Supporting document N°1

The impact of foot and mouth disease

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Summary

The global impact of foot and mouth disease (FMD) is colossal due to the huge numbers of animals affected. This impact can be separated into two components: the **direct losses** due to a reduction in production and changes in herd structure; and **indirect losses** that relate to the significant costs of FMD control and management and poor access to markets and limited use of improved production technologies. The paper estimates that **annual impact of FMD** in terms of production losses and vaccination alone are in the region of **US$5 billion.**

The balance of FMD impacts are not the same throughout the world, and the study identifies three broad regions:

1. Much of the global FMD burden of production losses falls on the world's poorest communities, and those which are most dependent upon the health of their livestock. In addition, the presence of FMD in these countries has an impact on the overall herd fertility, modifying the herd structure and affecting the selection of breeds. Overall the direct losses **limit livestock productivity** creating a **food security** issue and contributing to **malnutrition.**

2. In countries with ongoing control programmes, FMD **control** and management creates significant **costs**. These control programmes are often difficult to end due to risks of FMD incursion from neighbouring countries. The greater movement of people, livestock and commodities implies that risks of international transmission of FMD are increasing. This risk further compromises these countries in their ability to export livestock and livestock products as the presence, or even threat, of FMD prevents **access** to **lucrative international markets.**

3. In FMD free countries outbreaks occur regularly and the costs involved in regaining free status have been enormous.

The impact of FMD has led to successful national and regional campaigns for disease eradication most notably in Europe and the Americas. Therefore technologies and control methods exist to control and ultimately remove FMD virus from livestock populations. However, this requires significant management and coordination skills at a national and regional level due to FMD being highly contagious, and therefore, is a disease that generates high levels of **externalities**. These externalities imply that the control of FMD produces a significant amount of **public goods**, justifying the need for national and international public investment.

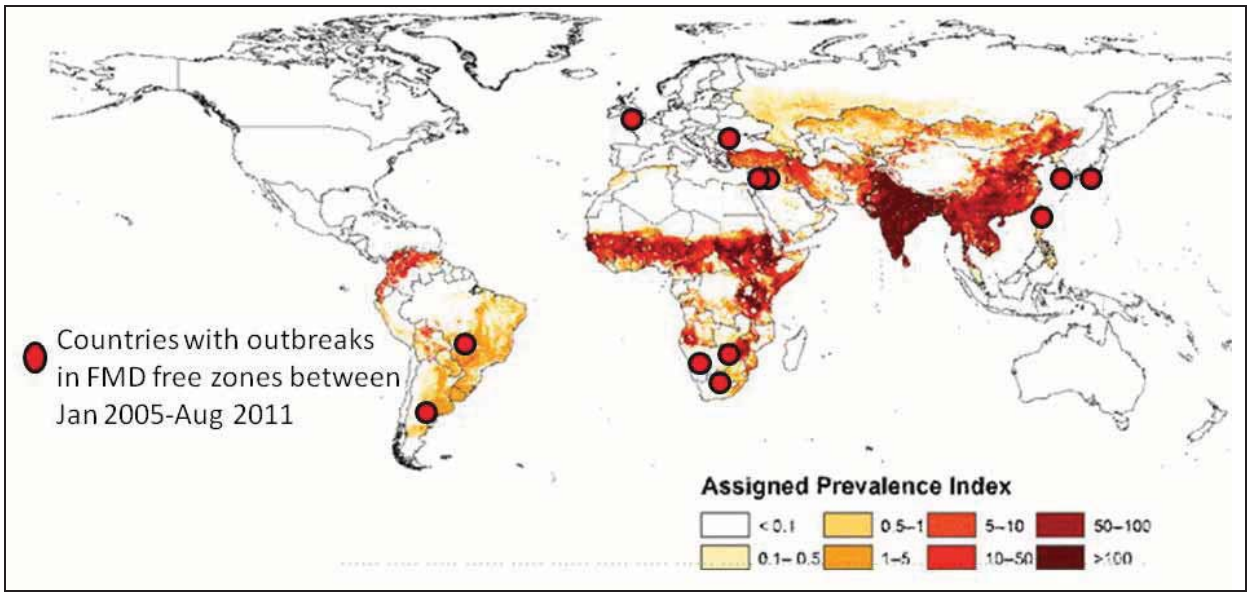
Equipping poor countries with the tools necessary to control FMD will involve the development of state veterinary services that in turn will deliver wider benefits to a nation including the control of other livestock diseases. Only through a sustained global effort can the risk of FMD and the heavy burden that it inflicts be controlled for rich and poor countries alike.

Introduction

Foot and mouth disease (FMD) is endemic in almost all developing countries. The seven different FMD serotypes circulate within regional viral pools with periodic incursions into virus free developed countries (see Fig. 1). FMD causes high morbidity and low mortality although high mortality of young stock does occur. Clinical signs are generally more severe in temperate breeds associated with intensive farming particularly in immunologically naive populations. The disease affects all the major non-avian livestock species, with cattle being the most susceptible and pigs the best amplifier of virus. Infection in wildlife can further complicate control efforts. It takes only 3 to 5 days (Charleston 2011) before a newly infected animal can spread the infection to other animals, with each case being able to infect many other animals. It is the most infectious human or animal disease agent known, infected cows have been estimated to be able to infect over 70 other cattle in a susceptible herd (Woolhouse 1996); these properties allow the disease to spread with great speed.

When this ease of biological transmission combined with widespread and long distance movements of animals, FMD can move quickly and spread effectively. By the time the first case of the UK 2001 epidemic was detected, it is estimated that over 57 farms around the country were already infected (Gibbens and Wilesmith, 2002). The importance of trade, both legal and illegal, in the spread of the disease implies that any FMD control strategy must have policies and actions to limit risks of FMD spread from an outbreak and the introduction from neighbouring countries and trading partners. These movement controls for FMD management have an economic impact of limiting trade that be local, national and international in its reach. The most extreme and costly impacts are the lack of access to lucrative international markets for countries where FMD is not controlled.

Fig. 1: Global burden of FMD in cattle, burden of FMD in sheep and goats had a similar distribution
Measured as a prevalence score based on estimates of incidence, population distribution and other risk factors. (Reproduced from Sumption et al. *2008)*



The paper reviews the economic impact of FMD and its control in different regions of the world using a framework that details the different aspects of the impact from production losses, costs of control, poor technology development through to trade. It presents a short description of the framework used to look at FMD impact followed by sections on what data and information are available FMD economic impacts. A section is included to describe the effect on poverty and food security of this major livestock disease.

The framework

The impact of disease is not equal across all countries and livestock populations due to differences in the genetics of the livestock; the management of the livestock; and the prevailing prices for the livestock systems inputs and outputs (see Rushton, 2009, pages 193-197). A framework has been suggested (Rushton *et al.*, 1999; Rushton, 2009; Rushton *et al.*; forthcoming) to assess disease impact that allows flexibility in terms of approaching this issue, identifying the following elements:

1. direct losses
   - *a)* visible impacts such as death of animals or reduced performance
   - *b)* invisible impacts where fertility is affected leading to the need to have a herd structure that contains extra breeding animals
2. indirect losses
   - *a)* costs of controlling and managing disease
   - *b)* revenue foregone where the presence of disease limits:
     - *i)* the use of technologies, particularly improved breeds and more intensive production systems; and
     - *ii)* market opportunities, both a local, national and international level.

