The Economics of Agricultural Bio-security:

An Interpretive Literature Review

By Levan Elbakidze

Department of Agricultural Economics

Texas A&M University

College Station, Texas

08/05/2003

This research was supported by the Texas A&M University based National Center for Foreign Animal and Zoonotic Disease Defense (FAZDD) that was established by the Department of Homeland Security. However, views expressed are those of the author and do not necessarily represent those of the FAZDD. All remaining errors are the author's.

The Economics of Agricultural Bio-security:

An Interpretive Literature Review

By Levan Elbakidze

Table of Contents

The Economics of Agricultural Bio-security:

An Interpretive Literature Review

1 Introduction

The dawn of September 11, 2001 began as a typical Tuesday morning for New Yorkers and Americans in general. For people around the country, the day was unfolding as it usually did. However, early morning of that day in New York proved to be unlike that of any other morning in the history of humanity. Unsuspecting citizens were shocked and terrified by the events that took place. The tragedy put a big question mark in the minds of many regarding the security of the nation and the American way of life. Instantaneously, the authorities and the population upgraded their assessment of the extent of vulnerability that the nation faced. September 11 proved to many that, in spite of enormous expenses on national defense, uninterrupted prosperity of the nation was far from being secured against deliberate acts of those who intended to disrupt everyday life of millions of Americans. It became clear that military forces alone were not sufficient to ensure peace and stability inside the country. Threats, such as a potential spread of anthrax or similar biological/chemical lethal agents became more realistic than ever before. Consequently, the authorities directed increased attention to safeguarding infrastructures, establishments and institutions, which were vital for uninterrupted perpetuity of the U.S. economy.

One of the primary pre-requisites of a well functioning economy is an abundant food supply. Today the average U.S. resident enjoys higher quantities of food and other amenities than ever before. In 2000, the agricultural sector accounted for $1.3 trillion in gross domestic product and employed nearly 24 million people (Bush 2002). However, the circumstances brought about by the events of September 11 demand attention toward food security. In particular, adjustments are needed to secure and protect the food sector of the economy from deliberate and unexpected actions that could disrupt the usual flow of agricultural commodities.

Sabotage of agricultural commodity markets could have devastating economic consequences. Deliberate as well as unintentional agricultural contamination incidents have been shown to have caused significant losses in welfare of both producers and consumers (Torok, T., et. al. 1997; FSIS, 2003; WHO 2002; Pinmentel et. al. 2000; Mermin et al. 1999; Mathews and Buzby, 2001; Atkinson, 1999; Mazzocchi 2002; Burton and Young 1996; Ryan et al. 1987; Hennessy, 1996; Halliday et al. 1991). In addition, agricultural contamination has been shown to have disrupted international trade (Atkinson 1999; Levine et. al. 1996; WHO, 2002). Economic losses that could be brought by agricultural contamination require development of policy options that would prevent and/or mitigate these losses. The purpose of this paper is to review the economic considerations of the policy options that could be adopted as response to agricultural terrorism.

Despite the national focus on dissemination of chemical and biological agents as aerosols or volatile liquids, deliberate food and water contamination remains the easiest way to distribute these agents (Khan et. al 2001). Consequently, current administration has increased spending on training and technology at the department of Agriculture to detect hazardous biological and chemical agents in order to prevent deliberate food contamination (Bush, 2002). To improve security measures directed towards the agricultural sector, the President has allocated $472 million, which will allow for more inspectors, new technologies such as computers and X-ray equipment, dog teams, and research and renovations of key laboratories (Veneman, 2003).

Although possible threats to food supply in the U.S. are numerous, this work will mainly revolve around an introduction of FMD (Foot and Mouth Disease) as an example of possible agricultural terrorism act. Such setting will allow us to analyze the implications of and possible counter activities to intentional as well as unintentional agricultural contamination on a regional level.

1.1 Economic Aspects of Agricultural Terrorism

From an economic perspective a major consequence of agricultural terrorism is that it would cause disruptions in agricultural commodity and related markets either because of the events itself or because of potentially expensive and intrusive preventative actions (Henson 2002). Several economic issues are related to agricultural market sabotage. Economic damages of agricultural contamination, in forms of lost consumer and producer surpluses, and costs of prevention, control and repair strategies are at the forefront of economic issues. In addition, a substantial component of economic analysis is related to prevention versus event management dimensions under the stochastic nature of the problem at hand.

1.1.1 Quantifying Economic Damages

Estimating the economic damages caused by either intentional or unintentional agricultural contamination gets rather difficult due to complex nature of agricultural markets (Atkinson 1999). Issues such as identifying affected parties (Paarlberg et al. 2003, Evans 2003) and calculating the economic values of damages to those parties, such as reduced sales (Smith et al 1988, Burton and Young 1996), and assessing the impact time line, are some of the complications related to event damage estimation. Due to highly integrated nature of modern economy the consequences of agricultural contamination at any given point along the supply chain could be manifested in other sectors of the economy. For example, major economic losses from recent FMD outbreak in the UK came from losses in tourism industry.

To estimate potential economic losses from agricultural contamination in form of infectious animal disease spread, biophysical information may be necessary to evaluate the extent of physical damages. For example, in case of animal disease some level of epidemiological insight is necessary to simulate the scope of an event (Jalvingh et al. 1999, Ferguson et al. 2001) and evaluate economic costs of a potential outbreak. In other words the spread rate of an infectious disease will determine the severity of economic damages and the combination of necessary prevention and response actions.

1.1.2 Mitigation of Agricultural Terrorism

Three broad categories of response polices to agricultural terrorism are prevention, detection, and control/repair. Prevention is perhaps the most desirable policy option when it comes to agricultural counter terrorism activities. Some of the preventative policy options relate to adjusting farm level production activities such as employing antimicrobial livestock drugs and vaccination, reducing access to chemical, biological and radioactive materials, etc. Others relate to processing and manufacturing procedures, storage and transportation facilities, retail distribution and food service facilities, and trade inspection. The basic purpose of prevention activities is to decrease the probabilities of intentional or unintentional agricultural contamination incidents.

Detection, which could be viewed as a part of prevention strategy, could facilitate avoidance of deliberate agricultural contamination by eliminating possible venues of agricultural terrorism. Surveillance and detection systems need to be set up or enhanced in order to identify and remove all affected commodities from the market in a timely manner. Tracking is an integral part of detection mechanism. Tracing systems could allow the authorities to identify the sources of outbreaks and remove all related commodities.

Response, control and repair are the least desirable but indispensable options of response to agricultural sabotage. Essentially control policies are intended to minimize the economic damages caused by agricultural contamination. This entails stopping the spread of a possibly infectious contamination and minimizing the bandwidth of the sabotage. Repairing the markets implies eliminating the sabotage sources, restoring or replacing the lost food branches along the food supply chain, and rebuilding consumer confidence.

1.1.3 Policy Responses to Terrorism

Prevention and response cost estimation entails designing a set of possible effective prevention, control and repair strategies (Khan et al 2001), realizing the necessary extent of such activities (Garner and Lack 1995, Ferguson et al 2001), and calculating the associated monetary and possible non-market costs of those activities. Some of the preventative and control activities at agricultural level involve: reducing access to chemical and biological materials, increasing security measures at central production, processing and distribution facilities, employee screening (WHO 2002), using antimicrobial drugs and vaccination (Schoembaum and Disney, 2003), enhancing and updating sanitary standards at production, transportation, storage and retail facilities, and establishing and/or improving detection, surveillance and tracing (Disney 2001) procedures. However, in this research, the attention will be concentrated on surveillance and detection, slaughter, and vaccination. Each of these measures has direct and possibly indirect costs, which need to be considered before a strategy is adopted.

When talking about response to agricultural terrorism the critical question is one of determining the optimal mix of apriori prevention/detection/tracing investment (APDTI) and expost control/repair/management (XCRM) strategies. From an economic stand point, the choice of the strategy needs to account for both economic costs of damages that could be brought by agricultural contamination and costs of preventing the incident (Berentsen 1992). In other words, a chosen APDTI strategy needs to pass benefit costs analysis, where the benefits correspond to avoided economic damages of agricultural sabotage while costs correspond to both monetary expenses and non-monetary losses related to executing the strategy. Similarly, XCRM strategies also need to satisfy benefit-cost criteria. In this case benefits entail an anticipated welfare increase from the total situation including the investment costs of the APDTI actions that aim to prevent, rapidly detect and manage agricultural sabotage events and the XCRM events that are directed toward repairing the damaged markets. Costs of such policies would correspond to expenses associated with implementing the strategy.

From an economic standpoint, the criteria for determining the optimal combination of prevention and control/repair strategies is based on cost benefit analysis. In other words, marginally, preventative activities are economically justified only as long as benefits from additional level of preventative actions outweigh benefits derived from additional control/repair activities and vise versa.

1.1.4 Stochastic Considerations

The choice of optimal mix of prevention and control/repair strategies is heavily affected by the stochastic characteristics of the issue. The sabotage probability values and severity of event consequences will influence whether it is more beneficial to invest in prevention activities or is it better to wait and respond with control and repair measures in case of an outbreak. At low probabilities of agricultural sabotage substantial investment in prevention, as well as surveillance and detection, will not look as attractive as in the case of high probability of agricultural contamination. It could also be argued that the probability of agricultural contamination is actually affected by prevention, surveillance and detection strategies (Shogren J.F., 2000). For example, a timely detection and destruction of infected animals will reduce the chances of regional spread of the infection, and thus will decrease the probability of outbreak occurring in the region. In other words, high levels of prevention, detection and surveillance will decrease the probability of a successful agricultural terrorism act. However, further in this analysis we will assume that prevention and response strategies do not affect the probabilities of planned agricultural sabotage but rather influence the severity of the attack. In other words, the probability of facing an attempt to sabotage agricultural markets is independent of implemented preventative activities. On the other hand, bandwidth[1] of the attack, and therefore, the severity of it, is directly affected by preventative and response measures. For example, vaccinating the animals before the attack does not decrease the probability of an attack but it may decrease the number of infected animals in case of an attack and decrease the probability that a specific farm

---

[1] *Disease bandwidth* refers to the extent of the impact caused by the food borne disease (Khan et. al. 2001).

or a farming community will be infected. Similarly, surveillance and detection activities could be argued to decrease the event severity, which could be represented by a probability of a given farm getting infected in case of an attack. Low levels of surveillance and detection, and consequent inability to detect and eliminate the threat in a timely fashion, could result in a severe event having high probability of a given farm getting infected. On the other hand, high levels of surveillance and detection could allow decreasing the probability of a given farm getting infected.

1.1.5 Prevention as a Public Good

Additional economic dimension of preventative strategy such as vaccination is that such activities carry characteristics of public goods. Specifically, if some of the farmers in a given area vaccinate than it will decrease the probability of infection for not only those farms that vaccinated but also for those that did not. Therefore, some farmers may choose to not adopt such preventative strategy and instead hope to “free ride” at the expense of those who adopt such preventative strategy. The Farmers that choose not to vaccinate can not be excluded from benefiting decreased infection probabilities due to vaccination activities of the neighbors. These benefits could also be argued to be non-rival. Specifically, enjoying decreased probability of infection spread by one farmer does not reduce corresponding benefits enjoyed by another farmer in the same vicinity.

1.2 Definitions

Using deliberately contaminated food to cause poisoning has been around probably since people have realized that the human body is not capable of digesting certain biological or chemical substances, and that these substances can cause discomfort, pain or even death.

However, using a food supply system to cause massive destruction is a relatively new concept. Consequently, there is no internationally accepted standard definition of agricultural or food terrorism.

One way that *food terrorism* has been defined is "an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and/or disrupting social, economic or political stability"(WHO, 2002). In this definition, chemical agents refer to manufactured or natural toxins, biological agents refer to infectious or non-infectious pathogenic organisms, including viruses, bacteria and parasites, and radionuclear agents are defined as radioactive chemicals capable of causing injury when present at excessive amounts. Clearly the objective of agricultural sabotage, such as food adulteration using chemical, biological or radioactive substances and agents, is to cause widespread injuries, inducing terror and panic, and disrupt social order (Sobel and Swerdlow 2002).

Agricultural adulteration can have diverse implications. While food contamination at a local restaurant can affect the customers of that particular restaurant, sabotage at centralized food processing or distribution facilities could affect a wide range of the population, even in diverse regions. Thus, food borne diseases caused by intentional or unintentional contamination, could be characterized by the amount of exposed people. *Disease bandwidth* refers to the extent of the impact caused by the food borne disease (Khan et. al. 2001). In other words, the more people are likely to be affected, the broader the bandwidth of the food borne disease.

In the context of bio-security, *risk* refers to the probability or probability distribution of agricultural contamination. Introduction of non-indigenous species may or may not result in undesirable agricultural contamination. Shogren (2000) argues that the odds of calamity are low, but with increased trade and easy mobility the risks of invasion by detrimental species are going up.

The most desirable option to combat deliberate agricultural contamination, as well as accidental contamination is *prevention*. Prevention could be defined as preventing agricultural sabotage during production, processing, distribution and preparation (WHO 2002). Establishing new and enhancing existing food safety programs on the basis of assessed vulnerability are key components of the counter terrorism agenda. Prevention includes activities such as restricting access to chemical, biological and nuclear agents, increasing security measures such as monitoring at agricultural harvesting, production, processing, manufacturing, storage, transport, retail distribution and food service facilities.

