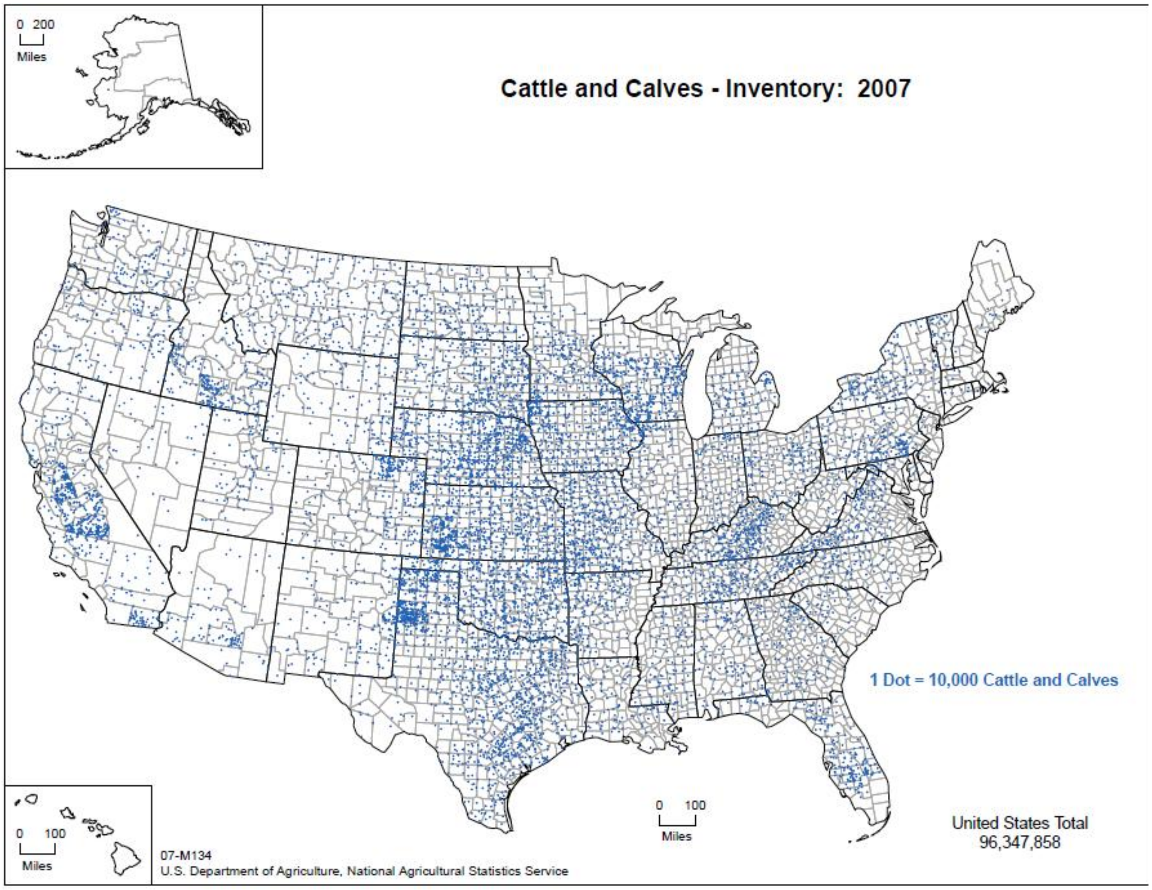
The potentially devastating economic impacts were evidenced by the economic impact of FMD in the UK and Taiwan (FAO, 2009; Yang et al., 1999). In Taiwan during the first year of the outbreak in 1997, the number of cases reached 1 million and more than 3.85 million animals were slaughtered (Shieh, 1997). The highly contagious nature of FMD led to an export ban on pork from Taiwan in March of 1997 which previously exported more than $1.6 billion dollars annually. Similarly, in the United Kingdom, an FMD outbreak in 2001, led to the destruction of six million animals at an estimated cost between $11 and $12 billion. It took eight months to eliminate the virus (FAO, 2009). Although livestock production differs between these countries and the U.S., these examples highlight the potential effects of a FMD outbreak on the U.S. livestock industry.

It has been estimated that if FMD were to enter the U.S. the economic losses could be $14 billion (Paarlberg et al., 2002). Such large potential losses are an example of the important economic contribution that livestock production makes to the larger U.S. economy.

U.S. Livestock Production

In the U.S., cattle and calf production represented 21% ($62.37 billion) of all agricultural products sold ($32.67 billion) in the U.S. (NASS, 2007). In 2008, the U.S. exported 1.89 billion pounds of beef (Stillman, 2009). As of January 1, 2009, cattle and calves inventory in the U.S. was 94.5 million head, which creates a regionally strong job base (U.S. and Canadian Cattle, 2009). Pork exports in 2008 totaled 4.7 billion pounds with more than a quarter of the exports going to Japan (Stillman, 2009).

Half of the U.S. beef cattle production occurs in the Southern and Northern Plains (Kansas, Nebraska, North Dakota, and South Dakota) where there is ample feed for weight gain; however, cattle production does occur over most of the U.S. (figure 1.1). Cattle are born, raised, shipped to feedlots and slaughtered in multiple regions within the U.S. One study found that feeder cattle can move up to 200 miles prior to finishing indicating the movement of livestock and the potential for disease spread across the country (Bailey et al., 1995). Additional publications have looked at the movement of livestock within the U.S. (e.g., Shields and Mathews, 2003; Bailey et al., 2005; Miller, 2001; McBride and Key, 2003) which states that cattle have the most movement throughout regions in the U.S. with the largest being in and within the Northern and Southern Plains.



Source: NASS, 2007

Figure 1.1: United States population of cattle and calves, 2007

With Kansas being in the Southern Plains and the focus state for this study it is necessary to discuss the agricultural characteristics for the state. Kansas consists of large feedlot operations (NASS, 2007). The majority of agricultural products sold in Kansas were from livestock sales (66% of agricultural sales) (NASS, 2007). The main livestock commodity was cattle and calves with the second largest commodity being grains (i.e., wheat and corn). This illustrates the importance of agriculture plays on the state's economy.

Beef, pork and poultry are the three main meats traded globally, with the largest exporters being the U.S., European Union, Australia, Canada, Brazil, and Argentina

(Dyck and Nelson, 2003). The largest importers of U.S. beef are Mexico, Canada, and Japan (table 1.1). An advantage for the U.S. is its distinction as a disease free country, specifically FMD. Having that distinction allows priority for world trade of fresh, chilled, or frozen beef and pork. FMD outbreaks in Taiwan, Britain, and Argentina in the 1990's illustrated the difficulty of controlling this disease and the importance of disease free status.

Table 1.1: Meat and Livestock Annual Cumulative Year-to-date U.S. Trade

Import/export		2006		2007		2008	
Beef and veal imports (Carcass wt. 1,000 pounds)	Canada	843,943	27.36%	789,464	25.87%	841,241	33.14%
	Australia	887,612	28.77%	887,650	29.08%	663,009	26.12%
	New Zealand	563,553	18.27%	507,661	16.63%	527,332	20.78%
	Uruguay	305,403	9.90%	355,224	11.64%	65,549	2.58%
	Brazil	273,209	8.86%	280,819	9.20%	212,907	8.39%
	Argentina	85,798	2.78%	69,264	2.27%	56,052	2.21%
	Nicaragua	62,590	2.03%	88,357	2.89%	99,326	3.91%
	Mexico	40,760	1.32%	49,788	1.63%	43,783	1.73%
	Costa Rica	19,377	0.63%	17,950	0.59%	19,239	0.76%
	Honduras	1,544	0.05%	457	0.01%	6,603	0.26%
	Other countries	878	0.03%	5,529	0.18%	3,105	0.12%
	Total	**3,084,666**	**100.00%**	**3,052,164**	**100.00%**	**2,538,146**	**100.00%**
Beef and veal exports (Carcass wt. 1,000 pounds)	Mexico	660,454	57.69%	586,434	40.90%	649,239	34.41%
	Canada	238,556	20.84%	339,106	23.65%	389,250	20.63%
	Japan	51,639	4.51%	159,411	11.12%	231,070	12.25%
	China (Taiwan)	67,364	5.88%	70,684	4.93%	85,397	4.53%
	South Korea	1,283	0.11%	77,919	5.43%	152,095	8.06%
	Vietnam	10,383	0.91%	41,869	2.92%	121,925	6.46%
	Hong Kong	12,624	1.10%	32,223	2.25%	32,363	1.72%
	Bahamas	12,732	1.11%	9,799	0.68%	8,539	0.45%
	Other countries	89,838	7.85%	116,520	8.13%	217,126	11.51%
	Total	**1,144,875**	**100.00%**	**1,433,964**	**100.00%**	**1,887,004**	**100.00%**
Cattle imports (Head)	Mexico	1,256,973	54.92%	1,090,094	43.69%	702,661	30.76%
	Canada	1,031,870	45.08%	1,404,871	56.31%	1,581,303	69.23%
	Other countries	0	0.00%	0	0.00%	29	0.00%
	Total	**2,288,843**	**100.00%**	**2,494,965**	**100.00%**	**2,283,993**	**100.00%**
Cattle exports (Head)	Canada	36,918	74.31%	44,098	66.43%	38,032	35.38%
	Mexico	727	1.46%	13,779	20.76%	49,203	45.77%
	Other countries	12,033	24.22%	8,506	12.81%	20,257	18.85%
	Total	**49,678**	**100.00%**	**66,383**	**100.00%**	**107,492**	**100.00%**

Source: USDA-ERS

Clearly, the economic consequences for a highly contagious livestock disease on a major livestock producing country, such as the U.S., would be severe. Likewise, the large number of cattle in Kansas would require significant costs to control and eradicate a highly contagious disease. Furthermore, there would be additional costs if the U.S. lost trade. One way to help reduce the risk of a catastrophic outbreak is through wildlife surveillance.

Objectives

The main objective of this research is to use a bioeconomic framework to analyze the impacts of a feral swine surveillance program as a tool to mitigate the risk of feral swine transmitting FMD to livestock in Kansas. Specific objectives include:

1) Model a hypothetical FMD outbreak in the state of Kansas using the North American Animal Disease Spread Model (NAADSM). NAADSM is an epidemiological model which simulates the spread of FMD resulting in the number of animals destroyed and the duration of the disease outbreak.
2) Output from NAADSM will be used in a partial equilibrium model (PEM). A PEM is an economic model that simulates the changes in prices and quantities of commodities resulting from the FMD outbreak in Kansas.
3) Changes in prices of the commodities from the PEM will then be used to analyze the economic impacts to producers at the farm level. Average farms and farm sizes will be developed. The resulting changes in prices of livestock, meat and grain commodities will be applied to each average farm and analyzed on a quarterly basis to determine the economic impacts at the farm level.

Figure 1.2 depicts the simplified flow diagram of this study. An introduction point will be specified for NAADSM. NAADSM output for each surveillance scenario, number of animals destroyed and duration of outbreak, will be used in a partial equilibrium model, which gives the changes in prices of commodities. Change in prices of the commodities will be incorporated into farm level budgets which will be evaluated.

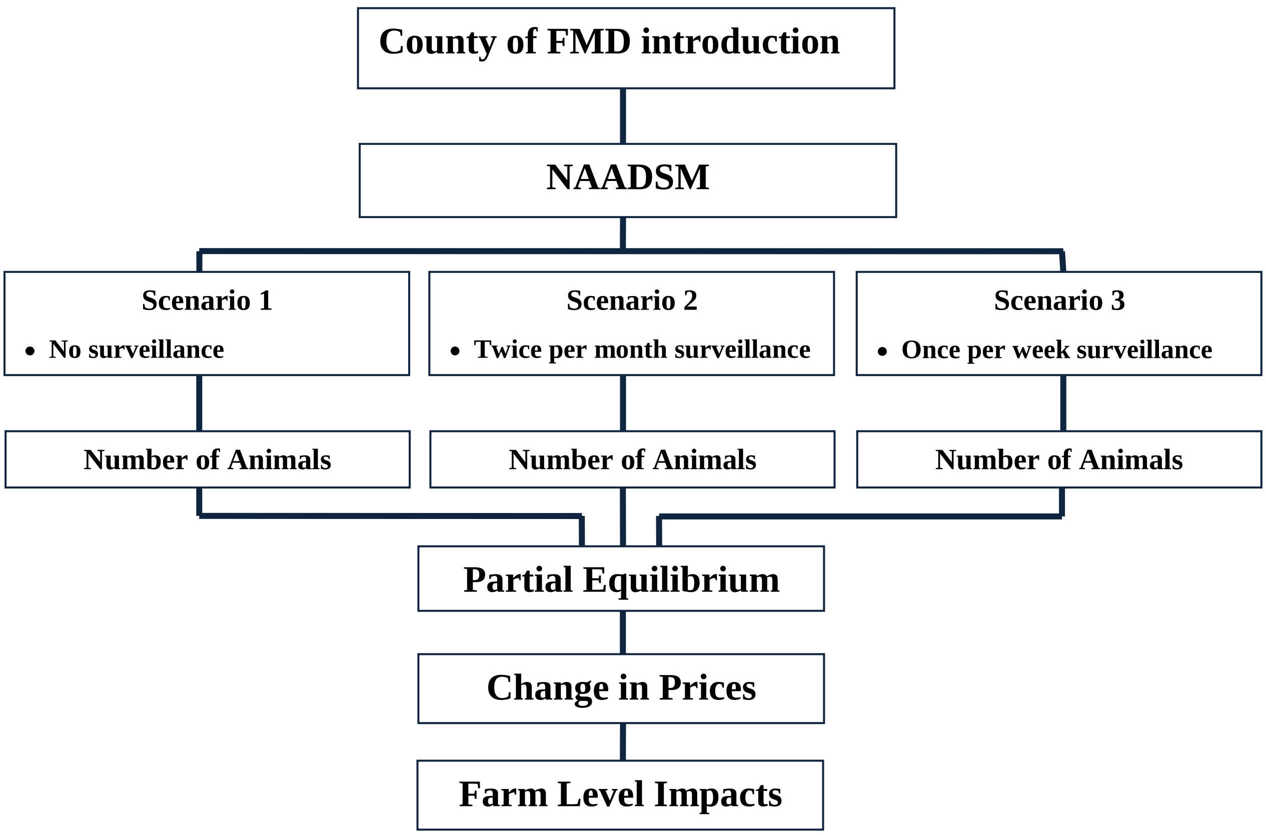


Figure 1.2: Flow Diagram of this Research

Organization of Thesis

The organization of the thesis will be as follows. Chapter 2 will give an overview of FMD, feral swine in the U.S., the current guidelines for FMD, the purpose for surveillance, the economic impacts of FMD in other countries and the contributions of this study. Chapter 3 discusses the epidemiological model used and the surveillance scenarios modeled. Chapter 4 discusses the economic framework used to model the impacts and how the resulting changes in prices of commodities were used to analyze the impacts to average farms in Kansas. Chapter 5 presents the results from the study. The final chapter, Chapter 6, discusses the summary findings, and limitations of the study and future steps.

CHAPTER 2 – LITERATURE REVIEW

This literature review will be divided into six sections. The first section is an overview of FMD. The second and third sections will discuss the impacts of invasive feral swine and the USDA's National Animal Health Emergency Management System Guidelines, respectively. The fourth section will review recent, relevant economic studies. The literature review will conclude with the contributions of this research.

Foot-and-Mouth Disease

FMD is a highly contagious viral disease which spreads primarily through direct or indirect contact with infected animals. FMD can be introduced to uninfected regions through wildlife, contaminated feed, illegal importation of animals, vehicles, humans, and aerosol spread (Musser, 2004). The current U.S. policy to control and eradicate FMD is through stamping-out infected animals on infected premises and, if necessary, those animals in other herds which have been exposed by direct or indirect contact (NAHEMS, 2010). This requires the slaughter of all animals that are clinically affected and at-risk as quickly as possible, restricting animal movement, and disinfecting and cleansing of infected areas (OIE, 2008).

FMD affects even-toed ungulates and is a highly contagious disease due to its ability to multiply rapidly prior to the appearance of clinical signs (Gay, 2007; Musser, 2004). Clinical signs vary from animal to animal, but are fairly consistent across susceptible animals and include: fever, excessive salivation, lameness, sores on the tongue, mouth, teats and coronary bands, skin between and above the hoofs, mastitis may develop in cattle, loss of production and abortions are likely (Gay, 2007; Musser, 2004; OIE, 2008).

FMD is characterized by high morbidity and low mortality. Young animals have a high likelihood of death due to cardiac involvement (Gay, 2007; Kitching and Hughes, 2002). The morbidity to the animals, as high as 90% in a herd, reduces productivity, and abortions in pregnant animals. It is the repercussions (e.g., fever, excessive salivation, lameness, sores on the tongue, mouth, teats and coronary bands, skin between and above the hoofs, mastitis in cattle, loss of production and abortions, and controlling spread of the disease) from FMD that are of greatest concern to producers (OIE, 2008).

With feral swine's high mobility and disease spread capabilities this makes them a likely candidate to contract and spread a highly contagious viral disease such as FMD. With an increasing range expansion in the U.S., uncontrolled movement and the ability to adapt to various climates, feral swine are the perfect host to transmit and spread a highly contagious disease such as FMD.

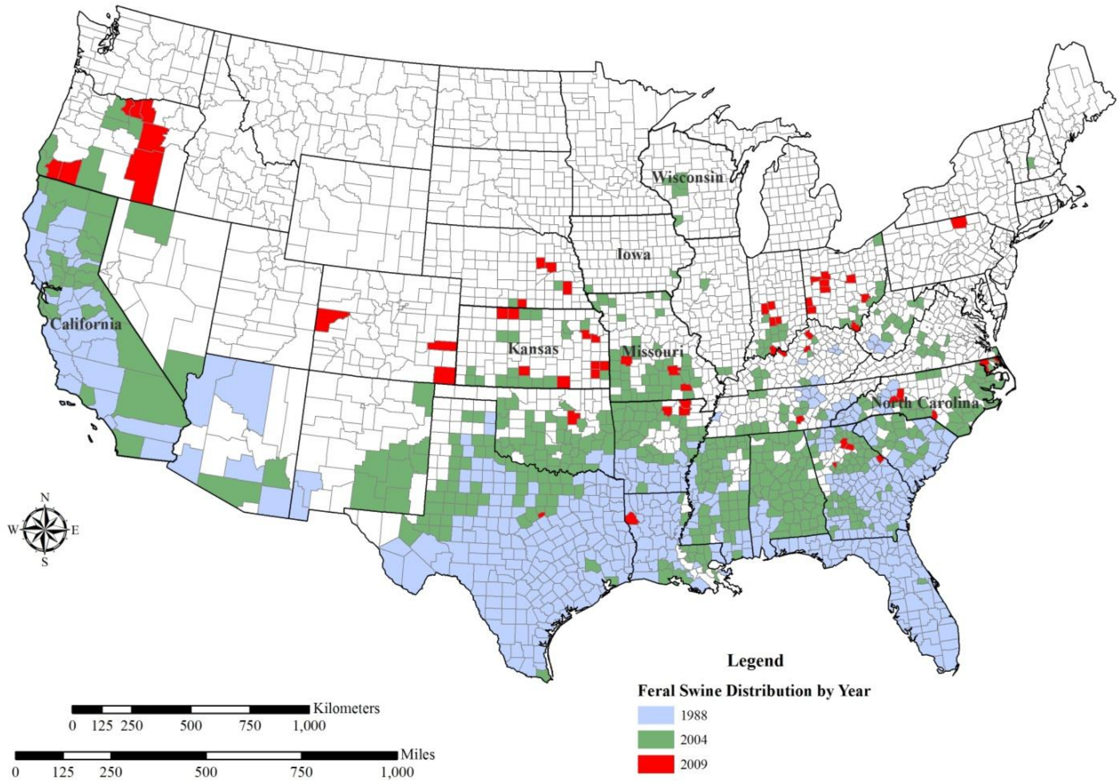
Invasive Feral Swine

Feral swine were first introduced into the United States by European explorers in the early 1400's and thereafter, to provide hunting opportunities (Witmer, Sanders, and Taft, 2003). Since their introduction into the U.S., feral swine populations have increased to over an estimated four million feral swine in 35 states (USDA-APHIS, 2009). Feral swine are considered the "World's Worst Invasive Alien Species" by the World Conservation Union and the Invasive Species Specialist Group. It has been estimated that each feral swine can cause $200 annually worth of damage to ecosystems which amounts to $800 million per year in damages in the U.S. (Pimentel, Zuniga, and Morrison, 2005; OIE, 2008). In 2008, the USDA-Animal and Plant Health Inspection Service's (APHIS)

Wildlife Services (WS) reported removing 28,472 feral swine in 29 states (USDA-APHIS, 2009). It has been suggested that feral swine can serve as a surveillance tool to monitor and/or catch foreign animal diseases and established diseases currently within the U.S. (Mason and Fleming, 1999; Lorigan, 2002). Producers, regulatory veterinarians, and trade associations have all expressed concern regarding feral swine as an introduction point for diseases.

Feral swine are known to serve as reservoirs for many pathogens and parasites while acting as vectors for others which can ultimately infect humans and domestic livestock (Witmer, 2003). They are highly mobile and have been known to carry 30 viral and bacterial diseases and 37 different parasites which could be transferred to domestic livestock which could potentially be devastating to the agricultural sector and, thereby, the entire economy (Williams and Barker, 2001; Forrester, 1991). For example, Wyckoff et al. (2009) sampled 373 feral swine in southern Texas and eastern Texas. They found that 5% of those sampled in eastern Texas and 24% of those sampled in southern Texas were infected with swine brucellosis (SB), respectively, while 36% and 18% were infected with pseudorabies virus (PRV) in southern and eastern Texas, respectively (Wyckoff et al. 2009).

Feral swine have the ability to rapidly reproduce. To keep up with the feral swine population growth in Missouri, populations must be reduced by 70% each year because a single group can triple in size in one year (Hutton et al., 2006). Additionally, the geographic location of feral swine has been expanding in the past decade (figure 2.1). Combining the high fecundity, increasing range expansion, disease carrying capabilities, and contact with domestic animals, feral swine pose a serious threat to domestic livestock and humans (Wyckoff et al., 2009).



Source: Southeastern Cooperative Wildlife Disease Study (SCWDS)
Figure 2.1: Map of Feral Swine Range Expansion in the U.S.

National Animal Health Emergency Management System Guidelines

The USDA-APHIS has established guidelines to be followed in the event a foreign animal disease (FAD) enters the U.S. The overall goal is to detect, control, and eradicate the disease as quickly as possible to minimize the negative impacts. Having the disease controlled within four months or less is the goal because if the disease is allowed to spread more than four months, it is hard to contain. If the disease is not contained within 12 months, then there will be a switch from emergency eradication to a national disease elimination program.