Impact of disease is an important estimation to guide where to apply resources to animal health, which needs to be strengthened through examining the marginal costs and benefits of applying disease control measures. For example if money is spent on disease control, which will increase the indirect losses of the disease, the intention is to reduce the direct losses due to losses in animal and herd productivity. A control campaign is, therefore, useful if the avoidable losses in production are greater than the costs of control. The underlying economic theory on animal disease and their control has been well explained by McInerney (1988; 1992; 1996) for small additions to disease control. An important extension on these theories is detailed by Tisdell (2009) who looked at the need for fixed cost investments in veterinary education, research and infrastructure.

Applying the framework the following impacts of FMD are shown in Figure 2.

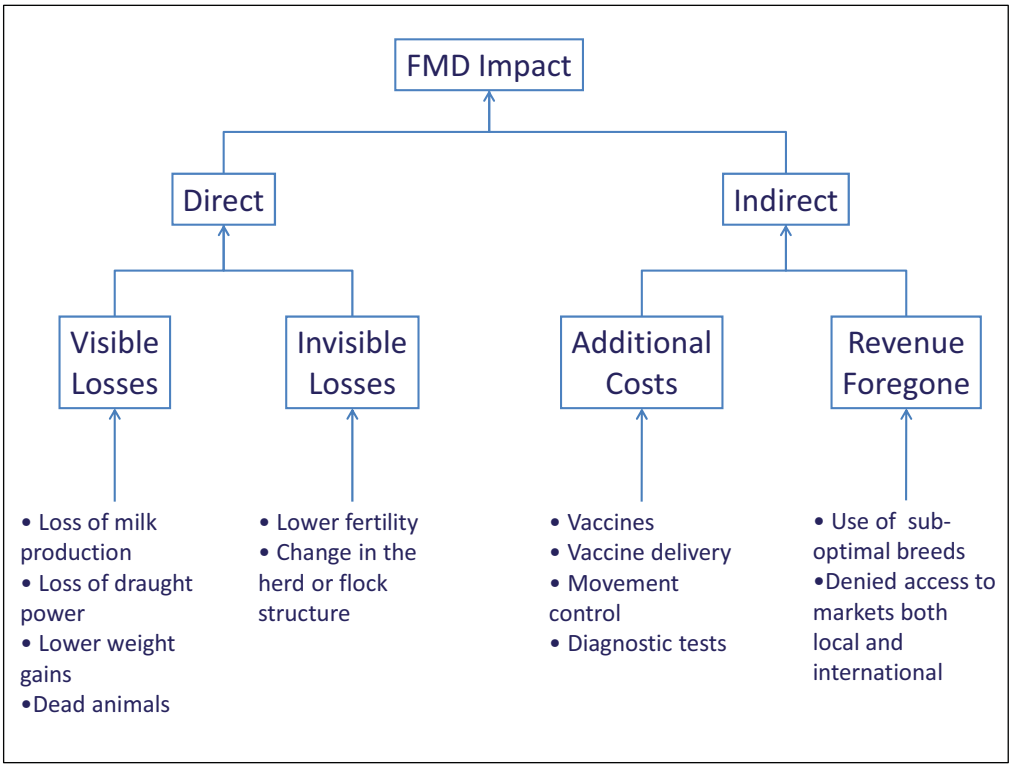


Fig. 2: The impacts of foot mouth disease

It is possible to apply the disease impact framework to different countries and make global estimates for FMD. The importance of this estimate is the nature of the impact that FMD causes. This is a disease that is highly contagious, affects many species and is not easily contained within one farm or one population. The presence of FMD creates problems to all livestock owners who are connected to a population infected either geographically or through input or output market chains (the livestock value chain). Therefore, FMD creates what economics calls **externalities**, which in this case are negative to all those connected to the problem. Similarly, where a livestock owner protects their animals from FMD they will generate a positive externality as they will be protecting the animals of livestock owner who are connected to the protected population. Where externalities are created there is a need for public investment as not all the costs, in the case of disease presence, or all the benefits, in the case of disease control, can be captured by the livestock owner implementing the actions. A strong role for government for FMD is creating an institutional environment where population level control costs reflect sufficiently the benefits that a livestock owner can capture in terms of benefits. In most cases this requires a combination of:

– investments in veterinary education, research and general infrastructure to develop the animal health system – what economists would call fixed costs
– specific programmes that cover the costs of FMD control and management – what economists would call variable costs

In many countries there is already a fixed cost investment in animal health systems, and adding a FMD control programme is relatively easy. However, countries that have low level investments in fixed animal health costs will not necessarily benefit with a FMD programme alone, there needs to be a combined effort to improve both the fixed and variable costs to get a potential control programme running. The importance of this observation is that the fixed cost element of the FMD programme will generate capacity and skills that will benefit other disease campaigns and therefore not all costs for this fixed cost element should be assigned to FMD.

Economic impact of FMD

Although other diseases can cause more severe disease in individuals, in order to appreciate the impact of FMD, one must step back and look at the disease at the population level. FMD is widely prevalent, with the disease circulating in an estimated 77% of the global livestock population. In this population it affects a large proportion of animals during an outbreak and affects many species. Collectively these factors lead to a huge burden of disease.

Direct impacts

Visible losses

Production losses due directly to FMD include:

– reduced milk production, affecting both the humans and calves that depend on it. This can account for 33% of losses in endemic settings
– reduced livestock growth
– mortality in young stock, typically reported to be between 2%-5%
– loss of traction power where draught animals are used. If this occurs during harvest the effects can be particularly severe (James and Ellis, 1976; Perry *et al.*, 1999)
– abortion: the cost of a single abortion is high as the farmer will have to pay to keep the cow without it producing anything for another year or more, or cull the animal

– although FMD typically has a short-term effect on an animal's health, chronic FMD typically reduces milk yields by 80% (Bayissa *et al*. 2011, Barasa *et al.* 2008; Bulman & Terrazas, 1976).

Visible production losses are most prominent in pigs in intensive production systems followed by dairy cattle. These two systems are important sources of animal protein in poor countries and their importance continues to grow (Delgado *et al.*, 1999). Extensive systems of production do not have such pronounced losses, and some species such as sheep and goats show limited clinical symptoms and minor economic losses.

Invisible losses

FMD causes problems with fertility, the most obvious are the abortion losses explained above, but there are longer lasting impacts of this loss of both foetus and a reduced probability of conception. These both translate into the need to have a greater proportion of breeding animals in a population implying that for every kilo of meat or milk produced there is an additional fixed cost to cover more breeding stock. These impacts are well detailed in Rushton (2009) for the extensive cattle systems in Bolivia.

Indirect impacts

Additional costs

Control costs

The cost of control measures carried out by the state veterinary services, such as vaccination, outbreak control and sometimes culling and compensation are borne by the tax payer.

– an estimated 2.6 billion doses of FMD vaccine are administered annually (Table I) (Hamond, 2011), with vaccine drug and delivery costs at between $0.4 to $3 per dose including delivery costs depending on the setting (Sutmoller, 2003; Barasa *et al.*, 2008; Forman *et al.*, 2009).

Table I: Estimated global FMD vaccine use (Hamond, 2011)

Region	Million doses/year	Comments
China	1.6 billion doses	5 government producers
South America	500	Brazil: 350 million doses
Asia (excluding China)	200	India: 150 million doses
Middle East	20	
European region	15	Mainly Turkey
Africa	15	

– some national FMD vaccination programmes vaccinate all bovines three times a year and all sheep and goats once a year, this limits resources available to combat other diseases

– in endemic settings significant amounts are spent on privately funded vaccination and control

– in some areas wildlife are kept out of FMD free zones with extensive fencing at great financial cost not to mention the impact this restriction has on wildlife.

In Africa it has been estimated that more is spent controlling FMD than any other veterinary disease (Le Gall and Leboucq, 2004).