It is nearly impossible to prevent every possible incident of deliberate or accidental agricultural contamination. In those unfortunate cases where suspected or adulterated food has reached the consumer, effective emergency *response* systems need to be activated. Response activities may include, but not be limited to, verification and assessment of threat, identification, tracing and removal of contaminated food, and management of consequences including aiding affected population.

2 Background on Terrorism towards Agriculture

The basic goal of terrorism acts is to inflict fear on population in order to draw attention to their purpose. Although up to now not very popular comparing to other forms of terrorism agricultural sabotage represents a serious threat to public health and to the economy. Therefore, in the next two subsections we compare agricultural sabotage to other forms of terrorism and discuss various options that are available for terrorists to inflict fear and chaos through agricultural venues.

2.1 Agricultural Sabotage vs. Other Forms of Terrorist Threats

Terrorist threats can take a wide variety of forms. Possibilities include hijacking airplanes, planting explosives in populated areas such as shopping malls or public transportation systems, attacking vital infrastructure facilities such as nuclear power plants or hydroelectric dams, contaminating water supplies, spreading lethal biological, nuclear or chemical agents through air or water, food adulteration, etc. Agricultural contamination is one of the possibilities, which needs to be investigated in order to prevent and, if necessary, respond to such an act of terrorism.

On one hand, agricultural sabotage, such as tampering with food supply might be easier to prevent and mitigate than other means of terrorism such as attacks through air or water. Food safety in developed countries is enforced in both government and private sectors. Hence, there already exist infrastructures that deal with food safety regulations and enforcement. Therefore, to account for increased probability of intentional contamination, these safety measures may only need to be enhanced rather than instituted. This aspect makes mitigation of agricultural adulteration a relatively easier task than fighting terrorism in military, transportation, or other areas. Moreover, the diversity of our food supply reduces the chances that the entire food supply will be adulterated. On the other hand, food is very vulnerable to intentional contamination. Centralized and widespread distribution of some agricultural commodities makes massive amounts of people susceptible to individual potential acts of agricultural terrorism.

Overall, the complexity of agricultural distribution channels and often massive consumption of certain commodities makes agricultural adulteration mitigation a rather complex task.

2.2 Potential Agents for Agricultural Contamination

Securing our nation's food supply depends on numerous factors. These factors vary from economic, political, and international aspects to climatic conditions. Crop and animal diseases have always been a concern of producers as well as consumers. Conceptually speaking, agricultural sabotage could be materialized through introduction of non-indigenous (non-native) species of plants, mammals, microbes, and other biological units, which could disrupt agricultural commodity markets (Pinmentel et. al. 2000). In fact, introduction of non-indigenous species into agricultural production could bring substantial costs to society, even if they pose no serious threat to human health. For example, Field Bindweed is estimated to cause over $40 million in crop damages in Kansas alone annually (Shogren, 2000).

Food borne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5000 deaths annually in the United States (Mead et. al. 1999). The threats to food supply are distinct and numerous. Recognizing possible agents that could cause such turmoil is essential in order to analyze the effects and prevention options of these threats. Today there are more than 250 documented food borne diseases (CDC 2003). These illnesses could generally be grouped into four major categories based on causation type. First are bacteria such as Campylobacter, Salmonella, E. coli O157:H7, etc. Second are viruses, such as a group of viruses known as Calicivirus, or Norwalk-like virus, and FMD. Third are parasites such as Giardia and Cyclospora. Fourth, natural or artificial chemicals such as mushroom toxins and heavy metals. Known pathogens cause 38.6 million illnesses, of which 5.2 million are due to bacteria, 2.5

million due to parasites, and 30.9 million due to viruses (Mead et. al. 1999). In terms of public health safety, the CDC has prepared a list of highest priority categories of agents, which include those agents which are easily disseminated, cause high mortality and morbidity, can produce social disruption, and need special actions for public health preparedness (Sobel and Swerdlow, 2002). This list contains a wide range of agents such as *Clostiridium botulinum* neurotoxin, the most lethal substance known to man (which results in death from respiratory arrest if untreated), *Shigella* spp, which can cause death rates of up to 20% among admitted patients without appropriate treatment, *E coli*, which is a highly infectious organism, *B anthracis*, Samonella serotypes, *Vibrio cholerae*, hepitatis A, *Cryptosporidium*, etc. Operationally any member of these categories could be used for intentional food contamination purposes.

Some of the most widely publicized agricultural contamination cases are FMD and BSE Outbreaks in UK. Prevention practices such as vaccination and plant treatment have been in place for a long time. In fact certain forms of diseases such as FMD and BSE in cattle have been almost completely eradicated by successful prevention practices. However, current situation demands extra caution when it comes to food safety. BSE has serious implications on human health. Cruetzfield_Jacob Disease (nvCJD), a human variant of BSE, is known to have caused 100 deaths worldwide. Fortunately, BSE outbreak has never been detected in the US (Mathews and Buzby, 2001). Unlike BSE, FMD is not usually fatal to livestock or humans, and consumption of the meat from infected animals is not considered a food safety issue (Ferguson et. al 2001). However, FMD is more contagious and easier to spread than BSE, which primarily spreads from consuming diseased meat. The spread and variability of FMD outbreaks depend on spatial distribution, size, and species composition of farms (Keeling et. al. 2001). There have been around 40 documented cases of FMD in humans worldwide (ERS 2001 a). The US has been free of FMD since 1929.

3 Economic Implications of Agricultural Sabotage

Agricultural adulteration can bring numerous and diverse consequences, which makes exhaustive estimation of associated economic losses to be rather difficult. An exhaustive estimate of the economic costs would include effects on the producer profits and consumer welfare, lost jobs, costs of responding to the incidents, such as costs of complying with enhanced regulations, clean up, medical treatment, etc. Currently, most of the existing estimates reflect certain components of total costs of agricultural contamination. For example, medical costs and lost wages due to food borne salmonellosis, only one of many food borne infections, have been estimated to be more than $1 billion/year (CDC 2003). Non-native species, such as plant pathogens and livestock pests could cause considerable economic losses. Plant pathogens cause crop losses equivalent to approximately $33 billion, while livestock losses due to pests are estimated to be approximately $9 billion per year (Pinmentel et. al. 2000). However, plant pathogens could cause additional economic losses in the form of damages to non-crop plants. Livestock pests could harm consumer welfare through increased livestock prices due to decreased production.

Most obvious economic effects of agricultural food contamination are changes in market prices for the affected commodities. For example the prices at retail, wholesale and producer levels in UK are estimated to fall by 1.7, 2.25 and 3.0 pence/kg, respectively over the 1990s due to BSE occurrence (T. Loyd, S. McCorriston, C.W. Morgan, A.L. Rayner, 2001). This implies that the economic consequences of agricultural contamination will vary along the supply chain in terms of magnitude. In addition to examine the price effects of agricultural contamination, one would need to decompose this price effect into supply and demand effects, combination of which makes up the prices and their changes in the market. For example it was estimated that the long run effect of BSE outbreak in the UK in 1990 was 4.5% reduction of consumer expenditures on beef (Burton and Young, 1996). Clearly, there also were changes in supply environment due to stricter regulations, not related to BSE, which also influenced the market price of beef products, consequently influencing demand for beef products.

Due to recent FMD outbreak in UK in 2001 the losses to the agricultural industry were projected to be anywhere from $720 million to $2.304 billion. Expected tourism losses were even higher (www.economist.com, 2003). Schoenbaum and Disney (2003) estimated that net changes in consumer and producer surplus due to a hypothetical FMD outbreak in the United States would amount to $789.9 million annually. However, their estimate was based on the assumption that the consumer demand would not be affected by the outbreak. Taking consumer response into account could potentially alter the estimate. The list of economic impacts could be quite lengthy but it is unlikely that every conceivable consequence could be accounted for.

3.1 Producers

Outbreaks of diseases through introduction of non-indigenous species affect producers and consumers through changes in agricultural product prices, costs of production and availability of goods. From a producer’s standpoint, agricultural contamination implies a ban or at least a substantial reduction in sales of the infected commodities. As a consequence, the producers could suffer significant economic losses, unless compensated by the government. For example, in 1982, 80% of milk produced in Oahu (Hawaii) was damaged due to heptaclor contamination. As a result, 36.2 million pounds of milk were recalled. Sales losses due to contamination and subsequent milk bans were estimated to be 41.7 million pounds (Smith et al. 1988)[2]. In 1996, contaminated radish sprouts served in school lunches led to an outbreak of *Eschria coli* 0157:H7 infection in Sakai City, Japan. The outbreak caused meat and fish sales to decline by 40-60 percent. In addition, consumers also responded by purchasing 40-60 percent fewer restaurant meals (Mermin et al. 1999), thus leading to losses in restaurant industry. The director of the school lunch program in Sakai City committed suicide after the outbreak.

Agricultural sabotage, such as introduction of animal diseases, could cause a significant decline in agricultural productivity. Although mortality is high among young animals infected with FMD (Ferguson et. al 2001), most animals recover from infection, but with permanently reduced weight gain and/or milk yield. Infected animals are usually quarantined and killed as part of prevention efforts, reducing supplies of livestock products. These actions result in substantial monetary losses for farmers who incurred costs associated with production of livestock, which can not be sold due to illness. In 2001 the losses to the UK agricultural industry due to FMD were projected to be anywhere from $720 million to $2.304 billion. Since July 9, 2001 more than $63 million has been paid to UK producers (www.economist.com, 2003) to compensate for some of their losses.

The 1996 outbreak of BSE in UK affected beef producers in general by decreasing demand and turning their beef into unmarketable products that had to be disposed of. The

---

[2] Calculatined the difference between the projected sales without incident and estimates of actual sales.

announcement in March 1996 about possible link between BSE and it's human version was followed by an immediate drop of 40 percent in sales of beef products. First year losses alone were estimated to be around $1.07-$1.4 billion (Mathews and Buzby, 2001). Between one half and two thirds of total losses from BSE were attributed to fall in value added of the meat production. The remainder of the losses resulted from the costs associated with various public schemes, compliance costs of new legislative requirements, and production adjustment costs (Atkinson, 1999). However, beef farmers were about 90% compensated for BSE induced revenue losses (Atkinson, 1999).

3.1.1 Supply Chain Effects

Most of the time, production reductions due to disease outbreaks affect a whole line of entities on the supply side of the market. For example, in the case of the BSE outbreak in the UK, there were losers as well as winners within the cattle sector. Specialist beef finishers suffered from the joint effect of higher calf prices and lower finished cattle prices. On the other hand, dairy farmers saw improved prices for their calves and cull cow (Atkinson, 1999). Cattle slaughterers, processors, manufacturers and renderers were also among the affected parties. Mainly, the extent of the effect depended on the ability of a party to substitute to a different product such as pork, poultry and lamb. Degree of substitutability varies depending on business type. Fore example, it is easier for a butcher to switch from beef to pork than it is for rancher to switch from cattle to swine.

Impacts of an outbreak of a food borne disease stretch beyond the immediate markets for the contaminated or suspected commodity. For example, due to UK government's announcement of a possible link between BSE and human health various types of firms in the beef and related sectors were impacted. Processors of beef, dairy products, animal feed, and pet food were negatively affected. On the other hand, manufacturers of other meats were positively affected by the announcement (Henson and Mazzocchi 2002)[3].

Food borne disease outbreak could also affect industries other than agriculture and food. For example, effects of BSE and FMD probably spilled over to clothing, furniture and other leather commodity markets. Highly contagious diseases also result in public scares, which affect industries such as tourism. Of the total estimated costs of £7.6-8.5 billion, £3,1 billion was borne by the public sector, farmers and related industries, while £4.5-5.3 billion was lost tourism and leisure industry (M-J. J. Mangen, A.M. Barrell 2003).

3.1.2 Welfare Measures

Welfare effects for producers are usually measured by changes in producer surplus values. For an outbreak of a food borne disease and/or for the introduction of non-indigenous species, the effects on producer welfare could be measured by the change in producer surplus before and after the outbreak. Figure 1 illustrates a situation with a hypothetical outbreak. As a result of an outbreak supply decreased from S_0 to S_1, while demand could decrease to D_1 or even D_2, consequently increasing or decreasing the price. However, for illustration purposes, suppose demand for uncontaminated food items did not change[4]. Then the change in producer surplus

---

[3] Financial security prices of relevant firms were used to assess the impact of the announcement.

[4] Direction of resultant price change is not important for the main argument, which is that not all producers are affected in the same manner.

would be $A_1A_0P_oP_1$. However, this measure of change in aggregate producer welfare could be misleading for certain types of food contamination incidents such as FMD. The reason is that not all producers of the same commodity are affected in the same manner (Paarlberg at al. 2003). Producers whose output had to be taken out of the market are affected differently from those whose product survived the outbreak and remained in the market. For producers whose product remained in the market, welfare change could be measured as area to the left of their supply and between the initial and new price (Figure 2a). Consequently these producers could be better off or worse off depending on the direction of price change. On the other hand, for the producers of a banned commodity, welfare is measured by losses in sales revenues, equal to $0P_0CQ_0$ (Figure 2b). Therefore, for cases such as FMD outbreaks, where not all of a given commodity supply is banned from the market, it may be more appropriate to decompose the effects on producers into two parts; the effect on producers who are directly affected by contamination, and the effect on producers whose products are not contaminated.