The U.S. is an Office International Des Epizooties (OIE) member, so in the event of a FAD outbreak, the standards to follow have been established by the OIE and the other member countries. The OIE standards state that disease eradication is done by "stamping-out." Upon confirmation of the disease and under the authority of the Veterinary Administration, stamping-out is the removal of the animals which are affected and those suspected of being affected in the herd, and where appropriate, those in other herds which have been exposed to infection by direct or indirect contact. Susceptible animals, vaccinated or unvaccinated, on an infected premises should be stamped-out and their carcasses destroyed by burning, burial, or by any other method that will eliminate the spread of infection. The stamping-out process must have the infected premises (IP) and contact premises (CP) animals euthanized within 24 hours. It is critical that wildlife be kept out of the infected area because they are a reservoir for a myriad of diseases and have uncontrolled movements furthering the spread of the disease. There can be other forms of stamping-out called modified "stamping-out" policies which modify the procedure discussed.

Once a FAD has been detected and the infected premises (IP) determined, an infected zone (IZ), a 6.2 mile (10km) perimeter established around the IP, is constructed. Once the IZ is designated, epidemiological investigations can begin and movement restrictions in and out of the IZ can be monitored. A buffer surveillance zone (BSZ) surrounds the IZ with a distance that will be specified as the situation is assessed. The surveillance zone (SZ), within and along the border of the free zone (FZ), separates the

FZ from the BSZ, and the FZ is the area absent of the disease which is specified by the OIE (figure 2.2).

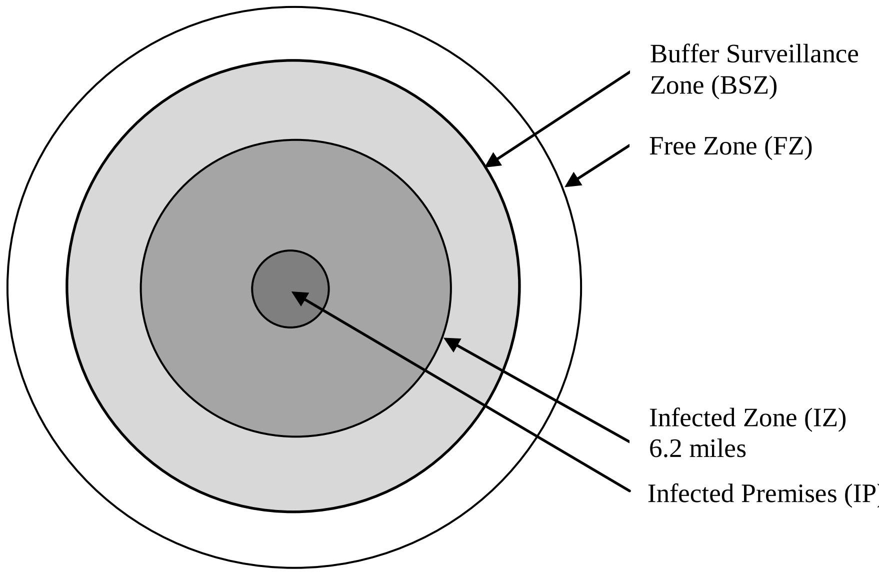


Figure 2.2: Quarantine Area

Disease Surveillance

The USDA's APHIS-WS has a cooperative effort with Veterinary Services (VS) and the National Surveillance Unit (NSU) to develop surveillance strategies to track and monitor multiple diseases that threaten livestock producers. Surveillance of feral swine is currently being conducted and samples from feral swine around the U.S. are being collected to monitor for two endemic diseases: PRV and SB (Swafford, 2009). More than 2,500 samples are collected and analyzed annually to monitor and track PRV and SB in feral swine populations (Swafford et al., 2009). The NSU is conducting pilot surveillance programs to track and monitor classical swine fever and FMD in feral swine to prevent a disease outbreak from one of these highly contagious FADs which are currently not in the U.S. (Swafford et al., 2009).

Economic Impacts of FMD

Outbreaks of FMD in other developed countries (e.g., Taiwan, United Kingdom, Netherlands, Ireland, France and Italy) during the past 15 years have led to increased concerns about possible domestic outbreaks (Paarlberg et al., 2003). These outbreaks provide examples of the potential for FMD to cause economic damage within the U.S. (ERS, 2000). In Taiwan during the first year of the outbreak (1997), the number of cases reached one million and more than 3.85 million animals were slaughtered (Shieh, 1997). The highly contagious nature of FMD led to an export ban on pork from Taiwan in March of 1997, which had previously exported more than $1.6 billion dollars annually. Similarly, in the United Kingdom, Ireland, France, and the Netherlands, FMD outbreaks in 2001 led to the destruction of six million animals at an estimated cost between $11 and $12 billion and it took eight months to eliminate the virus from these areas (FAO, 2009).

Multiple studies have linked an epidemiological model to an economic framework to project the expected impacts of a potential FMD outbreak in domestic livestock in the U.S. and in other parts of the world (see Rich and Winter-Nelson, 2004; Keeling, 2005).

Schoenbaum and Disney (2003) analyzed vaccination and slaughter strategies to minimize the epidemiological and economic impacts of FMD infection in the U.S. using a state transition model to measure changes in consumer and producer surpluses. The study found that control strategies depend on herd demographics and contact rates between herds.

Paarlberg et al. (2008) used NAADSM and a multi-period, multicommoidty economic model to analyze the impact of FMD introduction through garbage feeding to domestic livestock. The economic model shows the impacts to major agricultural products and the resulting effects to supply, demand and trade over 16 quarters. The study found that trade impacts for beef, beef cattle, hogs and pork could be significant. Total losses ranged from $2,773 million to $4,062 million (Paarlberg et al., 2008).

One study explored the potential epidemiological impacts to cattle in southern Texas caused by wildlife (deer and feral swine) transmitted FMD using a state transition model embedded in a geographic automata framework (Ward, 2007). Ward (2007) found that with a FMD introduction into the feral swine population there would be 698 head of cattle infected with an infected area of 166 km^2. In some of the scenarios FMD did not enter the domestic population so the disease may become extinct before it reaches domestic livestock.

Pech and McIlroy (1990) researched the affects of a FMD outbreak in the estimated 11 million head of feral swine in Australia. There were 24 swine tagged with a radio collar which took readings on the locations of each hog every three hours. This gave an idea of the home range for each swine. They found that feral swine remained in a well-defined home-range which overlaped with other feral swine home-ranges. This overlapping of home-ranges creates the opportunity for contact to occur with other feral swine, and thus the spread of FMD (Pech & McIlroy, 1990)

Dexter (2003) used a stochastic model of feral swine populations in Australia with a deterministic model of FMD in feral swine. The simulations were used to determine which control measures would best control a FMD outbreak in feral swine. The study found that depending on the density of feral swine, FMD may be easier to control (Dexter, 2003).

Pendell et al. (2007) demonstrate the economic impact of a FMD outbreak in southwest Kansas using NAADSM and an input-output (IO) analysis. The study looked at the local economic impacts of a FMD outbreak originating in a cow-calf operation, a medium-sized feedlot and a simultaneously in five large feedlots. The study found that each scenario results in different outcomes and regions with large densities of livestock need to have a greater awareness for disease surveillance, disease management, and disease mitigation strategies (Pendell et al., 2007). This study is relevant in that it only uses NAADSM to model the FMD outbreak, but the study region is southwest Kansas..

Zhao et al. (2006) used a bioeconomic framework that couple an epidemiological model with a dynamic economic model of the U.S. beef industry to analyze the effects on a livestock sector when there is an invasive species introduction. The study looks at welfare outcomes associated with different traceability and vaccination control strategies (Zhao et al., 2006).

Pendell (2006) evaluated the economic impacts of different levels of animal identification/trace-back systems in the event a FMD outbreak occurs in southwest Kansas. An epidemiological model (NAADSM) was used to simulate the disease spread of FMD in southwest Kansas. The NAADSM output was used to determine the resulting changes in producer and consumer welfare. The study found that increased levels of animal identification result in less animals being destroyed from the FMD outbreak (Pendell, 2006).

Contributions of this Research

There are an increasing number of studies that have investigated the economic impacts of alternate mitigation strategies using hypothetical FMD outbreaks. A majority of these studies have linked an epidemiological model to the economic framework.

Although this research is similar to previous research, it differs in several important ways. First, integrating wildlife (feral swine) into the epidemiological model as the active source of FMD infection is a necessary incorporation to the epidemiological model. Second, the strategies evaluated here focus on alternate surveillance strategies, not stamping-out or vaccination policies. Third, the region of interest is the entire state of Kansas which has a large livestock population. Finally, farm level impacts will be estimated with whole farm budgets.

The results from this study will provide insights to policy makers, government agencies, and livestock and meat industry groups. Policy makers, governmental agencies, and livestock and meat industry groups will have scientific evidence of the importance and value of surveillance strategies regarding feral swine. Additionally, this research will help inform future surveillance strategies guidelines.

CHAPTER 3 – EPIDEMIOLOGICAL MODELING

North American Animal Disease Spread Model

The North American Animal Disease Spread Model (NAADSM) is a stochastic, spatial, state-transition simulation model for the spread of highly contagious diseases of animals. NAADSM was developed by a team of scientists and scholars to assist policy development and decision making involving disease incursions (see Harvey et al. (2007) for an extended description of the model framework).

In NAADSM, disease spread occurs between production units at specified locations and is influenced by distance and contact events between units and the epidemiological characteristics of the disease. Production units follow predictable disease states moving from susceptible to latent to infectious and then to recovered or removed. The disease cycle may be interrupted through disease control mechanisms such as vaccination, culling, or quarantine. Stochastic processes are embedded in most parameters within the model including disease, contact, tracing, and surveillance parameters, and are based on distribution and relational functions described by the user. NAADSM uses daily time steps after which, the disease status of each herd is updated dependent on the outcome of the stochastic processes and control mechanisms that took place in that time step. Each simulation can be run until the disease is first detected, or the outbreak has gone on for a certain number of days, or until the end of the outbreak.

NAADSM Input Parameters

NAADSM consists of eight key simulation parameters: (1) production types, (2) disease, (3) disease spread, (4) detection, (5) surveillance, (6) destruction, (7) vaccination, and (8) cost accounting. See Hill and Reeves (2006) for a complete description of the key input parameters, The first parameter is production type. This parameter consists of different production types, location of herds and the size of each herd. The development of herds within the model is done by using data collected from Lawrence Livermore National Laboratory (LLNL, 2009) and NASS (2007) data. The herd population parameter is where this study is able to incorporate and model wildlife (feral swine) as a production unit with specific contact parameters. This incorporation will be discussed later.

The second parameter to be specified in NAADSM is disease. The disease or health states follow that of a state transition model implying herds progress through different disease health states: susceptible to latent to infectious subclinical to infectious clinical to immune. As described below in this section, the subclinical state is integrated into the clinical state.

The third parameter in NAADSM is the disease spread among herds. There are three ways FMD spread throughout the study region: (1) direct contact (between one or more animals from one herd to another), (2) indirect contact (movement between people, vehicles, animal products, etc.), and (3) airborne spread.

The fourth parameter is detection of the disease. Disease detection refers to identification and reporting of infected herds. There are two probabilities that are required to model the spread of FMD: (1) probability of observing clinical signs, given the number of days that a herd has been infectious, and (2) probability of reporting FMD, given the day since FMD was first detected. This key input parameter is where the model is modified to account for the surveillance scenarios evaluated in this study and will be discussed later.

The fifth key input parameter is surveillance, which is the process of identifying herds at high risk for FMD based on exposure or proximity to infected and detected herds. This key parameter includes both direct and indirect tracing.

The sixth input parameter is destruction. This parameter is used as a control method. The modeler needs to specify the number of days before a destruction program is implemented and the destruction capacity or the number of herds that can be culled per day. If destruction capacity is limited, then priorities for which herds are culled needs to be specified. Additionally, the modeler can cull herds through ring destruction and pre-emptive destruction.

The final two parameters, vaccination and cost accounting, are not used in this study. All input parameters used in this research can be found in Appendix A.

Scenarios Modeled

Understanding the scenarios introduced into NAADSM is important because the results (e.g., number of animals stamped-out and duration of outbreak) depend on these parameters. Three different surveillance scenarios are modeled to identify the difference, if any, in the stamping-out of livestock when surveillance is conducted. The three surveillance programs include: (1) no surveillance, (2) once-a-week surveillance, and (3) twice-a-month surveillance. Three parameters are modified within NAADSM to reflect surveillance changes including: (1) feral swine surveillance program, (2) feral swine population and (2) county of disease introduction.

The assumptions used to model the feral swine surveillance program are as follows:

- If one feral swine in the modeled feral swine herd has FMD, all members of that herd are assumed to have FMD.

- Trapping would be conducted often enough to capture at least one animal per surveillance time period.
- Surveillance consists of visual inspection of the feral swine for lesions and a nasal swab would be taken to identify the presence of antigens.
- Antigen analysis will take two days to complete. If a swab is taken on day one, results would be available on day three.

The effect of surveillance is modeled in NAADSM as a change in the probability of detection of the disease in the feral swine herd (figure 3.1). In NAADSM, detection is a combination of the probability of detecting FMD and the probability of reporting it to the authorities. These parameters are different for each production type to account for the possibility that the signs of disease may be more obvious in certain production types (such as in dairies). Day one for the probability of detecting disease in all production types, except feral swine, occurs when clinical signs first appear. Surveillance enables the detection of the disease in feral swine beginning when the animal first sheds the virus at the infectious, subclinical stage. To account for this, the parameters describing the subclinical stage are set equal to zero and the subclinical stage is integrated into the clinical stage.

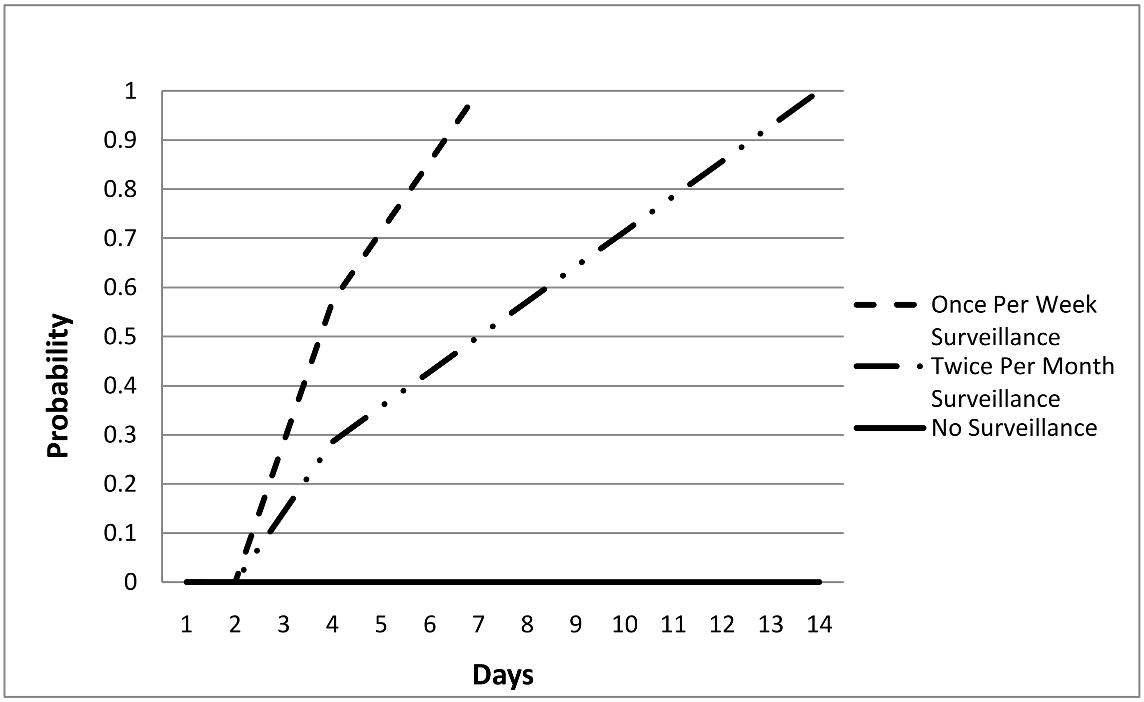


Figure 3.1: Probability of Detecting Disease in a Feral Swine Unit

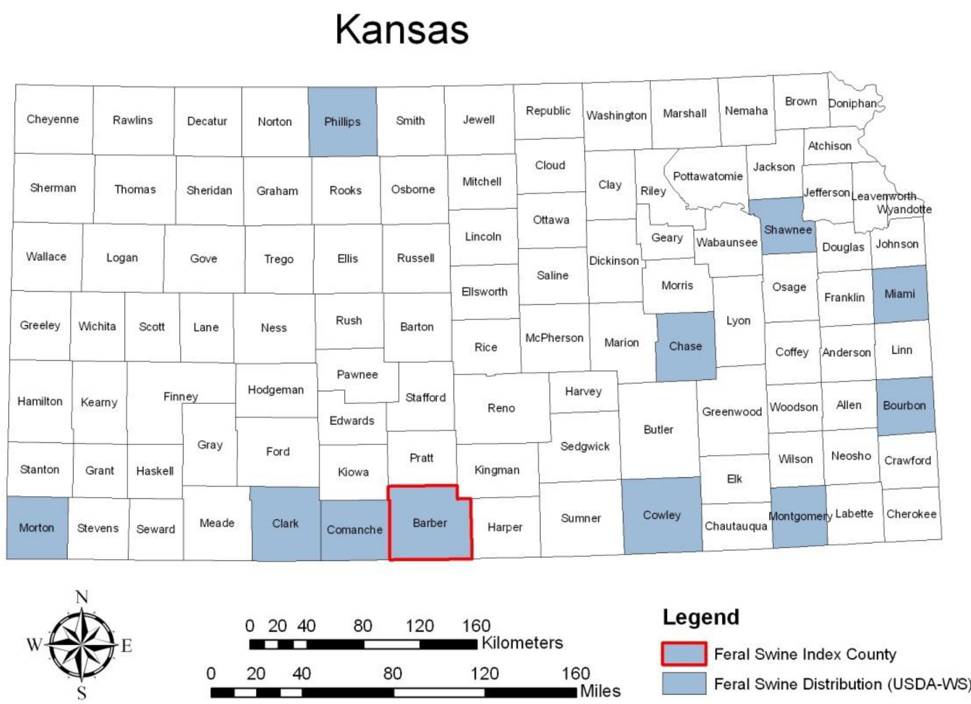
The feral swine parameters are constant between all three surveillance scenarios. Since feral swine have never been modeled in NAADSM as a unit, an extensive literature review was conducted and parameters are based on multiple studies (Wyckoff et al., 2009; Mansouri and DeYoung, 1987; Kroll, 1986; Ilse and Hellgren, 1995; Gabor Hellgren, and Silvy, 2001; Deck, 2006; Adkins and Harveson, 2007; Kurz and Marchinton, 1972; Wood and Brennemann, 1980; Singer et al., 1981; Baber and Coblentz, 1986; Sterner, 1990; Barrett, 1982; Ellisor, 1973; Springer, 1977; Freibel and Jodice, 2009; and Ward Laffan, and Highfield., 2007).

This study assumed that the feral swine are not clinically infectious until day three. Although it is not possible to observe clinical signs until day three, it is possible to collect a nasal swab on all days. This gives rise to a probability of detecting disease function equaling zero for the first two days, a rapidly increasing cumulative density function for days 3-4 (due to the possibility of visual inspection and the results from the serology have been obtained from the first two days), and a leveling off for day five through the end of the surveillance cycle.

The final parameter modified in NAADSM is the location where FMD is introduced. To determine the mostly likely introduction point for FMD to start and be transmitted to domestic livestock in Kansas selection criteria is developed as follows:

1. The county needs to have a known feral swine population as determined from information collected by Southeastern Cooperative Wildlife Disease Study (SCWDS) and the National Wildlife Disease Program collection of feral swine in Kansas.
2. Determine which counties have a large amount of livestock production. This information was collected and analyzed based on NASS (2007) data.
3. Determining which counties have a large amount of backyard livestock producers. For this study a backyard producer is defined as a producer with less than 25 head of animals. For example, a backyard producer could have less than 25 head of hogs and pigs and/or less than 25 head of cattle.
4. Lastly, determining counties with a large number of landfills and/or airports which could pose a threat in the form of bioterrorism.

Once the selection criteria of disease introduction are analyzed, it is determined that Barber County, Kansas would be the most likely county for a FMD introduction to occur (figure 3.2). Although Barber County does not have a large amount of cattle and hog production, when compared to other counties in Kansas, it does have the highest population of feral swine as determined by the USDA collection of feral swine and Southeastern Cooperative Wildlife Disease Study (SCWDS). FMD is introduced in the north central part of the county where the majority of the feral swine population is located.



Source: USDA-WS

Figure 3.2: Map of Kansas Showing Feral Swine Populations and County of Disease Introduction

Output from NAADSM for the three surveillance strategies should be of importance to animal health officials. These outputs will demonstrate the impact surveillance has on the number of animals stamped-out and length of outbreak and will be used in the economic framework.

CHAPTER 4 – ECONOMIC MODEL

Chapter 4 describes the economic framework used in this research. This chapter will be divided into three sections. The first section is the basic economic modeling strategy. The second section discusses the partial equilibrium model and the third section explains the development of the average farms used in this economic analysis.

Economic analyses are beginning to play a crucial role in assessing the impacts of current and future policies regarding management of potential FADs. As the epidemiological-economic framework is becoming increasing popular, the sophistication of the economic models is increasing. Five common economic models that have been used in conjunction with disease spread models include: partial equilibrium, input-output, computable general equilibrium, linear programming, and cost-benefit analysis.

Similar to other recent studies, this research uses a partial equilibrium model. Other recent studies that have used this model include Schoenbaum and Disney (2003) who analyzed vaccination and slaughter strategies to minimize the epidemiological and economic impacts of a FMD outbreak in the U.S. using a state transition model and measuring economic impacts through changes in consumer and producer surpluses. Zhao, Wahl, and Marsh (2006) modeled FMD in the U.S. beef industry and estimated the associated economic impacts of alternate traceability and vaccination strategies. Paarlberg et al. (2008) used a U.S. agricultural sector model to evaluate the impacts of alternate FMD control strategies in the Midwest. In addition to using a partial equilibrium model to estimate change in prices and quantities of different commodities, this study constructs whole farm budgets to estimate the farm level impacts.

