Animal Disease Outbreaks and Trade Bans

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Abstract

Contributions of this paper included a review of selected historical outbreak data for livestock across the world, an examination of rule-based trade policies, and an analysis of a simple game theory model focusing trade bans in the event of disease outbreaks with perceived risk. The data exhibit that temporal trends or skewness are important characteristics of disease outbreaks. Moreover, disease outbreaks can be spatially concentrated and clustered regionally around the world. Specific model outcomes are that perceived risks are critical to the likelihood of a trade ban; effective border monitoring of adjacent countries, border buffer zones, or regionalizing the outbreak are essential for a trade ban to be successful; generic rules for trade are not optimal even when focusing on trade bans; and because risks are often based on public perception it is vital to have effective risk communication strategies. General recommendations are that public policies should be mixed with innovative market-based mechanisms and private incentives to effectively control disease outbreaks.

Keywords: animal disease, trade bans, perceived risk, game theory

Introduction

Animal diseases are public goods that impose externalities on trade throughout the world.[1] Recent outbreaks include, but are not limited to, Bovine Spongiform Encephalopathy (BSE) found in cattle in the European Union (EU), Canada, and United States (US); swine fever in the EU; and Foot and Mouth Disease (FMD) found in cattle in Taiwan, Japan, Korea and other parts of the world. Typically, trade bans are imposed on exports coming from counties infected with such a disease. The single positive BSE test in 2003 in the state of Washington is a good example of the burden that bans impose on trade and how difficult it has been for the US to reopen its export market with certain countries (including neighbors). Even with comprehensive efforts in the US to meet international safety standards, South Korea and Japan have remained apprehensive about the ability of domestic producers/processors to meet those standards and thus have not resumed imports. Our interest is in examining selected animal disease outbreaks across the world and conceptually assessing the effectiveness of trade bans as a mechanism to control these outbreaks.

Fallout from animal disease outbreaks has had differing impacts on international and domestic markets. In the mid 1990s the United Kingdom (UK) experienced thousands of positive BSE occurrences, resulting in a significant decrease in the share of

[1] According to the United Nations Food and Agriculture Organization (FAO), one third of global meat exports is affected by bird flu and mad cow disease outbreaks. The resulting loss in trade could rise to US$ 10 billion in lost revenue in 2004 if import bans on the meat and poultry continue. The Asian region, which comprises nine out of the twelve nations affected, is set to lose at least US$ 500 million due to the bird flu crisis. One hundred million poultry have died or been culled in the region due to the disease. Export dependent countries are hardest hit; Thailand has already culled 25 percent of its domestic flocks. Consumption patterns in countries not directly affected by bird flu have also shifted, with India's poultry industry reportedly losing more than US$ 2.2 million daily due to lack of demand for chicken and eggs, accompanied by a one-third drop in chicken prices. Bovine spongiform encephalopathy, or mad cow disease, is affecting the exports of Canadian and US beef, valued at approximately US$4 billion. Demand for alternatives is expected to increase; shortages of beef and chicken have already led to a 40 percent surge in pork prices in Japan.

domestically consumed beef relative to other meats (Burton and Young).[2] Unlike the UK experience, domestic consumer demand for beef remained stable in the US after the single positive BSE test in 2003.[3] International markets have demonstrated quite different effects. While US exporters in beef have suffered due to trade bans after the BSE outbreak in the state of Washington, these exports were only about 10% of the annual US beef production. In contrast, trade bans dramatically impacted Canadian markets for beef after the positive BSE case in Alberta because they historically exported over 50% of annual beef production. Given BSE occurrences in the UK, Canada, and US, importing countries have been quick to ban beef products and slow (if at all) to reopen markets to imports from countries suffering outbreaks.

Even though the World Trade Organization (WTO) agreements call for scientific bases of trade barriers, the disputes over proper trade actions demonstrate that imposing trade bans are controversial and that re-establishing trade (which is a necessary first-step to recovering market share) is relatively difficult to achieve and not always transparent in nature. In part, this is because disease control under uncertainty will almost always lead to an overreaction in the event of an outbreak.[4] Moreover, importing countries impose trade sanctions based on perceived risks, which are both subjective and objective in nature, rather than real risks.[5] Furthermore, multilateral WTO regulations are centrally planned schemes that are rule-based and not market-based; implying they are not always effective in practice (highlighting public and private conflicts). Finally, WTO regulations

[2] In the 1990s, the UK BSE outbreak had limited impact on the excess supply of beef because the General Agreement on Tariffs and Trade (GATT) limit was the more binding constraint (FAPRI 2000).
[3] See Piggott and Marsh (2004) and Marsh, Schroeder, and Mintert (2004) for evidence of aggregate consumer response in the US to meat safety events.
[4] See Feder (1979) for a discussion of pest control under uncertainty.
[5] Under WTO Sanitary and Phytosanitary Agreement measures taken must be based on risk assessment, where the nature and magnitude of the perceived risk must be clearly established (so the sanitary and phytosanitary measure is commensurate with the risk).

are not disease specific, but rather generically defined to accommodate a myriad of animal and plant diseases. In effect, while central planning and coordination among countries and regions are important aspects of emergency response and control, it is becoming increasingly clear that identifying an appropriate mix of public investments and targeted private incentives are important for efficient and effective amounts of disease control and infrastructure over time.

The purpose of this paper is two fold. First, we review selected livestock outbreak data and policies governing major animal disease outbreaks across the world. This is relevant to understanding policy regimes applied in practice among countries. Second, we discuss multilateral rule-based trade policies as defined by the WTO between countries that are afflicted by animal disease outbreaks and those countries that are disease free. The conceptual methodology we follow is to examine a simple noncooperative game consistent with stated objectives of the WTO that assess perceived risk played by competing, interdependent countries. Here, among other interesting alternatives, we characterize Nash equilibrium(s), compare these to social outcomes of the model, and examine single versus multiple disease occurrences. Other considerations discussed are spatial dimensions of the problem (i.e., policies between adjoining relative to peripheral countries), regionalization, or attributes of the disease itself and how these impact markets.[6]

[6]Sanitary and Phytosanitary Measures (SPS) meetings at the WTO have focused on implementing "regionalization", the requirement that governments recognize regions within or straddling other countries as being safe sources for imports of food and animal and plant products, instead of basing their measures entirely on national boundaries (see http://www.wto.org/english/news_e/news05_e/sps_march05_e.htm). In March 2001, Argentina announced a change in FMD control strategy by ordering a 'border buffer zone' and a 'restriction zone' which can be categorized as FMD free zones where vaccination is practiced while maintaining a majority of the country's livestock as FMD free without vaccination (http://www.new-agri.co.uk/01-1/newsbr.html#nb5).

Disease Outbreaks

Animal diseases with international animal, human health, and economic impacts are public goods with global externalities. Externalities include animal death, depopulation, repopulation, decreased productivity, and treatment costs; human disease costs; food safety and environmental costs; domestic and international market losses; subsidies and compensation payments; and tourism and other business losses.

For illustrative purposes, we provide background material and reported impacts on four major diseases: Avian Influenza (AI), Bovine Spongiform Encephalopathy (BSE), Classical Swine Fever (CSF), and Foot and Mouth Disease (FMD). A complete list of livestock (cattle, sheep and goats, and avian) diseases as compiled by the World Organization for Animal Health (OIE) are presented in Appendix A. Data and information are taken from OIE's Handistatus II data base covering the years 1996-2003 and from the Food and Agriculture Organization of the United Nations (FAO).