3.2 Consumption

Usually, detected contamination of agricultural commodities results in bans of infected or suspected products. Consumers are affected by decreased availability of and increased prices for safe food products. At the same time, demand for a commodity, a certain brand of which has been contaminated, decreases. This implies change of consumer preferences at least in the short run. Although in the long run preferences are likely to return to pre-incident state, it is possible that small changes will occur permanently.

The actual effects of a “food scare” that result from agricultural sabotage in part depend on consumer perceptions, which could deem some commodities to be riskier then others. For example, sales of beef products in Great Britain decreased by 40% immediately after the announcement made by the British government in 1996 regarding a possible link between BSE and it's human version, nvCJD. Household beef consumption decreased by 26% relative to the previous year (Atkinson 1999). However, this decrease was uneven for different cuts of beef. Beef products such as burgers and mince experienced substantially larger decreases in consumption than better cuts, such as high quality steaks.

Outbreaks of certain food borne diseases could affect the restaurant industry. Demand for eating out is likely to decrease in times of elevated public concerns regarding food safety, regardless of the type of commodity that was contaminated. Consider the case of E. Coli outbreak in Japan in 1996 where white radish sprouts served at school lunches were contaminated (Mermin 1999). As a result of intense public anxiety, restaurants and hotels throughout Japan experienced a decrease in their businesses. In fact, sales of fish, meat, and all restaurant meals decreased by 40 to 60 percent.

As in a case of advertisement, publicity of food borne disease affects the demand in a dynamic manner. The demand for an infected commodity changes most notably in the short run, while over the long run the effects of “food scare” may decrease or even dissipate. This process applies not only to a commodity with possible infection but also to related goods. For example, maximum short run effect of BSE on the demand for beef, pork, lamb and poultry in Great Britain was a 6% reduction in beef and veal share, which occurred in the summer of 1990 when there was a maximum number of published news articles on BSE (735). In the long run, over the sample period (1961-1993), BSE has decreased the expenditure share of beef by 4.5 percent, while other meats gained in share (Burton and Young, 1996)[5].

3.2.1 Distribution of Welfare Change

Measuring the effects of agricultural disease outbreaks on consumer welfare is complicated by asymmetry in possible consumer responses. After contaminated items have been removed from the market, consumers could behave in different manners. One group of consumers could be relatively confident about safety of food commodities that are available in the market, while another *hypersensitive* (Paarlberg et. al. 2003) group, might no longer consume the commodity. If, as a result of an outbreak, the price for the commodity decreased then the group that is still consuming a given commodity experiences increased welfare, while those who completely stopped purchasing suffer welfare loss. If the price increased then both groups experience welfare losses, although to different extents. The proportion of hypersensitive consumers will affect the overall sign of consumer welfare change. Paarlberg et al. (2003) estimate that for a potential FMD outbreak in the US, if the proportion of hypersensitive consumers is less than 7%, then overall consumer welfare increases due to decreased beef price. However, if the proportion of hypersensitive consumers is greater than 7% then overall consumers lose even with a decreased price for beef. Therefore, it is important to find out how the consumers would react to a potential food contamination in order to estimate welfare effects.

---

[5] They use Almost Ideal Demand System combined with the quarterly data on the number of newspaper articles that mention BSE to estimate the effects.

3.2.2 Role of Information Media Coverage

The effect of food contamination on consumers essentially manifests itself through information passed on to the consumers. Publicized food contamination creates “food scares”, which have the opposite effect of advertising. The result is that the demand for contaminated or a suspected commodity of brand “A” decreases substantially or disappears. However, the demand for the same commodity of an uncontaminated brand “B” may decrease, increase, or stay approximately the same. Hence, depending on the level of “food scare” and degree of substitutability, the price for brand “B” may increase, decrease or stay roughly unchanged.

The extent to which consumers adjust their behavior largely depends on media coverage. Moreover, the information passed on to the consumers will have different effects on consumer behavior depending on the source of information. Sources perceived to have external reasons for making a persuasive argument are likely to have a greater propensity to be discounted. Credibility and trust are two key concepts that determine consumer response to a given information source. Outbreaks of food borne diseases could affect consumer attitudes toward various sources of information. For example, consumer trust in opinions of family and friends, rather than experts, increased immediately after the 1996 BSE outbreak in the UK (Smith et. al 1998).

When it comes to food contamination, the media has two fundamental roles. One is to inform the public of available details about the incident, such as disease type, affected commodity and brands, contagiousness, precaution and treatment specifics etc. Obviously, the extent and content of information passed on to the population will affect purchasing behavior of consumers. Second is to facilitate restoration of lost consumer confidence. This entails informing the population about safety of unaffected products and about containment of disease. The effectiveness of this coverage will play a significant role in the restoration of consumer confidence. In 1982, 80% of milk produced in Oahu (Hawaii) was contaminated due to heptaclor contamination. Smith et. al (1988) evaluated the effects of media announcements on the demand of milk in Hawaii during the sixteen months following the contamination incident. The model incorporated two types of media coverage. Negative coverage dealt with the recall of contaminated milk, while positive coverage reassured the population that unrecalled milk was safe for consumption. It was concluded that the effect of negative coverage dominated the effects of positive coverage. In other words, positive media announcements that followed negative announcements failed to fully restore consumer confidence lost due to media coverage of contamination incidents.

Media coverage of animal disease outbreaks will play a significant role in determining the response of consumers. Essentially media coverage is argued to alter public perceptions regarding food safety. However, it was found (Piggott and Marsh, 2004) that subsistence level demand for beef would decline by 0.144% in response to 10% increase in beef safety index, measured by the number of publications that appear in news paper and magazines regarding beef safety. This estimate implies a decline of 0.024 pounds of quarterly beef consumption per person as a result of 10% increase in beef safety index. Similarly there would be 0.25% decline in subsistence consumption of poultry as a result of 10% increase in poultry safety index. This implies a decline of 0.039 pounds of quarterly poultry consumption as a result of 10% increase in poultry safety publicity. Subsistence consumption of pork would decline by 0.13% as a result of 10% increase of pork safety publicity. Consumer response to food safety issues were found to be statistically significant but economically small especially relative to price effects and other health issues related to meat consumption such as health information.

3.3 Trade

Contamination of agricultural commodities could have devastating effects on trade. Businesses in many industries could potentially be put out of business because sabotage of agricultural production could result in abolishment of exports of a wide range of products related to infected or suspected commodities. For instance, in 1989 four outbreaks of staphylococcal food poisoning in the US were associated with eating mushrooms canned in China (Levine et. al. 1996). The incident affected 99 people who ate at a university cafeteria, hospital cafeteria, pizzeria and at a restaurant, 18 of which were hospitalized. Investigations of mushroom plants in China by FDA (US Food and Drug Administration) investigators and consultants found several reasons of mushroom contamination, including widespread sanitation deficiencies at the processing facilities. In response, US FDA restricted imports of all mushrooms produced in China, which was approximately 50 million pounds annually. In 1989 all Chilean grapes were recalled from US and Canadian markets due to cyanide contamination. As a result, several hundred growers and shippers went bankrupt (WHO, 2002).

Due to the announcement of the British government regarding BSE in March 1996, the European Union imposed a ban on all UK beef exports worldwide. As a result, UK lost all of its beef exports which in 1995 was 300,000 tons, worth about 600 million pound sterling, plus 70 million pound sterling in live calves. At the same time, the price of beef cattle fell by 25%. In addition, furniture and other leather commodity markets were affected (Atkinson 1999).

4 Venues of Agricultural Terrorism

In order to mitigate possible agricultural terrorism acts one needs to consider a variety of possible scenarios. Reviewing past agricultural and/or food contamination incidents could contribute to identification of vulnerable segments in the agricultural industry. Of particular importance are centralized processing and distribution channels, which, if sabotaged, could pose threats to market stability and potentially result in a disease outbreak with significant bandwidth. It is also important to consider international sources of contamination.

4.1 Intentional Contamination

Throughout history there have been some documented instances of terrorism through food supply with the purpose of causing injury and/or inducing terror on civilian populations. Food adulteration could originate anywhere along the food supply chain, starting from a farm and ending at a restaurant, food store or even a laboratory. For example, in 1996 a laboratory worker deliberately contaminated food to be consumed by co-workers with *Shegella dysenteria* type 2 and caused 12 people to become ill (WHO 2002). A more serious case of food adulteration occurred in 1984 when members of a religious cult deliberately contaminated salad bars in ten restaurants with the salmonella *serotype typhinurium* in Dalles, Oregon. This resulted in 751 people becoming ill, which caused serious strains on local medical resources and nationwide fear of recurrence (Torok, T., et. al. 1997; FSIS, 2003). The authorities responded to the outbreak by closing all salad bars in the town. It took approximately one year of investigative work to link the outbreak to the religious commune, which operated a clinical laboratory where open containers carrying *serotype typhinurium* were found. It was inferred that the bacteria were spread by the customers mainly on salad bars and also in liquid coffee creamer in some restaurants. This case demonstrates how vulnerable our open society is to intentional contamination of food. It is unlikely that any regulation could have prevented this outbreak. It would probably be unreasonable to suggest screening of customers at all restaurants where they sell self-serving food items. However, this incident does suggest using enhanced screening procedures when it comes to access to biological or chemical agents, such as those that were used in this incident.

Intentional food contamination could be originated at any level of food supply chain of nearly any agricultural commodity. However, vulnerability varies along the supply chain. Supply points which are most accessible to public are most vulnerable. Unfortunately, as the above examples demonstrate, supply points such as cafeterias and restaurants are difficult to safeguard against intentional food adulteration.

4.2 Unintentional Contamination

Naturally occurring agricultural introduction of non-indigenous species, which result in food borne disease outbreaks, demonstrate our potential vulnerability to biological and chemical terrorism directed towards food supply. Theoretically a terrorist organization could sabotage the food supply after assessing the disease bandwidth and investigating the points of vulnerability along the farm to table supply chain. Hence, it is advisable to identify and examine the most vulnerable foods and processes that could be used for intentional food contamination.

To get an idea of possible vulnerable segments and areas along the farm to table food supply chain (figure 3), we can reflect on many documented cases of unintentional outbreaks of food borne diseases. For example, in 1985 there was an outbreak of *S. typhimurium* infection caused by contamination of pasteurized milk at a diary plant in the U.S. affecting 170,000 people

(Ryan et al. 1987). The contamination was allegedly caused by unintentional mixing of contaminated milk with pasteurized milk. In September and October of 1994 *Salmonella enteritidis* gastroenteritis developed in 224,000 persons in the United States after they ate Schwan's ice cream. It was found that the outbreak was caused by contamination of pasteurized ice cream premix during transport in tanker trailers that had previously carried nonpasteurized liquid eggs containing *Salmonella enteritidis.* Consequently it was induced that food products, which did not require re-pasteurization should be transported in designated containers (Hennessy, 1996). Hepitatis “A” was responsible for almost half of the outbreaks of liver disease in Shanghai, China, affecting 292,301 people in 1988. It turned out that raw shellfish, such as clams, were responsible for causing outbreaks of hepatitis A (Halliday et al. 1991). The conclusion was made that it was necessary to enforce strict regulations related to harvesting and distribution of shellfish in order to ensure healthiness of marketed clams. In addition, it was suggested that residential effluent drainage into catching areas should be regulated. In 1996 in Sakai City, Japan, 7000 children became ill with Eschria coli 0157:H7 infection from contaminated radish sprouts served in school lunches, resulting in numerous deaths (Mermin et al. 1999).

4.3 Biological Invasive Species

More than 50,000 species of animals, plants and microbes have been either accidentally or intentionally introduced into the U.S. in the past 100 years (Pinmentel, 2002; Perrings, Williamson and Dalmazone, 2000). In the past 40 years the rates of biotic invasions have increased significantly due to population growth, rapid movement of people, alteration of the environment, and increased trade among nations. Some of these non-indigenous species have caused substantial economic losses in agriculture, forestry, the environment and other segments of the U.S. economy.

Alien plants, such as Purple Loosestrife, Aquatic Weeds, Crop weeds, etc. cause approximately $34,662 million in annual costs. Non-indigenous mammals, birds, reptiles, amphibians, and fish cause $39,711.1 million in annual costs. Imported arthropods, such as crop pests, forest pests, imported fire ants, and others cause $20,000 million in annual costs. Imported microbes such as plant pathogens cause $41,200 million in annual costs. Non-indigenous livestock diseases are responsible for $9,000 million in annual costs (Pinmentel, 2002). Generally, economic costs of biological invasions include impacts on production, price and market effects, trade, food security and nutrition, human health and the environment, and financial costs impacts (Evans, 2003).