Even if a country is FMD free there are ongoing costs due to:

– efforts to reduce the chance of disease re-introduction, including border and import controls and inspections and sometimes vaccination

– efforts to maintain the capability for early detection and control of FMD, including surveillance, ensuring sufficient organisational capacity in the veterinary services which are tested by outbreak simulation exercises (ref, outbreak exercises) and permanent restrictions on the livestock sector (such as post-movement standstills)

– dealing with outbreaks, which may involve culling, movement restrictions and vaccination. Outbreaks in animals lacking prior immunity to FMD are particularly dramatic:

  i) control measures can affect other industries, for example the UK 2001 outbreak restricted public access to the countryside costing in the region of US$4 to 5 billion in lost tourism revenue (Thompson *et al.* 2002)

  ii) the impact of culling based control measures can have other non-financial impacts, suicides increased amongst farmers of culled farms during the UK 2001 outbreak, in South Korea there was concern that burial of large numbers of culled animals would pollute water supplies. Culling healthy animals is a politically sensitive issue and is seen as unnecessary and inhumane by much of the wider public

  iii) movement restrictions disrupt production and may even lead to welfare problems that lead to further culling.

The 2001 UK FMD outbreak highlights how severe and widespread the consequences of an outbreak in an FMD free country can be. Following outbreaks in the Far East and subsequent outbreaks closer to Europe the disease appeared in the UK unexpectedly, in an area not thought to be linked to international trade. Widespread culling was used to contain the disease and ultimately 6.1 million animals were slaughtered. A high proportion of the animals slaughtered were on farms that did not have virus but were perceived to be under threat or the movement control measures had placed the animals under a welfare threat (Table I).

Table I: The cases and animals slaughtered during the 2001 FMD epidemic in the UK (DEFRA, 2002)

Type of premises	Cattle	Sheep	Pigs	Goats, deer and other	Total
Infected	303,242	952,440	20,200	1,277	1,277,159
DC* Contiguous	195,130	983,313	52,913	1,551	1,232,907
DC* Non Contiguous	81,113	1,296,490	69,083	978	1,447,664
Slaughter on suspicion	14,346	110,803	2,543	299	127,991
Welfare Disposal	169,033	1,586,983	286,912	5,429	2,048,357
Total	762,864	4,930,029	431,651	9,534	6,134,078
Percentage	12.44%	80.37%	7.04%	0.16%	100.00%

* Dangerous Contact

Asia has suffered major FMD epidemics in countries that were previously free. In Taiwan an outbreak of FMD mainly in the pig population decimated the sector and was estimated to have reduced the total GDP of the country by 028% (Hsu *et al.* 2005). Japan has had FMD outbreaks in 2000 and 2010, and the Republic of Korea experienced an outbreak in 2010 and 2011 with the destruction of 3.37 million pigs, cows, goats and deer with an early estimate of costs being in the region of US$ 2 billion.

In addition to the costs of vaccination and culling there are also costs incurred with the need for controlling movement and performing diagnostics for the confirmation of disease presence, or absence. There are no specific data on these additional items.

Revenue foregone

Market access

- Livestock trade is limited; those affected by FMD receive lower prices for their stock, those wishing to purchase animals from FMD free herds face a restricted supply
- countries infected with FMD cannot trade live animals with FMD free countries. Typically the countries with the best meat prices are FMD free (i.e. EU, USA and Japan) (James & Rushton 2002)
- the trade of livestock products is also restricted, if regular outbreaks occur only processed, tinned products can be exported to free countries; if FMD is effectively controlled with vaccination by a competent veterinary services able to detect outbreaks then deboned meat can be exported (James and Rushton, 2002)
- trade of fruit and vegetables can also be affected by FMD status (James and Rushton, 2002)
- the FMD status of nations that a country trades with also affects a country's ability to trade with FMD free countries irrespective of its own status (James and Rushton, 2002)
- lack of access to lucrative markets restricts the development of commercial farming, consequently employment and tax revenue from this area is limited by FMD status
- investment in the livestock sector is limited if there is a perceived risk that FMD may occur
- livestock and livestock products cannot be imported from FMD infected countries, this limits supply, although this is good for domestic producers it limits choice and leads to increased market prices for consumers.

Impacts at the national level ultimately impact on the individual farmer and vice-versa. Similarly impacts on the livestock producer have ripple effects along the entire market chain, impacting on other players, such as markets, abattoirs, dairies to mention a few (Le Gall and Leboucq, 2004).

Disruption of the rural economy

The overall cost to the UK economy was estimated to be US$9billion (Thompson *et al.*, 2002), furthermore it spread to the Netherlands (costing over $1billion) and Ireland and France (costing further hundreds of millions of dollars in losses). In the UK the ongoing outbreak became a focus point for the upcoming national elections, in the aftermath the government department dealing with agriculture (MAFF) ceased to exist and was entirely re-organised and rebranded (Defra); ten years on the outbreak still causes bitterness and anger.

Rich and poor countries alike go to great lengths to combat the disease in order to obtain the rewards associated with FMD free status. Although slaughtering animals to combat a non-fatal disease may initially seem illogical, the size of these indirect benefits may justify the use of control measures that have a greater negative impact than the direct costs of the disease (Perry 2007).

Use of sub-optimal technologies

High productivity breeds are typically more susceptible to FMD. The risk of FMD therefore restricts:

a) the use of these breeds and

b) prevents the development of more intensive production systems based on these breeds.

Calculating the economic impact of FMD

A country study Bolivia 1999

During the late 90s one of the authors was involved in project in Bolivia to establish a surveillance system that focussed on FMD. His role was to make assessments of the livestock sector, the impact of diseases and where appropriate the cost benefit analysis of strategies. An estimate was made on the impact of FMD in 1999 in the country. The results are presented in Tables II to IV and Figures 3 to 5.

The most important losses are found in the Departments of Santa Cruz and the Beni where a majority of the cattle are found and also where disease at that time was poorly controlled (see Table II).

Table II: Estimate of the direct economic losses, visible and invisible, caused by foot and mouth disease in Bolivia in 1999

Zone	Cattle population 1998*	Number of animals in the zones where there are disease reports	Estimation of the affected animals in 1998	Estimation of the economic losses (US$)	Human population
Santa Cruz	1,703,901	1,375,113	137,511	783,815	1,703,901
Beni	2,100,000	2,100,000	315,000	1,480,500	346,180
Other Departments	1,643,393	179,711	17,971	102,435	5,899,852
Total	5,447,294	3,654,825	470,482	2,366,750	7,949,933

In addition the departments of Santa Cruz and the Beni had a majority of the costs of control as these regions were vaccinating more animals per year (see Table III).

Table III: Estimates of the additional costs of foot and mouth disease control in Bolivia in 1999

Zone	Number of vaccines purchased	Cost of the vaccine and its application (US$/head)	Total cost (US$)
Santa Cruz	783,794	0.5	391,897
Beni	945,000	0.7	661,500
Other Departments	493,018	0.7	345,113
Total	2,221,812		1,398,510

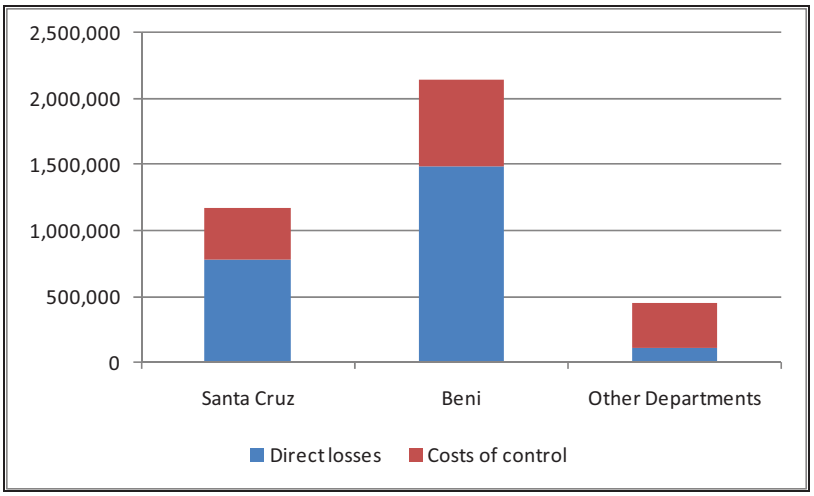
FMD in Bolivia was not well controlled at the time of the analysis as can be seen in Table IV where for every dollar spent of disease control a further two dollars were lost in direct losses due to the disease. The overall impact was calculated to be US$3.7 million in 1999. The impact per head of cattle was US$069 and per person was US$0.47.