Avian Influenza

Avian influenza (or "bird flu") is an infectious disease of birds that causes a wide range of disease syndromes, ranging from severe to mild, in domestic poultry. It was first identified over 100 years ago during an outbreak in Italy and has appeared at irregular intervals across the world. Recent epidemics have occurred in Hong Kong, Netherlands, and in the Republic of Korea in 2003. The current outbreak in Asia is the most serious AI outbreak ever experienced. Evidence suggests that trade in live poultry, mixing of avian species on farms and live bird markets, and poor biosecurity in poultry production units have contributed much more to disease spread than wild bird movements. According to the World Health Organization, there have been 42 confirmed human deaths from avian influenza since January 23, 2004. These occurred in Vietnam (29 deaths), Thailand (12 deaths) and Cambodia (1 death).

OIE and FAO recommend that long-term prevention and control of AI is recommended to be compatible with social, economic, and technical considerations and requires coordination at local, regional, national, and international levels. Means of control include eradication and vaccination of disease inspected birds.

Avian Influenza has had significant economic and social impact on affected countries and the disease situation could, in the worst case, lead to a new global human influenza pandemic. In 1983-84 an outbreak of AI in the United States resulted in the destruction of more than 17 million birds and cost taxpayers nearly $65 million (USDA-APHIS). The FAO estimates that nearly 140 million birds have died or been destroyed due to the epidemic that has recently hit Vietnam, China, Cambodia, Indonesia, Laos, Thailand, South Korea and Japan. Estimated total poultry farm losses in Asia for 2004 reached more than $10 billion. As a result of the ongoing outbreak in Asia, FAO estimates that around 20-25 million birds had been culled in the region as of 28 January 2004.[7]

Bovine Spongiform Encephalopathy

Bovine spongiform encephalopathy (or "mad cow disease") is a progressive and fatal disease of adult cattle characterized by degeneration of the central nervous system. BSE was first diagnosed in cattle in the UK in 1986. It is now prevalent in many other countries in and outside Europe. The transmission of the epidemic of BSE is thought to

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[7] FAO data suggest that this accounts for less than 1 percent of the region's total inventories. However, the impact can be devastating to local economies and to both commercial poultry operations and smallholders -- particularly in Thailand, where the industry is heavily reliant on trade. In 2003, poultry exports from Thailand accounted for nearly 7 percent of global poultry meat trade, with an export value of approximately $1 billion USD.

be the oral ingestion of animal feed containing BSE-infected meat and bone meal by cattle. There are many indications that BSE causes variant Creutzfeldt-Jakob Disease in humans, by consumption of beef products contaminated by tissue from BSE infected cattle. Clinical signs of BSE are found in adult animals and the incidence within-herd is low. The breed and gender do not seem to be associated with the development of the disease. The incubation period is on average 5 years. Various clinical signs and an insidious course characterize BSE in cattle (slow weight loss and, despite a normal appetite, a decrease in milk production).

The ultimate aims of BSE control and prevention programs have been to reduce exposure risk to both cattle and humans. Two levels of measures must therefore be considered: those that block the cycle of amplification in the feed chain and those that prevent infective material from entering human food. Treatment of infected animals is not effective and those animals must be disposed.

The single positive BSE test in 2003 is a good example of how difficult it has been for the US to reopen its export market with certain countries (including neighbors). Estimated impacts of this single event for Washington beef and cattle producers alone range from $41-165 million. Coffey et al. (2005) reported that the US beef industry lost $3.2-4.7 billion in exports during 2004.

Classical Swine Fever

Classical swine fever (or “hog cholera”) is a highly contagious viral disease of swine. CSF was eradicated from the United States in 1978 after a 16-year effort by the industry and State and Federal governments. Today, only 16 other countries are free of CSF. CSF does not cause foodborne illness in humans.

For example, disease strategies for CSF in Australia include quarantine, zoning, eradication, vaccination, and disposal/decontamination. Wildlife control also plays an important role. Treatment of infected animals includes vaccination.

Outbreaks in Belgium in 1990 caused serious economic and social losses with the total epidemic cost exceed 280 million USD. In the spring and summer of 1997, outbreaks of CSF were confirmed in Haiti and the Dominican Republic; both countries had eradicated the disease in the early 1980's. Also in 1997, several European countries, including the Netherlands and Belgium, experienced outbreaks and suffered heavy losses.

Foot and Mouth Disease

Foot and mouth disease is a highly contagious viral disease of cloven-hoofed animals. The disease is characterized by the formation of vesicles (fluid-filled blisters) and erosions in the mouth, nose, teats and feet. Although not very lethal in adult animals, it causes serious production losses and is a major constraint in international trade. Of the domestic species, cattle, buffaloes, pigs, sheep, goats and deer are susceptible. Neither horses nor humans are affected.

To eradicate the disease a stamping out policy can be applied. This involves quarantine, movement restrictions, and slaughter and disposal of all affected an in-contact livestock on affected premises followed by cleaning and disinfection. Inactivated vaccines have been successfully used in many parts of the world. Although protected against disease, vaccinated animals are not totally resistant and can still become infected and shed virus. Resistance falls fairly quickly, so animals must be revaccinated at regular intervals (4-6 months) to maintain immunity.

FMD outbreaks have imposed enormous costs across the world. In 1993 reports from 12 Asian countries indicated that national vaccination programs alone would cost the region 380 million USD annually. The Netherlands revealed that a 2001 epidemic, which was restricted to a relatively small part of the country, cost the equivalent of 250 million USD to control the outbreak. The 2001 outbreak in the UK cost $3.7-5.3 billion. Cost of a FMD outbreak in the US of similar degree to the 2001 UK event is projected to be in the billions for exports alone (USDA).

World Trends

Each of these livestock diseases has imposed costs on society and individuals in the US and across the world. A trade ban is a common mechanism used to control animal disease outbreaks.[8] However, outbreaks of these diseases are inherently different in nature. AI, CSF, and FMD are highly transmittable with potential for rapid spread with control-prevention options that include vaccination, while BSE is latent in nature. The predominant BSE pathway for transmission appears to have been through use of animal feed with meat and bone meal. AI and BSE create risks for both animal and human health. Meanwhile, FMD and CSF are predominately animal health concerns.

Figures 1-4 show historical data from 1996 to 2003 for outbreaks at the world level of AI, BSE, CSF, and FMD, respectively. AI has potential for a global epidemic in animals and humans, and has been temporally skewed (see Figure 1) as well as spatially clustered. Meanwhile, BSE poses lower and longer term risk for individuals consuming

[8] Britain lost millions of dollars in trade revenues after the European Union and more than 40 other countries banned British beef exports in 1996. In May 2003, Canada, the world's third largest beef exporter has confirmed a BSE case in a farm in Alberta Province. More than 30 countries have banned Canadian beef immediately including US (imports 90% of Canada's beef export), which created a total loss of $3 billion to Canada. The first outbreak in the US was confirmed in December 2003. The US lost nearly 90% of its beef export since 37 countries put import ban on its beef and beef products.

contaminated meat. BSE outbreaks have steadily decreased from nearly 9000 in 1996 to about 1000 in 2003 (Figure 2) and have been dominated by outbreaks in the UK. FMD outbreaks were highest in 1997 and 2001 (Figure 4), while CSF outbreaks exploded in 2003 (Figure 3).