Basic Modeling Strategy

Below are illustrations of the possible impacts of a FMD outbreak on prices and quantities for the U.S. beef and cattle industry. To simplify these figures, let's assume two marketing levels, retail and farm, and fixed input proportions. The primary demand and supply curves are denoted by $\mathbf{D^r}$ and $\mathbf{S^f}$, respectively. Derived demand for cattle at the farm-level is represented by $\mathbf{D^f}$ while derived supply for beef at the retail-level is denoted by $\mathbf{S^r}$. The intersection of the primary demand ($\mathbf{D^r}$) and derived supply ($\mathbf{S^r}$) curves and derived demand ($\mathbf{D^f}$) and primary supply ($\mathbf{S^f}$) curves depicts the initial equilibrium for retail beef and farm cattle, 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.

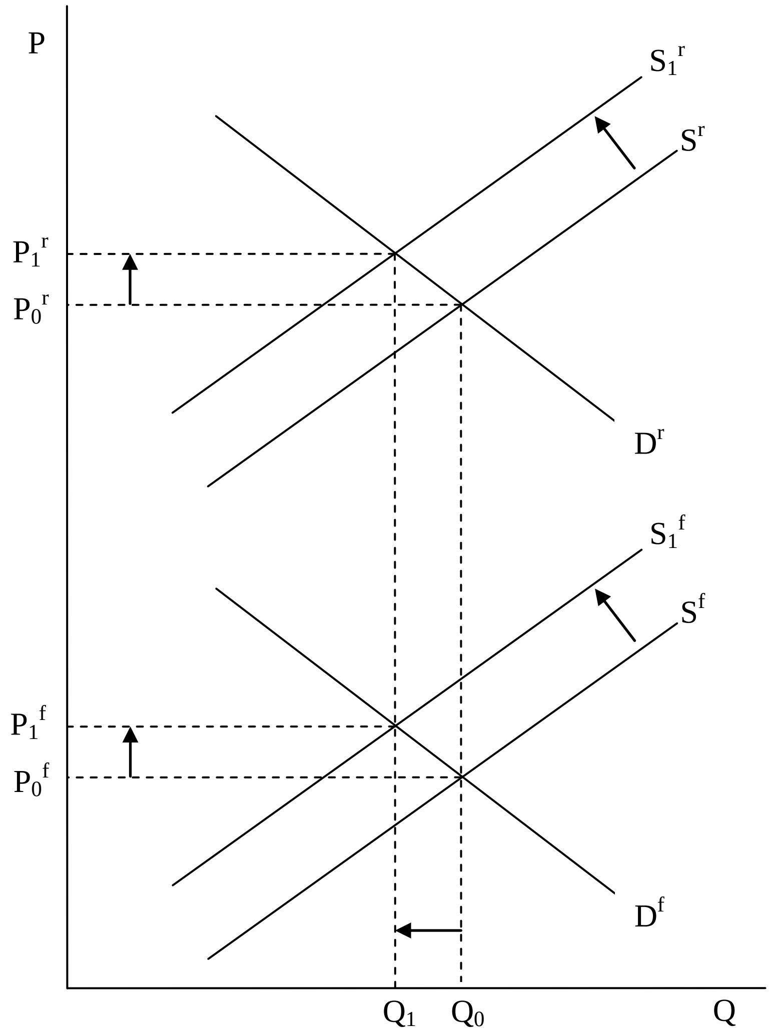


Figure 4.1: Effects of a One-time Supply Shock

In the event of a FMD outbreak, the effects of destroyed cattle quantities are reflected by a shift in the primary supply and derived supply curves to the left. 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 $\mathbf{Q^1}$ (figure 4.1).

Although primary demand did not change in this example, evidence from past outbreaks suggests there could be a small decrease in consumer demand. Allowing for consumer demand to decline, we would see a shift in the primary demand curve to the left (figure 4.2).

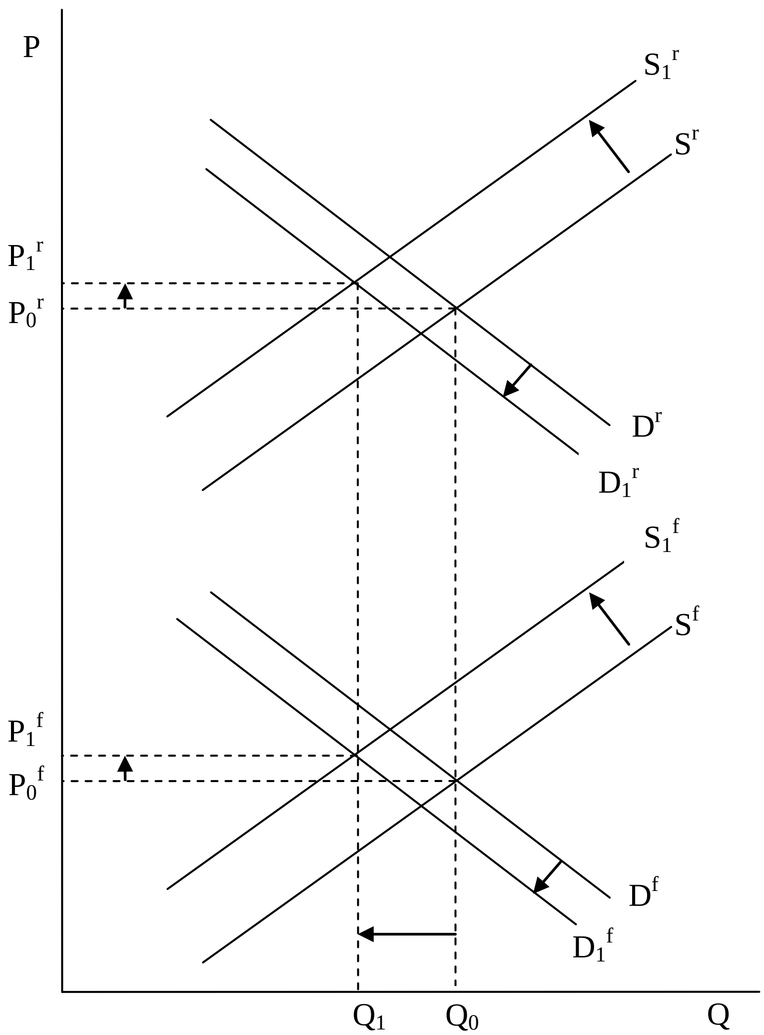


Figure 4.2: Effects of a One-time Demand Shock

With a decrease in consumer demand for beef, the derived demand for cattle would also decrease. Although the retail and farm level prices increase in figure 4.2, it could be constructed such that the new retail and farm level prices stay the same or decrease. The direction and size of change in the new prices depends on the size of demand and supply shock and elasticities of the supply and demand curves. However, the new quantity (**Q^1**) will be less than the initial quantity (**Q^0**).

Partial Equilibrium Model

This study uses a partial equilibrium model developed by Paarlberg et al. (2008), to measure changes in prices and quantities for different commodities caused by a FMD outbreak. The partial equilibrium model represents the U.S. agricultural sector. The model is designed as a quarterly and multicommodity model (18 commodities) which allows for vertical and horizontal linkages in the agricultural markets. Each agricultural sector is modeled in differential equation form requiring the model to depend on complementarity conditions. Each shock (supply, demand, and international trade) is introduced into the model as percentage changes. The percent changes are applied once the disease outbreak initially occurs in the second quarter of 2007 (i.e., base period). The model is then run through the first quarter of 2010 simulating the economic impacts of a FMD outbreak. Complete documentation of the model and parameters is provided in Paarlberg, et al. (2008).

The model framework developed by Paarlberg et al. (2008), and used in this study, has been used in several other studies that have examined the economic impacts due to a disease outbreak to the U.S. livestock sector. One such study, Paarlberg et al. (2007) used the model to examine the economic impacts in the United States from a highly pathogenic avian influenza outbreak. The study found that the economic impact to the poultry meat production sector would range from $500 to $718 million (Paarlberg et al., 2007).

Paarlberg et al. (2008) used the model to show that an FMD outbreak in the United States would cause economic losses of $2.7 to $4.1 billion (2008). The largest impact from this study was shown to be the losses in trade markets to other countries. Arguably, U.S. consumers could benefit from a FMD outbreak in the form of lower prices caused from increased meat supplies due to an export embargo.

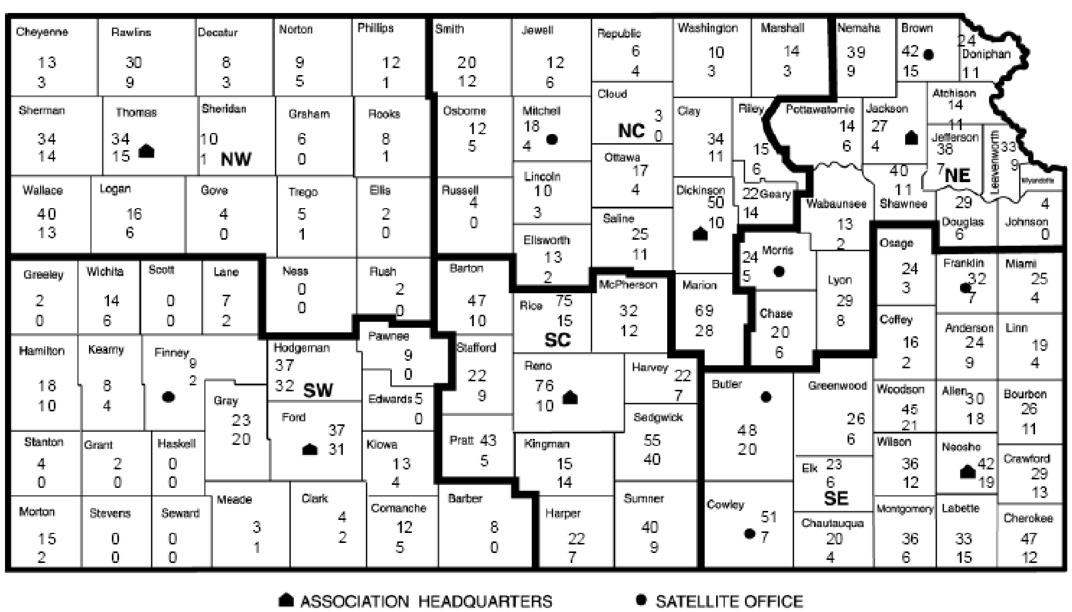
Paarlberg et al. (2009) used the model to analyze the economic impacts of a CSF outbreak. The study found that the pork industry would suffer a loss of $4.1 billion for hogs, and a reduction to returns on capital and management of $7.7 billion for all commodities (Paarlberg et al., 2009). Further, the study found that economic implications do depend on a few factors which will influence the results such as: total number of the animals destroyed, location of the animals destroyed, production type of animals destroyed, trade impacts, producer expectations, and length of the disease outbreak.

Average Farm Development

Studying the exogenous supply shift caused by feral swine transmission of FMD to Kansas livestock results in change in prices and quantities. Using the price changes from the partial equilibrium model, impacts at the farm level can be examined. To arrive at these farm level impacts, whole farm budgets are constructed. The Kansas Farm Management Association (KFMA, 2010) database is a comprehensive resource of farm data and is used to develop an accurate representation of Kansas producers. The section below will describe how average farms are developed.

Average farms are constructed from a weighted average process of farm populations provided by the KFMA database. With the FMD supply shock being a one-time occurrence over the short-run, developing an average farm for each region reveals the economic impacts at the farm level (Sharples, 1969). Prior work has followed the methodology of Day (1963), but with recent development of databases with information becoming readily accessible, the simple averaging approach has become used more often in conjunction with the use of expert panels comprised of producers to validate the accuracy of the farms (Bobst, Burris, and Hall 1980; Feinerman, Herriges, and Holtkamp; 1992; Gray, Richardson, and McClaskey 1995; Knutson, et al. 1997; Kobrich, Rehman, and Khan, 2003; Taylor, Koo, and Swenson, 2009.).

For this study, the KFMA database is used for its ease of access and availability to analyze and develop average farm sizes. Summary reports by region for net farm income are used to develop each average farm size. This data is used to find the average acres for each of the major crops produced and the number of livestock raised in each of the six KFMA regions (figure 4.1).



Source: www.agmanager.info/kfma/

Figure 4.3: Map of Kansas Farm Management Association Regions

A weighted average over the previous three years worth of data (2006, 2007, and 2008) is used to develop the total acres and number of livestock for each crop farm. The weighted average is calculated as follows:

(1)

For example, to determine the average number of acres of irrigated corn produced in Northwest Kansas, the number of farms located in Northwest Kansas that produced irrigated corn was 73, 79, and 83 in 2006, 2007, and 2008, respectively. The average acres of irrigated corn produced in Northwest Kansas for 2006-2008 were 470, 516, and 502, respectively. The total count of farms in the KFMA database for that region was 171, 153, and 166 in 2006, 2007, and 2008, respectively. Using equation 1, the weighted average acres of irrigated corn in Northwest Kansas is calculated as follows:

(2)

The remaining commodities are estimated in the same manner. Table 4.1 lists the average number of acres for each crop by region. These crop acres are used in developing whole farm budgets for each of the six KFMA regions.

Table 4.1: Average Farm Descriptions for Crops and Livestock

Location:	NORTH CENTRAL	NORTH EAST	NORTH WEST	SOUTH CENTRAL	SOUTH EAST	SOUTH WEST
Farm Type:	Crop Farm	Crop Farm	Crop Farm	Crop Farm	Crop Farm	Crop Farm
Irrigated Crop	**Acres**	**Acres**	**Acres**	**Acres**	**Acres**	**Acres**
CORN	12.65	34.48	239.36	113.23	6.23	109.23
GRAIN SORGHUM	2.40	0.00	3.42	6.61	0.00	28.55
SOYBEANS	10.26	21.85	21.84	63.29	4.81	19.27
WHEAT	2.65	0.59	61.03	29.66	0.00	52.69
ALFALFA	0.24	0.00	7.10	9.81	0.00	22.69
HAY & FORAGE	1.32	0.59	29.02	5.78	0.00	13.95
TOTAL	29.52	57.51	361.77	228.38	11.04	246.38
Non-Irrigated Crops	**Acres**	**Acres**	**Acres**	**Acres**	**Acres**	**Acres**
CORN	58.53	289.45	280.07	66.36	274.65	26.81
GRAIN SORGHUM	194.02	22.67	178.62	211.33	50.29	213.93
SOYBEANS	199.84	386.90	11.30	135.47	442.59	0.00
WHEAT	507.87	100.36	719.79	799.70	298.03	620.80
ALFALFA	59.73	14.50	12.94	59.12	12.85	5.13
HAY & FORAGE	122.72	124.41	79.36	44.96	135.70	46.97
TOTAL	1142.71	938.29	1282.08	1316.94	1214.11	913.64
TOTAL FARM ACRES	1172.23	995.80	1643.85	1545.32	1225.15	1160.02
Livestock	**Number of Head**	**Number of Head**	**Number of Head**	**Number of Head**	**Number of Head**	**Number of Head**
TOTAL CATTLE	**171.67**	**152.00**	**133.67**	**66.67**	**167.67**	**104.66**
BEEF COWS	43.67	46.00	42.67	25.67	58.00	9.33
BEEF PURCH. FOR RESALE SALES	128.00	106.00	91.00	41.00	109.67	95.33
TOTAL HOGS	**0.00**	**101.33**	**0.00**	**17.00**	**12.33**	**0.00**
SWINE PURCH. FOR RESALE SALES	0.00	101.33	0.00	17.00	12.33	0.00

Whole Farm Budgets

With the number of acres for each major crop grown in each of the six regions as defined in table 4.1, average farm budgets were constructed from individual enterprise budgets for each crop. To construct each crop and livestock enterprise budgets, data is collected at Kansas State University's AgManager website (AgManager, 2010). To maintain a consistent time frame with a majority of livestock production data originating from the NASS 2007 Census and the disease introduction occurring in the second quarter of 2007 enterprise budgets are developed based on Kansas 2007 prices as reported by

Kansas State University's AgManager website (AgManager, 2010). Once each enterprise budget is developed, it was assumed that these are the base prices. All price changes resulting from an FMD outbreak in Kansas will be simulated from the partial equilibrium model. The resulting changes in commodity prices will then be applied to the base budget levels to analyze the changes to six average farms in Kansas.

Table 4.2 shows a typical wheat enterprise budget for an average farm in southwest Kansas. The gross receipts for raising wheat are shown in the first section of the wheat enterprise budget. The next section shows the direct costs associated with raising wheat and the last line shows the returns from growing wheat for an average farm in southwest Kansas.

Table 4.2: Typical Enterprise Budget

Feral Swine FMD Transmission in Kansas				
WHEAT			***SOUTHWEST KANSAS***	
Cost Per Acre			**NUMBER OF ACRES**	**620.8**
GROSS RECIPTS FROM PRODUCTION				
GROSS RECEIPTS	**Yield**	**Price**	**$/Acre**	**Value for Operation**
YIELD (per acre)	45.00	$4.68	$210.60	$130,740
NET GOVERNMENT PAYMENTS			12.20	$7,574
INDEMNITY PAYMENTS			0.00	$0
MISCELLANEOUS INCOME			0.00	$0
Total Receipts			**$222.80**	**$138,314**
DIRECT COSTS				
			Cost/Acre	**Value for Operation**
OPERATING COSTS				
SEED			8.45	$5,246
HERBICIDE			9.44	$5,860
INSECTICIDE/FUNGICIDE			0.00	$0
FERTILIZER AND LIME			23.07	$14,322
CROP CONSULTING			0.00	$0
CROP INSURANCE			0.00	$0
DRYING			0.00	$0
MISCELLANEOUS			5.50	$3,414
CUSTOM HIRE/MACHINERY EXPENSE			72.00	$44,698
NON-MACHINERY LABOR			8.14	$5,053
IRRIGATION				
LABOR			0.00	$0
FUEL AND OIL			0.00	$0
REPAIRS AND MAINTENANCE			0.00	$0
DEPRECIATION ON EQUIPMENT			0.00	$0
INTEREST ON EQUIPMENT			0.00	$0
LAND CHARGE/RENT			60.00	$5
SUB TOTAL			**$186.60**	**$115,841**
INTEREST ON 1/2 NONLAND COSTS			4.75	$4,344
Total Direct Costs			**$191.35**	**$118,790**
RETURN TO MANAGEMENT & RISK			**$31.45**	**$19,524**

For this study it was assumed that costs of production for all commodities would remain constant over the duration of the disease outbreak. This assumption had to be made in order to account for the fact that the economic model does not have the ability to determine the changes that will occur to production costs from a disease outbreak. Once each enterprise budget is developed for all the crops and livestock produced on each average farm the budgets can then be compiled into a whole farm budget. The whole farm budget is a representation of the average farm at a point in time and this allows for the economic modeling to be conducted. Table 4.3 shows a whole farm budget for an average farm in southwest Kansas. Once the partial equilibrium model is simulated, the resulting percentage change in each commodities price are applied to the base price (in this case for wheat $4.68). It is from this point that the study is able to determine the economic impacts to producer's net farm income from a disease outbreak. Table 4.3 shows a typical whole farm budget for an average farm in southwest Kansas.

Table 4.3: Typical Whole Farm Budget

Feral Swine FMD Transmission in Kansas							
WHOLE FARM BUDGET							*Crop Farm*
SOUTHWEST KANSAS						NUMBER OF ACRES	1160.02
GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres	Value to Operation
CORN	826	322	Acres	109.23	26.81	136.04	$ 98,838
SOYBEANS	490		Acres	19.27		19.27	9,445
WHEAT	360	223	Acres	52.69	620.80	673.49	157,289
GRAIN SORGHUM	447	288	Acres	28.55	213.93	242.48	74,403
FORAGE SORGHUM SILAGE	553	186	Acres	13.95	46.97	60.92	16,438
ALFALFA	840	527	Acres	22.69	5.13	27.82	21,760
Crop Gross Income	**3,515**	**1,546**		**246**	**914**	**1,160**	**$ 378,174**
Livestock	($/Head)		Unit	Head		Total Head	Value to Operation
BEEF COWS	501		Head	9		9	$ 4,674
BEEF PURCH. FOR RESALE SALES	371		Head	95		95	35,392
Livestock Gross Income	**872**		**Head**	**105**		**105**	**$ 40,066**
TOTAL GROSS INCOME	**4,387**						**$ 418,240**
DIRECT COSTS							
CORN	677	279	Acres	109.23	26.81	136.04	$ 81,422
SOYBEANS	435		Acres	19.27		19.27	8,392
WHEAT	403	191	Acres	52.69	620.80	673.49	140,006
GRAIN SORGHUM	473	233	Acres	28.55	213.93	242.48	63,424
FORAGE SORGHUM SILAGE	621	178	Acres	13.95	46.97	60.92	17,007
ALFALFA	562	250	Acres	22.69	5.13	27.82	14,043
Total Crop Variable Costs	**3,172**	**1,131**	**Acres**	**246**	**914**	**1,160**	**$ 324,295**
Livestock	($/Head)		Unit	Head		Total Head	Value to Operation
BEEF COWS	619		Head	9		9	$ 5,775
BEEF PURCH. FOR RESALE SALES	448		Head	95		95	42,708
Total Livestock Variable Costs	**1,067**		**Head**	**105**		**105**	**$ 372,778**
Total Gross Margin							**$ 45,463**
OTHER EXPENSES							
Other							
Misc							
Total Other Expenses							
NET FARM INCOME							**$ 45,463**

The whole farm budget shows the total number of acres for each crop, the dollars per unit for each crop and the total value to the operation. A whole farm budget is constructed much like the individual enterprise budgets. The gross income for the farm is shown in the first section. The next section, direct costs, shows the combined fixed and variable costs associated with raising each crop. The total gross income for the farm is then subtracted from the variables costs to return the total gross margin for the farm. Minus any other expenses and the net farm income is found. The basic framework found in tables 4.2 and 4.3 are used to develop enterprise budgets for each commodity and whole farm budgets for each average farm. Table 4.4 shows the resulting base whole farm income levels that were found prior to any price changes.

Table 4.4: Base Whole Farm Income Levels

LOCATION	NORTH WEST	NORTH CENTRAL	NORTH EAST	SOUTH WEST	SOUTH CENTRAL	SOUTH EAST
GROSS INCOME	626,551	397,642	399,096	418,241	525,260	449,342
VARIABLE COST	559,835	367,350	363,259	372,778	456,532	404,008
NET FARM INCOME	**66,716**	**30,292**	**35,837**	**45,463**	**68,728**	**45,334**

Farm Level Impact Results

Once base whole farm income levels are determined the results from the partial equilibrium model are used to determine the farm level impacts. To calculate the changes in prices, a percentage change between the base price and the new post-outbreak price is calculated. This percentage change is then applied to base prices for Kansas to simulate the changes in net farm income for each quarter. The results for each of the six average farms are listed in the next section. The results are calculated for three years. An analysis was done for five years but it was found that prices begin to return to base levels once the trade restrictions are lifted and any further analysis would not be needed past three years.