4.3.1 Foot and Mouth Disease

One of the most widely publicized case of unintentional agricultural contamination was the recent FMD outbreak in the UK. Between February 20th and September 30th 2001 there was a total of 2026 cases of FMD confirmed in Great Britain (Scudamore 2002). Total losses from this outbreak were estimated to be £7.6-8.5 billion (M. J.J. Mangen, A.M. Barrell,2003). FMD could be spread though air, transport vehicles, artificial insemination, milk related transmission, direct contact, and by wildlife such as birds, dogs, cats, and rodents. Additional complication with FMD is that the infected animals don’t show the signs of the disease for a couple of weeks (Bouma et al. 2003). This means the infected animals are spreading the disease before they are diagnosed and removed from the heard. Variations in weather, regional geography, farming practices, and farm-level variability in bio-security could all introduce spatial and temporal heterogeneity into transmission patterns. However, it is speculated that the most likely origin of the outbreak in the UK was contaminated meat products, which were used as feed for pigs (Scudamore 2002). The US has been free of FMD since 1929. The most likely method of introducing FMD into the United States is from contaminated animal products, frozen semen, or animal feed imported from areas of the world, which have the disease (McCauley et. al. 1979).

FMD outbreak in Great Britain spread into neighboring countries such as Netherlands, France and Ireland. It was inferred (Bouma et al. 2003) that the most likely route of infection in Netherlands was the importation of Irish veal-calves via FMD infected staging point in France. As a result, in Netherlands alone 26 outbreaks were detected and 260,000 animals were killed, 1800 farms were vaccinated and consequently depopulated.

Based on the experience of recent FMD outbreak in Great Britain, farms 0.5,1 and 1.5 km. away from a single farm affected by FMD have probabilities 0.26, 0.06, and 0.02 respectively of becoming infected (Ferguson et. al. 2001). Farms 3-5 km away from an infected piggery have probability 0.0153 of being infected within 3 days of detecting clinical signs of the FMD outbreak due to wind borne and local spread (Sanson, 1993). Probabilities of infection spread for sheep and cattle farms are assumed to be approximately one tenth of the levels for pigs. The evolution of the epidemic depends in part on the distribution of times between the four key events: 1) infection of a farm, 2) the report of a suspected infection, 3) confirmation of disease, and 4) slaughter of the animals on the infected farms. Large farms are considered to be more susceptible to the disease. Cattle are more susceptible to the disease than sheep.

4.4 Centralized Distribution Channels

In recent years, centralized production, processing and distribution of agricultural products have been increasing features of US food supply. This development has increased the risk of large outbreaks of food borne diseases (Sobel and Swerdlow 2002, Khan et. al. 2001).

Centralized production, processing and distribution of agricultural commodities present serious threats when it comes to agricultural contamination. The 1996 outbreak of E. Coli in Japan was shown to have occurred due to contaminated white radish sprouts, which was served to school children through the lunch program (Mermin, 1999). Over 7,000 people where affected by the outbreak. As a result of intense public anxiety restaurants and hotels throughout Japan experienced a decrease in their businesses. Sales of fish, meat, and restaurant meals decreased by 40 to 60 percent. This case demonstrates the potential dangers of centralized food distribution. In the case of centralized food distribution channels, such as school lunches, many people tend to be affected because the same meals are served to many schools. This demonstrates the need for upgrading the food safety measures at facilities related to centralized food production, processing and distribution, especially those that are more vulnerable to intentional contamination and those with lower or outdated food safety criteria.

However, centralized food production and distribution also has certain advantages. For example, improvements in operations of a large producer might be easier instituted than simultaneous improvements in smaller producers that would lead to equivalent improvements in food safety. Raw consumption of certain foods implies the need for control measures directed at farms and other production establishments because consumers can do little to protect themselves.

4.5 International Sources of Contamination

Most countries have established food safety infrastructures, which could be adjusted or expended to reflect higher alert for acts of food supply sabotage. However, the diversity in the food supply system makes prevention extremely difficult especially when taking into account international sources. Many developing countries have less developed food safety infrastructures and are more vulnerable to intentional food contamination. Agricultural contamination in foreign countries, intentional or unintentional, poses threats to domestic food markets due to modern global complexity of international trade. Food commodities that have been intentionally or unintentionally contaminated and imported to the U.S could have substantial health effects.

For example, in 1995 there was an outbreak of Salmonella detected in 17 states and Finland (Mahon et. al. 1997). A total of more than 242 cases were documented out of a possible 5000-24000 cases considering underreporting. It was established that the infection among American and Finish patients was caused by consumption of contaminated alfalfa sprouts, which were produced by different growers. However, contaminated alfalfa sprouts were grown from the seed than came from a common seed shipper in the Netherlands. Hence it was concluded that seeds which were contaminated before shipment were the cause of the outbreak. To prevent future similar outbreaks the suggestion was made to enhance decontamination of seeds before shipping. This could be achieved by soaking the seeds in chlorine bleach at high concentrations.

In an another example, outbreaks of *cyclosporiasis*, with 1465 cases reported by 20 states in North America in 1996, were linked to consumption of Guatemalan raspberries (Herwaldt 1997). It was established that as few as five Guatemalan farms could have accounted for the 25 of the 29 events where raspberries were served and for which a single exporter could be traced.

The 1996 outbreak of E. Coli in Japan due to contaminated white radish sprout was attributed to contaminated seeds imported from the U.S. (Mermin, 1999). In response to this outbreak the Japanise national institute of health has placed one physician at the Division of Emerging Diseases at the World Health Organization and one physician at the Epidemic Intelligence Service at the Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services. The reason for those placements was to gain experience in communicable disease control and outbreak investigation.

5 Prevention

Deliberate food contamination incidents via massive disruption of food processing, storage, transportation or distribution, could seriously damage economic stability. Therefore, it is important to initiate and/or enhance preventative measures, which would provide increased security to the food supply of the economy. Clearly, food supply of a gigantic economy such as the U.S. is difficult, if not nearly impossible, to completely safeguard against any possible assault. Nevertheless, eliminating as many conceivable venues of disaster as possible is necessary to decrease the vulnerability of the economy. Along the farm to table food supply chain (Figure 3.) measures such as tracing systems and recalls, monitoring and examination of product qualities, reducing access to chemical, biological and nuclear materials, and other actions can be used to prevent agricultural and food sabotage.

Deliberate food contamination using chemical, biological or nuclear agents is a relatively new threat to national security. The key to preventing food adulteration is to enhance existing food safety measures, and to establish new food safety measures based on vulnerability assessments. Hence, the most vulnerable commodities and their production and supply processes need to be identified. For example, prevention measures should be enhanced at the most readily accessible agricultural and food processes, foods that are most vulnerable to undetected contamination, commodities that are most widely distributed, and the least supervised agricultural and food production areas and processes (WHO 2003).

It is also important to increase security measures at central production, processing and distribution facilities. The controlling and screening of access to certain areas, chemical and biological agents, raw products, equipment, and other key factors in the food supply chain, needs to be enhanced based on the vulnerability assessment.

5.1 Agricultural Production

Ensuring the safety and security of a food supply starts at the farm level of the food supply chain. Some of the areas of critical importance at this level are monitoring and quality control of animal feed and feed ingredients, seeds, pesticides, irrigation water, and harvesting practices, such as open air drying, etc. Different agricultural production processes will require different prevention methods.

5.1.1 Prevention of Contagious Animal Diseases

Enhanced monitoring and quality control measures might have detected contaminated meat and consequently prevented the massive FMD outbreak, which paralyzed beef farming in the UK. Enhanced monitoring and quality control measures might have also prevented an outbreak of Salmonella in the US and Finland caused by contaminated seeds exported from The Netherlands (Mahon et al 1997). Many more areas could probably be identified. However, since analysis of all possible threats is probably impossible, emphasis could be placed on the most vulnerable points and on determining deviations from normal characteristics.

Allegedly, the most likely origin of FMD outbreak in the UK was contaminated meat products, which were used as feed for pigs (Scudamore 2002). Therefore, close feed inspection on a regular basis is essential for prevention of an outbreak of FMD or similar diseases. In terms of designing regional mitigation policies for outbreaks of infectious diseases, such as FMD, estimates of spatial distribution, size, species composition of farms (Keeling et. al. 2001), and contact rates (Nielen, M. et. al. 1996) between farms need to be developed.

5.1.2 Anti-microbial Livestock Drugs and Vaccination

Anti-microbial drug (antibiotics) use at farms has been surrounded by controversy since the practice began in the 1940s (Mathews at. el. 2001). Anti-microbial drugs are designed to kill disease-causing microorganisms such as bacteria and fungi. However, at low levels these drugs are also used to promote livestock growth. This type of drug application raises some issues. The problem is that there are scientific uncertainties about implications of using anti-microbial drugs as growth promoters. There are different opinions within the government about the risks to public health posed by using anti-microbial drugs in farm animals. First, livestock drug residues may remain in final products and cause human illness. Second, microorganisms, such as bacteria may be developing resistance to anti-microbial drugs. In a related case, an outbreak of an anti-microbial resistant salmonellosis attributed to pasteurized milk in Illinois in 1985 affected about 168,791 to 197,581 people (Ryan et. al. 1987). It was considered that since many people who drank the contaminated milk would not have become ill if they had not been exposed to anti-microbial drugs, the anti-microbial resistance of the disease may have increased the size of the outbreak. It was also considered that the use of anti-microbial drugs in dairy farms could lead to the emergence of resistant strains of bacteria. However, it is uncertain what levels of drugs are sufficient to cause drug resistance. It is also uncertain whether bacterial drug resistance would decline if low-level use of anti-microbial drugs were stopped.

Vaccines for diseases such as FMD are available. However, vaccination presents it's own set of problems. For example, the European Union (EU) is against general vaccination because it would damage its export markets. The reason is that carrying "Disease free" status is extremely important for participants in international trade. Disease free countries such as the US have strict measures against diseased imports. Standard detection tests look for antibodies against FMD as a sign of infection (www.economist.com, 2003). These are the same antibodies that vaccination produces. Therefore, vaccinated animals are excluded from trade. In addition, vaccination provides protection for only six to twelve months. Hence, repeated vaccination, which is not cheap, is required to fight the disease. In addition, while vaccinated animals may appear to be healthy, they may still be carriers of the infection. This means that vaccinated animal could transmit the virus to other, healthy animal, thus leading to more vaccination costs.

Another problem with vaccination is that most vaccines are effective only against certain types of a given disease. This makes it difficult to protect the production from disease occurrence. Fore example, there are at least 7 immunologically distinct types of FMD, each with 3 to 29 different subtypes. A vaccine against one virus type does not necessarily protect against another virus type (McCauley et. al. 1979). So even if it was decided to vaccinate against FMD, which virus type and subtype should be fought against first? Perhaps the answer depends on relative probabilities of occurrence, and damages. The type and subtype that is most likely to occur and most destructive should be vaccinated against first.

Most studies that compare various vaccination regimes to various slaughter systems as preventative and responsive strategies respectively found vaccination strategies to be economically inferior to slaughter strategies (Berentsen et al. 1992, Schoenbaum and Disney 2003,). However, Bates et al. (July 2003) found that ring vaccination would be economically more effective than slaughter strategy if it was possible to differentiate vaccinated and FMD infected animals. In a similar study Bates et al. (February 2003) find that pre-emptive slaughter of high risk herds and vaccination of all animals within a specified distance of an infected herd decrease the duration of an epidemic compared with baseline eradication strategy.

5.1.3 Surveillance and Detection

Effective response to a food borne disease outbreak depends on timely detection of a contamination incident. Surveillance systems, including epidemiological investigations, could be used to identify the agent and contaminated food and eliminate the effected commodity from the market. The objectives, as well as the procedures, of epidemiological investigation would be similar whether the contamination was intentional or unintentional. In either case, the steps would involve identification of the causative agent as well as the manner of contamination and transmission.

Detection of an outbreak of food borne disease depends on the ability of public health officials to identify increased cases of a particular illness by observing multiple patients with a specific clinical syndrome. Laboratories and epidemiological investigations could provide vital information to be applied in surveillance systems. For example, the CDC in collaboration with the state health departments maintains a surveillance system for cases of botulism. The State

Department of Health is notified when a clinician faces a botulism case and requests an antitoxin treatment. State health departments in turn conduct an investigation to detect additional patients, and identify and eradicate the contaminated food supply (Sobel and Swerdlow 2002). PulseNet is a network of public health laboratories that generate unique DNA patterns for food borne pathogens. Detection of pathogens with identical patterns signals the possibility of an outbreak. Similarly, the salmonella outbreak detection algorithm is designed to detect increases in salmonella serotypes reported to the CDC. A state epidemiologist is alerted if the number of reported cases exceeds the expected number. However, these passive surveillance systems tend to underreport the incidents because not all ill patients seek medical care, not all clinicians test for every food borne pathogen, and not all laboratories report individual cases to health officials. For example, around 20 to 100 cases of salmonellosis are unreported for each reported case (Khan et. al. 2001). FoodNet conducts active surveillance of diagnosed cases of ten enteric bacterial as well as parasitic infections and of haemolytic-uraemic syndrome.