Treatment for AI, CSF, and FMD include eradication and vaccination. AI vaccinations have been temporally skewed (see Figure 1) and FMD vaccinations increased steadily over the timeline of the data, while CSF vaccinations have been more consistent from 1996 to 2003. There is no effective treatment for BSE other than eradication. In all, each disease has characteristics unique to identifying effective strategies to control outbreaks (see table 1).

Regional Trends

Figures 5-10 show trends in outbreaks and vaccination (except BSE) for five regions: Oceania, Europe, Americas, Asia, and Africa.[9] Table 2 includes percentages of cumulative outbreaks by region, while Table 3 reports mean and standard deviations by region. From 1996 to 2003 there were 739 reported AI outbreaks. The largest percentages of AI outbreaks have occurred in Europe (88%) and Asia (12%). Oceania had one and the Americas had two AI outbreaks. There were 27,262 reported BSE outbreaks from 1996 to 2003. Europe had the largest percentage of BSE outbreaks (99.96%), followed by Asia (0.04%) and Americas (0.01%). From 1996 to 2003 there were 13,068 reported CSF outbreaks. Asia had the largest percentage of CSF outbreaks (49%), followed by the Europe (33%), Americas (17%), and Africa (1%). Oceania had no CSF outbreaks. There were 51,666 reported FMD outbreaks from 1996 to 2003. Asia had the largest percentage of FMD outbreaks (75%), followed by the Americas (11%),

[9] See Appendix B for region definitions.

Africa (9%), and Europe (5%). Oceania and North America countries had no FMD outbreaks.

In all, these data exhibit that temporal trends or skewness are important characteristics of disease outbreaks. Moreover, disease outbreaks can be spatially concentrated and clustered regionally around the world. Next, we discuss trade policy issues relevant to animal disease outbreaks.

Trade Policy

WTO regulations address sanitary and phytosanitary trade constraints that countries may implement to protect their citizens and territories from disease threats. WTO regulations are multilateral schemes that are rule-based, covering risks to humans from diseases carried by animals, plants and their products; the entry or spread of pests; and additives, contaminants, toxins, and disease-causing organisms in food and beverages. The apparent role of the WTO and other international agencies is to maximize security against the international spread of disease with a minimum interference with world trade.[10,11]

WTO Agreement on Sanitary and Phytosanitary Measures

Here, we briefly summarize some issues of the WTO Sanitary and Phytosanitary Measures not discussed above. Under Article 2, member countries have the right to take sanitary and phytosanitary measures necessary for the protection of human, animal or plant life or health; provided that such measures are not inconsistent with the provisions

[10] Plotkin and Kimball (1997) compared policy and legal frameworks across international agencies, including the World Health Organization, World Trade Organization, FAO, and International Civil Aviation Organization.

[11] Interestingly, the stated mission for the World Organization for Animal Health (OIE) is “To improve the health and the welfare of animals all over the world regardless of the cultural practices or the economic situations in member countries.”

of the agreement. Member countries are to ensure that any sanitary or phytosanitary measure applied only to the extent necessary to protect human, animal or plant life or health (and is based on scientific principles and is not maintained without sufficient scientific evidence, except as provided for in paragraph 7 of Article 5). Member countries are to ensure that sanitary and phytosanitary measures do not arbitrarily or unjustifiably discriminate between members where identical or similar conditions prevail, including between their own territory and that of other members. Sanitary and phytosanitary measures shall not be applied in a manner which would constitute a disguised restriction on international trade.

Regionalization is also an important issue under development at the WTO. Under Article 6, members claiming that areas within their territories are pest (disease) free areas or areas of low pest (disease) prevalence need to provide the necessary evidence to objectively demonstrate to importing countries that such areas or regions are, and are likely to remain, pest (disease) free areas or areas of low pest (disease) prevalence. For this purpose, reasonable access shall be given, upon request, to the importing member for inspection, testing and other relevant procedures.

Key Concerns

Externalities from disease outbreaks have prompted countries throughout the world to invest in centralized control schemes to eradicate diseases or lower disease prevalence. However, and reiterating some concerns from above, it is not clear that WTO rules yield effective, efficient, or equitable outcomes especially for developing countries.[12] Key concerns are that WTO, OIE, and other regulatory agencies tend to prescribe generic policies based focused on perceived risk that distort market signals and remove incentives for disease control.[13] Indeed there appears to be little in the way of investigating a more efficient and effective balance between public policy and private incentives to control outbreaks (for an exception see Umali, Feder, and de Haan 1994).

Game Theory: Trade Bans

Consider the following trade ban game of perceived risks in response to an animal disease outbreak. Game theory is relevant in modeling interdependent behavior in the presence of risks, where risks faced by any one agent depend not only on its choices but also on those of all other (Heal and Kunreuther 2004). Von Neumann and Morgenstern (1972) applied game theory to vaccination policies, while Bauch and Earn (2004) integrated epidemic modeling into a game theoretic framework to analyze population behavior under voluntary vaccination polices for childhood diseases. Our approach is to examine a noncooperative game played by competing, interdependent countries focusing on trade bans on imports from countries with infected livestock. This model specification is consistent with WTO's objective to minimize animal and human health impacts and fallout on trade with emphasis on perceived risk.

Let P denote an individual country's strategy to ban trade and p be the proportion of other countries instituting a trade ban (i.e., the ban coverage level). Pure strategies are

[12] Lokuge, Lokuge, and Faunce (2005) suggest that SPS rules protect importers with financial, technical, and political barriers at the expense of exporters, especially for developing countries. As a result, SPS rules discourage efficient country-level investment into disease control strategies and infrastructure.
[13] See Bicknell, Wilen, and Howitt (1999) for discussion of private incentives and public policy in controlling bovine tuberculosis in New Zealand.

P=1 indicating the country will impose a ban with probability 1 and P=0 indicating the country will not impose a trade ban. A mixed strategy arises if $0 < P < 1$.

Define π_p as the probability that an unprotected country's livestock will be infected for the ban coverage level p.[14] Let r_v denote the perceived morbidity risks even with a trade ban in place. Let r_i denote the perceived morbidity risk from infection with no trade ban.[15] The expected payoff for the trade ban with perceived morbidity risks r_v and r_i is

$$E(P,p) = P(-r_v) + (1-P)(-r_i\pi_p)$$

which can be scaled r_i to achieve the relation

$$E(P,p) = P(-r) + (1-P)(-\pi_p)$$

where $r = r_v / r_i$ is the relative perceived risk.

Bauch and Earn (2004) proved there exists a unique convergently stable Nash Equilibrium (CSNE) for this mathematical formulation of a game.[16] If most of the countries adopt strategy P, and countries that adopt any other strategy Q always obtain a lower payoff than those adopting P, then P is a Nash equilibrium. If the trade ban is sufficiently risky, then the CSNE is not to institute a trade ban (P=0). Alternatively, if the ban is not to risky, the CSNE is to implement a trade ban with nonzero probability ($0 < P < 1$). Indeed, if with livestock population, the risk of infection far outweighs that of trade ban morbidity then the CSNE is to ban trade with nonzero probability.