CHAPTER 5 – RESULTS

This section presents the results of this study. This chapter is divided into two sections: epidemiological output and economic output. The economic output section is further divided into results from the partial equilibrium model and farm level impacts.

Epidemiological Output Results

The results from feral swine FMD transmission to domestic livestock in Kansas will be discussed in this next section. The epidemiological output is expressed as means derived from 1,000 iterations from each simulation. Table 5.1 reports mean number of animals destroyed by production type and the duration of the FMD outbreak. Although the mean number of animals destroyed is larger and the mean duration of the outbreak is longer than recent studies (e.g., Greathouse (2010), Paarlberg et al. (2008), Pendell et al. (2007),Pendell et al. (2006), and Schoenbaum and Disney (2003)), the mean values varied little across the three scenarios (e.g., 193 days vs. 192 days vs. 189 days), which is consistent with recent studies.

The epidemiological results from the NAADSM simulation are shown in Table 5.1. Under no surveillance the largest amount of animals are destroyed, 2,599,419, and the duration of the disease outbreak lasts the longest at 193 days. Under twice per month surveillance, 2,555,768 animals are destroyed and the outbreak lasts 189 days. Once per week surveillance shows that 2,585,666 animals are destroyed and the duration lasts 192 days. Even though there is a small number of animals saved under the surveillance scenarios there still are benefits to conducting surveillance on feral swine populations. With twice per month surveillance showing more animals being saved and shorter outbreak duration than once per week (best case scenario) could be due to the stochastic nature of NAADSM as it runs each iteration pulling the disease spread parameters from predefined probability distributions specified within the model. These results may show that a twice per month surveillance program would be a better program, but research by Shwiff et al. (2010) have shown similar NAADSM scenarios modeled in other large livestock producing states in the U.S. indicate a greater benefit for once per week surveillance. The NAADSM results also show that southwest Kansas, with its large density of livestock population, could potential have large livestock losses from a highly contagious and quick spreading disease such as FMD.

Table 5.1: Results of Animals Destroyed by Surveillance Levels

Surveillance Scenario:	No Surveillance		Twice Per Month		Once per Week	
	Animals Destroyed	St Dev.	Animals Destroyed	St Dev.	Animals Destroyed	St Dev.
Feral Swine	**0**	**0**	**5**	**0**	**5**	**0**
Total Cattle	**2,391,282**	**187,307**	**2,352,749**	**325,760**	**2,377,177**	**248,998**
Feedlot (L)	2,329,040	168,473	2,295,878	305,027	2,318,505	229,756
Feedlot (S)	24,220	5,225	20,366	4,961	21,031	4,435
Cow-Calf	3,618	992	2,471	975	2,036	804
Dairy	34,404	12,616	34,034	14,797	35,605	14,004
Total Swine	**207,133**	**46,895**	**202,340**	**54,674**	**207,883**	**50,486**
Swine (B)	**40**	**6**	**30**	**6**	**27**	**7**
Breeding	4	1	3	1	3	1
< 60	12	2	9	2	8	2
61-119	8	1	6	1	5	1
120-179	6	1	5	1	4	1
> 180	10	1	7	2	7	2
Swine (L)	**206,852**	**46,709**	**202,038**	**54,458**	**207,602**	**50,244**
Breeding	19,805	4,470	19,344	5,212	19,877	4,808
< 60	63,816	14,410	62,331	16,800	64,047	15,500
61-119	40,160	9,066	39,225	10,570	40,306	9,752
120-179	32,458	7,329	31,703	8,544	32,576	7,883
> 180	50,613	11,430	49,435	13,326	50,796	12,295
Swine (S)	**241**	**181**	**272**	**210**	**254**	**235**
Breeding	23	17	26	20	24	22
< 60	74	56	84	65	79	72
61-119	47	35	53	41	49	46
120-179	38	28	43	33	40	37
> 180	59	44	66	51	62	58
Sheep	**940**	**339**	**621**	**351**	**549**	**336**
Goats	**64**	**18**	**53**	**21**	**52**	**23**
TOTAL LOSS	**2,599,419**	**164,404**	**2,555,768**	**301,468**	**2,585,666**	**258,268**
Outbreak Duration (days)	193	42	189	45	192	45

(L) = Denotes a Large livestock operation
(S) = Denotes a Small livestock operation
(B) = Denotes a Backyard livestock operation

For the economic modeling process, some production types are broken down in to further categories of production phases. For example, there were five production phases for swine; breeding, swine weighing less than 60 pounds, swine weighing between 61 and 119 pounds, swine weighing 120 to 179 pounds and swine weighing greater than 180 pounds. NASS Census data, for each production type modeled, is collected for the state of Kansas. To find the number of animals in each production phase the number of animals in each production phase, as reported by NASS, is divided by the total number of swine on inventory. This gives the percentage, of total swine on inventory, for each production phase. The percentage is then multiplied by the number of animals destroyed for each production unit, which gave the number of animals destroyed in each production phase.

Surveillance Detection Results

A key part of the surveillance programs modeled in NAADSM was to determine if FMD is initially detected in the feral swine populations. If FMD is in fact detected initially in the feral swine population then the surveillance program is effectively detecting the disease in the wildlife population, and thereby minimizing the economic impacts. Detecting FMD initially in the feral swine population validates the surveillance program.

By conducting no surveillance, FMD is first detected 88% of the time in small backyard operations (table 5.2). This suggests that it may be necessary to monitor smaller swine operations as they may have less biosecurity and have the potential for increased contact with wildlife; thus, furthering the possibility for disease spread. Table 5.2 also reflects a benefit for feral swine surveillance in that 50% of the time FMD will be detected in the feral swine population, and 47% of the time FMD will be caught in smaller backyard swine operations. By conducting surveillance twice per month, the results suggest the benefit of surveillance and also the need to continue monitoring smaller swine operations. The ideal surveillance scenario modeled was the once per week. As table 5.2 shows once per week surveillance initially detects FMD in the feral swine population 74% of the time and 26% of the time in small swine operations. This further suggests that active surveillance of feral swine is a viable tool to early detection and potential elimination of the threat of diseases, specifically FMD. These results also show the inherent danger of wildlife disease transmission and the necessity for increased biosecurity on livestock.

Table 5.2: First Detection of FMD

No Surveillance			Twice per Month			Once per Week		
Production Type	First Detected	% of Total	Production Type	First Detected	% of Total	Production Type	First Detected	% of Total
Cow-Calf	4	0.40%	Cow-Calf	3	0.30%	Feedlot(L)	1	0.10%
Dairy	40	4.00%	Dairy	10	1.00%	Feedlot(S)	5	0.50%
Feedlot(L)	16	1.60%	Feedlot(L)	5	0.50%	Feral Swine	738	73.80%
Feedlot(S)	45	4.50%	Feedlot(S)	11	1.10%	Sheep	1	0.10%
Goats	5	0.50%	Feral Swine	504	50.40%	Swine(B)	255	25.50%
Sheep	4	0.40%	Goats	1	0.10%	Total	1000	100%
Swine(B)	883	88.30%	Swine(B)	466	46.60%			
Swine(L)	3	0.30%	Total	1000	100%			
Total	1000	100%						

Exogenous Shocks

The epidemiological results from NAADSM were converted to percentage changes and input into the partial equilibrium economic model. This was accomplished by taking the mean number of animals stamped-out and dividing it by the total U.S. livestock population, by production type, for each quarter. The results were a percentage change in the total U.S. supply of livestock by production type. Total livestock inventories were defined within the partial economic model. With the FMD outbreak occurring in the 2nd quarter of 2007, it was assumed that 75% of the animals were depopulated in that quarter. The remaining 25% of animals were destroyed during the 3rd quarter of 2007. Table 5.3 reports the exogenous supply shocks by surveillance scenario.

The partial equilibrium model has the ability to model changes in consumer demand. A 10% decrease in consumer demand for the first two weeks during the outbreak in the first quarter was assumed in this research. Annually, this equates to a

1.56% decrease in consumer demand. This seems reasonable as recent studies (e.g., Piggot and Marsh, 2004) have found food safety scares to be short-lived in the U.S. Additionally, this is the same size of consumer demand shock used by Paarlberg et al. (2008).

International trade is another major issue when dealing with animal diseases. It is assumed the U.S. would lose exports of meat and live animals during the outbreak and for one full quarter (3 months) after the outbreak ends. This follows directly from the OIE guidelines for a nation free of FMD and then returning to a FMD free state (OIE, 2010). Once the outbreak is officially over (three months after the last infected animal is destroyed), it is assumed that trade returns to pre-disease trade levels.

Table 5.3: Exogenous Shock (%)

	2007			2008
	Q2	Q3	Q4	Q1
Production Shocks				
Feedlot	-5.03%	-1.68%	0%	0%
Breeding Swine	-0.23%	-0.08%	0%	0%
Swine Late on Feed	-0.15%	-0.05%	0%	0%
Swine Early on Feed	-0.15%	-0.05%	0%	0%
Dairy	-0.23%	-0.08%	0%	0%
Consumption Shock				
10% of population out for 2 weeks	-1.56%	0%	0%	0%
Trade Shocks - Exports				
Beef	-95%	-95%	-95%	0%
Pork	-90%	-90%	-90%	0%
Lamb/Sheep Meat	-100%	-100%	-100%	0%
Milk	0%	0%	0%	0%
Live Beef Cattle	-100%	-100%	-100%	0%
Live Swine	-100%	-100%	-100%	0%
Live Lambs/Sheep	-100%	-100%	-100%	0%
Live Dairy Cattle	-100%	-100%	-100%	0%

For this study one economic analysis was conducted due to similar epidemiological results found from the NAADSM modeling. With approximately the same supply shocks occurring for each of the surveillance scenarios the no surveillance scenario is used for the economic analysis which will determine the results for a worst case scenario. The economic results for the no surveillance scenario are then used to analyze the economic impacts to the six average farms as developed previously.

Economic Model Results

Results from the partial equilibrium model (Figure 5.1) indicate that feral swine transmission of FMD to domestic livestock in Kansas has a producer loss of $5,771 million during the duration of the FMD outbreak and the trade embargo (i.e., first three quarters of the outbreak). Further, during the first three quarters of the outbreak consumers are gaining from a FMD outbreak in the form of lower meat prices as the export markets are closed. Once the disease has been eradicated (quarter 2) and export markets are fully open (quarter 3) we see a change in the welfare measures. Producers are not losing but gaining from higher livestock prices and consumers are losing from higher meat prices. By quarters 7 and 8 the consumer and producer welfare is returning back to pre-disease levels. These findings are similar to what was found by Paarlberg et al. (2008) who found that consumers can benefit from an FMD outbreak and Zhao, Wahl, and Marsh (2006) which found that producers can gain from higher beef prices once the disease outbreak has finished.

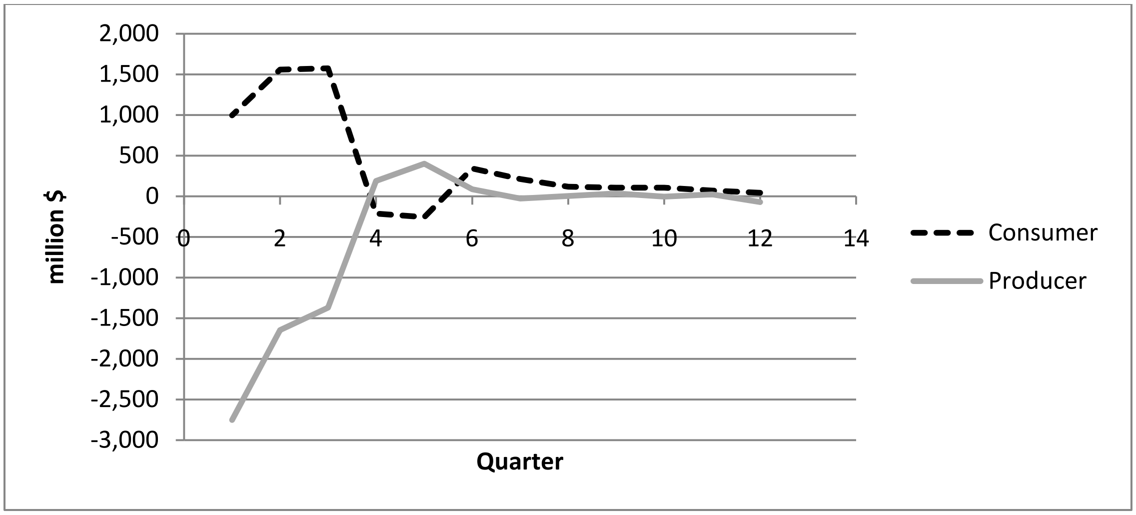


Figure 5.1: Consumer and Producer Welfare Impacts

The producer welfare for cattle and swine producers is found in Figure 5.2. Figure 5.2 shows that the FMD outbreak decreases producer welfare during the first three quarters of the outbreak, but once trade restrictions are lifted producer welfare increases. After quarter 6, producer welfare has returned to base levels.

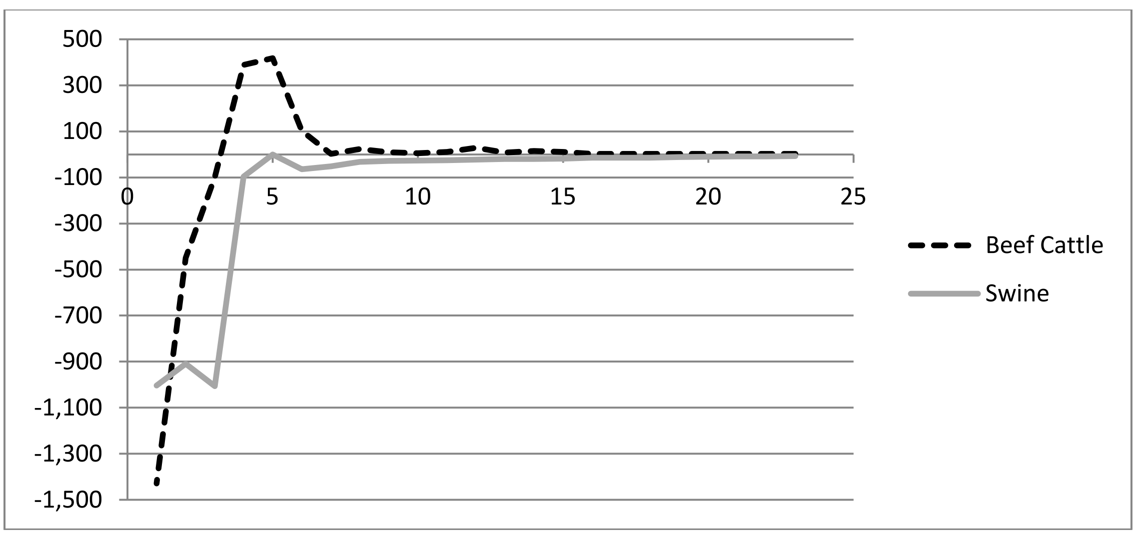


Figure 5.2: Producer Welfare for Cattle and Swine Producers

Swine producers in figure 5.2 have the largest negative impact ($2,920 million) during the first three quarters of the FMD outbreak when the disease spread is occurring and the trade restrictions are implemented. Similarly, beef producers also see large losses

($1,978 million) during the disease outbreak and trade restrictions. Although there is a larger loss to beef producers in quarter 1 ($1,429 million), the swine industry losses over the first three quarters are larger. Similar to beef, the swine industry sees a sharp decline in total producer welfare and once trade restrictions are lifted, welfare starts to increase. By quarter 6, welfare has returned to base levels, but there is not an increase above base levels similar to what was found with beef cattle.

The partial equilibrium model suggest that there is a small impact to eggs and layers, dairy cattle and milk, and lambs and sheep, but the impact is small and the economic significance to the study would be minimal. The impacts to crops will be discussed later, but it is necessary to point out that there were no government price supports for crops during the first two years of the economic analysis. In quarter 9, government price supports begin to factor into the economic results. Government price supports are not needed during the first two years of the FMD outbreak because crop prices are higher than government price support levels which are likely being driven by other factors external to the model such as the demand for ethanol during this time frame. Government support is an important factor to address because taxpayers are paying for the government supports in the form of taxes.

Economic Impacts to Livestock and Meat

With most of the livestock production in Kansas consisting of beef cattle production, these sectors were affected much more from a FMD outbreak. Figures 5.3 and 5.4 show that a FMD outbreak keep prices relatively constant through the duration of the outbreak, especially in retail level beef. Once the outbreak is finished then prices start to increase sharply once the trade restrictions are lifted. In the 1st quarter the price for live steers was $89.89/cwt, in quarter 2 price was $90.62/cwt, quarter 3 price was $91.59/cwt, and then prices start to increase to $97.92/cwt in quarter 4 and $99.68/cwt in quarter five (figure 5.3). After quarter 6, the price of cattle and retail prices start to follow the base levels indicating that market levels have returned to normal.

Beef

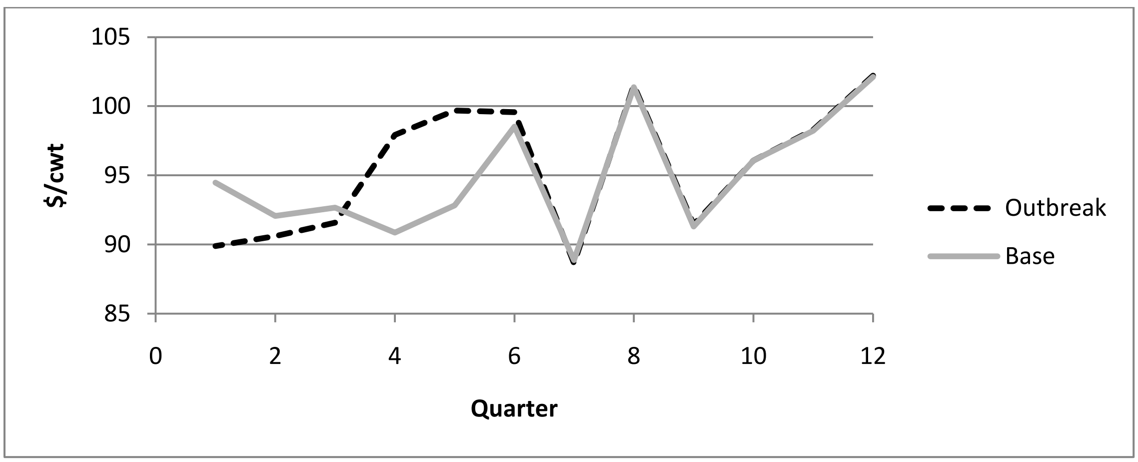


Figure 5.3: Price of Beef Cattle

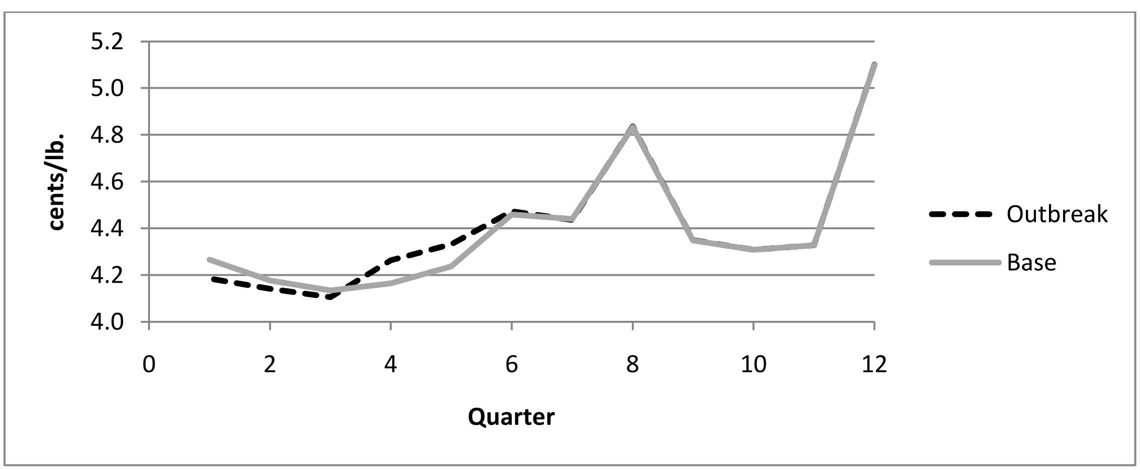


Figure 5.4: Price of Retail Beef

Even though there is not a large amount of hog production in Kansas, hog prices are still affected by a FMD outbreak. Figures 5.5 and 5.6 demonstrate the price for pigs and hogs declines quickly during the FMD outbreak from $49.36/cwt down to a low of $37.88/cwt. When the trade restrictions are lifted after the third quarter, the price for hogs starts to increase and follow the base prices. This demonstrates that the trade impacts that result from a FMD outbreak cause greater impacts then the depopulation shocks.