5.1.3.1 Farm animal Surveillance and Detection

Most of the studies that investigate FMD mitigation options concentrate on vaccination and slaughter. Less attention has been devoted to surveillance and detection systems, which would allow for timely and more effective response measures. Although some attention has been raised towards surveillance systems (Bates et al. 2003 d; Akhtar and White 2003), no empirical investigation has been performed, to the best of our knowledge, on the merit of such policies relative to vaccination and slaughter.

One of the possible surveillance and detection systems could be to conduct periodic screening of animals. This practice would assist in avoiding massive outbreaks of infectious diseases such as FMD. Regular screening and testing of farm animals directed towards evaluating animal health could assist in preventing a successful intentional spread of FMD or similar disease. Earlier detection through periodic testing would allow for timelier implementation of response strategies such as slaughter, disposal, cleaning and disinfection. Latent period of FMD infected animal is around one week (Garner and Lack, 1995), which means that frequent testing of animals could detect FMD carriers before the clinical signs of the disease appear. Hence, frequent animal testing could decrease the time of unobstructed spread of the disease. Therefore periodic testing of animals could decrease the magnitude and associated costs of needed response actions as well as the value of lost agricultural product. Moreover, screening and testing of animals could be conducted by either a regional veterinarian or employees of cattle operations provided adequate training in testing procedures.

5.1.4 Farm Level Decision Making

Adoption of enhanced food safety measures at the farm level depends on private implications of such strategy. From the farmer's perspective, the attractiveness of the preventative measures against possible food terrorism acts depends on the impacts of such measures on profitability and risk in the short run and in the long run. Hence, the strategy will be adopted either because of profitability and associated risks, or because of imposed constraints (McCarl 1981). Some of the issues related to farm level adoption of prevention strategies are:

1. How is the farmer's welfare is affected by various prevention strategies? That is, what are the effects on profits and profit variation? How are the farmer's welfare dimensions, such as profitability and risk aversion, valued when it comes to choosing

between strategies that have various degrees of prevention measures? Are there other dimensions of welfare affected by the strategy, and if so, to what degree?

2. Which one of the preventative strategies is most appropriate from a social welfare maximization standpoint? What are the dimensions of social welfare affected by "food terrorism and it's preventative measures? For example, what is the relative importance of having a low probability of an outbreak of a food borne disease? What is the probability level of a "food terrorism act" at which the society is willing to bare additional costs to prevent food tampering. Obviously at low probability of food contamination the society is not too concerned about it to be paying for extra costs of prevention measures. However, at some higher probability level, paying premiums for avoiding an outbreak of food borne disease becomes a reasonable move.

3. How could a food terrorism prevention policy be designed so that a socially optimal strategy is also most optimal from a farmer's perspective? Are subsidies and/or taxes going to be needed to encourage adoption of certain strategies rather than others? How effective would regulative strategies be in upgrading safety measures at farms?

4. Finally, what are the strategies that could be employed for preventing acts of food terrorism at the farm level? For example some of the options are, tamper resistant or tamper evident seeds and animal feed, increased monitoring of facilities, restricted access to vulnerable materials and areas, employee screening, animal vaccination, etc. How are these and other options ranked in terms of importance in prevention of food terrorism incidents?

5.1.5 Prevention as a Production Factor

It has been argued that prevention practices, often in the literature referred to as damage control, differ from production inputs in a way that needs to be reflected in optimal strategy selection. First, damage control agents, such as pesticides, antibiotics and immunization, do not generally enhance productivity directly as do standards production inputs (Lichtenberg and Zilberman, 1986). Damage control agents are meant to facilitate prevention of negative outcomes such as pest and/or disease outbreaks, fires, frosts, etc. This characteristic of prevention options needs to be reflected in modeling of strategies for preventing possible agricultural sabotage incidents. Second, direct production inputs could interact with damage control agents and, thus may affect effectiveness of damage control. For example, fertilizer stimulates the growth of weeds, thus changing the effectiveness of herbicides. Contrary to the first point, it has been argued that damage control inputs could affect output mean as well as variance. Variance effect is, in part, determined by the interaction between damage control input and stochastic element in the abetment, or damage control, function (Saha, Shumway, Havenner 1997).

5.1.6 Risk Considerations

At the farm level, risks of agricultural contamination are dealt with in two ways, mitigation and adaptation (Shogren, 2000). Mitigation essentially refers to actions that prevent or contribute to prevention of agricultural contamination. For example, enhancing feed inspections would reduce the chances of introducing non-indigenous species such as FMD or BSE infected livestock. Adaptation refers to activities, which will reduce the impact of a contamination incident if realized. For example, a farmer may choose to diversify a portfolio of produced commodities in order to decrease his/her risks of facing adverse impacts in case a given commodity gets contaminated. This behavior would represent adaptation to the possibility of an agricultural contamination.

Mitigation activities, such as applying sunscreen in order to reduce the risks of skin cancer, endogenously influence the probability of an adverse outcome. For example, the farmer may choose to vaccinate the cattle to reduce the chances of disease occurrence. Hence, the probability of agricultural contamination is in part determined by preventative activities, which are determined endogenously. Adaptation activities, such as adjusting crop mix, on the other hand, affect the magnitude of adverse outcomes if realized. Hence, mitigation and adaptation activities affect both odds and severity of adverse outcomes such as agricultural terrorism. Therefore, economic, as well as natural science, models of risk assessment need to consider the role of prevention and adaptation strategies as antecedents of the risk of agricultural contamination.

5.1.7 Preventative Slaughter

Slaughter of animals in a region not yet infected by a highly infectious disease could be considered a preventative measure. By slaughtering the animals under risk of exposure to the disease we reduce the likely number of diseased animals, thus we reduce the spread of the disease. Fore example, in 1997-98 outbreak of classical swine fever (CSF) in Netherlands preventative slaughter involved 26 farms within 1 km radius of the first two detected farms (Mangen and Burrell 2003). Moreover preemptive slaughter in case of an outbreak allows the producers to market their animals before they are possibly infected and become unmarketable.

5.1.8 Farmer Spillovers

Many of the preventative strategies involve secondary effects that are not usually considered in private decision making of a given farmer. When a farmer applies pesticides the benefits accrue not only to him but also to adjacent farmers (McCarl, 1981). In a similar fashion, the benefits of preventing an outbreak of a contagious disease in plants or animals to various degrees accrue to farms within certain proximity. Hence, even the farmers that would not adopt prevention strategies could benefit from prevention measures executed by neighboring farmers. This introduces a “free rider” problem of a public good, where private decision making will result in under-employment of preventative strategies. Consequently, for each prevention strategy, the extent of a “spillover” effect needs to be investigated and taken into account for proper policy design purposes. Proper policy would reflect true benefits and costs, which include spillover effects of adopting preventative measures, such as vaccination.

5.2 Processing and Manufacturing Procedures

The key to preventing food sabotage is to upgrade production processes and quality control measures at central production facilities. For example, in the outbreak of antimicrobial resistant salmonellosis attributed to pasteurized milk, which affected more than 168,000 people in Illinois in 1985, one of the possible reasons of the outbreak could have been the unusual sequence of operations at the plant where the outbreak originated. Pasteurization at this plant was an early step in processing, which was followed by careful post-pasteurization handling of milk during separation, blending, and other steps to prevent contamination of the milk. However, a few millimeters of contaminated milk mixed with pasteurized milk in later stages could have caused the outbreak (Ryan et. al. 1987).

There has been some advancement made in this respect. For example, recent declines in salmonellosis campylobacteriosis coincide with changes in meat and poultry slaughtering practices at processing facilities mandated by the Pathogen Reduction and Hazard Analysis and Critical Control Points (HACCP) rule of the USDA (Khan et. al. 2001).

5.3 Storage and Transport

Food borne disease could clearly originate from food contamination at storage or transportation facilities. Obvious options to enhance prevention measures at these facilities are to install monitoring systems, reduce access to vulnerable areas and lethal materials, screen personnel that have access to vulnerable areas and lethal materials, and monitor sanitary compliance of storage areas and transportation means. Although there are no documented cases of deliberate contamination at storage or transportation facilities, lessons could be learned from unintentional contamination cases. For instance, the 1994 Salmonella outbreak, which developed in 224,000 persons in the United States, was traced to eating Schwan's ice cream. Contamination of Schwan’s ice cream was caused by contamination of pasteurized ice cream premix, which was transported in tanker trailers that had previously carried nonpasteurized liquid eggs containing *Salmonella enteritidis.* Consequently it was concluded that food products, which did not require re-pasteurization should be transported in designated containers (Hennessy, 1996).

5.4 Retail Distribution and Food Service

Food sabotage at distribution outlets or food service points such as restaurants is likely to go undetected before contaminated produce reaches consumer’s plates. Unlike earlier stages along the farm to table food supply chain, products sold at retail distribution points and restaurants do not go through any additional inspection or processing, other than cooking, which rarely involves testing for chemical or nuclear agents. Therefore, measures that would facilitate prevention of food adulteration should be initialized or enhanced. Relying on tamper-resistant or tamper-evident seals, which have been used for some food items and for pharmaceuticals is one way to improve food safety at distribution outlets. Monitoring and surveillance of such facilities as retail or wholesale distribution points and restaurants may help to prevent deliberate food contamination. For example, surveillance systems might have prevented intentional restaurant salad bar contamination that occurred in The Dalles, Oregon in 1984 infecting 751 people (Torok, T., et. al. 1997).

5.5 Preparedness

Preparedness plans are developed and implemented before the incident occurs. To a great extent preparedness depends on surveillance, detection tracking mechanisms. In addition, preparedness includes clear formalization and delegation of responsibilities prior to the event of bio-terrorist alert. Law enforcement and public health authorities need to have guidelines developed for the effective response to take place. For example, some of the components of preparedness are, ability of detection, linkage between relevant government agencies, training, and vulnerability assessment as discussed in the Guidelines for Establishing and Strengthening Prevention and Response Systems (WHO 2002).

Simulated exercises organized by various governmental agencies have been used to test preparedness (Sobel and Swerdlow 2002). The exercises allow one to assess rapidity of detection and notification, evaluate the adequacy of existing resources for doing epidemiological investigations, establish time to collect, analyze, and disseminate data, evaluate the adequacy of available medical resources, and to practice collaboration between parties involved in response activities.

5.6 Trade Inspection

Due to the global nature of modern economy it is easy to conceive the possibility of agricultural sabotage, which could originate in remote countries and regions. In fact, there are numerous documented cases of unintentional contamination of agricultural commodities (Mermin et al. 1999, Levine et. al. 1996, Mahon et. al. 1997, Herwaldt 1997), which were manifested through international trade. Therefore, the importance of enhancing inspection of imported agricultural commodities cannot be overemphasized. Clearly, commodities that fail to meet international safety criteria should be excluded from trade.

Trade restrictions that arise due to detection of contaminated commodities are readily accepted. However, it is often difficult to determine whether a given barrier reflects a health concern or is a form of disguised protectionism. Under current trading rules nations are allowed to use trade barriers to protect human, animal and plant health, but such barriers cannot be used as disguised protectionism. Before the Uruguay Round of GATT (General Agreement on Tariffs and Trade), the U.S. did not import any cattle, sheep, swine, and some other forms of meat from countries that were not FMD free. After the Uruguay Round, imports from disease-free regions of a country could be allowed even if the disease may have occurred in other regions of the exporting country (Paarlberg and Lee, 1998).

6 Tracking

Effective mitigation of a food borne disease outbreak depends not only on detection of the outbreak, but also on identification of the sources of original contamination. Timely determination of the source of contamination can greatly facilitate rapid removal of all contaminated products along the food processing chain. Tracing systems, which allow for comprehensive market recalls, are critical in responding to food contamination, whether intentional or unintentional. This issue is especially relevant for agricultural production systems (WHO 2002), where raw products produced on small farms are often combined to form larger shipments. With no tracing system in place it is difficult to identify the producer of a contaminated product. Therefore, it is difficult to narrow and recall only potentially contaminated products along the food supply chain.

In the case of animal diseases, such as FMD or BSE, the benefits of tracking mechanisms, such as ear tags, include limiting the spread of the disease, faster trace back of infected animals, reducing production losses due to the disease, reducing the costs of government control, reducing trade losses, and boosting consumer confidence (Disney et. at., 2001). The objective of tracing systems is to find all farms linked to infected areas, and prevent any further disease dissemination from infected locations.

7 Response and Control

Response involves actions which are implemented after the event of agricultural sabotage has taken place and are intended to minimize the impact of contamination. These activities may include stopping the spread of and eradicating an outbreak of a possibly infectious contamination. Given that the agent, the carrier and the original source of contamination have been identified, it is necessary to remove all infected commodities from the reach of consumers and the public in general.   This requires establishing regulations that address marketability of suspected commodities, destruction of infected commodities, containment of the disease, accesses to vital facility, etc.

For instance in response to the 2000 FMD outbreak in England, in addition to the policy of slaughtering animals on infected farms, further control measures were introduced, such as a ban on all animal movements, closure of markets, and restricted public use of footpaths across agricultural land (Ferguson et. al. 2001). Generally the options to control disease transmission among animals include mass vaccination, culling and decreasing mixing rate. Likewise, Jalingh et. al. (1999) categorize the control mechanisms for the spread of classical swine fever in The Netherlands in 1997-98 into diagnosis of infected farms, depopulation of infected farms, movement control, tracing, and pre-emptive slaughter.