Table IV: Estimate of the total impact of foot and mouth disease in Bolivia in 1999

Zone	Direct losses	Costs of control	Impact		
			Total	US$/head of cattle	US$/ person
Santa Cruz	783,815	391,897	1,175,712	0.69	0.69
Beni	1,480,500	661,500	2,142,000	1.02	6.19
Other Departments	102,435	345,113	447,548	0.27	0.08
Bolivia	2,366,750	1,398,510	3,765,260	0.69	0.47

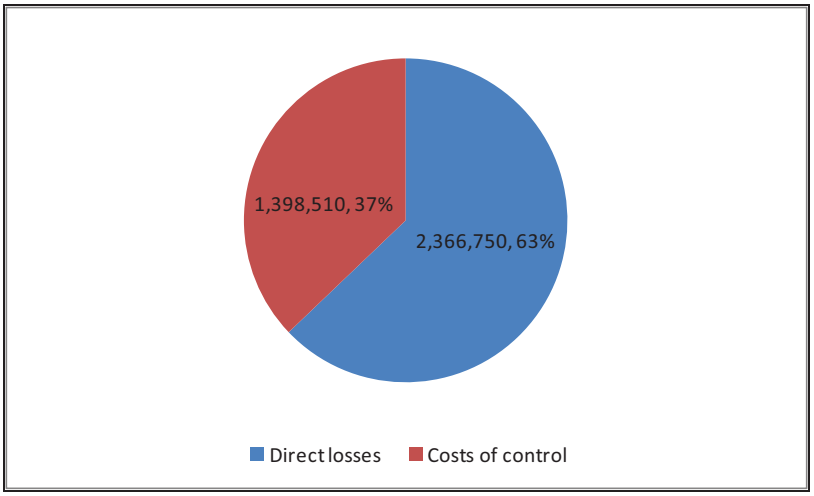
Over half of the FMD impact in Bolivia is in the Beni and a third in the Department of Santa Cruz. A high proportion of this impact in both these departments was due to direct losses (see Fig. 3).

Fig. 3: Estimated impact of foot and mouth disease in Bolivia in 1999 by zone



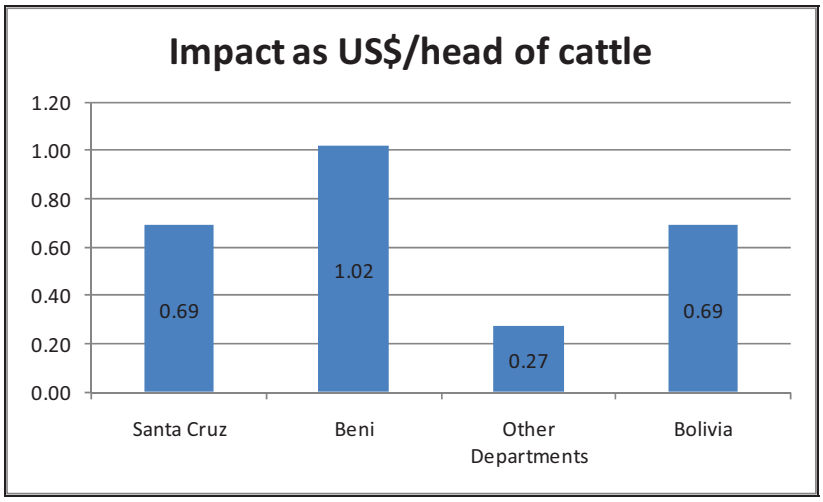
Approximately two thirds of the impact caused by the disease was estimated to be from direct losses (see Fig. 4).

Fig. 4: Total impact of foot and mouth disease in Bolivia in 1999 by type category of impact



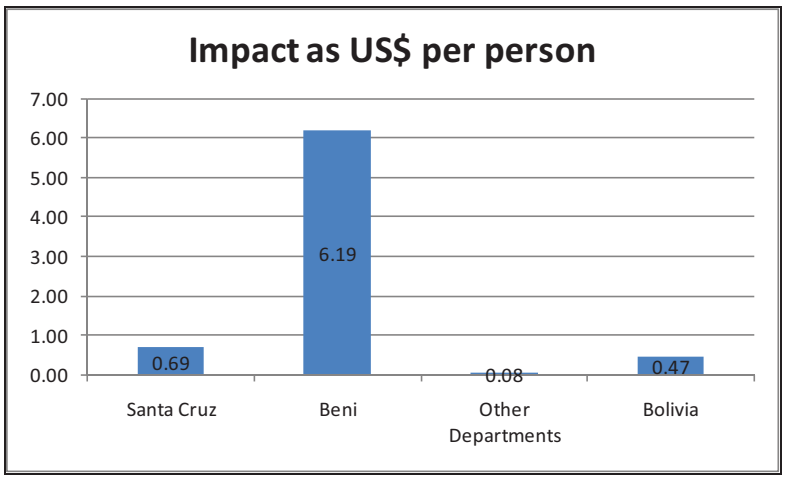
The impact measured as an amount per head of cattle was highest in the Beni followed by Santa Cruz (see Fig. 5).

Fig. 5: Impact of foot and mouth disease as an average per head of cattle and by zone.



The impact as an amount per person was US$6.19 in the Beni reflecting that there are many cattle per person in this part of Bolivia and that the disease was relatively poorly controlled.

Fig. 6: Impact of foot and mouth disease as an average per person by zone and the overall country



Global distribution and impact

The scale of FMD impact is determined by the losses and costs caused multiplied by the number of FMD susceptible animals in a country (Fig. 2). Perry and Grace (2009) found FMD was the only livestock disease to be consistently prioritised in countries by a range of different sources including those focussed on poverty reduction. By comparing the distribution of FMD (Fig. 1) to the global distribution of people living in poverty that depend on livestock (Fig. 3) it is apparent that those experiencing the highest incidence of FMD are those that are least able to absorb the losses it causes. Many poor livestock keepers limit the impact of a

single disease by keeping multiple species, this is less effective for FMD as it affects all ruminants and pigs. As well as being strongly associated with poverty, FMD is also correlated with poor governance (Garabed *et al.*, 2008) (Fig. 4); these associations are self-perpetuating as FMD causes losses and limits livestock development at the farm and national level, this in turn limits the resources available to control the disease. Due to the transboundary nature of the disease, this impact is felt at the regional and even global level.