Pork

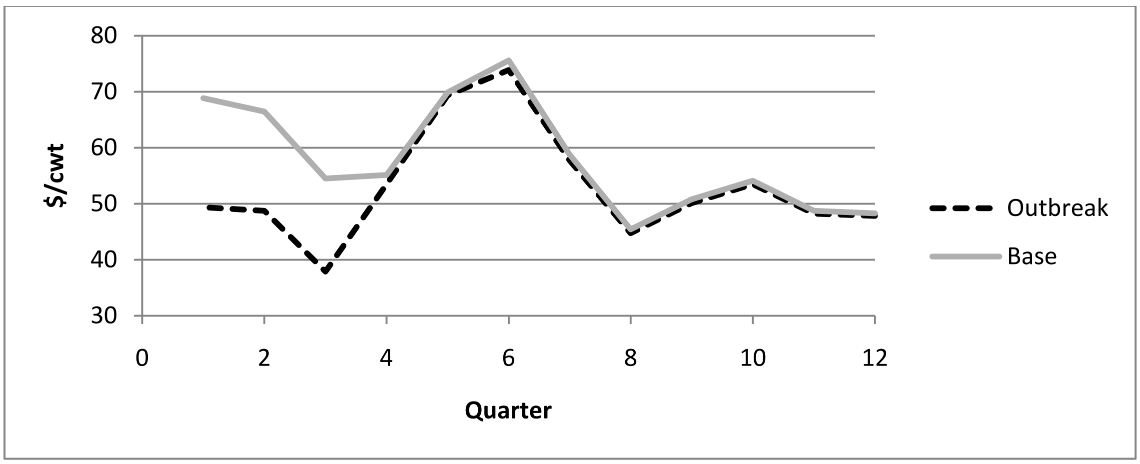


Figure 5.5: Price of Hogs

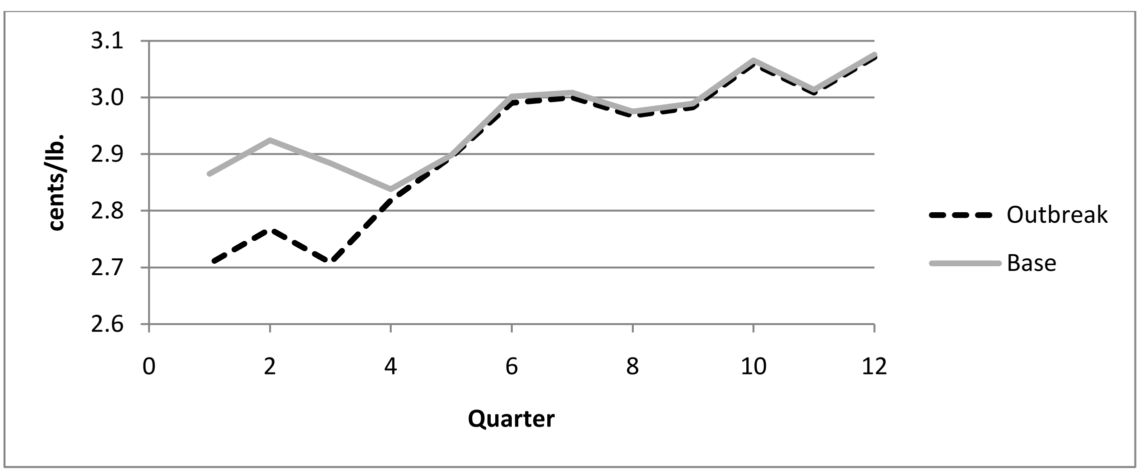


Figure 5.6: Price of Retail Pork

Economic Impacts to Crops

Although there are a significant amount of livestock destroyed from a FMD outbreak in Kansas, there is little affect on crop prices. Figures 5.7 - 5.9 show crop prices closely follow base level prices. These results indicate that even if there was a large change in crop prices, government price supports maintain the crop price. The crop price results are similar to those found in Paarlberg et al. (2008).

Corn

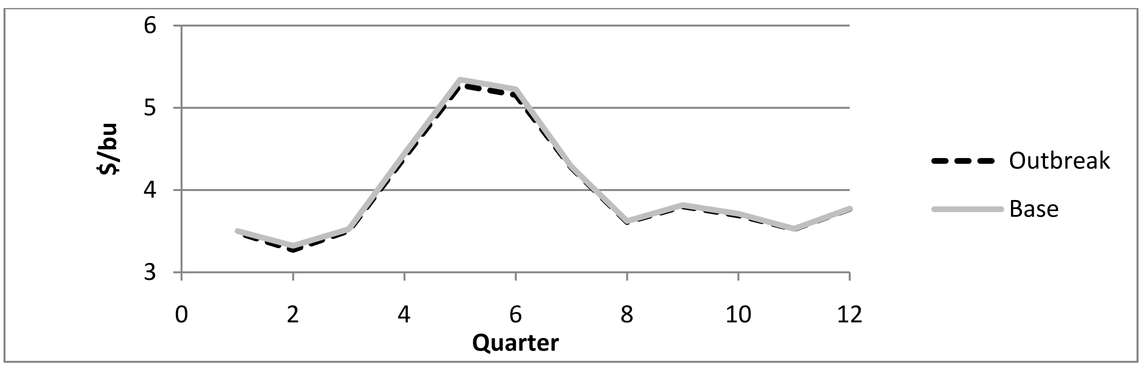


Figure 5.7: Price of Corn

Soybeans

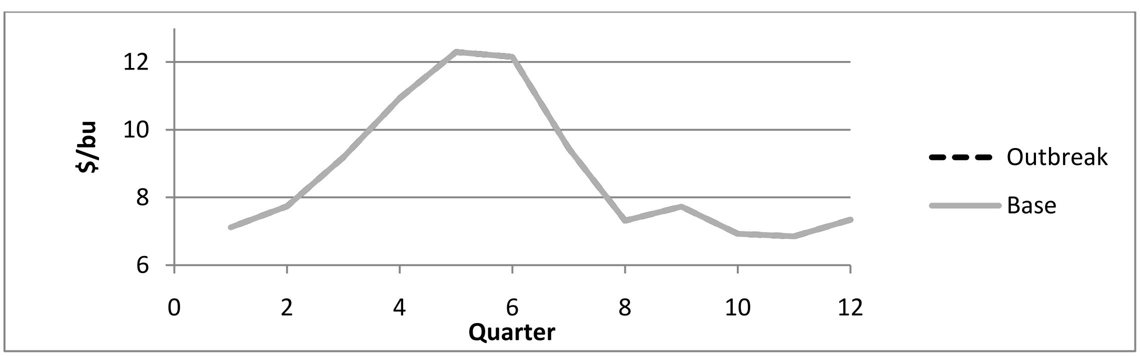


Figure 5.8: Price of Soybeans

Wheat

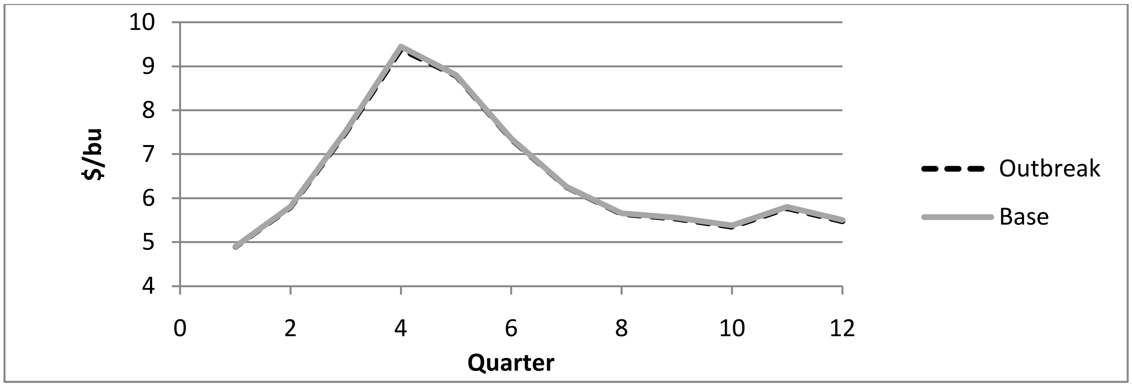


Figure 5.9: Price of Wheat

Results indicate that livestock industries are impacted by the FMD outbreak causing a drop in prices during the first three quarters of the outbreak. Once trade restrictions are lifted, prices begin to climb and return to base levels by quarter six. The economic modeling results demonstrate the impacts to the individual commodities, but the total economic loss to U.S. agricultural producers is over $5,771 million dollars. The largest impact comes during the first part of the outbreak when export markets are closed and officials are taking the necessary steps to contain and eliminate the disease.

For this study a time frame of three years was used to determine the economic impacts. The economic model analysis was run for five years, but it was found that commodities have returned to base levels and no further analysis past three years would be needed. Further, sensitivity analysis was conducted looking at the economic impacts during the first three quarters of the outbreak. The first three quarters where analyzed more closely because this is when the disease is spreading throughout the livestock population (first two quarters) and export markets are closed (first three quarters) causing the largest economic impacts. The findings discussed above show that the largest economic impacts occur during the disease spread phase and the trade restrictions. Once the disease is eliminated and trade markets are open again commodities start returning to base levels as soon as two years after the disease outbreak initially started.

Farm Level Impact Results

For this study, the focus is on a FMD outbreak to Kansas and the resulting impacts at the farm level. To conduct the farm level impacts, base average whole farm income levels were calculated for the six KFMA regions in Kansas (NW, NC, NE, SW, SC, and SE). Once these base income levels were calculated the price changes from the FMD outbreak were used to determine new average whole farm income levels (see Appendix B).

Table 5.4: Base Whole Farm Income Levels

LOCATION	NORTH WEST	NORTH CENTRAL	NORTH EAST	SOUTH WEST	SOUTH CENTRAL	SOUTH EAST
GROSS INCOME	626,551	397,642	399,096	418,241	525,260	449,342
VARIABLE COST	559,835	367,350	363,259	372,778	456,532	404,008
NET FARM INCOME	**66,716**	**30,292**	**35,837**	**45,463**	**68,728**	**45,334**

To calculate the changes in prices, a percentage change between the base price and the outbreak price was estimated. This percentage change was then applied to base prices for livestock and Kansas to simulate the changes in net farm income for each quarter. The results for each of the six average farms are below. The results are calculated for three years because prices begin to return to base levels once the trade restrictions are lifted after quarter three.

As a result of the FMD outbreak, farm level incomes drop below base levels as expected. Figures 5.10- 5.15 show the income levels follow the changes to livestock prices, in particular cattle, because there is little affect to crop prices. Average farms with large amounts of livestock have the biggest changes in net farm income.

The average farm for North Central Kansas has a 32.98% decrease in net farm income. By quarter three there is an 8.6% decrease in net farm income. Once trade restrictions are lifted after quarter three there is a sharp increase, 59.83%, in net farm income. By quarter five there is a 49.94% increase in net farm income and by quarter six net farm income levels are close to base levels.

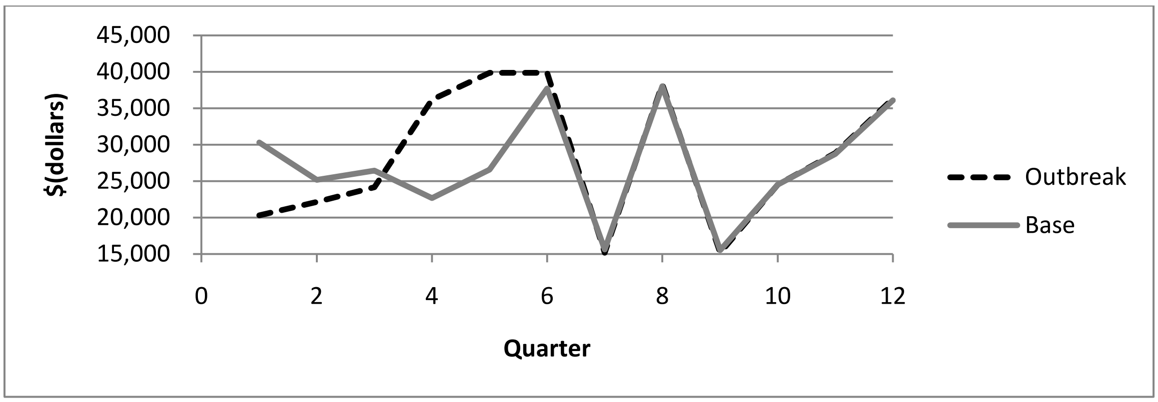


Figure 5.10: Change in Net Income: North Central Average Farm

The average farm in northeast Kansas has the second largest amount of cattle and the largest amount of swine. Once the FMD outbreak occurs there is a 39.48% decrease in net farm income. In quarter two there is a 24.21% decrease and in quarter three a 22.39% decrease in net farm income. When the trade restrictions are lifted after quarter three there is a 44.63% increase in net farm income above base levels. Quarter five reveals a 36.64% increase in net farm income and then net income starts to return to base levels in quarter six.

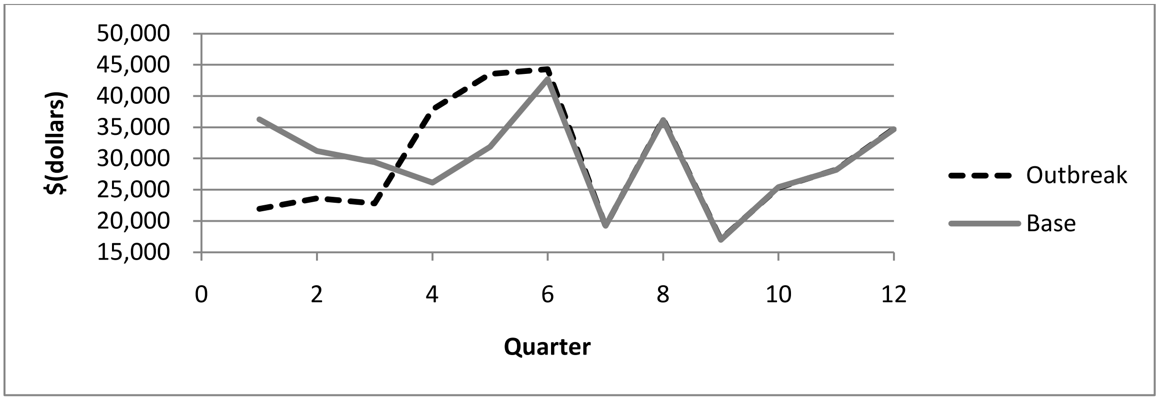


Figure 5.11: Change in Net Income: Northeast Average Farm

Average farms in northwest Kansas had an 11.66% reduction in net farm income in quarter one and once trade restrictions were lifted after quarter three there was a 17.39% jump in net farm income levels in quarter four and a 16.19% increase in quarter five.

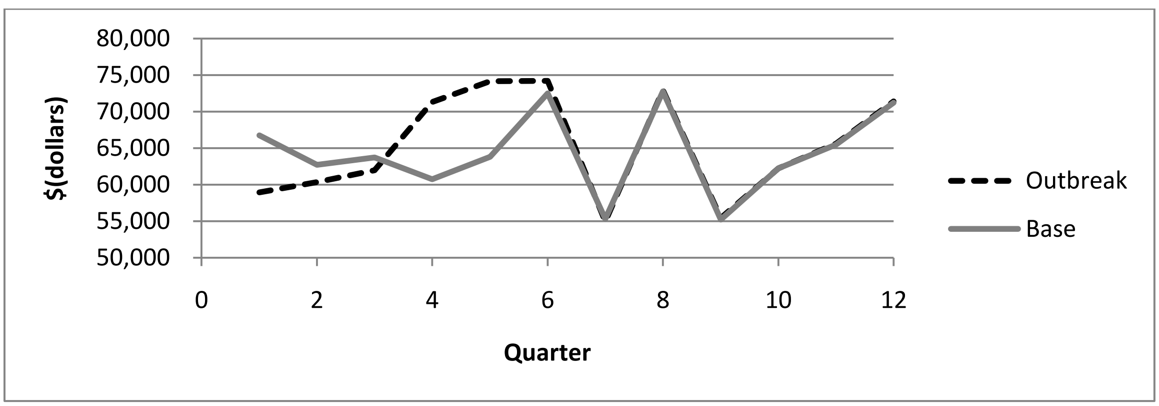


Figure 5.12: Change in Net Income: Northwest Average Farm

Average farms for south central Kansas see the smallest change in net farm income, 6.97%, relative to the other average farms. Once trade restrictions are lifted there is a 7.99% increase in net farm income in quarter four. It is necessary to point out that the average farm for south central Kansas has the smallest amount of livestock at 66.67 head of cattle and 17 head of swine. This reveals that farms with a small amount of livestock see the smallest changes in net farm income levels.

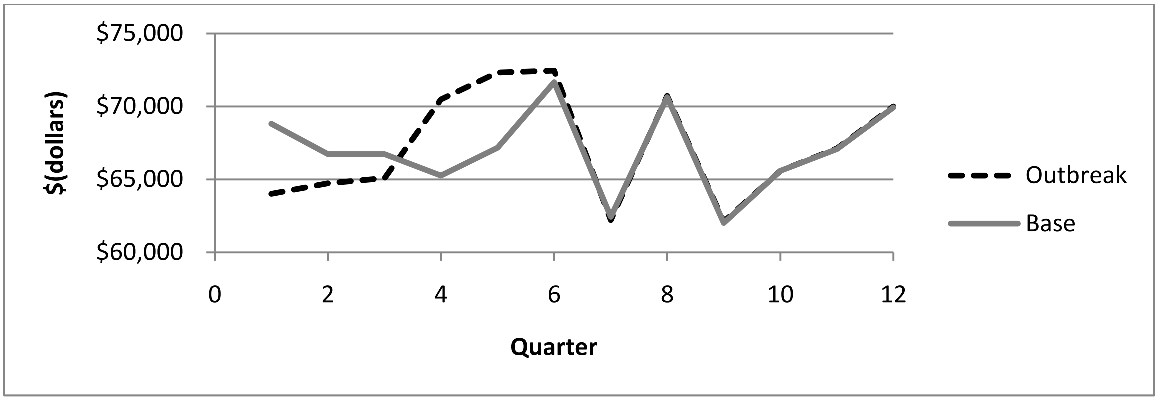


Figure 5.13: Change in Net Income: South Central Average Farm

Average farms in Southeast Kansas have the second highest amount of livestock as compared to the other five average farms. There was a 22.96% reduction in net farm income in quarter one of the FMD outbreak. As found in other average farm cases after trade restrictions are lifted there is a 35.24% increase in net farm income levels in quarter four, a 31.12% increase in quarter five and then start to return to base levels.

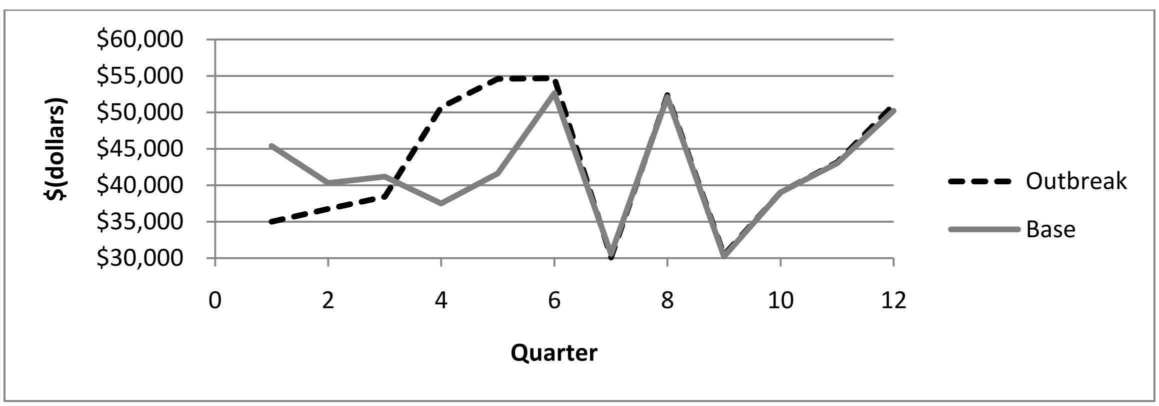


Figure 5.14: Change in Net Income: Southeast Average Farm

The average farm for southwest Kansas has similar results to other average farms in Kansas. In quarter one, there is a 13.40% reduction in net farm income levels and then a spike of 20.28% in quarter four and 18.73% in quarter five and finally returning to base levels.

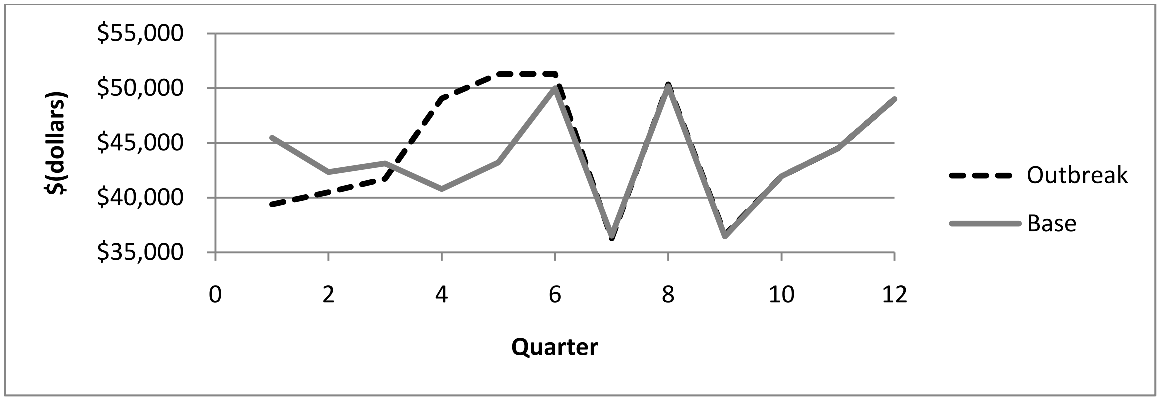


Figure 5.15: Change in Net Income: Southwest Average Farm

The average farm for northeast Kansas had the largest amount of livestock at 253 head. This average farm saw the largest percentage change in net farm income levels, a 39.48% initial reduction and a 44.63% increase in the quarter four. This is also the average farm with the highest amount of swine. The impacts to the average farm in northeast Kansas shows that producers with a large amount of livestock, in particular swine see the biggest percentage changes in net income levels. This would be expected as pig and hog prices decrease once the FMD outbreak occurs and return to base levels in quarter four showing that there is a loss in swine prices from a FMD outbreak. Those producers with large amounts of swine will have the greatest losses in that hog and pig prices drop below base levels and do not increase above base levels once trade restrictions are lifted like cattle prices do. Cattle prices initially decrease once the FMD outbreak occurs but then increase above base levels showing that average farms have the potential to regain lost revenues.

The implications from these whole farm income results indicate that a producer not in the quarantine zone have the potential to capitalize on increasing livestock prices once the trade restrictions are lifted after quarter three. Producers affected by the FMD outbreak may be looking to rebuild their operations and in need of replacement livestock. This provides the opportunity for some livestock producers to gain by selling their livestock at a higher price to make a profit.

Each of the average farms modeled in the study show what has occurred in the basic PEM framework discussed in Chapter 4. There is the initial supply shock from the FMD outbreak which results in a change in prices, but there is also a shift in the demand for cattle coming from the trade restrictions. This shifting of the supply and demand curves results in an initial decrease of livestock prices. Once the trade restrictions are lifted after quarter three the demand curve for meat starts to shift to the right resulting in higher livestock prices as is seen in beef cattle prices. The shifting of the supply and demand curves translates into changing net income levels at the farm level especially for producers with a large amount of livestock.