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[14] If there is background or spontaneous infection then $\pi_p > 0$.

[15] For simplicity assume morbidity risks $r_k = f_k(r_{ka}, r_{kh})$ for $k = v, i$ include risks to animal stocks (r_{ia}) or to humans (r_{ih}) from a zoonotic disease.

[16] It is expected that a strategy observed in a real population must be CSNE (Bauch and Earn 2004; Eshel 1996).

Some Implications

When focusing on short run considerations of a trade ban, AI, CSF, and FMD have relatively larger probabilities of π_p (that an unprotected country will be immediately infected) relative to BSE with different magnitudes of morbidity risks. For example, FMD and CSF only have morbidity risk for animals. Meanwhile, BSE exhibits temporal patterns that are latent in nature, having longer-term effects for animal and human morbidity risks.

Spatial patterns of occurrences of diseases are important. Assuming uninfected countries are isolated from infected regions of other countries, then the CSNE is to implement a trade ban with nonzero probability.[17] Alternatively, trade bans are likely to be ineffective and remain sufficiently risky (not CNSEs) if there is unfettered black market trade or livestock smuggling across borders.[18] Effective border monitoring of adjacent countries, border buffer zones, or regionalizing the outbreak are essential for a trade ban to be successful. In the event it is possible to completely regionalize an outbreak within an infected country, then the perceived risk of infection for livestock from outside infected area (but within the infected country) becomes important. If the perceived risk is lower (higher), then the likelihood of a trade ban would be lower (higher).

Moreover, with increased uncertainty of, say, BSE production protocols, testing and detection, the uninfected country's perceived risk of infection will be larger

[17] Note that for AI and FMD one could argue similar statements for a vaccination policy instead of a trade ban (see Bauch and Earn 2004).
[18] In a recent FMD outbreak, border controls between Swaziland and Mozambique were tightened after reports of smuggling of cattle into Mozambique from the Lubombo region of eastern Swaziland (http://www.new-agri.co.uk/01-1/newsbr.html#nb5). Farmers in infected areas sold their cattle to smugglers for sale across the border, despite the ban in Mozambique on all beef imports from Swaziland and South Africa.

suggesting a higher probability of a trade ban. As a result, high confidence in production protocols and testing are necessary to reduce the likelihood of a trade ban.[19]

Finally, several other observations are important. To make more precise predictions, Bauch and Earn (2004) demonstrate that optimal decision thresholds are dependent upon the infection probability π_p, which in turn is subject to dynamic epidemiological and biological constraints. In effect, precise predictions, and hence more efficient disease control, will depend on the underlying nature of the biological and environmental processes driving the epidemiological system.[20] Consequently, even in the trade ban framework, the generic rule-based trade approach (i.e., for all animal and plants) by WTO does not foster optimal disease control.

Discussion

The contributions of this paper included a review of historical outbreak data for livestock across the world, an examination of rule-based trade policies (as defined by the WTO and other international agencies), and an analysis of a simple game theory model focusing trade bans in the event of disease outbreaks with perceived risk to examine the impact of WTO policies on competing, interdependent countries.

The game theory model assessing perceived risk associated with trade bans is a simple reinterpretation of a mathematical model developed by Bauch and Earn (2004) to examine childhood vaccination strategies. While the model is simple, we argue that it is somewhat reflective of the current state of WTO's rule-based trade policy and stated SPS

[19] Currently, both Japanese and Korean representatives are demanding to observe US domestic production protocols and guidelines for BSE.
[20] See also Marsh, Huffaker, and Long (2000); Bicknell, Wilen, and Howitt (1999); and Umali, Feder, and de Haan (1994).

objectives. In other words, rule-based public policy is a centrally designed scheme that ignores potential effectiveness of private incentives. Implications of the model are not surprising and are reflective of observed outbreaks and fallout from outbreaks across the world. Specific outcomes are that (1) perceived risks are critical to the likelihood of a trade ban; (2) effective border monitoring of adjacent countries, border buffer zones, or regionalizing the outbreak are essential for a trade ban to be successful; (3) generic rules for trade are not optimal even when focusing on trade bans; and (4) because risks are often based on public perception it is vital to have effective risk communication strategies.

Given the generic nature of WTO rule-based trade policies, the Japanese and Korean responses to the 2003 US BSE outbreak are not surprising. These events highlight important tradeoffs between central public policies and private incentives. For instance, lessons from pollution externalities (drawing analogies between air and other pollutions relative to "disease pollution" seems relevant when exploring policy solutions) suggest that neither centralized mandatory control nor completely voluntary programs necessarily lead to cost effective solutions. Indeed, the pollution experience and insights are that innovative market-based mechanisms and private incentives are needed to effectively solve pollution problems.

It is clear that past, current, and future WTO SPS policies have and will continue to impact US Farm policy. The recent BSE experience in the US has dramatically altered the direction and funding of many research and educational programs at the state and federal level. For example, animal ID and COOL programs have been important topics of debate. Japanese and Korean representatives are exploiting SPS regulations to the extent that they concur that US production protocols are appropriate but that their concern is effective application of those protocols. This reiterates the importance of effective application of protocols in US production practices to protecting animal and human health.

Some of the limitations are that we ignore interdependencies between trade negotiations and anticipated political situations. For further research we suggest that game theory modeling be extended to investigate intertemporal or spatial issues inherent in disease modeling with emphasis of balancing public trade policies with private incentives. Finally, some degree of categorizing diseases that could be considered in formulating trade policy would likely lead to more efficient allocations of resources.

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Table 1. Assessment Categories

	Human Health Threat	Animal Health Threat	Highly Contagious	Available Vaccination
AI	X	X	X	X
BSE	X	X		
CSF		X	X	X
FMD		X	X	X

Table 2. Percentage of Cumulative Outbreaks by Region from 1996 to 2003.

	FMD	CSF	BSE	AI
Oceania	0.00%	0.00%	0.14%	0.14%
Europe	5.28%	33.43%	99.96%	87.96%
Americas	11.21%	17.05%	0.01%	0.27%
Asia	74.89%	48.89%	0.04%	11.64%
Africa	8.62%	0.64%	0.00%	0.00%
	100.00%	100.00%	100.00%	100.00%

Table 3. Mean and Standard Deviation of Outbreaks by Region from 1996 to 2003.