Fig. 7: Density map of foot and mouth disease susceptible species, i.e. cattle, pigs, sheep and goats (FAO, 2005)

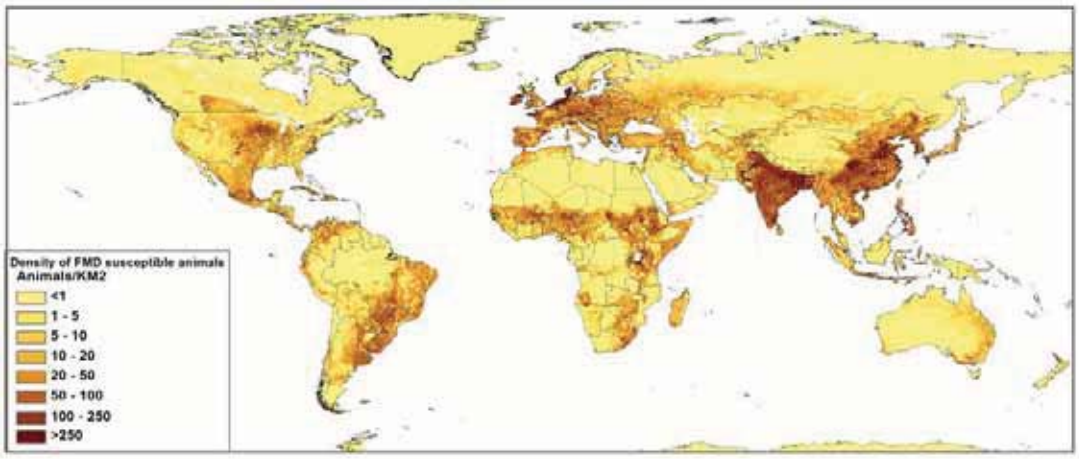


Fig. 8: Density map of the number of people living in poverty that are dependent upon livestock (Anonello, 200?)

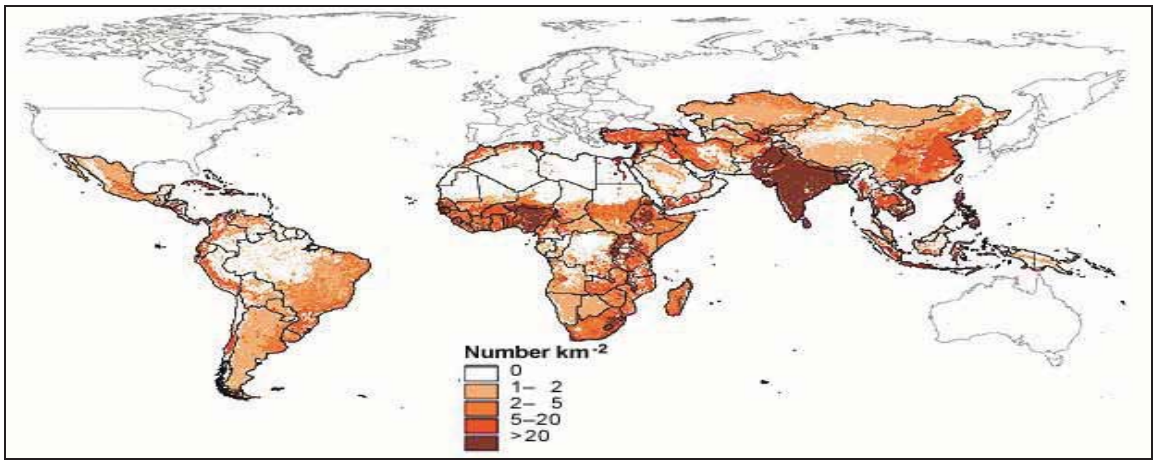
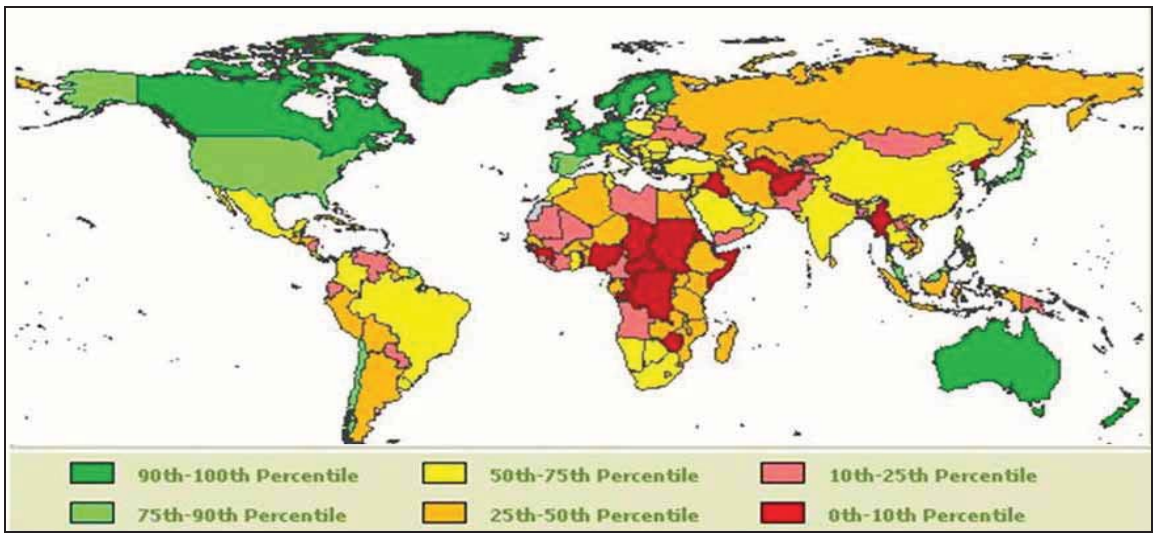


Fig. 9: Nations categorised by their relative Government effectiveness, the most effective are shaded green (World Bank, 2011)



An individual livestock keeper cannot adequately control FMD by his actions alone, but also depends upon a collective effort from their neighbours and trading partners. The same is true for a country, effective FMD control requires global cooperation (Foreman *et al.*, 2009). Although the benefits of FMD control are experienced by all susceptible livestock owners, the disease affects some production systems more severely than others (Perry *et al.* 2003). Left to individual livestock owners, unequal incentives for FMD control will always lead to pockets where control efforts are very limited. This results in reservoirs of infection that can then re-infect areas where FMD control has been achieved. A recent example of this effect is in Southern Africa, where a break down in FMD control in Zimbabwe has been followed by FMD outbreaks in Botswana and South Africa causing the closure of valuable export markets.

The production and supply of livestock and livestock products involves complex market chains involving many different actors. Trading and moving livestock facilitates the transmission of diseases along these market chains, however, this process is essential for adequate provision of goods and for the income that it generates (Rushton, 2009). Nowhere is this better illustrated than through the export of live animals from Somalia to the Middle East. In 2010 over 4 million livestock were exported via this trade, in addition informal exports could number half as many again (Knight-Jones *et al.*, 2011). The trade is essential, about 55% of the Somali population depend directly upon livestock for a living (Abdirahman SOLICEP press) and there is a huge demand for these animals in the Middle East, particularly during the Islamic festival of Eid when 10 to 15 million sheep and goats are slaughtered in a short space of time. However, FMD frequently disrupts this trade, with the importing authorities rejecting whole ships carrying up to 200,000 animals if FMD is suspected. These animals do not return to Somalia however, but are unloaded elsewhere in the region further spreading disease in the wider region (Knight-Jones *et al.*, 2011) (see Fig. 4, Di Nardo, 2011).

A global estimate

The authors have made an estimate of the impact of FMD globally as of 2011. This focuses on the numbers of animals that have FMD and the associated losses in terms of death and production and the costs of control focussing on an estimation of vaccination and the costs of vaccine production and delivery.

Numbers of animals affected

Based on FMD incidence estimates (Sumption *et al.*, 2008) and adjustments for under reporting an estimate was made on the number of animals affected by FMD on a year basis with the current control measures in place (see Table V).