CHAPTER 6 – CONCLUSIONS AND SUMMARY

Summary

Feral swine have an increasing range expansion in the U.S., are highly reproductive, have uncontrolled movements, and are a reservoir for a host of diseases. One highly infectious disease of concern to the U.S. livestock sector is FMD. FMD has caused large economic impacts in other nations such as Taiwan where the economic impacts were $1.6 billion. The recent outbreak in the UK in 2001 was estimated to cause $11-$12 billion and if FMD were to get into the U.S. damages could be $14 billion.

The purpose of this study was to analyze the economic impacts of feral swine FMD transmission to livestock in Kansas. With Kansas having a large amount of livestock production, a FMD outbreak in the state could have large economic consequences. Surveillance of feral swine is modeled in this study as a tool to mitigate the risk of FMD transmission through feral swine to livestock in Kansas. To conduct the research, a bioeconomic modeling framework is constructed. NAADSM simulates the disease spread which reports the number of animals destroyed and the duration of the outbreak. The NAADSM output is then used in a partial equilibrium model to simulate the changes in prices and quantities of several commodities. The changes in prices of commodities are applied to average whole farm budgets in Kansas to determine the economic impacts at the farm level.

The results from this study show that conducting surveillance on feral swine does detect FMD first in the feral swine population 73.8% of the time and 25.5% of the time in small backyard swine operations. Under twice per month surveillance, first detected FMD in the feral swine population 50.4% of the time and 46.6% of the time in small backyard operations. With no surveillance, FMD was first detected 88.3% of the time in the small backyard operations. Surveillance does detect FMD in the feral swine populations, and if it is not detected in the feral swine population, then it most likely will be detected in the small backyard operations with less than 25 head of swine. This analysis highlights that the small livestock operations with less biosecurity have an increased threat of foreign animal disease transmission and need to be monitored closely.

Comparing the surveillance scenarios to the no surveillance scenario there are 43,655 fewer animals stamped-out under twice per month surveillance and 13,751 fewer animals under once per week surveillance. The duration of the outbreak is reduced by four days under twice per month and one day under once per week surveillance. The surveillance results suggest that FMD is a highly contagious disease which can spread quickly in areas with large populations of livestock, such as in Kansas.

Modifying NAADSM to incorporate feral swine as a production unit enabled the development of NAADSM to incorporate wildlife and the impacts they could potentially have on U.S. livestock production. Determining the economic impact to the Kansas economy was done by taking the NAADSM output (number of animals dead) and inputting those results into the partial equilibrium as a percentage reduction in the U.S. supply which gave the changes in price. The changes in price were then incorporated into average whole farm budgets which created the bottom line impact at the farm level.

This study demonstrates, in addition to the supply shock, the ban of international trade plays a significant role in economic impacts, especially at the farm level. As shown, a producer not affected by a FMD outbreak has the potential to greatly benefit from higher livestock prices once trade restrictions are lifted after a disease outbreak has occurred. Consumers have the potential to gain from lower meat prices resulting from an FMD outbreak, but can loss from higher meat prices once trade restrictions are lifted.

Limitations

One considerable challenge to any modeling study is parameterization. In particular, assessing the many unknown and immeasurable parameters that allow the model to capture the details associated with disease spread. There are many known data gaps associated with this project, especially as it relates to disease spread between different herds. The data uncertainty associated with these scenarios should not be minimized. It is a large limitation to this study and needs to be fully appreciated by all involved in applying the resulting output.

The current version of NAADSM does not allow for the modeling of mixed operations, livestock markets, or interstate spread. The incorporation of feral swine into these scenarios represents a novel application of NAADSM, and many simplifying assumptions were made in order to accommodate this.

Development of average Kansas farms was based on available data and acreage sizes. It is necessary to point out that this was done on a weighted average basis and some averages may not be representative of a typical farm in Kansas. The goal of this study was to analyze the impacts of an FMD outbreak and give the resulting impacts at the farm level based on the available data for average farms in Kansas.

With this disease introduction occurring in quarter 2 of 2007 this does influence the economic impacts found in this study. Starting the FMD outbreak in a different quarter may yield varying results. Due to varying livestock production practices (e.g.

breeding, weaning, etc.) the spread of the disease may vary which would in turn vary the results found in the economic modeling process of this study. Timing of the FMD introduction is important for disease modeling.

Future Research

Conducting further research into the actual contact parameters and disease spread capabilities of feral swine would aid in the development of this study. This study only looked at two hypothetical surveillance programs and it may be necessary to modify the surveillance scenarios modeled to better reflect an actual surveillance program for the state of Kansas. Developing the costs for a surveillance program, to conduct a benefit-cost analysis, would be beneficial for policymakers to gain funding for a surveillance program. In addition to surveillance programming costs and consumer and producer welfare impacts, to conduct a benefit-cost analysis the costs of government price supports would also need to be included.

The NAADSM results indicate small benefits for surveillance. The NAADSM is the state of the art in epidemiological modeling and one would hypothesis that there would be a benefit for feral swine surveillance. Further research needs to address the small benefits for feral swine surveillance in Kansas.

This study looks at average farms in Kansas based on available data from KFMA. Future research could look at developing representative farms for Kansas. Updating the budgets for each of the crops and livestock modeled in this study would need to be addressed as prices will change and production costs will change.

This study furthers the knowledge of FMD impacts to the U.S. economy and the impacts at the farm level. Many studies have looked at the national and/or regional impacts regarding disease outbreaks. This study observes the impact at the farm level and the potential ripple effects to the regional economy. Although there are limitations to this study, the framework developed will aid in future decision making to mitigate the economic impacts of a FMD outbreak in the U.S. livestock industry.

LITERATURE CITED

AgManager. 2010. Kansas State University. Department of Agricultural Economics. http://www.agmanager.info/default.asp. Accessed June 14, 2010.

Alexandersen, S., Quan, M., Murphy, C., Knight, J., Zhang, Z., 2003a. Studies of quantitative parameters of virus excretion and transmission in pigs and cattle experimentally infected with foot-and-mouth disease virus. Journal of Comparative Pathology 129:268–282.

Alston, J., Norton, G., Pardey, P., 1995. Science Under Scarcity. Cornell University Press, Ithaca.

Adkins, R.N., and L. A. Harveson. 2007. Demographic and spatial characteristics of feral hogs in the Chihuahuan Desert, Texas. Human–Wildlife Conflicts 1:152–160.

Baber, D. W. and B. E. Coblentz. 1986. Density, home range, habitat use, and reproduction in feral pigs on Santa Catalina Island. Journal of Mammalogy, 67:512-525.

Bailey, D., B.W. Brorsen, and M.R. Thomsen. 1995. Identifying Buyer Market Areas and the Impact of Buyer Concentration in Feeder Cattle Markets Using Mapping and Spatial Statistics. American Journal of Agricultural Economics 77: 309-18.

Barrett, R.H. 1982. The feral hog on the Dye Creek ranch. Hilgardia, 46:283-355.

Blair, J. P. 1995. Local Economic Development: Analysis and Practice. Sage Publications, Inc., California.

Bobst, B.W., Burris, A.E., and Hall, H.H. 1980. Economic Selection and Farm Employemnt in Northeast Thailand. Journal of Developing Areas 14(3): 349-359.

Bouma, A., A. Dekker, and M.C.M. de Jong, No foot-and-mouth disease virus transmission between individually housed calves. Veterinary Microbiology, 2004. 98(1): p. 29-36.

Colorado State University, Animal Population Health Institute. 2009. Movement data from Wisconsin. Unpublished raw data. Fort Collins, Colorado: Colorado State University, Animal Population Health Institute.

Cox, S.J., P.V. Barnett, P. Dani, and J.S. Salt, Emergency vaccination of sheep against foot-and-mouth disease: protection against disease and reduction in contact transmission. Vaccine, 1999. 17(15-16): p. 1858-1868.

Day, L.M. 1963. Use of Representative Farms in Studies of Interregional Competition and Production Response. Journal of Farm Economics. Volume 45, No. 6 (December 1963), pp. 1438-45.

Deck, A. L. 2006. Spatio Temporal Relationships Between Feral Hogs and Cattle with Implications for Disease Transmission. MS Thesis. Texas A&M University. College Station, TX. http://txspace.tamu.edu/bitstream/handle/1969.1/5884/etd-tamu-2006A-WFSC-Deck.pdf?sequence=1 Accessed August 6, 2009.

Dexter, N. 2003. Stochastic models of foot and mouth disease in feral pigs in the Australian semi-arid rangelands. The Journal of Applied Ecology, 40(2):293-306.

Disney, W.T., J.W. Green, K.W. Forsythe, J.F. Wiemers, and S. Weber. Benefit-cost analysis of animal identification for disease prevention and control. Revue Scientifique Et Technique De L Office International Des Epizooties, 2001. 20: p. 385 - 405.

Doran, R.J., and S.W. Laffan. 2005. Simulating the spatial dynamics of foot and mouth disease outbreaks in feral pigs and livestock in Queensland, Australia, using a susceptible-infected-recovered cellular automata model. Preventive Veterinary Medicine, 70:133-152.

Dyck, J., and K. Nelson. “Structure of the Global Markets for Meat.” Agriculture Information Bulletin Number 785. Washington D.C., USDA/ERS, September, 2003.

Eble, P., A. de Koeijer, A. Bouma, A. Stegeman, and A. Dekker, Quantification of within- and between-pen transmission of Foot-and-Mouth Disease Virus in pigs. Veterinary Research, 2006. 37(5): p. 647-654.

Ekboir, J.M. 1999. Potential impact of foot-and-mouth disease in California: The role and contribution of animal health surveillance and monitoring services. Agricultural Issues Center, Division of Agriculture and Natural Resources, University of California. http://aic.ucdavis.edu/pub/fmd.html Accessed August 13, 2009.

Ellisor, J.E. 1973. Feral hog studies. Federal Aid Project Number. W-101-R-4 Final Report. 6p.

Esteves, I.G., J.E. Ryan, S. Durand, and S. Alexandersen, Natural aerosol transmission of foot-and-mouth disease in sheep. EU website conference report, 2004.

Feinerman, E., J. Herriges, D. Holtkamp, 1992. Crop Insurance as a Mechanism for Reducing Pesticide Usage: A Representative Farm Analysis. Review of Agricultural Economics. 1992; 169-186.

Food and Agriculture Organization (FAO) of the United Nations. 2009. Major drive launched against FMD aims to bring disease under progressive global control. http://www.fao.org/news/story/en/item/29028/icode/ Accessed July 24, 2009.

Forrester, D.J. 1991. Parasites and diseases of wild mammals in Florida. University of Florida Press. Gainesville, FL, USA.

Freibel, B.A. and P.G.R. Jodice. 2009. Home range and habitat use of feral hog in Congaree National Park, South Carolina. Human and Wildlife Conflicts 3(1):49-63.

Gabor, T.M., E. C. Hellgren, and N.J. Silvy. 2001. Multiscale habitat partitioning in sympatric suiforms. Journal of Wildlife Management 65:99-110.

Gardner, B.L. 1975. "The Farm-Retail Price Spread in a Competitive Food Industry." American Journal of Agricultural Economics 57:399-409.

Gay, C.G., 2007. National Veterinary Stockpile Countermeasures Working Group Report Foot-and-Mouth Disease.

Gray, A.W., J.W. Richardson, and J. McClaskey. Farm-Level Impacts of Revenue Assurance. Review of Agricultural Economics 17(May 1995): 171-83.

Greathouse, B.D. "Vaccination Strategies for a Foot-and-Mouth Disease Outbreak in Southwest Kansas." MS Thesis, Dept. of Ag. and Reource Econ., Colorado State University.

Harvey, N., A. Reeves, M.A. Schoenbaum, F.J. Zagmutt-Vergara, C. Dubé, A.E. Hill, B.A. Corso, W.B. McNab, C.I. Cartwright, and M.D. Salman. 2007. The North American Animal Disease Spread Model: A simulation model to assist decision making in evaluating animal disease incursions. Preventive Veterinary Medicine, 82:176-197.

Hill, A., and A. Reeves. 2006. User's Guide for the *North American Animal Disease Spread Model* 3.0. Animal Population Health Institute, College of Veterinary Medicine & Biomedical Sciences, Colorado State University, Fort Collins, Colorado.

Hughes, G.J., Hughes G.J., Mioulet V., Haydon D.T., Kitching R.P., Donaldson A.I. & Woolhouse M.E.J., Serial passage of foot-and-mouth disease virus in sheep reveals declining levels of viraemia over time. Journal of General Virology, 2002. 83: p. 1907-1914.

Hullinger, P., L. Tammero, C. Melius, A. Robertson, and L. Holmstrom. Modeling Foot and Mouth Disease in the U.S. Livestock Industry. October 2008.

Hutton, T., T. DeLiberto, S. Owen and B. Morrison. 2006. Disease risks associated with increasing feral swine numbers and distribution in the United States. Midwest Association of Fish and Wildlife Agencies.

KFMA. Kansas Farm Management Association. http://www.agmanager.info/kfma/. Accessed June 14, 2010.

Kitching, R.P. and G.J. Hughes, Clinical variation in foot and mouth disease: sheep and goats. Revue Scientifique Et Technique De L Office International Des Epizooties, 2002. 21(3): p. 505-512.

Knutson, R.D., R. Romain, D.p> Anderson and J.W. Richardson. 1997. Farm-Level Consequences of Canadian and U.S. Dairy Policies. American Journal of Agricultural Economics. 79: 1563-72.

Kobrich, C., T. Rehman, and M. Khan, 2003. Typification of Farming Systems for Constructing Representative Farm Models: Two Illustrations of the Application of Multi-variate Analyses in Chile and Pakistan. Agricultural Systems. 76:141-157.

Ilse, L. M., and E.C. Hellgren. 1995. Spatial use and group dynamics of sympatric collared peccaries and feral hogs in southern Texas. Journal of Mammalogy, 76:93–1002.

Invasive Species Specialist Group. 100 of the World's Worst Invasive Alien Species. http://www.issg.org/database/species/search.asp?st=100ss&fr=1&str=&lang=EN. Accessed July 21, 2009.

Jones, R.W. "The Structure of Simple General Equilibrium Models." In International Trade: Selected Readings, J.H. Bhagwati (ed.), pp. 30-49. Cambridge, MA: The MIT Press, 1981.

Keeling, M.J. 2005. Models of foot-and-mouth disease. Proceedings: Biological Sciences, 272(1569):1195-1202.

Kinnucan, H.W., and E.T. Belleza. 1995. "Price and Quantity Effects of Canada's Dairy Advertising Programs." Agricultural and Resource Economics Review 24:199-210.

Kitching R.P., and G.J. Hughes. 2002. Clinical variation in foot and mouth disease: sheep and goats. Revue Scientifique et Technique de l Office International Des Epizooties (21):505-12.

Kroll, J. C. 1986. Interspecific competition between feral hogs and white-tailed deer in the post oak savannah region of Texas. Federal Aid Project. W-109-R-8 Job. No. 44, Final Performance Report 404pp.

Kurz, J.C., and R.L. Marchinton. 1972. Radiotelemetry studies of feral hogs in South Carolina. Journal of Wildlife Management. 26:214-217.

Lahr, M.L., and E. Dietzenbacher. 2001. Input-Output Analysis: Frontiers and Extensions. Palgrave Publishers Ltd, New York.

Lawrence Livermore National Laboratory (LLNL). 2009. FMD Interaction Matrices. Unpublished raw data. Livermore, California: Lawrence Livermore National Laboratory.

Lorigan, R.D. 2002. The use of deer, pigs, and ferrets as indicator species for detecting Tb. Proceedings of the Vertebrate Pest Conference 20:249-252.

Mansouri, A., and C. A. DeYoung. 1987. Feral hog fidelity to home range after exposure to supplemental feed. Texas Journal of Agriculture and Natural Resources. 1:46-49.

Mason, R J., and P.J. Fleming. 1999. Serological survey for Brucella antibodies in feral pigs from eastern Australia. Australian Veterinary Journal 77: 331-332.

McBride, W. and N. Key, 2003. Economic and Structural Relationships in U.S. Hog Production, Economic Research Service, USDA. Agricultural Economic Report No. 818, February 2003.

McCann, P. 2001. Urban and Regional Economics. Oxford University Press, Oxford.

McVicar, J.W., and P. Sutmolle., Experimental Foot-and-Mouth Disease in Sheep and Goats - Epizootiological Model. Archiv Fur Die Gesamte Virusforschung, 1972. 38(1): p. 85-88.

Melius, C., A. Robertson, P. Hullinger, Developing Livestock Facility Type Information from USDA Agricultural Census Data for use in Epidemiological and Economic Models, UCRL-TR-226008, October 2006.

Mersinger, R.C., and N.J. Silvy. 2007. Range size, habitat use, and dial activity of feral hogs on reclaimed surface-mined lands in east Texas. Human-Wildlife Conflicts, 2007. 1(2): p. 161-167.

Merianos, A. 2007. Surveillance and response to disease emergence. Current Topics in Microbiology and Immunology, Wildlife and Emerging Zoonotic Diseases: The Biology, Circumstances and Consequences of Cross-Species Transmission, J.E. Childs, J.S. Mackenzie, and J.A. Richt, Eds., 315:477-508.

Miller, J. 2001. Heifer Math & the Western Dairy Industry. Agricultural Outlook. Economic Research Service, USDA. December 2001.

Mullen, J.D., M.K. Wohlgenant, D.E. Farris. 1988. Input Substitution and the Distribution of Surplus Gains from Lower U.S. Beef-Processing Costs. American Journal of Agricultural Economics 70:245-254.

Musser JM. A practitioner's primer on foot-and-mouth disease. Journal of the American Veterinary Medical Association. 004(224)1261-8.

NAHEMS. 2010. National Animal Health Emergency Management System Guidelines http://www.aphis.usda.gov/animal_health/emrs/nahems.shtml. Accessed May 21, 2010.

OIE, World Organisation for Animal Health. 2008. Foot and mouth disease. In: Terrestrial Animal Health Code. 17th ed., World Organization for Animal Health, Paris, France. Available online: http://www.oie.int/eng/maladies/fiches/a_A010.htm. Accessed July 21, 2009.

OIE, World Organization for Animal Health. Available online: http://www.oie.int/eng/normes/mcode/en_chapitre_1.8.5.htm#rubrique_fievre_aphteuse_inactivation. Accessed April 3, 2010.

Orsel, K., A. Dekker, A. Bouma, J.A. Stegeman, and M.C.M. de Jong, Quantification of foot and mouth disease virus excretion and transmission within groups of lambs with and without vaccination. Vaccine, 2007. 25(14): p. 2673-2679.

Paarlberg, P.L., J.G. Lee, A.H. Seitzinger. 2002. Potential Revenue Impact of an Outbreak of Foot-and-Mouth Disease in the United States. Journal of American Veterinary medical Association 220,7(April 1, 2002):988-92.

Paarlberg, P.L., J.G. Lee, A.H. Seitzinger. 2003. Measuring welfare effects of an FMD outbreak in the United States. Journal of Agricultural and Applied Economics, 35(1):53-65.

Paarlberg, P.L., A.H. Seitzinger, J.G. Lee. 2007. Economic Impacts of Regionalization of a Highly Pathogenic Avian Influenza Outbreak in the United States. Journal of Agricultural and Applied Economics, 39(2):325-333.

Paarlberg, P.L., A.H. Seitzinger, J.G. Lee, and K.H. Mathews, Jr. 2008. Economic Impacts of Foreign Animal Disease. ERR-57. U.S. Dept. of Agriculture, Econ. Res. Serv. May 2008.

Pech, R.P., and J.C. McIlroy. 1990. A model of the velocity of advance of foot and mouth disease in feral pigs. The Journal of Applied Ecology, 27(2):635-650.

Pendell, D.L. 2006. Value of Animal Traceability Systems in Managing a Foot-and-Mouth Disease Outbreak in Southwest Kansas. Ph.D. dissertation, Dept. of Ag. Econ., Kansas State University.

Pendell, D.L., J. Leatherman, T.C. Schroeder, and G.S. Alward. 2007. The economic impacts of a foot-and-mouth disease outbreak: A regional analysis. Journal of Agricultural and Applied Economics, 39:19-33.

Piggot, N.E. and T.L. Marsh. 2004. Does Food Safety Information Impact U.S. Meat Demand? American Journal of Agricultural Economics. 2004. 86(1): 154-174.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52:273–288.

Reid, S.M., S. Parida, D.P. King, G.H. Hutchings, A.E. Shaw, N.P. Ferris, Z. Shang, J.E. Hillerton, D.J. Paton. Utility of automated real-time RT-PCR of the detection of foot-and-mouth disease virus excreted in milk. Veterinary Research, 2006. 37(1): p. 121-132.

Rich, K.M., and A. Winter-Nelson. 2007. An integrated epidemiological-economic analysis of foot and mouth disease: Applications to the Southern Cone of South America. American Journal of Agricultural Economics, 89(3):682-697.

Sanyal, K.K., and R.W. Jones. "The Theory of Trade in Middle Products," American Economic Review 72(1982):16-31.

Sharples, J.A. 1969. The Representative Farm Approach to Estimation of Supply Response. American Journal of Agricultural Economics. 51, 353.

Shieh, H.K. Update on foot-and-mouth disease outbreaks in Taipei, China, OIE, May, 22, 1997.

Shields, D.A., and K.H. Mathews. 2003. Interstate Livestock Movements. Electronic outlook report from the Economic Research Service United States Department of Agriculture. Available at: http://www.ers.usda.gov/publications/ldp/jun03/ldpm10801/ldpm10801.pdf

Shwiff, S.A., T.W. Cozzens, K. Gebhardt, S. Swafford, M. Lutman, K. Pedersen. 2010. "Economic Impact of Feral Swine Transmitted Foot-and-Mouth Disease to Livestock: An Eight State Analysis." Economics Project, National Wildlife Research Center. Working paper.

Shwiff, S.A., K.N. Kirkpatrick, and R.T. Sterner. 2008. Economic evaluation of an oral rabies vaccination program for control of a domestic dog–coyote rabies epizootic: 1995–2006. JAVMA, 233(11):1736-1741.

Singer, F.J., D.K. Otto, A.R. Tipton, and C.P. Hable. 1981. Home ranges, movements, and habitat use of European wild boar in Tennessee. Journal of Wildlife Management 45:343-353.

Springer, M.D. 1977. Ecologic and economic aspects of wild hogs in Texas. Pages 37-46 in G. W. Wood, ed. Research and management of wild hog populations. The Belle W. Baruch For. Sci. Inst., Clemson Univ., Georgetown, S.C.

Sterner, J.D. 1990. Population characteristics, home range, and habitat use of feral pigs on Santa Cruz Island, California. M.S. Thesis, Univ. California, Berkeley. 105pp.

Stillman, R. 2009. Livestock, Dairy, and Poultry Outlook. Economic Research Service. February 17, 2009. LDP-M-176.