	FMD		CSF		BSE		AI	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Oceania	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.35
Europe	341.00	738.44	546.00	240.94	3406.25	2603.75	81.25	152.78
Americas	724.13	1597.88	278.50	89.19	0.25	0.71	0.25	0.71
Asia	4836.38	3153.67	798.63	1201.86	1.25	1.75	10.75	15.65
Africa	556.75	313.68	10.38	8.93	0.00	0.00	0.00	0.00

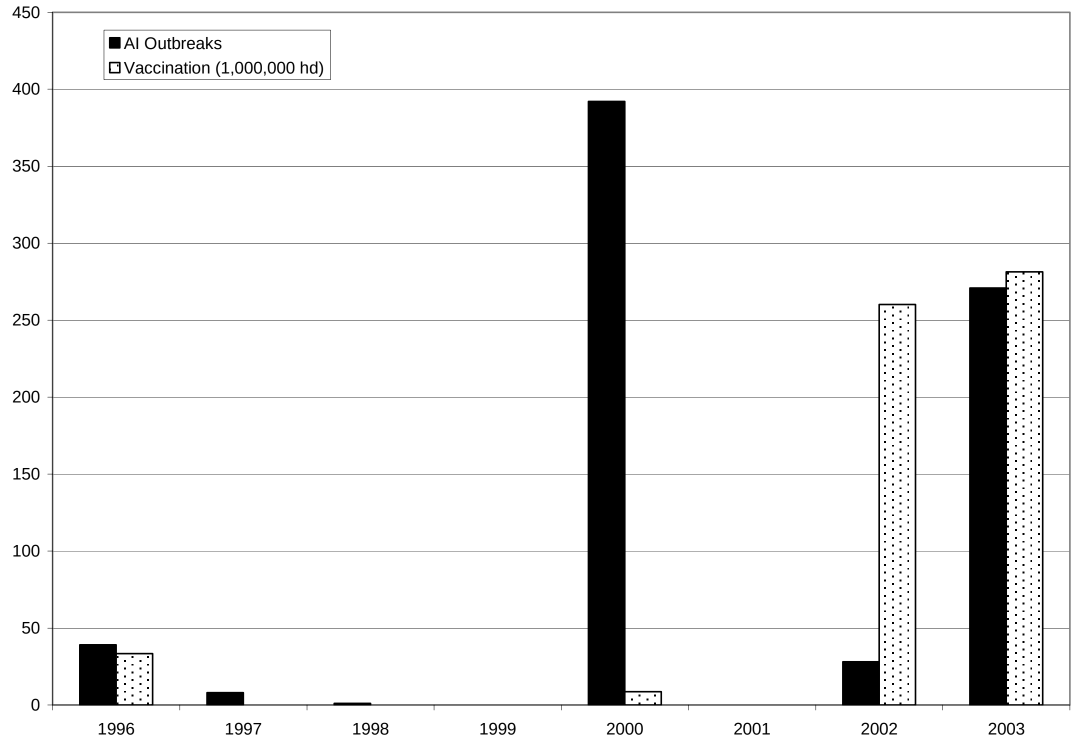

Figure 1. World AI outbreaks and number of head vaccinated.

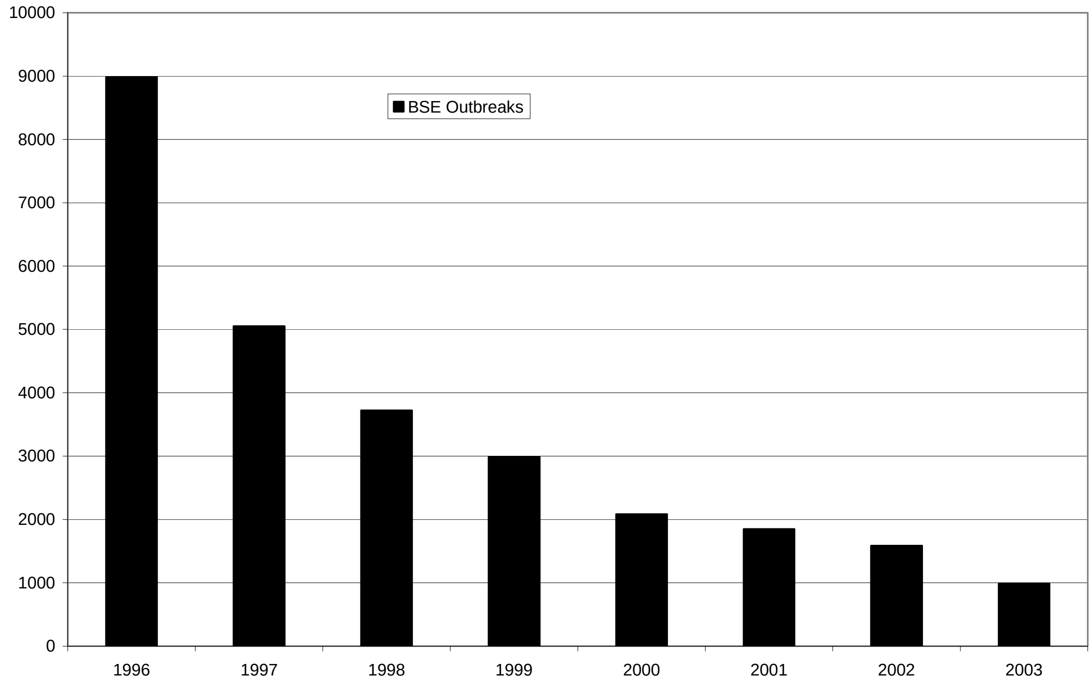

Figure 2. World BSE outbreaks.

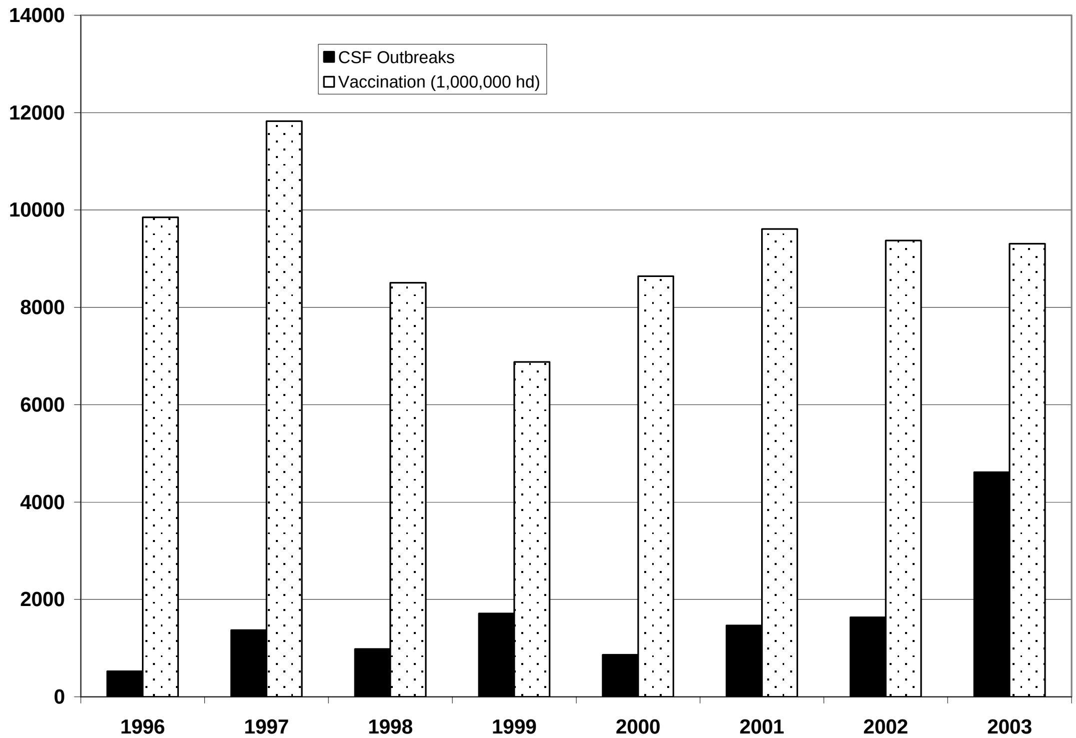

Figure 3. World CSF outbreaks and vaccinations.