Effectiveness of response depends on surveillance, preparedness and communication levels. The better the surveillance and communication, the more prompt is the detection of an outbreak which will lead to timelier, more effective response measures. On the other hand, better preparation levels should lead to more effective response measures such as medical treatments, identifying the sources of an outbreak, banning contaminated products, etc.

7.1 Movement Ban and Transportation

An immediate response to infectious agricultural contamination is to ban movement of contagious commodities across regions. The purpose of movement bans is obviously to stop or at least slow down the spread of infection. In case of an outbreak of a disease such as FMD it is necessary to ban movement in and out or the general area of the outbreak. For example, in the Netherlands after detecting FMD infected animals the immediate regulative response was a 72h movement ban in the whole country for all transports of livestock, poultry and conveyances for transporting these animals (Bouma et al. 2003). This strategy will reduce the mixing of animals and thus will reduce the likelihood of healthy animals getting infected by diseased animals at staging points, sale barns, and other livestock facilities. It also decreases movement in and out of infected areas, thus reducing the spread of the disease.

Transporting infected animals from one region to another is the surest way of spreading the disease. Therefore, it is vital to regulate animal movement as a response to FMD outbreak to slow down the spread of the disease. For example, During 1997-98 outbreak of classical swine fever in Netherlands all transportation was banned within a quarantine zone of 10km for at least 42 days (M-J.J. Mangen, A.M. Barrell, 2003). However implementation of transportation ban necessitates depiction of animal movement system in the region. Both heterogeneity of animal movement related to specific farms and the dynamics of flow of animals between farms are to be taken into account when examining the animal transportation system (Bigras-Poulin, M. Thompson A., Chriel M,, Mortensen S., and M Griener, 2004). In addition, a highly contagious disease such as FMD could be also spread by public vehicles moving from infected to uninfected regions.

7.2 Slaughter and Vaccination

In the case of a highly contagious disease such as a FMD outbreak, it is essential to stop the spread of and eradicate the disease as quickly as possible. Vaccination and slaughter have been the most common responses to highly infectious animal disease outbreaks. Ferguson et. al.

(2001) call for cost-benefit analysis of mass vaccination options versus culling based control of infrequent outbreaks. Schoenbaum and Disney (2003) investigated the effectiveness of four slaughter and three vaccination strategies under varying conditions of herd sizes and rates of disease spread in the U.S. The slaughtering options included slaughtering only infected herds, slaughtering herds with direct contact with the infected herd in the 14 days prior to the detection of the infection, slaughtering herds within 3km distance of infected herd, and slaughtering herds with both direct and indirect contact with the infected herd. Vaccination options included no vaccination, vaccinating all herds within 10 kilometers of the infected herds after 2 herd infections were detected, and vaccinating all herds within 10 kilometers of the infected herds after 50 herd infections were detected. The choice of the best mitigation strategy depended on herd demographics and the rate of contact among herds. Generally, ring slaughter (3 km) was more costly than other slaughter strategies. Ring vaccination was more costly than controlling with slaughter alone. However, early ring vaccination decreased the duration of outbreaks.

Garner and Lack (1995) investigated the effectiveness of four control options for FMD, involving “stamping out”, where no vaccination is applied but animals in contact farms are slaughtered and destroyed (Berentsen, Dijkhuizen and oskam, 1992), dangerous-contact slaughter, and early or late ring vaccination in three different regions of Australia. They found that if FMD is likely to spread rapidly then slaughter of dangerous contact and infected herds reduced the economic impact of the FMD outbreak. Early ring vaccination turned out to reduce the size and duration of an outbreak, but was uneconomic when compared to stamping-out alone. Keeling, et al. (2001) found that both ring culling and ring vaccination are effective if implemented rigorously, although ring culling is more effective. Neighborhood culling is found to be more effective than neighborhood vaccination. They also argue that spatial distribution, size, and species composition of farms all influence the pattern and regional variability of outbreaks.

Morris et. al. (2001) found that delaying the slaughter of animals at the infected farms beyond 24 hours would have slightly increased the size of the FMD epidemic in Great Britain in 2001. Failure to carry out pre-emptive slaughter of animals at the susceptible farms would substantially increase the size of the epidemic. Vaccination of up to three of the most outbreak dense areas, in addition to an adopted control policy, such as slaughter, would slightly decrease the number of infected farms. However, relying solely on vaccination and disregarding other control policies would significantly increase the size of an outbreak.

As a response measure, farmers have the options to enhance vaccination and to preemptively slaughter their animals in case of an outbreak in the region. Although culling option has been shown to be most affective in most circumstances for eliminating the disease (Schoenbaum and Disney 2003, Garner and Lack 1995, Keeling et al 2001, Morris et al 2001, Berentsen et al. 1992), it is possible that the farmers may choose not to slaughter their animals unless given monetary incentives in the form of compensation/subsidy. Therefore it is relevant to investigate what type of compensation will need to be provided to prompt preemptive slaughter of healthy animals in case of an FMD outbreak?

7.3 Communications

Rapid and effective response to an unintentional, and especially to an intentional massive food contamination incident, requires prompt communication between health care providers, public health officials at various levels and government agencies. Currently the CDC has a 24-hour capacity to respond to reports of food borne disease emergencies. The CDC can contact all state epidemiologists and directors of public health laboratories regarding surveillance issues and outbreaks.

Intense media coverage of food adulteration is to be expected. Accurate information is to be delivered regarding the nature of the incident, suspected and/or affected food commodities, possible measures to prevent exposure, and applicable immediate treatment actions in case of exposure.

7.4 Decision Support Tools

Level of preparedness is to a great extent determined by the availability of decision support tools. Such tools include procedures to detect infected agricultural segments, such as farms, protect uninfected segments from exposure to the virus, and to manage response and control strategies. Decisions made during the first couple of weeks of an outbreak are likely to be crucial in reducing the size and length of an infectious disease outbreak. Decision support tools, such as EpiMAN, developed in New Zealand for response and control of potential FMD outbreaks, could be used for detection of an outbreak, management of infected farms, movement control measures, and cleaning and disinfection measures (Morris, et. al. 2002, Sanson, 1993). Decision support tools could allow the choosing of a portfolio of response and prevention actions, including examinations of the fixed costs and irreversibility dimensions of certain actions (McCarl, 2003).

7.5 Medical Response

Medical response is a critical component of food borne disease outbreak mitigation. Whether the contamination is intentional or unintentional, medical response steps in terms of treatment of casualties is approximately the same. Depending on the agent and number of casualties, medical personnel and supplies may need to be transported to the outbreak site.

8 Existing Prevention and Response Costs Estimates

McCauley et. al. (1979), who evaluated the economic consequences of a potential outbreak of FMD in the US, assume a $0.30 cost of production per dose of vaccine in the U.S. in 1976 dollars. They also estimate that it would cost $152,160 to test 1 million doses of FMD vaccines. Transportation costs are assumed to be around $10 per 1,000 pounds for 1,400 miles. Storage costs were estimated to be $0.72 per hundred pounds for unloading and reloading, plus $0.52 per 100 pounds per month for refrigerated storage. They also report calculated costs of vaccination teams, costs of district offices, costs of state offices, costs of emergency programs, and costs of vaccine evaluation teams. Costs of a one-year surveillance program, conducted by replacing vaccination teams with evaluation teams, that would follow the completion of a vaccination program were estimated to be $34,197,872 for 37,895,000 livestock heads. When it comes to slaughter programs they assume that 0.5 percent of cattle, swine and sheep will be slaughtered due to infection or exposure. Costs of depopulation were estimated to be $79, $48, $27, $24, $24 per head for dairy cattle, Feedlot cattle, beef heard, swine and sheep respectively. Indemnification costs were $190, $80, and $37.5 per head for cattle, swine, and sheep respectively.

Schoenbaum and Disney (2003) derived slaughter, surveillance and vaccination costs from 1998 NIMBY test exercises. Slaughter costs include costs of appraisal, euthanasia, carcass disposal and cleaning/disinfection. Surveillance costs include costs of testing per herd and costs per surveillance visit. Vaccination costs are given in terms of costs per herd. All of their estimates are broken down in terms of three herd categories, small (<100), medium (100-450), and large (>450), her sizes.

9 Prevention of and Response to Food Sabotage on International Level

Bioterrorism is of concern on both national and international levels. Security and safety of the food supply is vital not only for the U.S. economy but also for the welfare of any other country and for the prosperity of the global economy as a whole. Although vulnerability of food supply varies across the countries it is clear that similar basic principals of preventing, and if necessary responding to, food supply adulteration should apply in different countries. Moreover, given the global nature of today's economies, both prevention and response measures have to be internationally coordinated. The authorities of participating countries have to fight bioterrorism in the ways that are compatible and complementary to one another. International cooperation is needed to prevent possible sabotage of exported food. There are numerous documented unintentional incidents of international food contamination. For example, the 1989 cyanide contamination of Chilean grapes exported to the U.S. and Canada (WHO, 2002), the 1995 salmonella outbreak in the US and Finland due to contaminated alfalfa sprouts seeds obtained from The Netherlands (Mahon et. al. 1997), the 1996 outbreak of cyclosporiasis in the North America due to contaminated raspberries imported from Guatemala (Herwaldt 1997) and many more.

International initiatives need to be developed to enhance food inspection and, if necessary, response activities to prevent and respond to food terrorism. Figure 3 shows the proposed linkages (WHO, 2002) between national and international food safety systems to facilitate detection and response to food terrorism incidents. Instituting and/or improving these linkages will allow for prompter exchange of relevant information, which will facilitate rapid removal of unsafe food from the markets. This graph illustrates how food safety-related institutions need to be interrelated not only on national but also on international levels.

Prompt response is important on both national and international levels. International organizations such as WHO could provide response guidelines for particular food contamination incidents at national levels. Detailed procedures directed towards increasing counter terrorism awareness and strategies are outlined in Specific Measures for consideration by the Food Industry (WHO 2002). At international levels WHO could be viewed as an organizational unit when it comes to communication and launching international response.   As such, WHO's functions would include, but not be limited to, implementation of International Health Regulations, coordination of worldwide disease and food safety surveillance networks, coordination of international response to communicable diseases, and provision of technical assistance for national preparedness and response.

Measures to prevent international food adulteration incidents could be beyond the resources of many member countries. International cooperation is essential in order to assist many developing countries to implement and/or enhance food safety programs. Hence, international guidelines and recommendations for fighting food terrorism need to be established to increase the effectiveness of battling bioterrorism. World Health Organization (WHO, 2002) has prepared international guidelines and technical information on recommended food supply safety measures primarily intended for policy makers in national governments who are responsible for food safety issues.

10 Regulatory Background

The primary agencies involved in detection and epidemiological investigation of both intentional and unintentional food borne disease outbreaks include local and state health epidemiological departments, local and state public health laboratories, the Council of State and Territorial Epidemiologists, the Association of Public Health Laboratories, and the CDC (Sobel and Swerdlow 2002). In addition the US Food and Drug Administration (FDA), and the US Department of Agriculture (USDA) along with state departments of agriculture and food safety divisions have the authority to regulate food supply.

10.1 Increased Political Awareness

Intentional contamination of food/agricultural commodities is one of the most viable scenarios of terrorist attacks (Khan et. al 2001) in the United States. Dramatic economic consequences of food scares call for appropriate measures to prevent and mitigate possible food contamination events. Te task force members of Council for Agricultural Science and Technology (2004) recommend development of strategic approaches that will identify critical points within the food chain at which effective prevention and response strategies will have the greatest impact on decreasing public health hazards. This implies the need for investigations and studies of possible scenarios of intentional as well as unintentional agricultural contamination. In fact recent plan proposed by president Bush calls for significantly increased spending on homeland security research projects financed by U.S. department of Agriculture (Arnone, M., 2004). Under this plan, grants for research to protect American agriculture from terrorism and foreign diseases, such as Foot and Mouth Disease (FMD) in cattle, would increase by 275 percent, to $30-million.

10.2 Bioterrorism Act of 2002

On July 12th 2002 President Bush signed into law the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, usually referred to as Bioterrorism Act of 2002. Title III of this document deals with protecting the safety and security of the food and drug supply in the U.S. The goal of this document is to facilitate development of crisis communication and education strategy with respect to bioterrorist threats to food supply. The document promotes strategies that “address threat assessments; technologies and procedures for securing food processing and manufacturing facilities and modes of transportation; response and notification procedures; and risk communications to the public”.

Subtitle A of title III concentrates on regulating imported food supplies. Section 302 discusses measures for protection against food adulteration. The measures include increasing inspections for detecting adulteration of food, providing for research on the development of tests and sampling methodologies, assessments of the threat of intentional food adulteration, and improvements of information management systems. The remaining sections address such critical issues as debarment for repeated or serious food import violations, registration of food facilities, maintenance and inspection of food records, authority to mark articles which are refused admission into the U.S., surveillance and information grants, etc.

Subtitle C of title III elaborates on upgrading agricultural security. Several issues of critical importance are discussed.