Swafford, S. 2009. Comprehensive Feral Swine Disease Surveillance Monitoring. NAHSS Outlook. http://nsu.aphis.usda.gov/outlook/issue21_apr09/outlook_apr09_feral_swine.pdf. Accessed August 6, 2009.

Tammero, L., P. Hullinger, L. Holmstrom, C. Melius, and A. Robertson, Modeling Foot-and-Mouth Disease in the U.S. Livestock Industry. 2008.

Taylor, R.D., W.W. Koo, and A.L. Swenson. 2009 North Dakota Agriclutlral Outlook: Representative Farms, 2009-2018. Agribusiness & Applied Economics Reprot No. 652, August 2009. Center for Agricultural Policy and Trade Studies, North Dakota State University. Fargo, ND.

U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). 2007 Census of Agriculture. Washington D.C., November 2009.

U.S. Department of Agriculture, Economic Research Service (ERS). Available at http://www.ers.usda.gov/news/bsecoverage.htm. Accessed December 2009.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS). Feral Swine Damage Management Business Plan. 2009.

USDA National Agriculture Statistics Service (NASS). Census of Agriculture 2007.

USDA Economic Research Service (ERS). 2000. Taiwan's hog industry – 3 years after disease outbreak. U.S. Department of Agriculture, Economic Research Service. Agricultural Outlook, Special Article, October 2000. 4p.

USDA. 2000. Feedlot 1999, Part I: Baseline Reference of Feedlot Management Practices, 1999. USDA:APHIS:VS, CEAH, National Animal Health Monitoring System. Fort Collins, CO. #N327.0500

USDA. 2008. Dairy 2007, Part III: Reference of Dairy Cattle Health and Management Practices in the United States, 2007 USDA–APHIS–VS, CEAH. Fort Collins, CO #N482.0908

USDA. 2008. Beef 2007-08, Part I: Reference of Beef Cow-calf Management Practices in the United States, 2007-08 USDA-APHIS-VS, CEAH. Fort Collins, CO #N512-1008

USDA. 2001. Swine 2000, Part I: Reference of Swine Health and Management in the United States, 2000, National Animal Health Monitoring System. Fort Collins, CO. #N338.0801.

Ward, M.P., S.W. Laffan, and L.D. Highfield. 2007. The potential role of wild and feral animals as reservoirs of foot-and-mouth disease. Preventive Veterinary Medicine, 80:9-23.

Williams, E.S., and I.K. Barker, editors. 2001. Infectious diseases of wild mammals. Iowa State University Press, Ames, USA.

Wood, G.W., and R.E. Brenneman. 1980. Feral hog movements and habitat utilization in coastal South Carolina. J. Wildl. Manage. 44:420-427.

Witmer, G.W., R.B. Sanders, and A.C. Taft. 2003. Feral swine—are they a disease threat to livestock in the United States? Proceedings of the Wildlife Damage Management Conference 10:316–325.

Wyckoff, A. C., S.E. Henke, T.A. Campbell, D.G. Hewitt, and K.C. Vercauteren. 2009. Feral swine contact with domestic swine: a serologic survey and assessment of potential for disease transmission. Journal of Wildlife Diseases 45:422-429. 261K

Yang, P.C., R. M. Chu, W. B. Chung, and H. T. Sung. 1999. Epidemiological characteristics and financial costs of the 1997 foot-and-mouth disease epidemic in Taiwan. The Veterinary Record, Volume 145, Issue 25, 731-734.

Zhao, Z., T.I. Wahl, and T.L. Marsh. 2006. Invasive Species Management: Foot-amd-Mouth Disease in the U.S. Beef Industry. Agricultural and Resource Economics Review 35(1): 98-115.

APPENDIX A – Epidemiological Model

Model

The North American Animal Disease Spread Model (NAADSM) version 3.1.23 was used to simulate the spread of FMD from feral swine to domestic livestock.

Disease Parameters for the Model

Table A.1: Latent Period

Production type	***Duration of the* latent period *(days)***	References
Cattle	Gaussian (4.1, 1.1)	Alexandersen 2003, Bouma 2004, Cox 2005, 2006, Reid 2006
Swine	Gaussian (1.2, 0.5)	Alexandersen 2003, Eble 2004, 2006, 2007, Orsel 2007
Small ruminants	Gaussian (5, 1.7)	Cox 1999, Esteves 2004, Hughes 2002, Kitching 2002, McVicar 1972
Feral swine	0	Ward 2007

Table A.2: Subclinical, Infectious Period

Production type	***Duration of the* subclinical, infectious period *(days)***	References
Cattle	Gaussian (2.2, 0.8)	Alexandersen 2003, Bouma 2004, Cox 2005, 2006, Reid 2006
Swine	Gaussian (1.1, 0.7)	Alexandersen 2003, Eble 2004, 2006, 2007, Orsel 2007
Small ruminants	Gaussian (2.6, 1.5)	Cox 1999, Esteves 2004, Hughes 2002, Kitching 2002, McVicar 1972
Feral swine	0	The duration of the subclinical infectious period in feral swine was assumed to zero because serological surveillance of feral swine will be conducted.

Table A.3: Clinical, Infectious Period

Production type	***Duration of the* clinical, infectious period *(days)***	References
Cattle	Uniform (0, 3.5)	Alexandersen 2003, Bouma 2004, Cox 2005, 2006, Reid 2006
Swine	Normal (3.9, 1.7)	Alexandersen 2003, Eble 2004, 2006, 2007, Orsel 2007
Small ruminants	Uniform (0, 3.5)	Cox 1999, Esteves 2004, Hughes 2002, Kitching 2002, McVicar 1972
Feral swine	Uniform (15, 17)	Ward 2007

Table A.4: Herd-Level Duration of the Clinical, Infectious Period

Production type	Herd-level duration of the *clinical, infectious period* in days[1]
Feedlot (Small)	BetaPERT (11, 15, 20)
Feedlot (Large)	BetaPERT (16, 18, 22)
Cow-calf	BetaPERT (11, 15, 19)
Dairy	BetaPERT (10, 13, 17)
Swine	BetaPERT (10, 12, 15)
Small ruminants	BetaPERT (6, 13, 17)
Feral swine	Uniform (15, 17)

[1] The domestic herd estimates are based on individual disease state distributions for the latent, subclinical, and clinical states of disease which have been detailed in previous tables. These individual disease state distributions were used to inform a Reed-Frost model of within herd transmission to estimate the duration of the clinical period at the herd level. Estimates were based on 100 iterations of the Reed-Frost model.

Table A.5: Immune Period

Production type	Duration of the *immune period* in days (minimum, most likely, maximum)
Cattle	BetaPERT (180, 270, 360)
Swine	BetaPERT (180, 270, 360)
Small ruminants	BetaPERT (180, 270, 360)
Feral swine	BetaPERT (180, 270, 360)

Table A.6: Cattle – Direct Contact Parameters

Production type combination	***Contact rate[2] (Shipments/day)***	***Movement distance in km (Min, most likely, max)[3]***	Effect of movement control[4]
Cow-calf to cow-calf	0.0063	BetaPERT (1.6, 32.2, 320)	1.0 to 0.1 in seven days
Feedlot (large) to Cow-calf	0.0003	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days
Feedlot (small) to Cow-calf	0.0003	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days
Dairy to Cow-calf	0.00003	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days
Cow-calf to Feedlot (small)	0.055	BetaPERT (1.6, 96.5, 320)	1.0 to 0.1 in seven days
Feedlot (small) to Feedlot (small)	0		
Feedlot (large) to Feedlot (small)	0		

[2] A contact rate is used to indicate the average number of contacts (shipments of animals) that are generated by each herd on each day.
[3] The variable "movement distance" defines the distance between a herd of the source production type and its contact with herds of the recipient production type.
[4] The variable "movement control" is used to simulate the effect of movement restrictions on the number of contacts between units.

Dairy to Feedlot (small)	0		
Cow-calf to Feedlot (large)	0.22	BetaPERT (1.6, 193.1, 320)	1.0 to 0.1 in seven days
Feedlot (small) to Feedlot (large)	0.17	BetaPERT (1.6, 160.9, 320)	1.0 to 0.1 in seven days
Feedlot (large) to Feedlot (large)	0		
Dairy to Feedlot (large)	0.025	BetaPERT (1.6, 80.5, 241.4)	1.0 to 0.1 in seven days
Feedlot (large) to dairy	0.0003	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days
Feedlot (small) to dairy	0.0003	BetaPERT (1.6, 80.5, 241.4)	1.0 to 0.1 in seven days
Dairy to Dairy	0.0075	BetaPERT (1.6, 80.5, 241.4)	1.0 to 0.1 in seven days
Cow-calf to Dairy	0.00012	BetaPERT (1.6, 80.5, 241.4)	1.0 to 0.1 in seven days

Justification/Assumptions[5]

According to NAHMS Beef 2008[6], cow-calf producers received an average of 1.1 shipments from another beef operation and 1.2 shipments from auction markets over the previous 12 months. The ultimate source of auction market cattle that a cow-calf operation would buy is another cow-calf operation.

Movement of cattle from feedlots, backgrounders, and dairies to cow-calf operations are rare events.

[5] One considerable challenge to any modeling study is parameterization, in particular assessing the many unknown and immeasurable parameters that allow the model to capture the intricacies associated with disease spread.

Occasionally feedlots will feed cattle not meant for U.S. slaughter. According to Feedlot ’99, Part I, 1.1% of feedlot placements are not for slaughter.

Backgrounder/stocker operations receive virtually all of their cattle from cow-calf operations. It is estimated that backgrounder/stocker operations receive approximately 20 shipments per year from cow-calf operations.

There is no movement of cattle from finish feedlots to backgrounder operations.

Movement of cattle from finish feedlots and backgrounder operations to dairy operations are rare events.

The median size of a finish feedlot is an estimated 15,000 head. On average, feedlots turn over twice per year. Assuming 200 head pens, there is an estimated 150 shipments from a cow-calf operation to a finish feedlot operation per year.

> An estimated 85 shipments per year are from an auction market of which 60% (51 shipments) are from a cow-calf operation while 40% (34 shipments) are from backgrounder/stocker operations.
>
> An estimated 28 shipments per year are directly from a backgrounder/stocker operation.
>
> An estimated 28 shipments per year are directly from a cow-calf operation.
>
> An estimated nine shipments per year are directly from a dairy operation.
>
> There is no movement of cattle from finish feedlots to finish feedlots.

According to NAHMS Dairy 2007, Part III dairy operations averaged 2.6 and 0.12 shipments of females and bulls, respectively, from one dairy operation to another each year.

According to NAHMS Dairy 2007, 1.5% of dairy operations receive beef bulls, 2% receive steers, and 0.9% receive beef heifers from cow-calf operations.

According to Feedlot ’99, Part I 1.1% of feedlot placements are not for slaughter (0.2% are beef breeding animals, 0.1% are dairy breeding animals, and the other 0.8% are “other” cattle). It was estimated that an average of one shipment is received by a dairy each year.

The probability of infection transfer was determined by the within-unit prevalence.

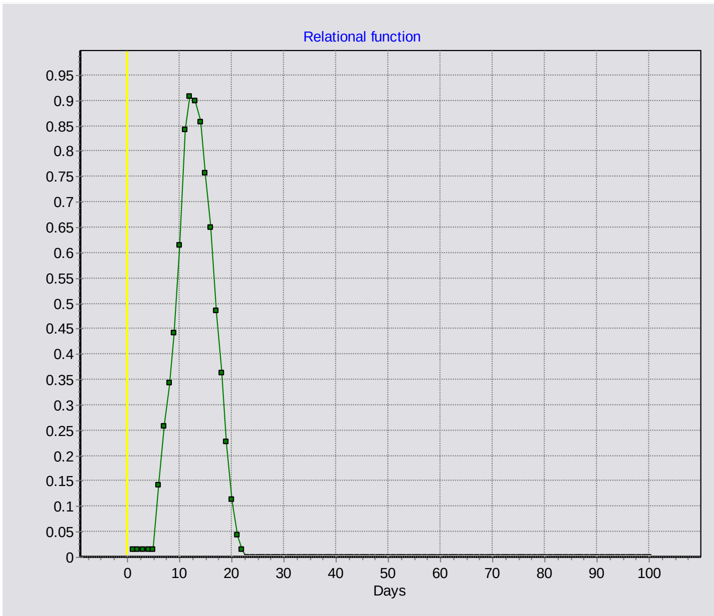


Figure A.1: Illustrates the within-unit prevalence for cow-calf operations.

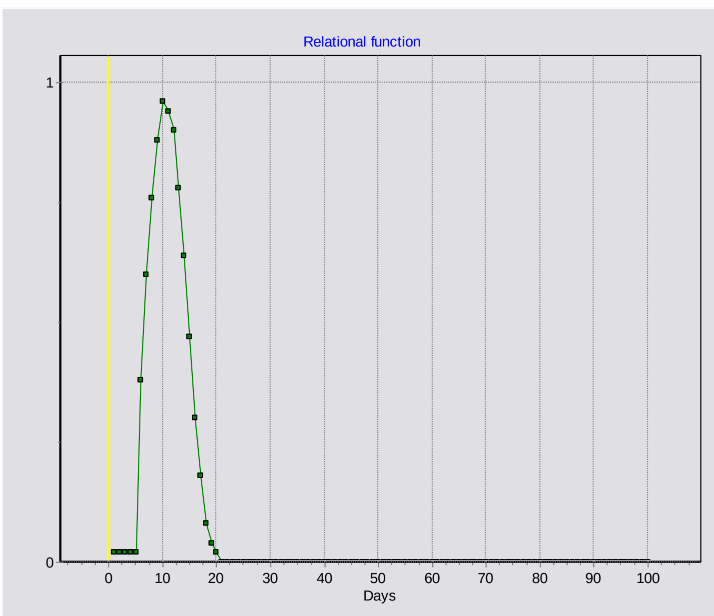


Figure A.2: Illustrates the within-unit prevalence for dairy operations.

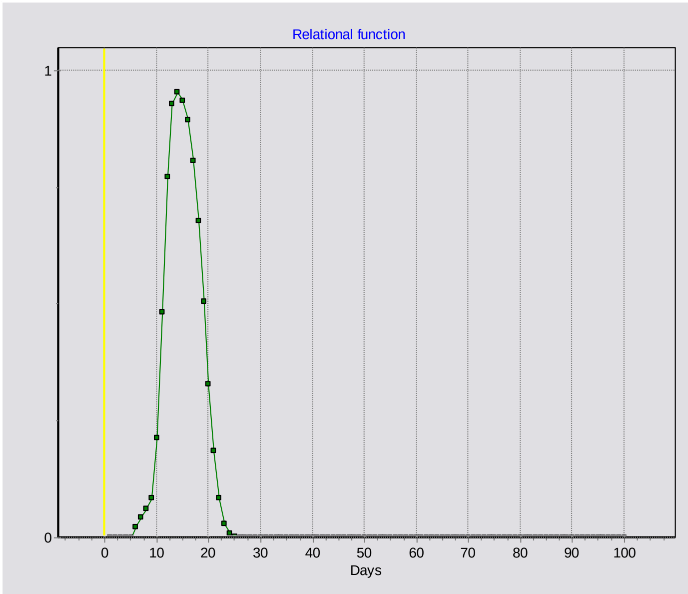


Figure A.3: Illustrates the within-unit prevalence for large feedlot operations.

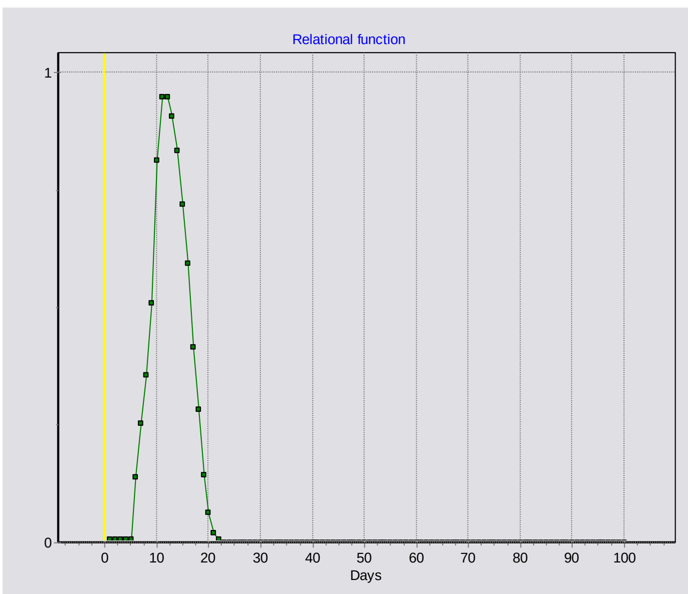


Figure A.4: Illustrates the within-unit prevalence for small feedlot operations.

Table A.7: Swine – Direct Contact Parameters

Production type combination	***Contact rate (Shipments/day)***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Swine (large) to Swine (large)	0.29	BetaPERT (0, 20, 181)	1.0 to 0.1 in seven days
Swine (small) to Swine (small)	0.014	BetaPERT (0, 20, 181)	1.0 to 0.1 in seven days
Swine (small) to Swine (large)	0		
Swine (small) to Swine (backyard)	0		
Swine (large) to Swine (small)	0		
Swine (large) to Swine (backyard)	0		
Swine (backyard) to Swine (small)	0		
Swine (backyard) to Swine (large)	0		
Swine (backyard) to Swine (backyard)	0		

Justification/Assumptions

The probability of infection transfer was determined by the within-unit prevalence.

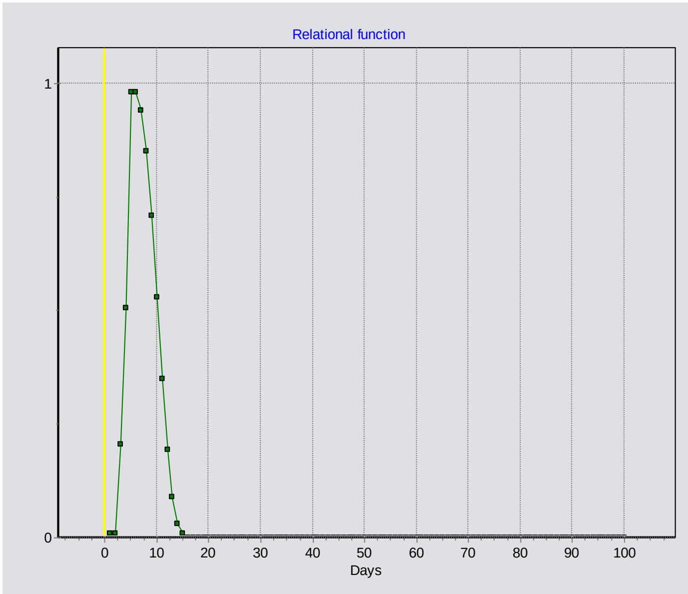


Figure A.5: Illustrates the within-unit prevalence for swine operations.

Table A.8: Sheep – Direct Contact Parameters

Production type combination	***Contact rate (Shipments/day)***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Sheep to sheep	0.005	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days

Justification/Assumptions

Many sheep that are removed from various small fenced/farmed sheep operations are moved directly to slaughter.

The number of major movements of sheep from larger sheep operations to backgrounder and/or feedlot operations is one to two per year which is limited by the natural reproductive cycle. The second or third and final move will be directly to slaughter.

The probability of infection transfer was determined by the within-unit prevalence.

Table A.9: Goats – Direct Contact Parameters

Production type combination	***Contact rate (Shipments/day)***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Goats to goats	0.005	BetaPERT (1.6, 80.5, 160.9)	1.0 to 0.1 in seven days

Justification/Assumptions

Many goats that are removed from various small fenced/farmed goat operations are moved directly to slaughter.

The number of major movements of goats from larger goat operations to backgrounder and/or feedlot operations is one to two per year which is limited by the natural reproductive cycle. The second or third and final move will be directly to slaughter.

The probability of infection transfer was determined by the within-unit prevalence.

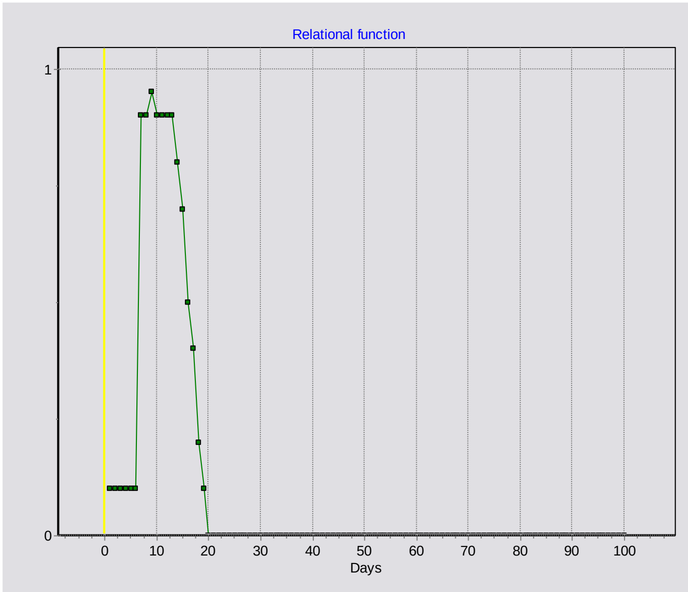


Figure A.6: Illustrates the within-unit prevalence for small ruminant operations.

Table A.10: Feral Swine – Direct Contact Parameters

Production type combination	***Contact rate (Shipments/day)***	***Movement distance in km***	Effect of movement control
Feral swine to cattle, sheep, goats, and swine (backyard)	0.06	Uniform (0, 50)	Remains 1.0
Feral swine to Swine (large) and Swine (small)	0		

Justification/Assumptions

Feral swine are wild animals and are free roaming. It is possible for feral swine are able to interact with any domestic animal in an outdoor facility.

Many small and large swine farms are indoor facilities with adequate biosecurity to eliminate direct contact with feral swine.

According to Deck (2007), feral swine directly contacted cattle in Texas 0.06 times per day either through interacting within 50m of cattle or utilizing the same livestock pond, water trough, etc. within 24 hours of each other.

According to Wyckoff (2009), Adkins and Harveson (2007), and Mersinger and Silvy (2007), feral swine home range is between 6.5 and 58.7 square kilometres.

According to Friebel and Jodice (2009), core home ranges are 0.34 square kilometres.

High densities of feral swine exist in many locations. According to Adkins and Harveson (2007), feral swine density per square kilometre ranged from 0.65 to 9.5.

To partially account for the existence of other feral swine herds in the area, a relatively large movement distance was used as the estimated parameter.