Table V: Estimated number of animals infected with foot and mouth disease by species and region

Region	Cattle	Goats	Pigs	Sheep	Buffalo
China	2,805,782	2,469,838	10,965,121	2,346,703	90,993
India	5,912,399	2,162,590	2,313	1,117,811	411,047
Rest of Asia	3,549,507	2,454,426	659,516	1,174,235	174,213
Africa	7,402,839	4,149,367	3,450	3,269,222	219
Europe	108,177	28,825	33	120,708	86
Middle East	434,004	695,858	1	1,643,611	3,603
South America	380,282	11,712	176	37,029	62
Total	20,592,988	11,972,617	11,630,611	9,709,319	680,223

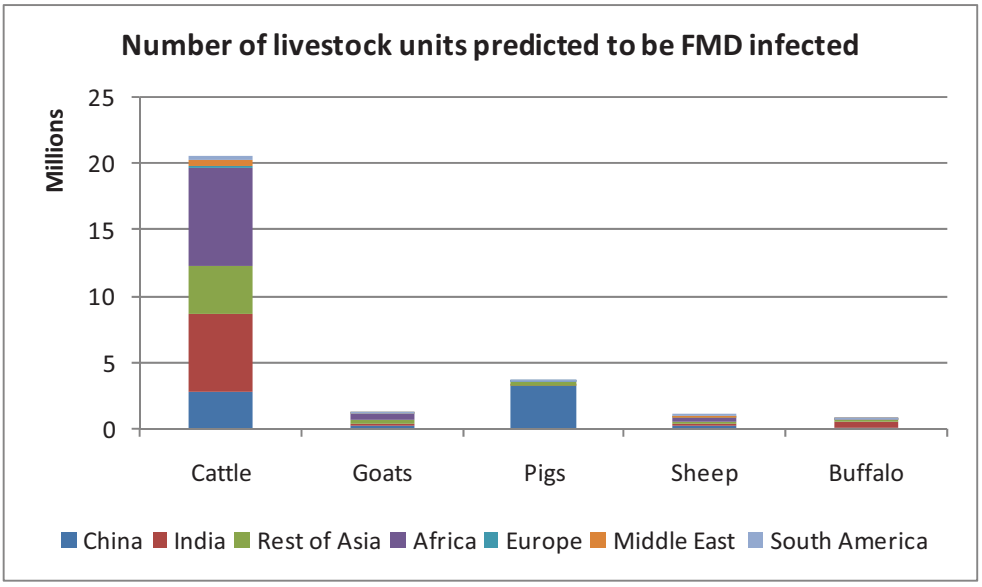
The numbers of animals was converted to livestock units to get an impression of the economic value of livestock affected on a yearly basis. It was estimate that 27 million livestock units are affected by FMD in a year with the current control measures in place. The worse affected regions in terms of absolute numbers are China, Africa and India (see Table VI).

Table VI: Estimated Livestock Units infected with foot and mouth disease by species and region

Region	Cattle	Goats	Pigs	Sheep	Buffalo	Total	%
China	2,805,782	246,984	3,289,536	234,670	90,993	6,667,965	24.8
India	5,912,399	216,259	694	111,781	411,047	6,652,179	24.7
Rest of Asia	3,549,507	245,443	197,855	117,424	174,213	4,284,440	15.9
Africa	7,402,839	414,937	1,035	326,922	219	8,145,952	30.2
Europe	108,177	2,882	10	12,071	86	123,226	0.5
Middle East	434,004	69,586	0	164,361	3,603	671,554	2.5
South America	380,282	1,171	53	3,703	62	385,271	1.4
Total	20,592,988	1,197,262	3,489,183	970,932	680,223	26,930,588	100.0
%	76.5	4.4	13.0	3.6	2.5	100.0	

Three quarters of the livestock units affected by FMD are predicted to be cattle and 13% pigs. The impact on cattle is greatest in Africa, India, rest of Asia and China, whereas the impact of the disease in pigs is estimated to be greatest in China (see Fig. 7).

Fig. 10: Estimated Livestock Units infected with FMD by species and region



In terms of the proportion of livestock affected we estimate that around 2% of the world's cattle population has FMD in a year, but there are region differences with no animals affected in North and Central America, Australasia and the Caribbean and that China and India are the worst affected areas (see Table VII).

Table VII: Estimated proportion of the populations affected by FMD by region and species.

Region	Cattle	Goats	Pigs	Sheep	Buffalo
China	3.39	1.72	2.46	1.72	0.39
India	3.39	1.72	0.02	1.72	0.39
Rest of Asia	2.65	1.43	0.76	1.04	0.36
Africa	2.73	1.41	0.01	1.13	0.01
Europe	0.08	0.12	0.00	0.07	0.02
Middle East	3.15	1.47	0.00	1.55	0.39
South America	0.11	0.06	0.00	0.05	0.01
Global	1.78	1.45	1.42	1.02	0.37

Control costs – vaccination

Our estimates on vaccination have been based on the production of vaccine rather than an estimate of what vaccines need to be delivered to achieve vaccine strategies across the world. For example vaccine strategies are known for:

- South America – vaccination of cattle twice a year for animals under two years of age and once a year for animals greater than two years of age
- India – vaccination of cattle twice a year
- China – vaccination of cattle, sheep and goats twice a year with pigs vaccinated once a year.

Most other regions have no official policy on vaccination against FMD. Table 8 presents an estimation of the vaccinations across the world.

Table VIII: Estimated foot and mouth disease vaccinations by country (based on Hamond, 2011) and the population targeted (based on author's consultations)

	Vaccinations		Population targeted		
Region	Number	%	Species	Population	% population
China	1,600,000,000	68.1	Cattle, shoats, pigs and buffalo	832,581,205	192.2
India	150,000,000	6.4	Cattle and buffalo	279,637,000	53.6
Rest of Asia	50,000,000	2.1	Cattle, pigs and buffalo	282,928,840	17.7
Africa	15,000,000	0.6	Cattle	271,502,418	5.5
Europe	15,000,000	0.6	Cattle	140,021,135	10.7
Middle East	20,000,000	0.9	Cattle and shoats	166,810,147	12.0
South America	500,000,000	21.3	Cattle	342,339,150	146.1
Total	2,350,000,000	100.0		2,035,788,464	115.4

The table indicates that estimated vaccination coverage for China and South America is close to achieving their strategy. However, India falls well short of vaccinating the population targeted twice each year.

Impact of foot and mouth disease

In summary FMD affects 27 million livestock units each year which is approximately 0.64% of the total livestock units globally. In attempt to minimise the economic losses of this disease 2.35 billion vaccines are produced and applied (see Table IX).

Table IX: Livestock units at risk and affected by foot and mouth disease and the number of vaccinations applied by region

Region	Livestock Units			Estimated vaccinations
	At risk	Affected		
		Number	%	
China	832,581,298	6,668,118	0.80	1,600,000,000
India	484,128,039	6,652,238	1.37	150,000,000
Rest of Asia	553,802,584	4,284,496	0.77	50,000,000
Africa	886,172,080	8,146,056	0.92	15,000,000
Australasia	69,850,904	0	0.00	0
Caribbean	10,580,360	0	0.00	0
Europe	517,722,541	123,228	0.02	15,000,000
Middle East	167,952,502	671,579	0.40	20,000,000
North America	172,838,710	0	0.00	0
South America	496,711,006	385,273	0.08	500,000,000
Total	4,192,340,024	26,930,988	0.64	2,350,000,000