- High priority is assigned to enhancing and expanding the capacity of the Food Safety Inspection Service to conduct activities, such as increasing inspections at international points of origin and ports of entry, developing strategies for dealing with international outbreaks of animal and plant diseases, and implementing automated record keeping system.

- Attention is also directed towards increasing security at colleges and universities, which have programs in food and agricultural sciences. Under this Act qualified universities may be awarded one-time grants of up to $50,000 to enhance security standards at their facilities.

- The subtitle also states that the Secretary of agriculture may award grants to associations of food producers for the development and implementation of educational programs to enhance biosecurity measures on farms. Under this provision individual associations are eligible to receive one-time grants of up to $100,000.

- Support for research and development is also given high importance. Close partnerships with higher education and research institutions are recognized to be critical to increase biosecurity and food safety in the U.S. Such close ties with the intelligence community promise advanced researches related to vulnerability analysis, incident response, detection and prevention technologies, as well as effective planning and training activities. For fiscal year 2002 it was authorized to allocate $190,000,000 for research, development and outreach programs related to enhancement of biosecurity measures in the U.S.

- Finally the penalties for those individuals who violate the provisions are discussed. The penalties are instituted to be commensurate with the economic and health damages caused by violations.

10.3 The Role of Food Safety and Inspection Service

The Food Safety and Inspection Service (FSIS) is a public health regulatory agency of the U.S. Department of Agriculture, which has ensured wholesomeness of meat, poultry and egg products for almost 100 years. This agency employs more than 7600 inspectors and veterinarians in more than 6000 locations such as meat, egg, and poultry plants and ports of entry (FSIS 2003). FSIS works in cooperation with Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), the Department of Defense (DOD), the Animal and Plant Health Inspection Service (APHIS) and with state and local health organizations to prevent the entry of intentionally or naturally contaminated products in the food supply.

In response to September 11, 2001, FSIS has taken numerous steps to increase the security of the U.S. food supply. The most notable action was creation of the Food Biosecurity Action Team. This team is responsible for improving food safety and security. The tasks of this team include: 1) assessing potential vulnerabilities along the farm-to-table chain (figure 1); 2) increasing FSIS cooperation with law enforcement agencies; 3) enhancing security measures at all FSIS laboratories; 4) expanding the capacities of the agency's laboratories to test for additional food safety hazards and biological and chemical agents; 5) providing guidelines on increasing food safety and security to the industry.

FSIS has also taken on major projects and initiatives to protect America's meat, poultry and egg supply from intentional or unintentional contamination. FSIS has established the Office of Food Security and Emergency Preparedness (OFSEP), which is to prevent, and if necessary, coordinate a response to any intentional food supply contamination. In order to prevent using food as a terrorist weapon, FSIS has prepared a food security plan 2003-2007, which identifies specific goals and responsibilities related to prevention activities. FSIS has also prepared and distributed Security Guidelines for Food Processors in order to assist the plants that produce meat, egg and poultry products to improve their biosecurity procedures. Imports inspections have been intensified by adding 20 new inspectors at port cities around the nation to assist traditional FSIS import inspectors assigned to the 146 import Houses around the country. FSIS has completed food supply vulnerability, which identifies the most susceptible products, agents and sites for intentional contamination of domestically produced meat, poultry and egg products. In addition, FSIS has enhanced capacity and security of the laboratories, and began educating and training of all employees on food security issues.

11 Summary

Security of agricultural markets is a major concern of policy-making arena especially during current elevated terrorism awareness. Even though agriculture is not usually thought of as a possible venue for terrorism, a number of documented incidents demonstrate the feasibility of such events. Numerous documented incidents of intentional as well as unintentional agricultural contamination point out vulnerable segments along the food supply chain. Agricultural contamination could cause wide range of implications, from minor discomfort of several people to massive infections and/or disruptions of markets in several industries and trade. Recent spread of FMD in Great Britain is the most notable example of how Agricultural Contamination could cause serious economic damages in a number of industries. Both, producers and consumers bear the consequences of agricultural contamination. Precise effects depend on distribution of those effects within producers and within consumers.

The most desirable option of counter sabotage efforts is prevention. Prevention practices could be adopted at any vulnerable segment along a food supply chain. Clearly priority should be assigned to the most vulnerable segments within agricultural production, processing and manufacturing, storage and transport, retail and distribution, and trade. However, adoption of preventative measures depends on private incentives of producers, distributors, and retailers. The private incentives include consideration of both, mean and variance of net returns, which are affected by marginal costs and effectiveness of prevention strategies.

Response to agricultural sabotage and control of a spread of infectious diseases such as FMD to great extent depend on effective surveillance, detection and tracking of contaminated products. Investing in surveillance, detection and tracking systems will increase our level of preparedness in case agricultural terrorism incident occurs. Response and control, as well as prevention, strategies need to be developed by considering multiple scenarios and options in the decision support systems.

In order to safeguard the economy from the possible devastating effects of agricultural sabotage, decision support tools need to be developed. The points discussed in this review of related literature should provide the grounds for developing the support tools. These tools will facilitate determination of the optimal level of prevention and response measures and are the subject of further investigations.

12 References:

Akhtar S. and F. White, “Animal Disease Surveillance: Prospects for Development in Pakistan”, *Scientific and Technical Review International Office of Epizootics.* 22(3)(December 2003):977-987.

Arnone, M., “Bush’s Plan Would Triple Money for Agricultural Research Against Terrorism.” The Chronicle of Higher Education. 02/03/2004.

Atkinson N. *The Impact of BSE on the UK Economy*. Argentine Scientific Advisory Committee on Bovine Spongiform Encephalopathy (3rd. Meeting) August 9-11, 1999. [Online]. Available at http://www.iica.org.ar/Bse/14-%20Atkinson.html

Bates T. W., M. C. Thurmond, and T.E. Carpenter, “Direct and Indirect Contact Rates Among Beef, Dairy, Goat, Sheep, and Swine Herds in the Three California Counties, with Reference to Control of Potential Foot-and-Mouth Disease Transmission”, *American Journal of Veterinary Research*. 62(July 2001):1121-1129.

Bates T. W., M.C. Thurmond, and T.E. Carpenter, “Description of an Epidemic Simulation Model for use in Evaluating Strategies to Control an Outbreak of Foot-and-Mouth Disease” *American Journal of Veterinary Research*. 64(February 2003):195-204.

Bates, T.W., M.C. Thurmond, S.K. Hietala, K.S. Venkatesvaran, T.M Wilson, B.W. Colston Jr., J.E. Trebes, and F. P Milanovich, “Surveillance for Detection of Foot-and-Mouth Disease.” Commentary in *Journal of the American Veterinary Medical Association*, 223(September 2003):609-14.

Bates, W. T., M. C. Thurmond, and T.E. Carpenter, “Results of Epidemic Simulation Modeling to Evaluate Strategies to Control an Outbreak of Foot-and-Mouth Disease”, *American Journal of Veterinary Research*, 64(February 2003):205-10.

Bates, W. T., T. E. Carpenter, M. C. Thurmond, “Benefit-Cost Analysis of Vaccination and Preemptive Slaughter as a Means or Eradicating Foot-and-mouth Disease”, *American Journal of Veterinary Research*, 64(July 2003):805-12.

Berentsen, P.B.M., A.A Dijkuizen, and A.J. Oskam. “A dynamic Model for Cost-Benefit Analysis of Foot-and Mouth Disease Control Strategies.” *Preventive Veterinary Medicine.* 12 (March 1992):229-243.

Bigras-Poulin, M., A. Thompson, M. Chriel, S. Mortensen, and M. Greiner, “Network Analysis of the Danish Cattle and Swine Industry Trade Patterns as an Evaluation of Risk Potential for Disease Spread: The heterogeneity Issue.” Meeting Proceedings, *Society for Veterinary Epidemiology and Preventative Medicine*, Martigny Switzerland, (March 2004):189-199.

Bouma A., A.R.W. Elbers, A. Dekker, A. de Koeijer, C. Bartels, P. Vellema, P. van der Wal, E.M.A. van Rooij, F.H. Pluimers, and M.C.M de Jong, “The Foot-and-Mouth Disease Epidemic in the Netherlands in 2001”. *Preventive Veterinary Medicine*. 57(March 2003): 155-166.

Burton M. and T. Young. “The Impact of BSE on the Demand for Beef and other Meats in Great Britain.” *Applied Economics*, 28(June 1996):687-693

Bush, G.W. Remarks by the President to the Cattle Industry Annual Convention and Trade Show, Denver, Colorado, February 8, 2002.

Carpenter, T.E., “Veterinary Economics – tips, tricks, and traps”. *Preventive Veterinary Medicine.* 18(December 1993):27-31.

Carpenter, T.E., Thurmond, C.M., and T. Bates, “A Simulation Model of Intraherd Transmission of Foot and Mouth Disease with Reference to Disease Spread Before and After Clinical Signs”. *Journal of Veterinary Diagnostic Investigation.* 16(January 2004):11-16.

Center for Disease Control. Food borne Illnesses. Division of Bacterial and Mycotic Diseases, 2003. [Online]. Available at: http://www.cdc.gov/ncidod/dbmd/diseaseinfo/foodborneinfections_g.htm accessed on 07/28/03.

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.” *Scientific and Technical Review International Office of Epizootics*. 20(August 2001):385-405.

Evans E. A. “Economic Dimensions of Invasive Species.” *Choices*. Second Quarter, (June 2003). [Online]. Available at: http://www.choicesmagazine.org/current/2003-2-02.htm , accessed on 07/28/03.

Ferguson N. M., C.A. Donnelly, and R. M. Anderson, “The Foot-and-Mouth Epidemic in Great Britain: Pattern of Spread and impact of Interventions.” *Science*. 292 (May 2001):1155-1160.

Fox, J.A., and D. A. Hennessy, “Cost-Effective Hazard Control in Food Handling”. *American Journal of Agricultural Economics*. 81(May 1999):359:372.

Garner M. G., and M. B. Lack., "An evaluation of Alternative Control Strategies for Foot-and-Mouth Disease in Australia: a Regional Approach." *Preventative Veterinary Medicine*. 23(May 1995):9-23.

Halliday M. L., L. Kang, T. Zhou, M. Hu, Q. Pan, T. Fu, Y. Huang, and S. Hu, "An Epidemic of Hepatitis A Attributable to the Investigation of Ra Clams in Shanghai, China." *Journal of Infectious Diseases.* 164(November 1991): 852-9.

Hennessy T.W., C.W. Hedberg, L. Slutsker, K.E. White, J. M. Besser-Wiek, M. E. Moen, J. Feldman, W. W. Coleman, L. M. Edmonson, K. L. McDonald, M. T. Osterholm, and Investigation Team, "A national Outbreak of Salmonella Enteritides Infections from Ice Cream." New England Journal of Medicine. (May 1996), 334:1281-6.

Henson S., and M. Mazzocchi. "Impact of Bovine Spongiform Encephalopathy on Agribusiness in the United Kingdom: Results of an Event Study of Equity Prices." *American Journal of Agricultural Economics*. 84 (May 2002):370-386.

Herwaldt B. L., M. Ackers, and Cyclospora Working Group. "An Outbreak in 1996 of Cyclosporiasis Associated with Imported Raspberries." *The New England Journal of Medicine.* 336(May 1997):1548-56.

Jalvingh A.W., M. Nielen, H. Maurice, A. J. Stegeman, A. R.W. Elbers, and A.A. Dijkhuizen. "Spatial and Stochastic Simulation to Evaluate the Impact of Events and Control Measures on the 1997-1998 Classical Swine Fever Epidemic in the Netherlands." *Preventative Veterinary Medicine.* 42(December 1999):271-295.

Keing M. J., M. E. J. Woolhouse, D. J. Shaw, L. Mattews, M. Chase-Topping, D. T. Haydon, S. J. Cornell, J. Kappey, J. Wilesmith, and B. T. Grenfell, "Dynamics of the 2001 UK Foot and Mouth Epidemic: Stochastic Dispersal in Heterogeneous Landscape." *Science.* 294 (October 2001):813-817.

Khan A. S.L., D. L. Swerdlow, and D. D. Juranek. "Precautions Against Biological and Chemical Terrorism Directed at Food and Water Supplies." *Public Health Reports.* 116 (Jan.-Feb. 2001):3-14.

Levine W. C., R. W. Bennett, Y. Choi, K. J. Henning, J. R. Rager, K. A. Hendricks, D. P. Hopkins, R. A. Gunn, and P. M. Griffin. "Staphylococcal Food Poisoning Caused by Imported Canned Mushrooms." *The Journal of Infectious Diseases*. 173(May 1996): 1263-1267.

Loyd, T., S. McCorriston, C.W. Morgan, and A.J. Rayner, "The Impact of Food Scares on Price Adjustments in the UK Beef Market." *Agricultural Economics,* 25 (September 2001):347-357.

Mahon B. E., A. Ponka, W. N. Hall, K. Komatsu, S. E. Dietrich, A. Siitonen, G. Cage, P.S. Haues, M. A. Lambert-Fair, N. H. Bean, P. M. Griffin, and L. Slutsker "An Intentional Outbreak of Salmonella Infections Caused by Alfalfa Sprouts grown from Contaminated Seeds." *The Journal of Infectious Diseases*. 175(April 1997):876-82.