Domestic livestock is fenced or otherwise restrained to a particular geographic area; therefore livestock does not initiate direct contact with the feral swine herd.

The probability of infection transfer was determined by the within-unit prevalence.

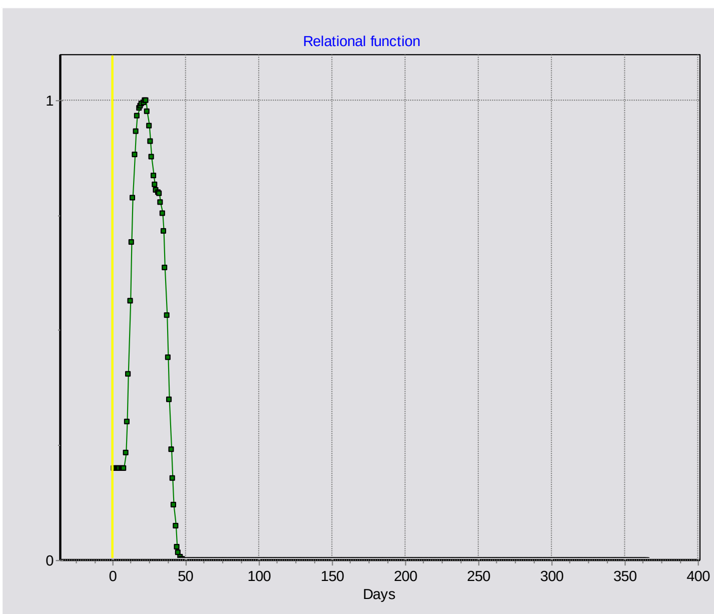


Figure A.7: Illustrates the within-unit prevalence for feral swine units.

Domestic herd **indirect contact** is movement of people, materials, vehicles, equipment, etc. among units and is simulated in the same manner as direct contact.

Feral swine **indirect contact** was identified as feral swine located between 0m and 200m of domestic animals within 15 minutes of each other or when feral swine and domestic animals visited the same livestock pond, water trough, etc. within 24 hours of each other.

The parameters for indirect contact are similar but independent of those for direct contact.

It is assumed that only infectious, subclinical and clinical units can be a source of infection.

Table A.11: Cattle and Swine - Indirect Contact Parameters

Production type combination	***Contact rate (Contacts/day)***	***Probability of infection given exposure***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Cow-calf to cow-calf	0.02	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (small) to cow-calf	0.005	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to cow-calf	0.055	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Dairy to cow-calf	0.026	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cow-calf to Feedlot (small)	0.147	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (small) to Feedlot (small)	0.036	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to Feedlot (small)	0.395	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days

Dairy to Feedlot (small)	0.199	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to Feedlot (large)	3.011	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (small) to Feedlot (large)	0.266	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cow-calf to Feedlot (large)	1.152	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Dairy to Feedlot (large)	1.549	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Dairy to Dairy	0.172	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cow-calf to Dairy	0.104	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (small) to Dairy	0.022	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to Dairy	0.259	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cow-calf to Swine (large)	0.035	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cow-calf to Swine (small)	0.004	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to Swine (large)	0.220	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (large) to Swine (small)	0.017	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Feedlot (small) to Swine (large)	0.031	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days

Feedlot (small) to Swine (small)	0.002	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Dairy to Swine (large)	0.049	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Dairy to Swine (small)	0.006	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Swine (large)	0.128	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (small) to Swine (small)	0.003	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Swine (small)	0.009	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (small) to Swine (large)	0.022	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Cow-calf	0.010	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Dairy	0.033	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Feedlot (large)	0.432	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (large) to Feedlot (small)	0.061	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (small) to Cow-calf	0.003	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (small) to Dairy	0.017	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (small) to Feedlot (large)	0.175	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days

Swine (small) to Feedlot (small)	0.023	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Feedlot (large)	0.0377	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Feedlot (small)	0.0048	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Dairy	0.0038	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Goats	0.005	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Sheep	0.005	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Swine (small)	0.005	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Swine (large)	0.0039	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Cow-calf	0.0006	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine (backyard) to Swine (backyard)	0.0001	0.3	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Cattle and Swine to Feral Swine	0			

Justification/Assumptions

Indirect contacts considered include veterinarians, feed and feed truck deliveries, milk truck pick-ups (dairy), salesmen, nutritionists, AI technicians (dairy or cow-calf), hoof trimmers, rendering trucks, external contract processors, employee contact, and neighbors. Indirect contacts through contract livestock haulers are included between swine and cattle.

According to Beef 2008, the following table represents the percent of herds, by number of visits, during an average month (employees, veterinarians, nutritionists, commercial haulers, etc.):

Number of visits per month	Central Region	All Regions
0	10.4%	17.9%
1-2	28.6%	24.7%
3-5	18.6%	21.1%
6-9	7.3%	6.9%
10+	35.1%	29.4%

The maximum movement distance was assumed to be longer between large feedlots given that consulting veterinarians may cover a larger area.

Domestic livestock are fenced or otherwise restrained to a particular geographic area; therefore livestock do not initiate indirect contact with feral swine.

Table A.12: Sheep – Indirect Contact Parameters

Production type combination	***Contact rate (Contacts/day)***	***Probability of infection given exposure***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Sheep to sheep	0.01	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Sheep to all other livestock	0.005	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine to Sheep	0.005	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
All other livestock to Sheep	0.005	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Sheep to Feral swine	0			

Justification/Assumptions

The high cost of veterinary services along with narrow profit margins dictate the restriction of veterinarian visits for serious disease problems only.

Rams undergo breeding soundness evaluation exams one to two times per year.

Routine visits by the veterinarian are limited as many commonly administered vaccines and biological products are purchased and administered by producers from livestock supply companies.

Information from health-professional sources will be transferred to producers at producer meetings away from most farms or producers will visit the office of a professional. Professionals are not likely to visit the farm premises.

Shearer crews may shear sheep at multiple sites/locations that belong to a single producer. Visits by shearer crews are mostly applicable to large open-range flocks.

Only 10% of U.S. sheep producers used livestock haulers during 2001.

Sheep are a relatively isolated production type with limited contact with all other livestock types.

Domestic livestock are fenced or otherwise restrained to a particular geographic area; therefore livestock do not initiate indirect contact with feral swine.

Table A.13: Goats – Indirect Contact Parameters

Production type combination	***Contact rate (Contacts/day)***	***Probability of infection given exposure***	***Movement distance in km (Min, most likely, max)***	Effect of movement control
Goats to goats	0.01	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Goats to all other livestock	0.005	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Swine to Goats	0.005	0.30	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days

All other livestock to Goats	0.005	0.20	BetaPERT (1.6, 40.2, 160.9)	1.0 to 0.3 in seven days
Goats to Feral swine	0			

Justification/Assumptions

The high cost of veterinary services along with narrow profit margins dictate the restriction of veterinarian visits for serious disease problems only.

Routine visits by the veterinarian are limited as many commonly administered vaccines and biological products can be purchased and administered by producers from livestock supply companies.

Bucks undergo breeding soundness evaluation exams one to two times per year.

Information from health-professional sources will be transferred to producers at producer meetings away from most farms or producers will visit the office of a professional. Professionals are not likely to visit the farm premises.

Only 10% of U.S. sheep producers used livestock haulers during 2001. This percentage for sheep may be similar for goats, or even lower.

Goats are a relatively isolated production type with limited contact with all other livestock types.

Domestic livestock are fenced or otherwise restrained to a particular geographic area; therefore livestock do not initiate indirect contact with feral swine.

Table A.14: Feral Swine - Indirect Contact Parameters

Production type combination	***Contact rate (Shipments/day)***	***Probability of infection given exposure***	***Movement distance in km***	Effect of movement control
Feral swine to cattle, sheep, goats, and backyard swine	3.35	0.4	Uniform (1, 50)	Remains 1.0

Feral swine to swine (small) and swine (large)	0

Justification/Assumptions

Feral swine are wild animals and are free roaming. It is possible for feral swine to interact with any domestic animal in an outdoor facility.

Many small and large swine farms are indoor facilities with adequate biosecurity to eliminate direct contact with feral swine.

The probability of infection for feral swine is 0.4 because swine are amplifiers of foot-and-mouth disease and it is impossible to have any biosecurity in a wildlife population.

Recent publications have analyzed contact between feral swine and cattle (see Deck 2007 and Wyckoff 2009). Contact between feral swine and other domestic animals have not been analyzed. We assumed that all outdoor domestic animals have an equal chance of indirect contact with a feral swine herd.

Domestic livestock are fenced or otherwise restrained to a particular geographic area; therefore livestock do not initiate indirect contact with the feral swine herd.

Table A.15: Local Area Spread

Production type combination	***Probability of spread between two herds of average size located 1 km apart***	***Maximum distance of spread in km***	**Range of direction**
All production type combinations (with the exception of those listed below)	0.005	3	0 to 360
Swine (small) to Cow-calf or Feedlot (small)	0.1	3	0 to 360
Feral swine to all domestic operations	0.005	50	0 to 360

APPENDIX B – Whole Farm Budgets

Table B.1: North Central Kansas Average Farm

Feral Swine FMD Transmission in Kansas								
WHOLE FARM BUDGET								*Crop Farm*
NORTH CENTRAL KANSAS						NUMBER OF ACRES		1172.23
GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres		Value to Operation
CORN	632	334	Acres	12.65	58.53	71.18	$	27,529
SOYBEANS	484	304	Acres	10.26	199.84	210.10		65,636
WHEAT	360	264	Acres	2.65	507.87	510.52		135,174
GRAIN SORGHUM	389	323	Acres	2.40	194.02	196.42		63,575
FESCUE HAY	553	186	Acres	1.32	122.72	124.04		23,534
BROME HAY	840	211	Acres	0.24	59.73	59.97		12,794
Crop Gross Income	**3,258**	**1,621**		**30**	**1,143**	**1,172**	**$**	**328,243**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**		**Value to Operation**
BEEF COWS	501		Head	44		44	$	21,877
BEEF PURCH. FOR RESALE SALES	371		Head	128		128		47,521
Livestock Gross Income	**872**		**Head**	**172**		**172**	**$**	**69,399**
TOTAL GROSS INCOME							**$**	**397,641**
VARIABLE COST								
CORN	550	321	Acres	12.65	58.53	71.18	$	25,750
SOYBEANS	354	219	Acres	10.26	199.84	210.10		47,344
WHEAT	403	244	Acres	2.65	507.87	510.52		124,921
GRAIN SORGHUM	396	261	Acres	2.40	194.02	196.42		51,629
FESCUE HAY	621	178	Acres	1.32	122.72	124.04		22,619
BROME HAY	562	177	Acres	0.24	59.73	59.97		10,714
Total Crop Variable Costs	**2,885**	**1,400**	**Acres**	**30**	**1,143**	**1,172**	**$**	**282,978**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**		**Value to Operation**
BEEF COWS	619		Head	44		44	$	27,028
BEEF PURCH. FOR RESALE SALES	448		Head	128		128		57,344
Total Livestock Variable Costs	**1,067**		**Head**	**172**		**172**	**$**	**367,350**
Total Gross Margin							**$**	**30,291**
OTHER EXPENSES								
Other								
Misc								
Total Other Expenses								
NET FARM INCOME							**$**	**30,291**

Table B.2: Northeast Kansas Average Farm

Feral Swine FMD Transmission in Kansas							
WHOLE FARM BUDGET							***Crop Farm***
NORTHEAST KANSAS						**NUMBER OF ACRES**	**995.79**
GROSS INCOME	**Irrigated ($/Unit)**	**Non-Irrigated ($/Unit)**	**Unit**	**Irrigated**	**Non-Irrigated**	**Total Acres**	**Value to Operation**
CORN	632	415	Acres	34.48	289.45	323.93	$ 141,955
SOYBEANS	484	297	Acres	21.85	386.90	408.75	125,378
WHEAT	360	232	Acres	0.59	100.36	100.95	23,457
GRAIN SORGHUM		290	Acres		22.67	22.67	6,580
BROME HAY	553	211	Acres	0.58	124.41	124.99	26,549
FESCUE HAY		186	Acres		14.50	14.50	2,694
Crop Gross Income	**2,029**	**1,630**		**58**	**938**	**996**	**$ 326,614**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	501		Head	46		46	$ 23,045
BEEF PURCH. FOR RESALE SALES	371		Head	106		106	39,354
SWINE PURCH. FOR RESALE SALES	99		Head	101		101	10,025
Livestock Gross Income	**971**		**Head**	**253**		**253**	**$ 72,423**
TOTAL GROSS INCOME							**$ 399,036**
VARIABLE COST							
CORN	550	366	Acres	34.48	289.45	323.93	$ 124,767
SOYBEANS	354	224	Acres	21.85	386.90	408.75	94,221
WHEAT	403	271	Acres	0.59	100.36	100.95	27,484
GRAIN SORGHUM		259	Acres		22.67	22.67	5,863
BROME HAY	621	177	Acres	0.58	124.41	124.99	22,394
FESCUE HAY		178	Acres		14.50	14.50	2,576
Total Crop Variable Costs	**1,927**	**1,474**	**Acres**	**58**	**938**	**996**	**$ 277,305**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	619		Head	46		46	$ 28,470
BEEF PURCH. FOR RESALE SALES	448		Head	106		106	47,488
SWINE PURCH. FOR RESALE SALES	94		Head	101		101	9,528
Total Livestock Variable Costs	**1,161**		Head	**253**		**253**	**$ 362,791**
Total Gross Margin							**$ 36,245**
OTHER EXPENSES							
Other							
Misc							
Total Other Expenses							
NET FARM INCOME							**$ 36,245**

Table B.3: Northwest Kansas Average Farm

Feral Swine FMD Transmission in Kansas

WHOLE FARM BUDGET — ***Crop Farm***

NORTHWEST KANSAS — NUMBER OF ACRES 1643.85

GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres	Value to Operation
CORN	807	322	Acres	239.36	280.07	519.43	$ 283,178
SOYBEANS	490	237	Acres	21.84	11.30	33.14	13,381
WHEAT	360	223	Acres	61.03	719.79	780.82	182,348
GRAIN SORGHUM	447	288	Acres	3.42	178.62	182.04	53,005
FORAGE SORGHUM SILAGE	553	186	Acres	29.02	79.36	108.38	30,786
ALFALFA	840	211	Acres	7.10	12.94	20.04	8,691
Crop Gross Income	**3,496**	**1,466**		**362**	**1,282**	**1,644**	**$ 571,389**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	501		Head	43		43	$ 21,376
BEEF PURCH. FOR RESALE SALES	371		Head	91		91	33,785
Livestock Gross Income	**872**		**Head**	**134**		**134**	**$ 55,161**
TOTAL GROSS INCOME							**$ 626,550**
VARIABLE COST							
CORN	666	277	Acres	239.36	280.07	519.43	$ 236,866
SOYBEANS	435	201	Acres	21.84	11.30	33.14	11,787
WHEAT	403	191	Acres	61.03	719.79	780.82	162,306
GRAIN SORGHUM	473	233	Acres	3.42	178.62	182.04	43,294
FORAGE SORGHUM SILAGE	621	178	Acres	29.02	79.36	108.38	32,120
ALFALFA	562	177	Acres	7.10	12.94	20.04	6,285
Total Crop Variable Costs	3,161	1,257	Acres	362	1,282	1,644	$ 492,658
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	619		Head	43		43	$ 26,409
BEEF PURCH. FOR RESALE SALES	448		Head	91		91	40,768
Total Livestock Variable Costs	**1,067**		**Head**	**134**		**134**	**$ 559,835**
Total Gross Margin							**$ 66,715**
OTHER EXPENSES							
Other							
Misc							
Total Other Expenses							
NET FARM INCOME							**$ 66,715**

Table B.4: South Central Kansas Average Farm

Feral Swine FMD Transmission in Kansas

WHOLE FARM BUDGET ***Crop Farm***

SOUTHCENTRAL KANSAS **NUMBER OF ACRES 1545.32**

GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres	Value to Operation
CORN	826	349	Acres	113.23	66.36	179.59	$ 116,691
SOYBEANS	490	244	Acres	63.29	135.47	198.76	64,007
WHEAT	360	234	Acres	29.66	799.70	829.36	197,851
GRAIN SORGHUM	447	296	Acres	6.61	211.33	217.94	65,537
FORAGE SORGHUM SILAGE	553	341	Acres	5.78	44.96	50.74	18,507
ALFALFA	840	417	Acres	9.81	59.12	68.93	32,893
Crop Gross Income	**3,515**	**1,881**		**228**	**1,317**	**1,545**	**495,487**

Livestock	($/Head)		Unit	Head		Total Head	Value to Operation
BEEF COWS	501		Head	26		26	$ 12,860
BEEF PURCH. FOR RESALE SALES	371		Head	41		41	15,222
HOGS	99		Head	17		17	1,682
Livestock Gross Income	**971**		**Head**	**84**		**84**	**29,763**

TOTAL GROSS INCOME	**525,250**

VARIABLE COST							
CORN	677	297	Acres	113.23	66.36	179.59	$ 96,389
SOYBEANS	435	181	Acres	63.29	135.47	198.76	52,058
WHEAT	403	211	Acres	29.66	799.70	829.36	180,784
GRAIN SORGHUM	473	232	Acres	6.61	211.33	217.94	52,137
FORAGE SORGHUM SILAGE	621	312	Acres	5.78	44.96	50.74	17,596
ALFALFA	562	273	Acres	9.81	59.12	68.93	21,635
Total Crop Variable Costs	**3,172**	**1,505**	**Acres**	**228**	**1,317**	**1,545**	**$ 420,599**

Livestock	($/Head)		Unit	Head		Total Head	Value to Operation
BEEF COWS	619		Head	26		26	$ 15,888
BEEF PURCH. FOR RESALE SALES	448		Head	41		41	18,368
HOGS	94		Head	17		17	1,599
Total Livestock Variable Costs	**7,504**	**3,011**	**Head**	**84**		**84**	**456,454**

Total Gross Margin	**$ 68,797**

OTHER EXPENSES	
Other	
Misc	
Total Other Expenses	

NET FARM INCOME	**$ 68,797**

Table B.5: Southeast Kansas Average Farm

Feral Swine FMD Transmission in Kansas

WHOLE FARM BUDGET — ***Crop Farm***

SOUTHEAST KANSAS — NUMBER OF ACRES 1225.15

GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres	Value to Operation
CORN	807	414	Acres	6.23	274.65	280.88	$ 118,727
SOYBEANS		321	Acres		442.59	442.59	142,288
WHEAT	360	228	Acres	4.81	298.03	302.84	69,635
GRAIN SORGHUM		340	Acres		50.29	50.29	17,116
FESCUE HAY		186	Acres		135.70	135.70	25,216
ALFALFA		417	Acres		12.85	12.85	5,359
Crop Gross Income	**1,167**	**1,907**		**11**	**1,214**	**1,225**	**$ 378,342**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	501		Head	58		58	$ 29,056
BEEF PURCH. FOR RESALE SALES	371		Head	110		110	40,716
HOGS	99		Head	12		12	1,220
Livestock Gross Income	**971**			**180**		**180**	**$ 70,992**
TOTAL GROSS INCOME							**$ 449,334**
VARIABLE COST							
CORN	666	339	Acres	6.23	274.65	280.88	$ 97,267
SOYBEANS		234	Acres		442.59	442.59	103,693
WHEAT	403	243	Acres	4.81	298.03	302.84	74,495
GRAIN SORGHUM		292	Acres		50.29	50.29	14,699
FESCUE HAY		178	Acres		135.70	135.70	24,105
ALFALFA		273	Acres		12.85	12.85	3,503
Total Crop Variable Costs	**1,069**	**1,559**	**Acres**	**11**	**1,214**	**1,225**	**$ 317,762**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	619		Head	58		58	$ 35,897
BEEF PURCH. FOR RESALE SALES	448		Head	110		110	49,132
HOGS	94		Head	12		12	1,159
Total Livestock Variable Costs	**1,161**		**Head**	**180**		**180**	**$ 403,951**
Total Gross Margin							**$ 45,382**
OTHER EXPENSES							
Other							
Misc							
Total Other Expenses							
NET FARM INCOME							**$ 45,382**

Table B.6: Southwest Kansas Average Farm

Feral Swine FMD Transmission in Kansas

WHOLE FARM BUDGET ***Crop Farm***

SOUTHWEST KANSAS **NUMBER OF ACRES** **1160.02**

GROSS INCOME	Irrigated ($/Unit)	Non-Irrigated ($/Unit)	Unit	Irrigated	Non-Irrigated	Total Acres	Value to Operation
CORN	826	322	Acres	109.23	26.81	136.04	$ 98,838
SOYBEANS	490		Acres	19.27		19.27	9,445
WHEAT	360	223	Acres	52.69	620.80	673.49	157,289
GRAIN SORGHUM	447	288	Acres	28.55	213.93	242.48	74,403
FORAGE SORGHUM SILAGE	553	186	Acres	13.95	46.97	60.92	16,438
ALFALFA	840	527	Acres	22.69	5.13	27.82	21,760
Crop Gross Income	**3,515**	**1,546**		**246**	**914**	**1,160**	**$ 378,174**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	501		Head	9		9	$ 4,674
BEEF PURCH. FOR RESALE SALES	371		Head	95		95	35,392
Livestock Gross Income	**872**		**Head**	**105**		**105**	**$ 40,066**
TOTAL GROSS INCOME	**4,387**						**$ 418,240**
VARIABLE COST							
CORN	677	279	Acres	109.23	26.81	136.04	$ 81,422
SOYBEANS	435		Acres	19.27		19.27	8,392
WHEAT	403	191	Acres	52.69	620.80	673.49	140,006
GRAIN SORGHUM	473	233	Acres	28.55	213.93	242.48	63,424
FORAGE SORGHUM SILAGE	621	178	Acres	13.95	46.97	60.92	17,007
ALFALFA	562	250	Acres	22.69	5.13	27.82	14,043
Total Crop Variable Costs	**3,172**	**1,131**	**Acres**	**246**	**914**	**1,160**	**$ 324,295**
Livestock	**($/Head)**		**Unit**	**Head**		**Total Head**	**Value to Operation**
BEEF COWS	619		Head	9		9	$ 5,775
BEEF PURCH. FOR RESALE SALES	448		Head	95		95	42,708
Total Livestock Variable Costs	**1,067**		**Head**	**105**		**105**	**$ 372,778**
Total Gross Margin							**$ 45,463**
OTHER EXPENSES							
Other							
Misc							
Total Other Expenses							
NET FARM INCOME							**$ 45,463**