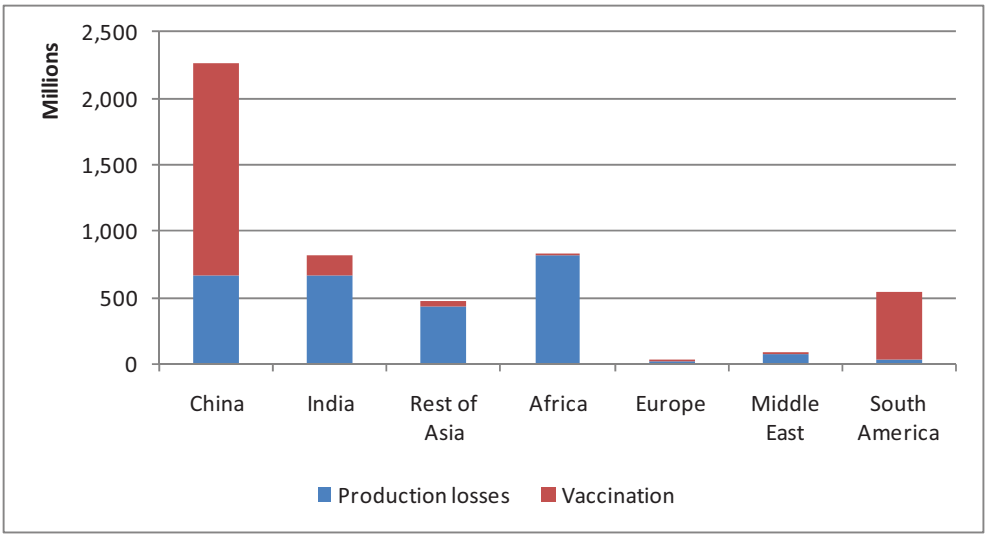
The overall economic impact was calculated based on the costs of a vaccine and its application being US$1 and that for any livestock unit affected by FMD it would cause a loss in production equivalent to US$100. The latter estimate takes into account the death of an animal, loss in weight gain, milk production and draught power and is felt to be a conservative estimation. The total annual impact of FMD is calculated to be US$5 billion (see Table X).

Table X: Estimated annual impact of foot and mouth disease by region

	Impact			
	Direct impact	Indirect impact	Total	
Region	Production losses	Vaccination	US$	% LSU Value
China	666,811,784	1,600,000,000	2,266,811,784	0.54
India	665,223,780	150,000,000	815,223,780	0.34
Rest of Asia	428,449,598	50,000,000	478,449,598	0.17
Africa	814,605,600	15,000,000	829,605,600	0.19
Australasia	0	0	0	0.00
Caribbean	0	0	0	0.00
Europe	12,322,822	15,000,000	27,322,822	0.01
Middle East	67,157,897	20,000,000	87,157,897	0.10
North America	0	0	0	0.00
South America	38,527,315	500,000,000	538,527,315	0.22
Total	2,693,098,798	2,350,000,000	5,043,098,798	0.24

The majority of FMD impact occurs in China, India and Africa. Impact in South America is largely due to the costs of vaccination applications, a control measure to limit the production and trade losses this region would suffer if FMD was prevalent (see Fig. 8).

Fig. 11: Foot and mouth disease impact by region and by the type of cost



The impact estimated does not include the losses due to trade restrictions which are large at both local and international levels, but are difficult to estimate with any accuracy and tend to be very variable. It also does not take into account that the development of the livestock sector tends to be restricted by the present of FMD in terms of production system technology and breed advancement and investment slaughter, processing and marketing systems. Finally, there was no estimate in these calculations in terms of the costs of diagnostics and surveillance required to prevent and control FMD. Therefore US$5 billion is likely to be a very conservative estimate of global FMD annual impacts.

Foot and mouth disease impact on the poor

Due to the importance of livestock to the world's poor, livestock disease control can cause significant poverty reduction. Pastoralist and agro-pastoralist communities are highly dependent upon livestock for milk, meat and as assets of economic and social value. A questionnaire based survey of African veterinary services found FMD to have the greatest impact on poverty of all the ruminant bacterial and viral diseases (Gall and Leboucq 2004). Livestock keepers living in poverty are particularly vulnerable to FMD. They live in countries which lack the veterinary services to control the disease and depend upon the use of common grazing and water facilities and markets where risk of infection is greatest. Furthermore, quality FMD vaccines are expensive, must be given repeatedly and must be kept refrigerated; this is not feasible for many livestock keepers.

Productivity losses are particularly hard hitting to those that depend upon their stock for traction, particularly where outbreaks in cattle occur during the planting season (Perry *et al.* 2003; Perry *et al.* 1999; Ellis and James 1976). The importance of reduced milk production is clear in commercial dairy operations, however, for many pastoralists milk provides a vital source of nutrition, particularly in children, accounting for over 50% of gross energy intake. By reducing the supply of milk FMD impacts on food security, particularly when outbreaks occur during the times of year when other food sources are limited and dependency upon milk is at its greatest (Barasa *et al.* 2008). Abortions due to FMD further limit milk supply by delaying the next lactation. A benefit-cost analysis found effective vaccination based control of FMD in agro-pastoralist communities of South Sudan could yield $11.5 for every dollar invested.

Control is possible

Successful FMD control has not been restricted to wealthy countries. FMD freedom with vaccination has been achieved in large parts of South America and Southern Africa and elsewhere, e.g. recently the Philippines and Turkish Thrace (OIE 2011).

By and large control is achieved through widespread vaccination and outbreak control, incorporating movement restrictions with or without culling. Having an effective state veterinary service is Key to coordinating such a zonal or national control programme. The veterinary services must be competent in several different areas, specifically, disease surveillance, outbreak control with the necessary authority and support required to enforce some level of movement restrictions, additionally they must be able to supply and deliver quality vaccines to huge numbers of animals. Support and collaboration with livestock owners is required, in some cases vaccine is even provided to the livestock owners who then vaccinate the animals themselves.

The case of Uruguay emphasises the benefits of FMD disease control, particularly if it allows export markets to open up. Upon gaining free status without vaccination in 1996 the value of exports increased by over 50%, providing an added $120 million of revenue to the country through exports to America and the Pacific rim (Otte *et al.* 2007). Saving of $8 to 9million per year were initially made via avoided vaccination costs, however, vaccination was re-introduced due to the threat of infection from neighbouring countries (Sutmoller 2003).

Unlike Uruguay, many countries are not in a position to benefit from export markets even if FMD was eradicated. In any case, lack of both veterinary infrastructure and an organised livestock sector are major barriers for FMD eradication in many countries. However, there are still very strong incentives to control the disease, they include:

1. improved food security through improved livestock productivity

2. stabilised trade; FMD disrupts trade even between non-FMD free countries and regions

3. focussed efforts to control FMD would incorporate improving state veterinary services. A veterinary service that could control FMD would be competent to control many other livestock diseases such as. Peste des Petits Ruminants, Contagious Bovine PleuroPneumonia and Brucellosis that are often controlled by the same measures, such as movement restrictions, vaccination and outbreak control

4. countries that can export struggle to control FMD adequately without similar control in neighbouring countries. These neighbouring countries may have fewer incentives for control even though the region at large benefits. FMD control can be both an externality, with benefits not captured by the market, and a regional or global public good, as the reduction in risk of FMD is also experienced by countries other than ones controlling the disease; external funding and cooperation is therefore required.

A key issue will be to what extent will vaccination alone control FMD in very poor countries unable to implement other aspects of control? Global Rinderpest eradication was achieved under such conditions, showing that vaccine delivery is possible even in remote areas. But rinderpest was a very different disease with a heat stable vaccine where a single dose gave lifelong immunity. Any global FMD control strategy would have to address the following:

1. can refrigerated FMD vaccines be delivered two to three times a year to large numbers of animals (FMD vaccine immunity is short lived)?

2. to what extent does vaccination reduce losses in productivity and how does this increase in productivity compare to vaccination costs?