Mangen, M-J. J., and A.M. Burrell, "Who Gains, Who Losses? Welfare Effects of Classical Swine Fever Epidemics in the Netherlands." *European Review of Agricultural Economics,* 30(June 2003):125-154.

Mathews K. H. Jr., and J. Buzby. "Dissecting the Challenges of Mad Cow and Foot and Mouth Disease." Agricultural Outlook. Economic Research Service USDA. August 2001

Mathews K. H. Jr., J. C. Buzby, L. R. Tollefson, and D. A. Dargatz. “Livestock Drugs: More Questions Than Answers?” Agricultural Outlook. Economist Research Service. September 2001.

McCarl B. “Economics of Integrated Pest Management. An interpretive Review of Literature.” Special Report 636. Agricultural Experiment Station. Oregon State University. August, 1981.

McCarl, B.A. “Linked Bio-economic Risk Assessment of Invasive Species Policy and Programs.” Research Funding Proposal, to USDA PREISM. 2003.

McCauley E. H., A.A. Nasser, J. C. Jr. New, W.B. Sundquist, and W. M. Miller. “A Study of Potential Economic Impact of Foot and Mouth Disease in the United States.” Pp.242. University of Minnesota. St. Paul Minnesota, 55108. May 1979.

Mead P. S., L. Slutsker, V. Dietx, L.F. McCaig, J. S. Bresee, C. Shapiro, P. M. Griffin, and R. V. Tauxe. “Food Related Illness and Death in the United States.” *Emerging Infectious Diseases,* 5(Sep.-Oct. 1999):607-625.

Mermin J. H., and P. M. Griffin. “Invited Commentary: Public health in Crisis: Outbreaks of Escherichia Coli O157:H7 Infections In Japan.” *American Journal of Epidemiology.* 150(October 1999):797-803.

Morris R.S., J.W. Wilesmith, M.W. Stern, R.L. Sanson, and M.A. Stevenson. “Predictive Spatial Modeling of Alternative Control Strategies for the Foot-and Mouth Disease Epidemic in Great Britain, 2001.” *The Veterinary Record.* 149(August 2001):137-144.

Morris R.S., R.L. Sanson, M.W. Stern, M. Stevenson, and J. W. Wilesmith. "Decision-support Tools for Foot and Mouth Disease Control." *Scientific and Technical Review International Office of Epizootics.* 21(December 2002):557-567.

Nielen, M., A. W. Jalvingh, H.S. Horst, A.A. Dijkhuizen, H. Maurice, B.H. Schut, L.A. van Wuijckhuise, , and M.F. de Jong, "Quantification of Contacts Between Dutch Farms to Assess the Potential Risk of Foot-and-Mouth Disease Spread." *Preventive Veterinary Medicine.* 28(September 1996):143-158.

Paarlberg, P. L., and J.G. Lee, "Import Restrictions in the Presence of a Health Risk: An Illustration Using FMD." *American Journal of Agricultural Economics.* 80 (February 1998):175-183.

Paarlberg, P. L., J. G. Lee, and A. H. Seitzinger, "Measuring Welfare Effects of an FMD Outbreak in the United States." *Journal of Agricultural and Applied Economics,* 35 (April 2003):53-65.

Piggott, N.E., and T. March, "Does Food Safety Information Impact U.S. Meat Demand?" *American Journal of Agricultural Economics*. 86(May 2004):154-174, 2004.

Pinmentel D. "Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species." CRC Press LLC, 2000 N.W. Corporate Blvd. Boca Raton, FL 33431. 2002.

Pinmentel D., L. Lach, R. Zuniga, Morrison D., "Environmental and Economic Costs of Nonindigenous Species in the United States." *BioSciences.* 50 (January 2000):53-65.

Ryan C. A., M. K. Nickels, N. T. Hergrett-Bean, M. E. Potter, T. Endo, L. Mayer, C. W. Langkop, C. Gibson, R. C. McCdonald, R. T. Kenny, N. D. Puhr, P. J. McDonnell, R. J.

Martin, M L. Cohen, and P. A. Blake. "Massive Outbreak of Antimicrobial-Resistant Salmonellosis Traced to Pasteurized Milk." *Journal of American Medical Association*. 258 (December 1987):3269-3274.

Saha, A., C. R. Shumway, and A. Havenner, "The Economics and Econometrics of Damage Control." *American Journal of Agricultural Economics.* 79(August 1997):773-785.

Sanson, R. "The development of A Decision Support System for an Animal Disease Emergency." Unpublished Ph.D. Dissertation, Massey University, New Zealand. 1993 .

Schoenbaum M. A., and W. T.Disney. " Modeling Alternative Mitigation Strategies for a Hypothetical Outbreak of Foot-and-Mouth Disease in the United States." *Preventative Veterinary Medicine*, 58(April 2003):25-52.

Scudamore J. M. "Origin of the UK Foot and Mouth Disease Epidemic 2001." Department for Environment, Food and Rural Affairs. UK. June 2002. [Online] Available at: http://www.defra.gov.uk/corporate/inquiries/lessons/fmdorigins.pdf Last accessed 10/29/03.

Shogren, J. "Risk-reduction strategies against the `explosive invader'," in Perrings, C., M. Willliamson, and S. Dalmazzone (eds.), The Economics of Biological Invasions, pp. 56-69. Northampton, MA: Edward Elgar, 2000.

Smith M. E., E. O. Raveswaay, and S. R. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii." *American Journal of Agricultural Economics.* 70 (August 1988,):513-20.

Smith A. P., J. A. Young, and J. Gibson. "How Now, Mad-Cow? Consumer Confidence and Source Credibility During the 1996 BSE Scare." *European Journal of Marketing*. 33 (November-December 1998):1107-1122.

Sobel J., Khan A. S., Swerdlow D. L. "Threat of a Biological Terrorist Attack on the US Food Supply: the CDC Perspective." *The Lancet.* 359(March 2002):874-880.

The Economist. Foot, Mouth and Public Policies. From the Economist Global Agenda. Apr 4th, 2001 [online] available at: http://www.economist.com/agenda/printerfriendly.cfm?story_id=560922 , Accessed 07/28/03.

Torok T. J., R. V. Tauxe, R. P. Wise, J. R. Livengood, R. Sokolov, S. Mauvais, K. A. Birkness, M. R. Skeels, J. M. Horan, and L. R. Foster. "A Large Community Outbreak of Salmonellosis Caused by Intentional Contamination of Restaurant Salad Bars." *Journal of American Medical Association*. 278 (August 1997):389-395.

United States Department of Agriculture. Food Safety and Inspection Service, "Protecting America's Meat, Poultry and Egg Products." A Report to the Secretary on the Food Security Initiatives of the Food Safety and Inspection Service. Washington, D.C. 01.31. 2003

Veneman, Ann M. United States Department of Agriculture, 2003. http://www.usda.gov/homelandsecurity/homeland.html. Accessed 04/25/03.

World Health Organization, Terrorist Threats to Food: Guidance for Establishing and Strengthening Prevention and Response Systems. Food Safety Issues. Food Safety Department. Geneva, Switzerland, 2002.

107th Congress, Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Public Law 107-188. June 12, 2002.

Figures

Figure 1. Aggregate Producer Surplus

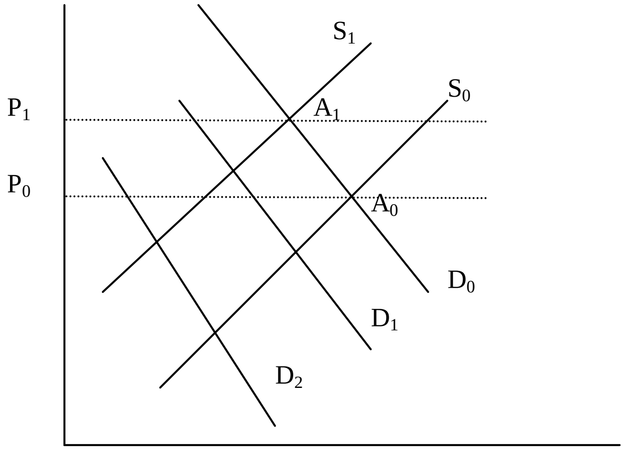


Figure 2a. Unaffected Producers.

Figure 2b. Banned Producers.

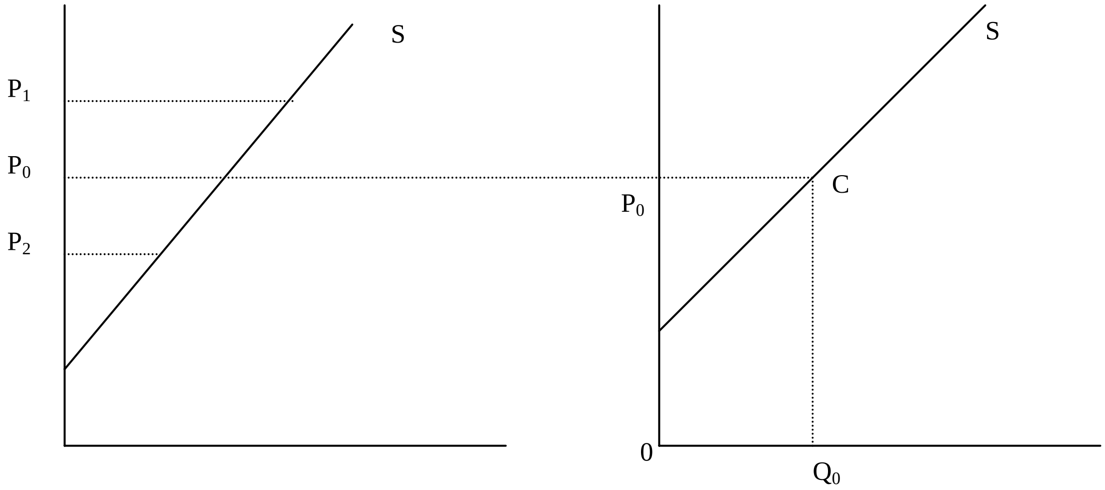
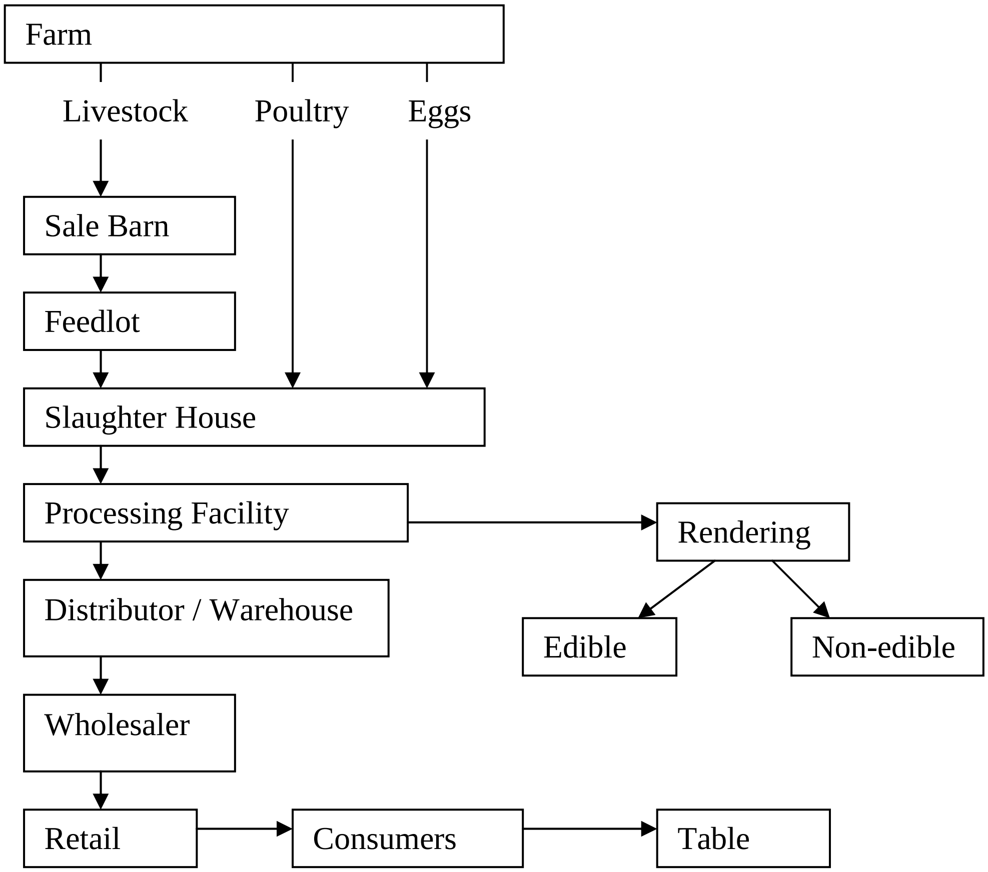


Figure 3. The food Process: Farm-to-table



Source: FSIS 2003

Figure 4. Proposed linkages between existing national alert and response systems and food safety systems (WHO 2002)