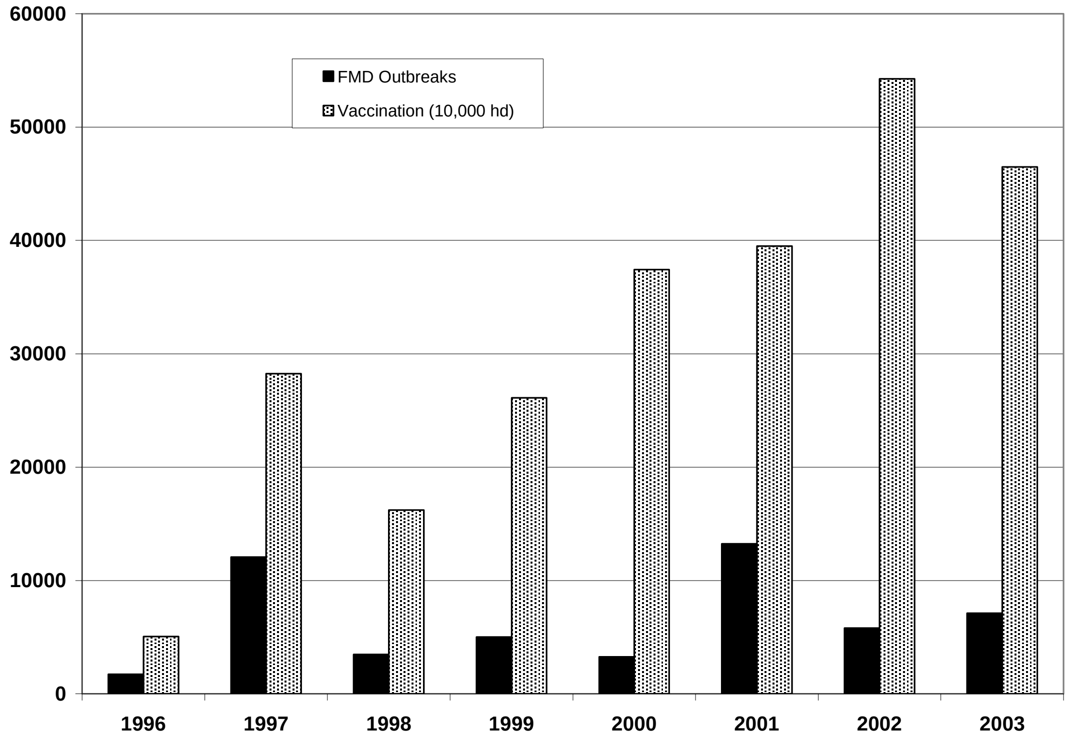

Figure 4. World FMD outbreaks and number of head vaccinated.

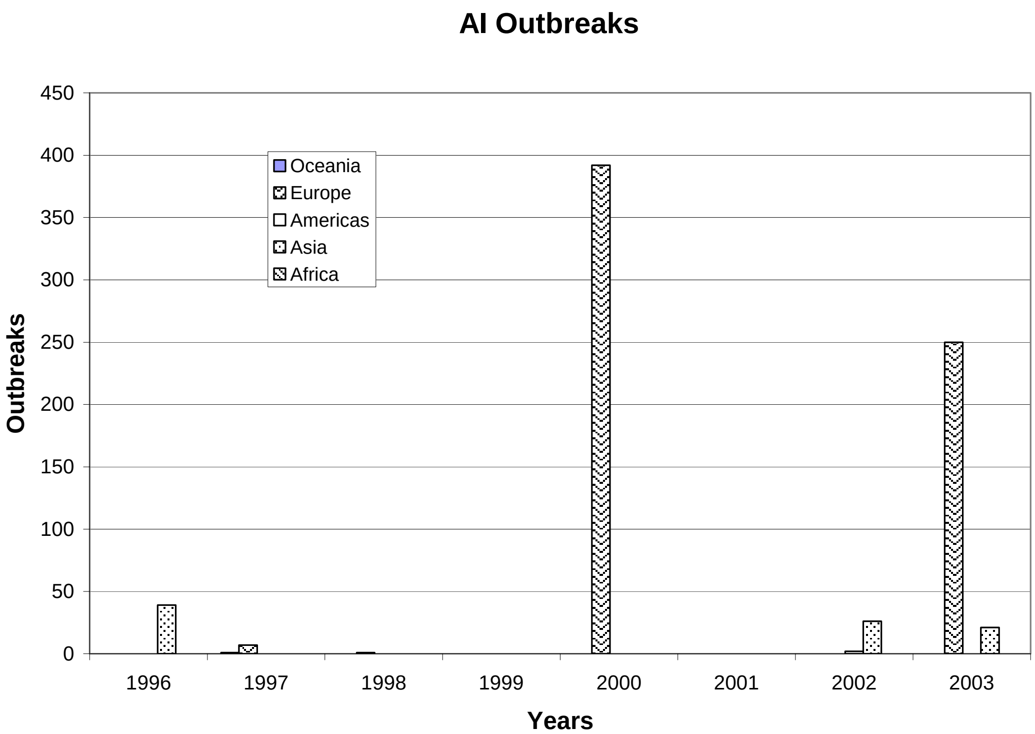

Figure 5. Regional AI outbreaks.

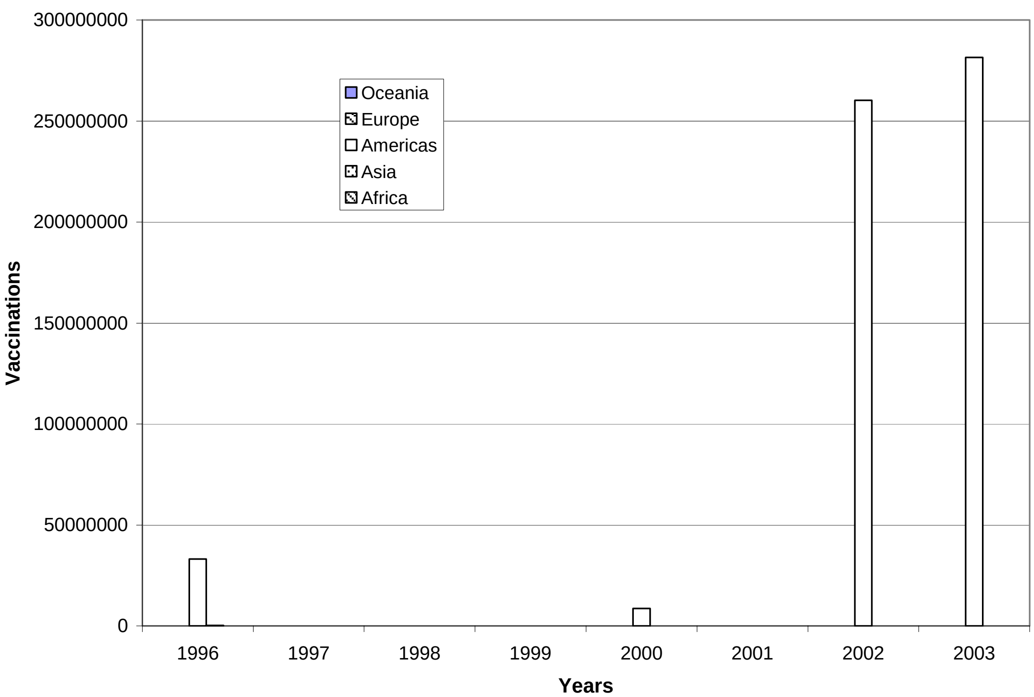

Figure 6. Regional AI vaccinations.