3. which species should be included for cost-effective vaccination, just cattle or sheep and pigs as well?

Regardless, with adequate veterinary services the available methods for controlling FMD have repeatedly proven effective even in extensive mixed species production systems.

Cost benefit analyses studies of foot and mouth disease control and eradication

The literature was searched for all the cost benefit analysis studies that have been carried out around the world. There has been no study carried out for a global strategy for FMD control and eradication, but just over 30 country and region studies have been published in the peer reviewed and grey literature. A large number of these are ex post evaluations after large outbreaks in previously free countries. Countries that are free and have concerns of getting disease have also carried out a number of studies based on simulations of disease, control response and impacts on the economy. Finally there are set of studies looking at the analysis of the control of FMD in countries have the disease and are looking at investment for control. The major findings from all these evaluations are:

– control programmes in countries previously free generate positive returns to the economy

– countries free from FMD that suffer an outbreak lose between 0.6% to 0.3% of their GDP

– in countries with international trade in livestock and livestock products the control of FMD has good economic returns

– in countries with limited or no international trade in livestock and livestock products a positive return on FMD control requires targeted programmes

There has been very limited work carried out on the economic analysis of farm-level control of FMD, an important consideration in the success of disease control. Ellis and James (1976) and Bulman and Terrazas (1976) both indicate high impact of FMD and positive returns to its control for dairy systems in India and

Bolivia, respectively. Rushton *et al.* (2002) indicate that FMD in the UK would have high impact in dairy and pig systems, but limited or no impact on sheep and beef systems. For Bolivia a study indicated that there was no positive return to farm-level control of FMD with preventive vaccination (Rushton, 2008).

Table XI: Cost benefit analyses studies of foot and mouth disease control and eradication programmes

Country/region	Export potential	Returns to control	Type of analysis	Author
Australia	Large	A six month outbreak would reduce GDP by 0.6%	Simulation	Garner *et al.* (2002)
Australia	Large	Overall losses to the national economy of $2-3billion or $8-13billion can be expected depending on outbreak length. Emergency ring vaccination may be appropriate	Simulation	Productivity commission, (2002)
Bhutan	Nil	Negative if the control is unfocussed. Positive if the control is focused on endemic areas	Data analysis	Pasang (1995)
Bolivia	Small	Negative, but the analysis was based on a prolonged programme and also on reliable data	Data analysis	FAO (1995)
Bolivia	Small	Positive, but with an short intensive vaccination campaign in the endemic areas	Data analysis	PANAFTOSA (1997)
Bolivia	Small	Positive, but control of FMD is not economic for extensive systems, hence, greater public funding is required	Data analysis	Rushton (2008)
Botswana	Large	Positive with exports, negative without exports	Data analysis	Oarabile (1994)
Canada	Large	Even a small outbreak could cost $2billion over 5 years	Simulation	Krystynak & Charlebois (1987)
France	Large	Rapidly regaining export market access is key, this is best achieved by stamping out	Simulation	Mahul & Durand, (2000)
Great Britain	At the time of the analysis small	Positive for both a stamping out policy and for vaccination	Data analysis	Power and Harris (1973)
India	Small	Positive due to the large returns in the milk sector	Data analysis	Ellis and James (1976)
Netherlands	Large	Culling is preferable in areas of low livestock density, vaccination is preferable areas of high density. Market acceptance of products from FMD vaccinated animals reduces the impact of an outbreak	Simulation	Backer *et al.* (2009)
Netherlands	Large	The 2001 FMD outbreak cost the nation €1billion	Data analysis	Huirne *et al.* (2002)
New Zealand	Large	An outbreak could cost $NZ10billion, with eradication by slaughter being preferable to vaccinate to live	Simulation	Belton (2004)
Philippines	Unknown	Positive, particularly benefiting the commercial pig sector	Data analysis	Randolph *et al.* (2002)
Sudan	Nil	Positive with increased food security	Data analysis	Barasa *et al.* (2008)
Southern Cone	Large	Positive for both culling and vaccination strategies, does not deal with social impacts and feasibility of implementation	Data analysis and simulation	Rich & Winter-Nelson, 2007)
Taiwan	Large in terms of exports of pig products to Japan	Returns according to the information on eradication are large with costs of eradicating 1997 outbreak estimated to be US$ 378.9 million, but with potential export losses of approximately US$ 1.2 billion	Data analysis	Yang *et al.* (1999)
Taiwan	Large	Losses due to the 1997 FMD outbreak were experienced in many sectors, causing a 0.28% loss to GDP	Data analysis	Harel *et al.* (2005)

Country/region	Export potential	Returns to control	Type of analysis	Author
Thailand	Possible	Positive with or without export of livestock products	Data analysis	Perry *et al.* (1999)
Turkey	Unknown	Culling certain highly susceptible cattle could be viable	Data analysis	Senturk & Yalcin, (2008)
United Kingdom	Large	Whether vaccination or culling only depended on other factors, such as outbreak size	Simulation	Risk solutions, (2005)
United Kingdom	Large	Vaccination may not be the most effective way of controlling an outbreak, however, speed of regaining export market access is not the only consideration	Data analysis	Rushton *et al.* (2002)
United Kingdom	Large	GDP fell by less than 0.2% due to the 2001 FMD outbreak	Data analysis	Thompson *et al.* (2002)
USA	Large	Vaccination based eradication provides the best return if the vaccine is effective	Simulation	Bates *et al.* (2003)
USA, California	Large	Delayed detection of incursions causes massive losses	Simulation	Carpenter *et al.* (2011)
USA	Large	A large FMD outbreak could lead to $14billion loss in farm income, with loss of exports and fall in demand due to consumer fears the major factors	Simulation	Paarlberg *et al.* (2002)
Uruguay	Strong	Strong positive returns based on the access to important export markets	Data analysis	Leslie, *et al.* (1997)
Zimbabwe and Southern Africa	At the time of analysis strong	Positive benefit, particularly for commercial farms, less so for the poor	Data analysis	Perry *et al.* (2003) Randolph, *et al.* (2005)

Conclusion

Wealthy countries that have eradicated FMD (see Fig. 1) face ongoing costs from periodic outbreaks and the costs of being prepared to rapidly detect and deal with these outbreaks via means of movement controls, culling and/or vaccination. Many countries reduce the impact of the disease with extensive ongoing or intermittent vaccination programmes, the global scale and costs associated with these programmes is vast with an estimated 2.6 billion doses administered annually (Hamond, 2011).

The impact of FMD in endemic countries has received less attention than the impact of outbreaks in free countries, despite the huge numbers of animals affected by the disease and the importance of livestock to the economies of endemic countries. Direct losses due to death and disease are easy to appreciate, however, in endemic countries the burden of FMD often manifests as widespread and ongoing losses that limit development opportunities for developing the livestock sector.

Overall the production losses and the application of FMD vaccines around the world are causing an annual impact of US$5 billion, with additional costs on restrictions on trade and adoption of improved technologies across the livestock sector. FMD affects livestock all around the world particularly those in poor countries. In many places little is done to control FMD largely due to a lack of resources and a failure to recognise the benefits that control brings. FMD prevents agricultural development and reduces food security, in many countries it leads to massive losses due to control costs and in some cases by limiting export market access.

These estimates are considered to be of a very conservative nature as the Government of India (2002, 2006) state that Foot and Mouth Disease (FMD), the direct loss due to milk and meat is estimated at Rs. 20,000

crores per annum. Indirect losses due to reduced work capacity abortions, subsequent infertility and sterility (that account for the reduced milk production subsequently) have not been quantified (ICARs Task Force Report, 2005). For these losses in India alone, not considering any control costs, sum to US$4.8 billion.

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