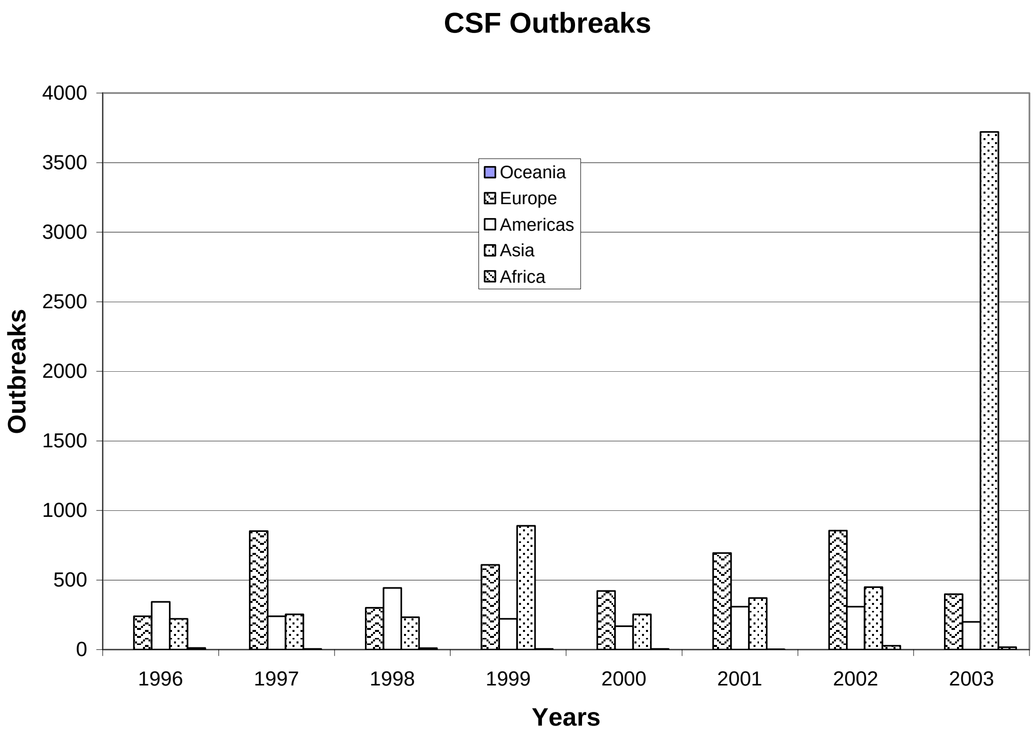

Figure 7. Regional CSF outbreaks.

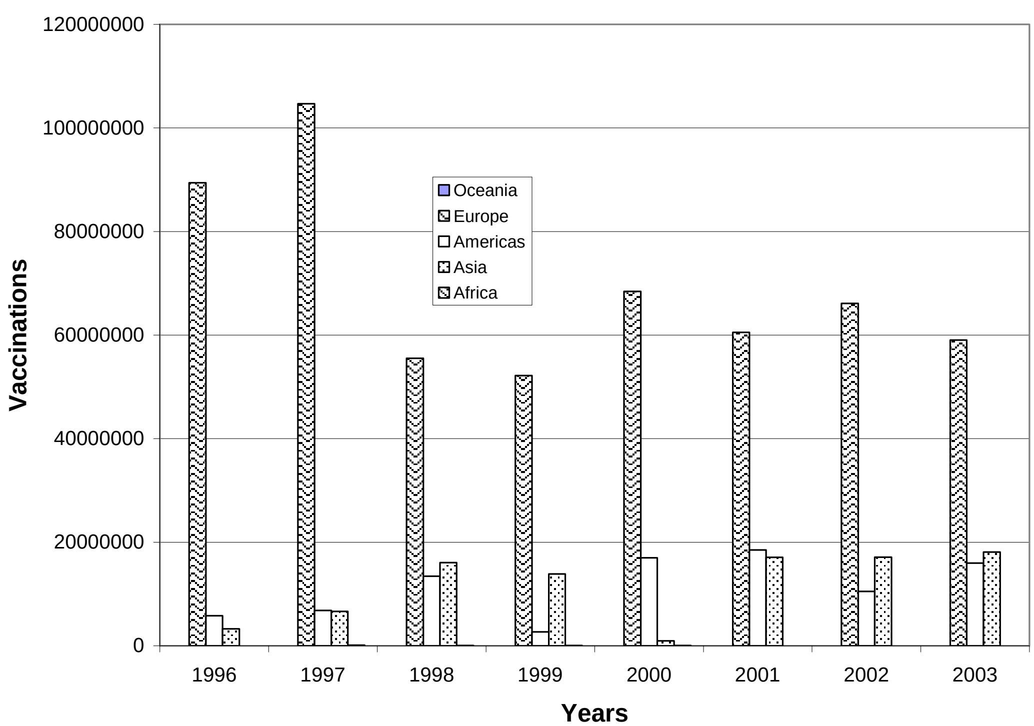

Figure 8. Regional CSF vaccinations.

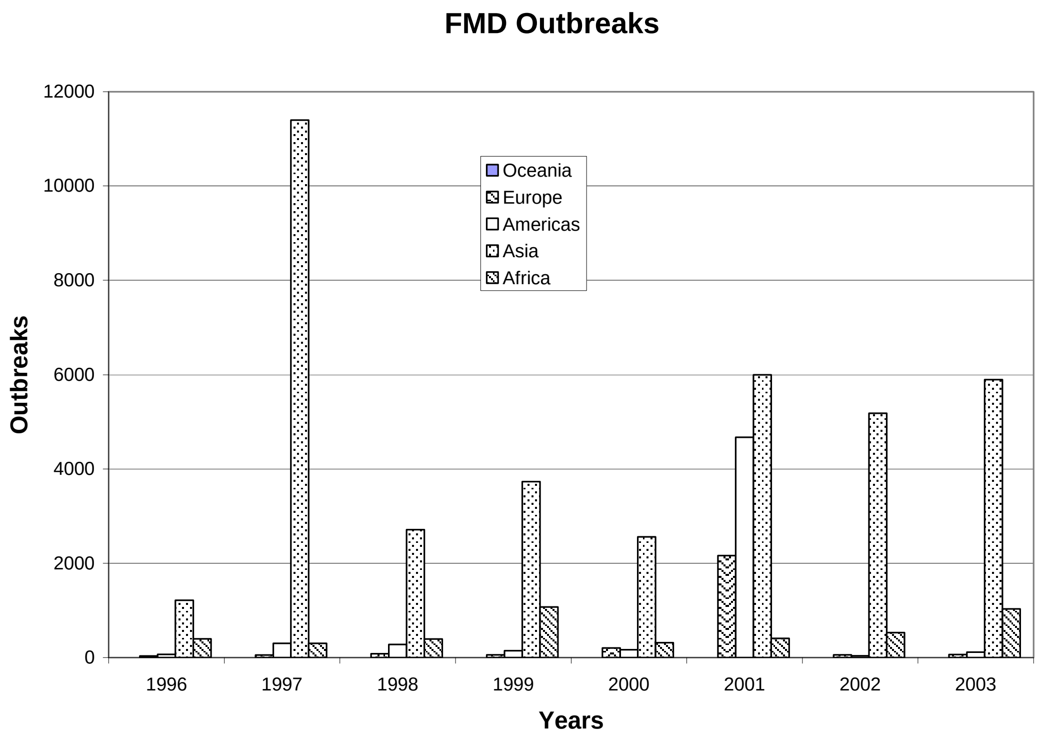

Figure 9. Regional FMD outbreaks.

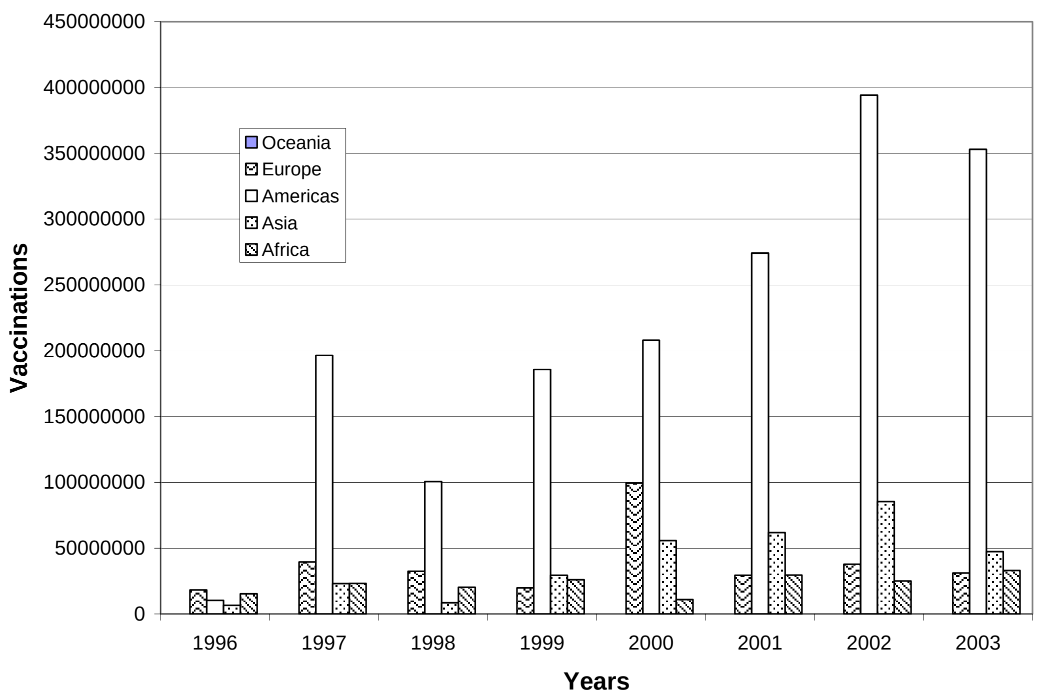

Figure 10. Regional FMD vaccinations.

Appendix A: OIE's Former List A and B Diseases

List A Transmissible diseases that have the potential for very serious and rapid spread, irrespective of national borders, that are of serious socio-economic or public health consequence and that are of major importance in the international trade of animals and animal products.

Foot and mouth disease
Swine vesicular disease
Peste des petits ruminants
Lumpy skin disease
Bluetongue
African horse sickness
Classical swine fever
Newcastle disease
Vesicular stomatitis
Rinderpest
Contagious bovine pleuropneumonia
Rift Valley fever
Sheep pox and goat pox
African swine fever
Highly pathogenic avian influenza

List B Transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of animals and animal products.

Multiple species diseases
Anthrax
Aujeszky's disease
Echinococcosis/hydatidosis
Heartwater
Leptospirosis
New world screwworm (Cochliomyia hominivorax)
Old world screwworm (Chrysomya bezziana)
Paratuberculosis
Q fever
Rabies
Trichinellosis

Cattle diseases
Bovine anaplasmosis
Bovine babesiosis
Bovine brucellosis
Bovine cysticercosis

Bovine genital campylobacteriosis
Bovine spongiform encephalopathy
Bovine tuberculosis
Dermatophilosis
Enzootic bovine leukosis
Haemorrhagic septicaemia
Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis
Malignant catarrhal fever
Theileriosis
Trichomonosis
Trypanosomosis (tsetse-transmitted)

Sheep and goat diseases
Caprine and ovine brucellosis (excluding B. ovis)
Caprine arthritis/encephalitis
Contagious agalactia
Contagious caprine pleuropneumonia
Enzootic abortion of ewes (ovine chlamydiosis)
Maedi-visna
Nairobi sheep disease
Ovine epididymitis (Brucella ovis)
Ovine pulmonary adenomatosis
Salmonellosis (S. abortusovis)
Scrapie

Equine diseases
Contagious equine metritis
Dourine
Epizootic lymphangitis
Equine encephalomyelitis (Eastern and Western)
Equine infectious anaemia
Equine influenza
Equine piroplasmosis
Equine rhinopneumonitis
Equine viral arteritis
Glanders
Horse mange
Horse pox
Japanese encephalitis
Surra (Trypanosoma evansi)
Venezuelan equine encephalomyelitis

Swine diseases
Atrophic rhinitis of swine
Enterovirus encephalomyelitis
Porcine brucellosis

Porcine cysticercosis
Porcine reproductive and respiratory syndrome
Transmissible gastroenteritis

Avian diseases
Avian chlamydiosis
Avian infectious bronchitis
Avian infectious laryngotracheitis
Avian mycoplasmosis (M. gallisepticum)
Avian tuberculosis
Duck virus enteritis
Duck virus hepatitis
Fowl cholera
Fowl pox
Fowl typhoid
Infectious bursal disease (Gumboro disease)
Marek's disease
Pullorum disease

Appendix B: Regions

Oceania: Australia, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, New Caledonia, New Zealand, Palau, Vanuatu

Europe: Albania, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yug. Rep. of Macedonia, France, Georgia, Germany, Greece, Greenland, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldavia, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, U.K./Great Britain, U.K./Guernsey, U.K./Isle of Man, U.K./Jersey, U.K./Northern Ireland, Ukraine

Americas: Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, British Virgin Islands, Canada, Chile, Colombia, Costa Rica, Cuba, Curaçao (Netherlands Antilles), Dominican Rep., Ecuador, El Salvador, Falkland Islands/Malvinas, French Guiana, Guadeloupe (France), Haiti, Martinique (France), Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Trinidad and Tobago, United States of America, Uruguay, Venezuela

Asia: Bahrain, Bhutan, Brunei Darussalam , Hong Kong (P.R. China), India, Israel, Japan, Jordan, Korea (Rep. of), Kuwait, Lebanon, Malaysia (Peninsular), Malaysia (Sabah), Malaysia (Sarawak), Mongolia, Myanmar, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Taipei China, Tajikistan, Thailand, United Arab Emirates, Uzbekistan

Africa: Algeria, Angola, Botswana, Burkina Faso, Cape Verde, Central African Republic, Chad, Côte d'Ivoire, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea, Kenya, Lesotho, Madagasca, Malawi, Mali, Mauritius, Morocco, Mozambique, Namibia, Niger, Reunion (France), Senegal, Seychelles, South Africa, Sudan, Swaziland, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe