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Impact of Animal Disease Outbreaks and Alternative Control Practices on Agricultural Markets and Trade

THE CASE OF FMD

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OECD

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IMPACT OF ANIMAL DISEASE OUTBREAKS AND ALTERNATIVE CONTROL PRACTICES ON AGRICULTURAL MARKETS AND TRADE - THE CASE OF FMD

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EXECUTIVE SUMMARY

1. Foot and Mouth Disease is a highly contagious disease that affects all cloven-hoofed animals. Because of its easy transfer between animals, the relevance of the disease is not restricted to the domestic market of the infected country: Exports of livestock products are likely to be faced with trade restrictions, as importing countries try to minimize the risk of importing the virus. When the infected country is an important exporter of livestock products, these trade restrictions will have notable repercussions on domestic and international markets.

2. A review of the international regulatory framework reveals that an important factor determining the extent of trade restrictions and the concomitant market disturbance is the control strategy chosen to fight the disease. Trade costs, that have been found to be an important cost item in this context, are directly linked to the control strategy chosen: A stamping-out strategy minimizes the waiting period internationally required to regain disease free status. The waiting period can be twice as long under certain vaccination strategies.

3. Historic evidence suggests that stamping-out has been the control strategy predominantly followed by OECD member countries. It also shows that in practice it took countries longer than the official waiting period before disease free status was regained. This lag can be attributed to administrative and bureaucratic procedures that are required for recovery of disease free status.

4. Hypothetical case studies were carried out to assess the *costs related to the trade ban* for the US, Canada and the Netherlands. Four scenarios have been defined for each country. These scenarios are a stamping-out strategy, a stamping-out strategy in combination with regionalization, a vaccination-to-live strategy and a vaccination-to-live strategy combined with regionalization. They differ basically in the duration of the trade restriction and the region affected by the latter.

5. The main findings of the scenario analysis are the following:

- A control strategy that minimizes the time that must elapse before a country can resume its exports will also minimize the cost of the trade ban on the domestic and the international market. For example, the global loss of welfare is reduced by roughly 25% if Canada fights an FMD outbreak by stamping-out instead of a vaccination-to-live strategy.

- Regionalization reduces the opportunity costs related to trade restrictions. The smaller the region, the more cost savings can be realized. Estimates suggest that the cost of implementing regionalization is well below the gains that can be made through this effort. Taking the example of Canada, the avoided economic losses through regionalization are more than three times higher than the costs implied.

- The extent of the market disturbance does not only vary between control strategies. Comparison across countries reveals that the same control strategy may have a very different impact depending on the market structure of the affected country. The results indicate that over 50% of revenue generated in the pork sector is lost under a stamping-out scenario if the hypothetical

outbreak is in Canada or in the Netherlands. The loss of revenue amounts to only 16% under the same control strategy if the outbreak is assumed to be in the US.

- While the infected country always experiences economic losses, at international level there are losers as well as winners. While countries that depend on imports from the international markets loose due to reduced international supply and higher prices, meat exporting countries can benefit from trade embargos erected against their competitors.

6. Two modelling systems were employed in the analysis, the Aglink-Cosimo model and the GTAP modelling system. Aglink-Cosimo is well adapted for the analysis of the impact on narrowly defined agricultural commodities, and allows the observation of market developments over time. GTAP on the other hand permits bilateral trade analysis as well as an assessment of welfare changes implied. None of the two modelling systems allow for endogenous modelling of epidemiological aspects of FMD, making assumptions on these issues inevitable. However, the combination of the two approaches allows for putting numbers on a broad range of economic indicators.

Introduction

7. Foot and Mouth Disease (FMD) is one of the most contagious animal diseases. It affects all cloven hoofed animals, and has been repeatedly occurring in OECD and non-OECD countries. It causes high mortality in young animals, and decreases the performance of adult animals. FMD is one out of only four animal diseases that is examined by a specific commission of the International Animal Health Organisation (OIE). Despite considerable investment of resources and effort by countries to prevent outbreaks, FMD is a recurring phenomenon in many parts of the world.

8. Because of the easy transfer between animals, FMD is of high importance not only to the domestic market, but also to international agricultural trade. Infected countries are often confronted with rigorous measures implemented by their trading partners: To minimize the risk of introducing the disease into their domestic herds, livestock product importing countries usually react with imposing trade restrictions such as import bans on any country experiencing an outbreak of the disease. These measures are backed up by the international regulations and procedures for control and eradication set by the International Animal Health Organisation (OIE).

9. There are several ways of fighting an FMD epidemic. One consists of culling infected and suspect animals in and around the confirmed outbreak, which is often referred to as stamping-out. This approach has been increasingly questioned by the broad public, as alternatives to mass slaughter are at hand: Another option is the slaughter of infected animals and the vaccination of animals in a zone surrounding an outbreak, provided there is sufficient and effective vaccine available.

10. In the past, stamping-out has been the standard approach in most OECD countries. This can be explained by the economic consequences of a vaccination policy, unless all vaccinated animals are killed and destroyed: To declare a country or zone FMD free, international guidelines require a waiting period of three month after the last outbreak has occurred if only stamping-out is implemented. This waiting period is prolonged to six month if animals are vaccinated and *not* killed and destroyed (vaccination-to-live). During the waiting period, the exporting country is likely to be faced with restrictions on its exports.

11. The different control strategies imply different costs, both to the national and the international markets. The latter aspect is rarely taken into account, and the present paper aims to shed light also on these more international market aspects of FMD outbreaks and different control practices.

12. The first part of the study is intended to provide an overview of policy options, the history of FMD and sketches the economic effects out in a qualitative manner.

13. This part of rather descriptive nature starts off with providing information on the regulatory framework related to FMD. The different options for policy interventions and the consequences on the disease status of the country are outlined, and definitions of some technical terms needed for the understanding of the study are given.

14. After the different policy options and their possible consequences for trade relations have been described, an historic overview of FMD outbreaks in OECD and some selected non-OECD countries is given. This will among others provide information on the duration and the extent of the epidemics in the respective countries. It will provide information on which of the possible control strategies have actually been chosen by the different countries.

15. In the second part of the study, an attempt is made to quantify the impact that alternative control strategies may have on agricultural markets and trade. The paper takes two perspectives at this issue: One is from an infected country perspective, where the losses to domestic producers are in the focus of interest. The other is from a global perspective, where the impact of the temporary trade ban on international trade

patterns and the impact on net importing countries is analysed. This analysis is limited to the impact of trade restrictions and the consequential adjustment processes. Given the coverage of the available modelling systems and background information available, this analysis does not take into account the epidemiological evolution of the disease and how this may be influenced by the control strategy chosen. For the same reasons, losses of production through the disease itself or through the control measures chosen have been abstracted from. This seems defendable as historic evidence and simulation exercises indicate the limited importance of production losses at national level in most cases (Paarlberg *et al.* 2008).

16. Though the cost related to the trade have been said to be the most relevant ones (see for example (Abdalla *et al*. 2005); (Dijkhuizen, Huirne and Jalvingh 1995)), an overview of direct control costs drawn from the literature is given in Annex A.

Foot and Mouth Disease: Options for policy intervention, history and the economic framework

Options for policy interventions: some background information

17. The purpose of this section is to describe the options for policy interventions in response to an FMD outbreak, and within the international regulatory framework related to animal diseases, the implications of this choice for international trade.

18. In case of an outbreak of FMD, a variety of measures is usually taken by regional or national authorities in order to control the disease. These often include movement restrictions, as well as testing and surveillance of animals in the proximity of the outbreak. As FMD is a highly contagious disease, these aforementioned measures are often deemed to be insufficient. They are then complemented by stamping-out, vaccination and slaughter, or combinations of these measures.

- **Vaccination:** Vaccination means the successful immunisation of animals through the application of a vaccine (OIE 2007). Here, the term *emergency vaccination* will be used when vaccines are applied in immediate response to an outbreak in order to protect high-risk animals from being infected.[1] The term *routine vaccination* shall be related to preventive, on-going vaccination programmes that are carried out on a regular basis.

- **Stamping-out or culling:** Stamping-out[2] means the killing of all infected and potentially contaminated vaccinated or unvaccinated animals. The carcasses are not introduced into the food chain, but disposed of by incineration, burying etc. The premises in which the animals were kept are cleaned and disinfected. *Modified stamping-out* means any incomplete implementation of stamping out (OIE 2007).

- **Slaughter:** Slaughter shall here be related to the killing of animals for disease control purposes. As opposed to stamping-out, there are no further restrictions on the handling of the carcass or of the slaughter products.

19. The implementation of th*ese measures can have* significant impacts on international trade relations of the infected country, and can be controversial in certain circumstances. An introduction into the discussion of whether or not to vaccinate is given in Box 1.

1 Ring vaccination is a sub-category of emergency vaccination, where animals within a certain radius around the outbreak are immunized through vaccines.

2 The term "culling" will here be used synonymously to stamping-out.

Box 1. The dilemma of vaccination against FMD

An animal that is vaccinated against FMD is considered to be protected from an infection with the same strain against which it has been vaccinated. While vaccination is an effective tool to protect an animal population, it cannot guarantee that all vaccinated animals could not be infected. Some countries that have a high risk of FMD outbreaks have therefore chosen to vaccinate large parts of their herd as a preventive measure. Other countries do not vaccinate on a routine basis, but rather as an emergency measure in case of an outbreak.

Advantages of emergency vaccination are seen in slowing down or even stopping the spread of the disease without having to kill large numbers of animals. This can especially be of interest when rare and geographically concentrated breed populations are among the suspicious animals (FAO 2007).

The main argument put forward against both types of vaccination is its impact on the animal health status of the infected country. This can have pronounced repercussions on the countries' external trade, because importing countries usually react with trade bans to an infection. Other disadvantages of vaccination are seen in the cost of vaccination. Moreover, restrictions on the handling of meat from vaccinated animals can drive the economic value of immunised animals down significantly. Non-economic reasons include the fact that vaccinated animals are hard to distinguish from infected ones through laboratory tests in case of an epidemic.

Not in the least, vaccination is not always effective. Even in countries that attempt to vaccinate large parts of their animal population against FMD, outbreaks of the same disease occur. This can be due to the use of vaccines of insufficient quality (*e.g.* not containing enough antigen or not the antigen matching the field strain) or inappropriate handling and application of the vaccine. As in all cases of vaccination, it could also be due to inability of individual animals to acquire sufficient immunity to protect against an infection.

Vaccination is often discussed as an alternative to stamping-out. However, these two control measures are not necessarily mutually exclusive. In case of an outbreak, some animals might be culled, while others can be vaccinated. Routine vaccination does not exclude the use of emergency vaccination. If the routine vaccination was not effective, an outbreak may nevertheless occur and governments may additionally carry out emergency vaccination.

20. As mentioned before, the occurrence of FMD and the actions taken by the veterinarian authorities impact on the animal health status of the affected country. As this is highly relevant to international trade, the complex relations between the status of the country prior to the outbreak, the control measures taken and the waiting period before the status can be recuperated will be discussed in detail later in this paper. For a better understanding, an introduction into the principles of zoning is necessary.

The principle of zoning

21. With zoning[3], countries can define a subpopulation with a different animal health status inside the national boundaries for international trade or disease control purposes. Zoning is the separation of an animal sub-population with a distinct health status, primarily on the basis of geographical criteria, for example defining a FMD free zone within an infected country (OIE 2007).[4] But it could also mean to establish a zone that if free *without* vaccination within a country that is free *with* vaccination. Zoning was introduced in 1993, and has been widely applied by countries affected by FMD and allowed them to maintain exports while being infected with FMD in some parts of the country. A schematic overview of the principle of zoning is given in Figure 1.

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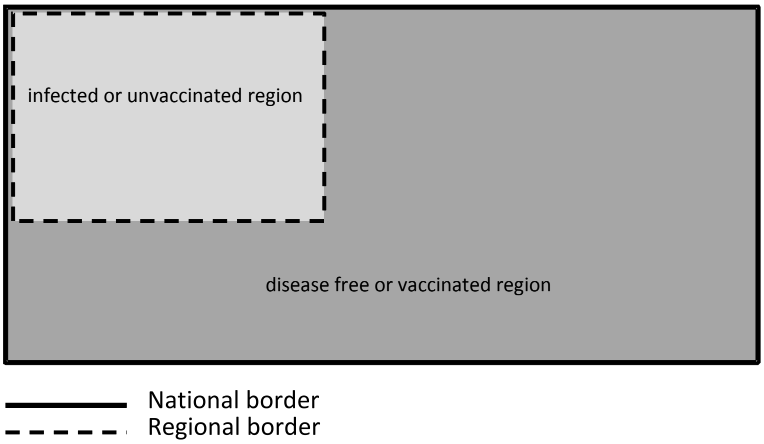
3 Zoning is also often referred to as regionalisation.

4 "Zone/region means a clearly defined part of a country containing an animal subpopulation with a distinct health status with respect to a specific disease for which required surveillance, control and biosecurity measures have been applied for the purpose of international trade"(OIE 2007).

Figure 1. Zoning



22. The OIE sets the guidelines on how to implement zoning[5] and officially recognises the free zones, with or without vaccination. Through the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS agreement) (World Trade Organization), there is a treaty level obligation to consider regionalisation through Article 6 of the agreement. At the same time, Article 3.3 of the SPS agreement indicates that WTO members may not follow the OIE recommendations if doing so can be justified by achieving a higher level of protection. In other words, the final decision whether or not to accept the proposed zone is on the side of the trading partners of the infected country. Past experience has shown that zoning has not always been accepted by trading partners.

23. The establishment of a *containment zone* is a particular application of the concept of zoning. A containment zone is established as a rapid response to an FMD outbreak and is also governed by OIE regulations. The recognition of the containment zone is conditional on a number of criteria, for example the infected country has to provide evidence that the outbreak is limited, a stamping-out policy has to be applied, and no new cases of FMD have been found within 28 days (OIE 2008).

24. Once the containment zone has been recognised by the OIE, the suspension of the free status in remainder of the previously free country of zone can be lifted irrespective of the waiting periods outlined below (OIE 2008).

25. The concept of the containment zone has been included into the OIE regulatory framework only in 2007, but it has been applied and recognized during the 2007 epidemic in the UK already. If the containment zone can be kept sufficiently small and is accepted by trading partners, the impact of the FMD outbreak on international trade can be expected to be negligible. For this reason, this concept is not further considered in this study.

Animal health status and domestic control measures

26. The OIE is the institution that classifies countries according to their animal health status. Principally, in the case of FMD, three different classifications are distinguished: FMD free country/zone where vaccination is *not* practised, FMD free country/zone where vaccination *is* practised, and FMD

5 The OIE outlines the steps on which the trading partners' decisions should be based. They include an evaluation of the infected countries veterinary service, a risk assessment and its own animal health situation among others (OIE 2007).

infected country or zone (OIE 2007). The criteria for countries and zones are similar but not identical, and shall briefly be described in the following Box 2.

Box 2. Classification of countries and zones according to OIE Terrestrial Animal Health Code

I. FMD free country where vaccination is *not* practiced

In order to qualify for inclusion in the list of FMD free countries where vaccination is *not* practised, a country must comply with a number of requirements related to disease reporting, surveillance and administration. Additionally, it has to declare that

a) no FMD outbreak or evidence of FMD virus (FMDV) infection has occurred during the last 12 months;

b) no vaccination against FMD has been carried out during the last 12 months;

c) it has not imported (*introduced* for a zone) since the cessation of vaccination any animals vaccinated against FMD.

(Article 2.2.10.2)

An **FMD free *zone* where vaccination is *not* practiced** must additionally prove the separation of the subpopulation through geographical or physical barriers or a buffer zone, and provide a description of a system preventing the virus to enter into the free zone (Article 2.2.10.4).

II. FMD free country where vaccination *is* practiced

To be included in the list of FMD free countries where vaccination *is* practised, a country must provide records of animal disease reporting, surveillance of FMD and FMDV according to OIE standards and in addition send a declaration to the OIE stating that

a) no outbreak of FMD has occurred for the past two years and no circulation of FMDV was observed during the last 12 months;

b) routine vaccination is carried out for the prevention of FMD

c) the vaccine used complies with the OIE standards

(Article 2.2.10.3)

An **FMD free *zone* where vaccination *is* practiced** must provide evidence of either geographical or physical separation of the subpopulation to be recognized as free of FMD, or establish a buffer zone. It must prove that a system to prevent the virus from entering the zone has been implemented (Article 2.2.10.5).

III. FMD infected country or zone

The countries and zones that do not fulfil the criteria to qualify either as FMD free country where vaccination is not practised or FMD free country where vaccination is practised, are classified as FMD infected country or zones.

(Article 2.2.10.6)

(OIE 2007)

Recovery of FMD free status

27. After an infection, a waiting period is required before the country can be recognized of being free from FMD. The time that must pass before it can regain the status for FMD free with or without

vaccination depends on two aspects: 1) The status the country had prior to the FMD outbreak or FMDV infection; 2) The control measures taken to fight the disease.

28. Table 1 summarizes the combinations of the status the country or zone wishes to recover, the control measures taken and the length of the waiting period.

Table 1. Waiting periods

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="5">Status to be recovered</th></tr>
<tr><th colspan="3">Country or zone where vaccination is not practised</th><th colspan="2">Country or zone where vaccination is practised</th></tr>
<tr><th rowspan="4">Control measures</th><th></th><th>No emergency vaccination</th><th colspan="2">Emergency vaccination</th><th>Emergency vaccination</th><th>No emergency vaccination</th></tr>
<tr><th rowspan="2">stamping out + serological surveillance</th><td rowspan="2">3 months
after the last case
(Article 2.2.10.8. 1 a)</td><td>Slaughter of all vaccinated animals</td><td>No slaughter of all vaccinated animals</td><td rowspan="2">6 months
after last case**
(Article 2.2.10.8. 2 a)</td><td rowspan="3">24 months
after the last outbreak, 12 months after the last FMDV circulation
(Article 2.2.10.3.)</td></tr>
<tr><td>3 months
after slaughter of all vaccinated animals
(Article 2.2.10.8.1 b)</td><td>6 months
after the (later of) the last case or last vaccination*
(Article 2.2.10.8.1 c)</td></tr>
<tr><th>no stamping out + serological surveillance</th><td colspan="3">12 months
after last outbreak, last FMDV infection and last vaccination
(Article 2.2.10.2. for country or article 2.2.10.4. for zone)</td><td>18 months
after last case**
(Article 2.2.10.8. 2 b)</td></tr>
<tr><td colspan="7">* if FMDV is proven to be absent in the remaining vaccinated population
** if FMDV circulation is proven to be absent</td></tr>
</table>

Source:(OIE 2007).

29. Table 1 shows that the following waiting periods apply for countries/zones that wish to recover the status of FMD free *without* vaccination.[6]

1. **Three months** after the last case if a stamping-out policy is applied and *no* emergency vaccination is carried out.

2. **Three months** after slaughter of the last vaccinated animal if stamping-out is applied, but additionally animals *are vaccinated* as an emergency response and all vaccinated animals are subsequently killed. This procedure is also known as suppressive vaccination or vaccination-to-die strategy.

3. **Six months** after the later of the last case or the last vaccination, if stamping-out is carried out, and complemented with emergency vaccination *without* killing of the vaccinated animals. This is also known as a vaccination-to-live strategy.[7]

4. **Twelve months** after the last outbreak for a country or zone that does *not* react to an outbreak with a stamping-out strategy. Independent on whether emergency vaccination is applied or not, this waiting period is required for whatever country or zone that wants to achieve (not necessarily *recover*) the status of FMD free without vaccination.

6 Given that serological surveillance according to OIE standards is applied.

7 If this is the control strategy chosen, the absence of FMDV has to be proven in the remaining vaccinated population.

30. The following waiting periods are relevant for countries/zones that wish to recover the status of a FMD free country or zone where (routine) vaccination *is practiced*:

1. **Six months** after the last case if an outbreak is followed by stamping-out and emergency vaccination.[8]

2. **18 months** after the last case if no stamping-out is carried out, but emergency vaccination is applied.[9]

3. **24 months** after the last outbreak and 12 months after the last FMDV circulation if no emergency vaccination is applied, with stamping-out or without. The waiting period is the same as for any country that wants to receive the status of FMD free with vaccination.

31. This overview reveals that the waiting period for recovery of free status is shortest when a pure stamping-out strategy is followed, which is an important reason for choosing this option. However, the waiting period after a vaccination-to-die strategy is only slightly longer, as its counting starts after killing of the vaccinated animals, not after the last case. How much the actual difference is in reality depends on the available infrastructure for killing of the vaccinated animals. A vaccination-to-live strategy ranges in between those two options and the option of doing nothing. From a trade perspective it might not seem the most attractive one, but it might find larger acceptance in the public than the other two options with shorter waiting periods.

32. The abovementioned waiting periods must be understood as minimum *official* waiting periods[10]. The infected country has to prepare a dossier showing the measures taken and the results of the surveillance activities. This dossier has to be evaluated and approved in different commissions within the OIE. These administrational procedures may extend the period before the country is officially recognised as free of the disease.

33. As mentioned before, if the infected country establishes a containment zone, the area outside of the containment zone can return to its previous status 28 days after the last case.

Report of recent FMD outbreaks in selected countries

34. This section will provide the reader with an historic overview of recent FMD outbreaks and the control measures actually applied in OECD countries. Where available, the analysis includes the starting and end date of the epidemic in terms of the first and the last outbreak, the source of infection, the number of outbreaks and information on the control measures taken. If possible the date of regaining the status held previous to the outbreak and the waiting period after the last outbreak is indicated. As the availability of information is not the same across countries, the country sections necessarily vary in structure and content.

35. The information in this section has been compiled mainly based on official reports to the OIE (Immediate Notification and Follow-up reports; several editions of the World Animal Health Report), that can partially be accessed through the internet and has in some cases been complemented by information obtained from national governments, national veterinary services or OIE staff. Only if other sources other than these were used they will be explicitly mentioned in the text.

8 FMDV circulation must be proven to be absent.

9 FMDV circulation must be proven to be absent.

10 . Outside the international legal framework, trading partners are naturally free to resume trade prior to official disease free declaration of the exporting countries.

36. Some confusion may arise from the definition of an outbreak according to the OIE. An outbreak is defined as "*the occurrence of one or more cases of disease or infection in an epidemiological unit*[11]"(OIE 2007). This implies that in countries where animals are kept on common grounds, an outbreak may not be related to a single farm only. The herd of an entire village can be regarded as one epidemiological unit and therefore as infected. For the years prior to 2004, i.e. for most of the outbreaks in OECD countries, it is not reported whether an infected farm or a different epidemiological unit is counted as one outbreak. Reports from years after 2004 indicate that at least in some cases in Turkey an outbreak might be counted not as having occurred on a single farm, but as having affected the herd of an entire village.

37. Another uncertainty in this context is the purpose of zoning. As mentioned, zoning can be applied both for disease control purposes of for international trade purposes. The reporting does not distinguish between these two ends of zoning, thus no distinction can be made here either.

38. Three non-member economies, Argentina, Brazil and Uruguay have been included into the analysis because of their significant role in international meat trade, but for a more limited number of years.

39. An overview of the occurrence of FMD in OECD countries and selected non-member economies is given in Table 2. While both Japan and Korea where affected in 2000 and Korea again in 2002, a large FMD epidemic occurred in Europe in 2001. Turkey is a country where FMD is endemic. In Latin America, the disease is prevalent in Brazil and Argentina, with Uruguay having been able to protect its livestock more efficiently.

Table 2. Occurrence of FMD in OECD countries and selected non-member economies

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Occurrence previous to 1996
FRANCE						■						1981
GREECE	■				■							1995
IRELAND						■						1941
JAPAN					■							1908
KOREA					■		■					1934
NETHERLANDS						■						1984
TURKEY	■	■	■	■	■	■	■	■	■	■	■	1995
UNITED KINGDOM						■						1981
ARGENTINA					■	■	■	■			■	1994
BRAZIL	■	■	■	■	■	■			■	■		n.a.
URUGUAY					■	■						1990

Source: (OIE), (OIE), OIE World Animal Health Reports.

40. In the following section, historic FMD events in the individual countries are discussed. The description starts with the FMD epidemic in Europe in 2001, and the country sections are arranged according to the date of the first outbreak. Other epidemics in European OECD countries are presented thereafter. Subsequently, the outbreaks in two Asian OECD member countries, Japan and Korea, are described. This section concludes with the three aforementioned South American countries.

41. A more detailed tabular overview can be found at the end of this section in Table 3.

11 "Epidemiological unit means a group of animals with a defined epidemiological relationship that share approximately the same likelihood of exposure to a pathogen. This may be because they share a common environment (e.g. animals in a pen), or because of common management practices […]" (OIE 2007).

FMD in OECD countries

FMD in the United Kingdom

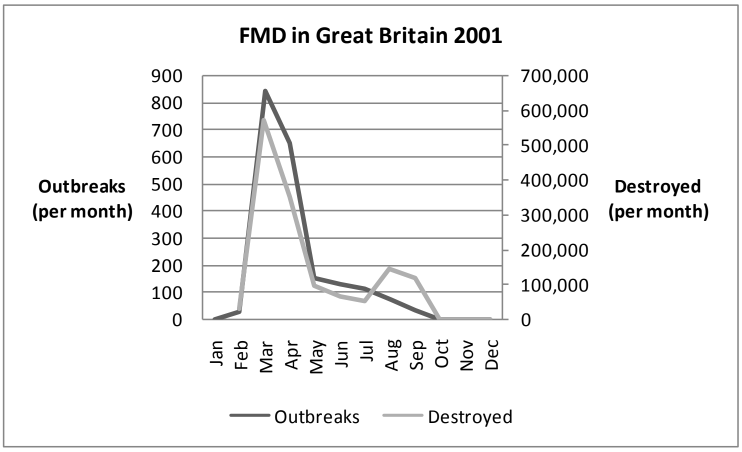
42. The latest epidemic occurred in the United Kingdom in August 2007 in Surrey, where beef cattle were confirmed to be infected on 3 August. A second farm was found be infected three days later. Stamping-out of a total of 183 animals was carried out on the two farms. No further outbreaks were detected. Vaccination was permitted, but it was not applied. Investigations revealed that the virus had escaped from a laboratory. The issue was declared as resolved on 1 January 2008. The U.K. regained its status as a country officially free from FMD without vaccination on 19 February 2008, roughly 6.5 months after the first outbreak. As both outbreaks occurred directly after each other, this corresponds closely to the period between the last outbreak and regaining disease free status (DEFRA 2008).

43. A large epidemic occurred in the UK in 2001, both Great Britain and Northern Ireland were infected. The previous outbreak prior to this one was in 1981, and the United Kingdom was considered free of FMD without vaccination. In February 2001, the first case was confirmed in pigs in an abattoir in the county of Essex. The pigs where traced back to a holding in North-East England, where sheep in a neighbouring holding had already been infected by airborne spread. These sheep where moved through animal markets in Northumberland and Cumbria, carrying the disease to Northern Ireland and other parts of Great Britain. The source of infection of the pigs was not notified to the OIE, but there was some evidence that the pigs where infected by contaminated feed (Scudamore, Harris).

44. The veterinary authorities in Great Britain reacted with movement restrictions and stamping-out. Any kind of vaccination was, as in the entire EU, prohibited. For the stamping-out, all FMD susceptible livestock on affected holdings and on those judged to be at risk of disease where killed. The carcasses where consequently disposed of by burial, burning or rendering.

45. An overview of the development of the number of outbreaks and the animals destroyed is given in Figure 2, where the number of outbreaks and the number of animals destroyed[12] are depicted. Beginning in February, the epidemic reached its peak in March, before the number of new outbreaks per months started to decrease.

Figure 2. FMD in Great Britain, 2001



Source: Author's representation based on OIE World Animal Health Reports

12 The number of animals destroyed includes cattle, sheep, goats and swine.

46. Between 20 February and 30 September, when the last outbreak of this epidemic was confirmed, a total of 2 030 outbreaks where registered in Great Britain. In total, over 4.1 million animals were destroyed. The principle of zoning was applied. Great Britain achieved FMD free status in January 2002, three and half month after the last outbreak. From the first confirmed case to the recovery of free status, about eleven months passed.

47. In Northern Ireland, the epidemic did not reach the same scale as in Great Britain. The first outbreak was confirmed among sheep on 1 March 2001 in the county of Armagh. Animals imported from England were identified as the source of infection. The number of outbreaks in Northern Ireland remained limited to four, two in sheep and two in cattle. The last outbreak was notified to the OIE to have been on 22 April 2001. A total of over 4 300 sheep and nearly 42 000 head of cattle were destroyed. The reactions to the outbreak were the same as in Great Britain, and zoning was applied too. Almost ten months after the last outbreak[13], Northern Ireland was recognized as free of FMD in February 2002. From the first case to recovery, roughly eleven months passed.

FMD in France

48. France was another country affected during the FMD epidemic in Europe in 2001. Prior to this, it had been free of FMD for 20 years and was recognized by the OIE as free without vaccination. On 13 March 2001, six cattle presenting clinical signs of FMD were detected in a farm in the Department of Mayenne. The animals had been kept at short distance from a group of infected sheep that had been imported from Great Britain, but had been slaughtered end February 2001.

49. The infected cattle and all other animals on the farm were slaughtered immediately. Two pig farms with a total of 2 000 animals within the zone of airborne spread were preemptively culled, as were some gilts that had been sold from these farms beforehand. Movement restrictions at regional level were put in place. A second outbreak was confirmed in the department of Seine-et-Marne ten days after the first one. Infected sheep, which originated from the department of Mayenne, were suspected to be the source of infection.

50. All animals in the infected farms were culled. Additionally, investigations were carried out on animals imported from Great Britain after 15 January. These animals and all susceptible animals that had been in contact with them were euthanized. The same measures were carried out on animals originating from the Netherlands and from Ireland, as soon as outbreaks in these countries were announced.

51. In total, the measures taken led to the preemptive culling of nearly 55 000 animals in France, including approximately 47 000 sheep.

52. The principle of zoning was applied in France. The country regained its status as a country free of FMD without vaccination in September 2001, almost six months after the last outbreak. The overall period during which the country was considered as being infected was also six month.

13 The minimum waiting period if the disease is fought by stamping-out only is three months. In this case as in others to be seen later, the waiting period was longer in reality. As outlined in the previous section on recovery of FMD free status, administrational procedures can delay the process of being officially recognised as free of the disease.

FMD in Ireland

53. In Ireland, a case was suspected and later confirmed on 20 March 2001, for the first time after 60 years. The disease was detected in a group of sheep in the county of Louth. Epidemiological investigations regarding the source of infection remained inconclusive, but there was some evidence that the virus originated in Northern Ireland, as the infected farm was in a 10 km surveillance zone of the outbreak in Northern Ireland. It was suspected to have been imported through illegal animal movements.

54. The control measures taken by the Irish authorities included preemptive culling of all susceptible species on the infected holding and of several wild and domestic species within a radius of one km and of all sheep within a radius of three km. This led to a total of over 52 000 animals destroyed, of which over 51 000 were sheep. A national standstill of all movement of susceptible species was put in place, together with a ban on livestock markets.

55. The disease was confined to only one farm. Zoning was not applied. Ireland regained its status as a country free of FMD without vaccination on 19 September 2001, six months after the first and only outbreak.

FMD in the Netherlands

56. On 22 March 2001, the Dutch veterinary services reported three outbreaks of FMD in the provinces of Overijsel and Gelderland to the OIE. All three outbreaks were detected by veterinarians. The farm in Gelderland had previously imported calves from Ireland, and these had stayed at a staging point in Mayenne, France, where sheep from an outbreak in the United Kingdom had stayed before. One of the other two farms was believed to be infected by transport or personal contact, the third one was located in its proximity. All susceptible animals on the three infected farms and in a zone with a radius of 1 km were culled as a precautionary measure, and movement restrictions were put in place.

57. The disease spread further through the Netherlands. By 22 April, 27 outbreaks were confirmed. Some of them could be related to previous outbreaks, for others the source of infection could not be determined.

58. Slaughtering capacities depleted in some regions, so the Dutch authorities applied suppressive vaccination, *i.e.* vaccination followed by killing of the animals. A total of over 186 000 animals were vaccinated, and subsequently killed. A total of over 247 500 vaccinated and non-vaccinated animals were culled, of which over 120 000 were swine and over 85 000 cattle. Zoning was applied.

59. The last outbreak was confirmed on 22 April, the last vaccinated animal slaughtered on 25 May. The OIE International Committee recognized that the Netherlands regained the status of FMD free without vaccination on 19 September 2001, roughly four months after the last vaccinated animal was culled. In total, the Netherlands were considered as infected for roughly half a year.

FMD in Greece

60. Greece was not affected during the FMD epidemic in 2001. The latest FMD epidemic that Greece suffered was in 2000. The first outbreak was detected on 10 July when a farmer from the Evros Prefecture applied for a permit to move animals, which is subject to a clinical examination and serological testing. During the epidemiological survey that was carried out subsequently, another infected herd was detected. In the course of July, August and September, a total of 14 outbreaks were registered, both among sheep and beef cattle. For some herds, the way of transmission was through common grazing grounds. The source of the first infection was direct contact with infected animals at the Turkish border (Evros is

bordering with Turkey). The disease spread further to the Prefecture of Xanthi, through movement of personnel and inanimate objects.

61. In order to fight the disease, stamping-out policies were applied. This led to the destruction of nearly 1 700 cattle and 624 sheep. Vaccination was prohibited as in the entire EU. Zoning was applied. Greece regained the status of FMD free without vaccination for the first time on 30 May 2001, roughly seven months after the last outbreak, but more than ten months after the first outbreak.

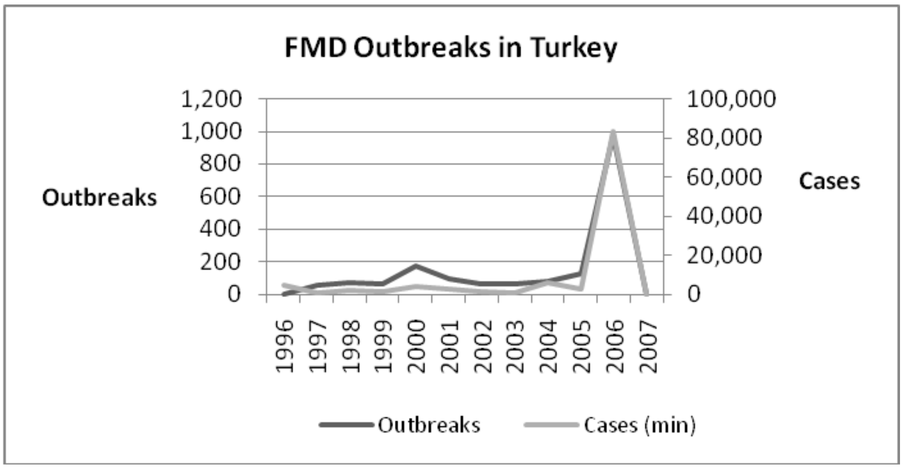
62. Prior to 2000, the previous epidemic occurred in 1996. Again, the Evros Prefecture was affected, and again the disease was believed to have been introduced from Turkey through indirect contact. The control measures taken were similar to those in 2000 and included the prohibition of vaccination and stamping-out of infected and in contact herds. Altogether, over 6 200 animals were destroyed. Zoning was not applied.

FMD in Turkey

63. Turkey is the only OECD country that at the time of writing this report was not free of FMD without vaccination. The disease is endemic in the Anatolia region. In Turkey, large parts of the cattle and sheep herd are vaccinated against FMD on a routine basis, plus in the case of an outbreak ring vaccination is applied around the foci.

64. An overview of FMD outbreaks and cases[14] in Turkey for the period between 1996 and 2007 is given in Figure 3, where both the number of outbreaks and the number of cases is plotted. It should be noted that in Turkey, an outbreak does not always relate to a farm, but might also relate to a village.

Figure 3. FMD outbreaks in Turkey



Source: Author's representation based on OIE World Animal Health Annual Reports

65. Two periods with a higher incidence of FMD can be identified. In the year 2000 there was a peak in the number of outbreaks reaching 177. An exceptional epidemic occurred in 2006, with 979 reported outbreaks. The number of cases reached 80 000 animals in 2006.

14 These figures must be understood as a lower limit of the cases, as for some years and species the number of cases is not reported.

66. The reaction of Turkish authorities to FMD outbreaks has varied over the years. The usual measures of movement controls inside the countries and screening have been applied throughout the period under consideration in this report. In this period, Turkey has always made use of preventive vaccination. In some years like in 2006 and 2005, stamping-out was carried out to a limited extent. In 2006 for example, only 18 heads of cattle and three sheep were destroyed. In most of the other years, this measure was not applied. Infected animals were slaughtered but not destroyed, *i.e.* it entered the food chain. Zoning was applied for the first time in 1999, and then in all following years.

FMD in Japan

67. Japan was free of FMD for almost one hundred years before experiencing three outbreaks in 2000. The disease was confirmed in cattle on a farm in the prefecture of Miyazaki in March 2000. The animals were culled, and movement controls on animals and animal products was carried out within a 50 km radius, complemented by surveillance. As a result of the surveillance, another farm was found to be infected, one in a distance of seven km from the primary outbreak. All animals on the two farms were stamped-out.

68. Nevertheless, a third outbreak was notified in May in the prefecture of Hokkaido. The control measures were the same as in the cases in Miyazaki, 705 heads of cattle were culled. Japan regained its status as free from FMD without vaccination in September 2000, approximately four months after the last outbreak, with a total of 740 heads of cattle stamped out. The source of infection was not identified, but epidemiological investigations showed some evidence that the virus was introduced via contaminated wheat straw imported from China. The Japanese authorities did not establish any FMD free zones within the country. Japan was officially recognized as free from FMD without vaccination in September 2000, four and a half month after the last outbreak of the epidemic. Japan had the status of an infected country for about 6 months.

FMD in Korea

69. After being free of FMD for almost 70 years, Korea experienced two outbreaks of FMD in the 21st century.

70. The latest epidemic occurred in 2002. On 4 May, two outbreaks among pigs were confirmed on two farms in the provinces of Kyonggi and Chungbuk. The virus spread to 14 other pork holdings by the end of June, ten of them were located within a nine km radius of the first two outbreaks.

71. The control measures implemented were among others stamping-out of all susceptible species in the infected farms and within a radius of 500 m and all pigs within a radius of 3 km of the primary outbreaks. This led to the destruction of over 160 000 animals. Vaccination was prohibited.

72. The virus was identified to be imported from an overseas source, the mode of spread between the farms has not been identified. Korea was recognized as an FMD free country where vaccination is not practiced at the end of November 2002, roughly four months after the last outbreak but more than six month after the *first* outbreak.

73. Another epidemic occurred in 2000, when on 20 March an outbreak on a dairy farm in Kyunggi province comprising 12 dairy cows and three calves was confirmed. Subsequently, the disease was detected on 14 other farms, 11 of them clustered in ChungNam province. All outbreaks occurred in March and April 2007.

74. The Korean veterinarian services responded with stamping-out of over 2 200 cattle in infected and adjacent farms, and the establishment of moving restrictions. Additionally, emergency vaccination of

over 660 000 cattle within the protection zones was carried out. The Korean government purchased the vaccinated animals and sent them to designated slaughterhouses. The source of infection could not be identified, but it was suspected to have been imported from infected places overseas, either through imported hay or through items carried by humans.

75. Korea regained its status of FMD free country where vaccination is not practiced in September 2001, almost one and a half years after the last outbreak, a period that closely responds to the one between the *first* outbreak and the recovery of free status. As the epidemic was of short duration, this corresponds roughly to the period between the first outbreak and the recovery of free status.

76. In both 2002 and 2000, Korea applied the principle of zoning.

FMD in non-OECD countries

77. Some South American countries range among important beef exporters. Though they are non-member economies to the OECD, some interesting insight into FMD fighting strategies can be gained from their experience. For these countries, only the years from 2000 onwards are included. Not all the aspects that were included for OECD countries could be incorporated due to limited availability of information.

Argentina

78. Argentina has experienced a series of outbreaks since the beginning of this century. Vaccination had been prohibited in Argentina in the years covered by this report until 2001. Since May 2007, Argentina is divided into two zones, a FMD free zone without vaccination in the south, and FMD free zone with vaccination in the northern part of the country.

79. The latest epidemic at the time of writing was in early February 2006; starting in the province of Corrientes, a total of two outbreaks was registered. A stamping-out policy was applied, but at the same time emergency vaccination was applied, and when the routine vaccination campaign was started, priority was given to the Corrientes province. Around 5 000 cattle and sheep were culled, and over 95 000 were ring vaccinated. The source of the primary infection remained unknown. This was the first year covered by this report that Argentina applied the principle of zoning. Prior to this outbreak, Argentina was recognised as free with vaccination.

80. In 2003, just one month after Argentina had regained its status of FMD free with vaccination, pigs on a farm in the province of Salta showed clinical signs. The outbreak was confined to one farm. Infected and in-contact animals were slaughtered, leading to 73 in total. Vaccination was concentrated around the outbreak and along the borders with Bolivia and Paraguay. The pigs were believed to be infected by contaminated offal from a slaughterhouse, in which animals irregularly introduced from neighbouring countries had been slaughtered.

81. Two more outbreaks of FMD occurred in Argentina in this century, one in January 2002, where only one farm was infected in the province of Córdoba. Both stamping-out and vaccination were practiced among other control measures, and the disease was limited to only one farm.

82. An epidemic of larger extent was experienced in 2001, with 2 394 outbreaks and an unknown number of animals culled. For the first time in years, vaccination, in this case ring vaccination, was carried out. The disease affected several provinces in Argentina, among them the large cattle producing regions of Buenos Aires and La Pampa.

Uruguay

83. The latest FMD epidemic Uruguay experienced was in 2001, when in April the existence of FMD was confirmed in the district of Palmitas on two adjoining farms. Uruguayan authorities responded with culling, movement restrictions and screening. When it became clear that the epidemic could not be controlled by stamping-out only, a comprehensive vaccination campaign was also initialized for the first time since 1990, and stamping-out was suspended by the end of April. By August 2001 when the last outbreak was notified, 2063 outbreaks were registered among cattle and sheep.

84. Slightly more than 6 900 animals were destroyed. Over 11 million animals were vaccinated. Zones free of FMD were defined. Uruguay was recognized as free of FMD with vaccination in May 2003, almost 22 months after the last outbreak.

85. Just one year earlier in October 2000, there had also been an outbreak of FMD in Uruguay. It has been limited to only one establishment in the department of Artigas, with an animal population of cattle, sheep and swine. The susceptible animals in the establishment where culled and destroyed, as where all susceptible animals in a 5 km radius, totaling over 20 000 head of livestock. Vaccination was prohibited as it was in all the years before 2001 covered by this report. Before this outbreak, Uruguay was listed as a country free of FMD without vaccination.

Brazil

86. Brazil is a country that has regularly been affected by FMD and has, despite this fact, continuously been able to expand its exports of beef meat. It has experienced outbreaks of FMD in 2005, 2004, and all the years between 1996 and 2001 inclusive. Only in 2002 and 2003, no outbreaks of FMD were notified to the OIE.

87. Since 1999, Brazil has applied the concept of zoning. Some states are recognized as zones free of FMD with vaccination, and some states even gained the status for FMD free without vaccination. At the time of drafting this report, the state of Santa Catarina was recognized as FMD free zone where vaccination is not practiced, and Acre, Rio Grande do Sul, Rondonia as well as parts of Amazon state and parts of Pará are declared as FMD free zones where vaccination is practiced (OIE 2008).

88. Throughout the period of this report, Brazilian veterinary authorities have in at least some parts of the country vaccinated against FMD, and in most of the years, stamping-out or modified stamping-out was applied.

89. However, the share of animals destroyed was never significantly high. The highest number of cattle culled was in 2005, were over 14 500 heads of cattle were destroyed[15].

90. Table 3 summarizes FMD epidemics that occurred in OECD and selected non-member economies in the past ten years, including the number of outbreaks and the policy measures applied in the following order: Number of outbreaks, Policy Measure I, Policy Measure II.

15 An unknown number of other species was destroyed.

Table 3 Number of outbreaks and control measures taken

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Occurrence previous to 1996
FRANCE						2, S-O						1981
GREECE	39, S-O				14, S-O							1995
IRELAND						1, S-O						1941
JAPAN					3, S-O							1908
KOREA					15, S-O, V		16, S-O					1934
NETHERLANDS						27, S-O, V						1984
TURKEY	n.a., V	56, V	75, V	62, M S-O, V	177, M S-O, V	93, V	61, V	64, V	81, V	65, M S-O, V	714, M S-O, V	1995
UNITED KINGDOM						2030, S-O						1981
ARGENTINA					n.a., S-O	n.a., S-O, V	1, S-O, V	1, S-O, V			2, S-O	1994
BRAZIL	7, M S-O, V	197, M S-O, V	44, M S-O, V	44, S-O, V	48, M S-O, V	38, M S-O, V			5, V	27, S-O, V		n.a.
URUGUAY					1, S-O	2063, S-O, V						1990

S-O: Stamping-out
M S-O: Modified stamping-out
V: Vaccination

Source: (OIE), (OIE), OIE World Animal Health Reports

Basic economics of FMD outbreaks and alternative control practices

91. In this section, the possible market effects of FMD outbreaks and alternative control practices will be analyzed in a qualitative manner. First, the general mechanisms at national and international level are identified, and then further analysed in a comparative-static framework. The analysis carried out here has been specifically tailored to the case of FMD, but may at least in parts be valid for other infectious animal diseases as well. It should be noted that this section addresses a broad range of effects. It will not be possible to address all of these in a quantitative manner, and the quantitative analysis that will be carried out will focus on a more limited set of issues.

92. Some other important economic effects that are not captured through the comparative-static analysis will be discussed.

93. A stylised representation of the incidence of FMD outbreaks and alternative control strategies is given in Figure 4. Generally, effects can take place on *domestic level* and on *international level*. On both levels, the outbreak and the different control strategies can *directly* affect quantities produced, consumed or traded, but *indirect* effects might also take place[16]. It should be noted that it is assumed that the agent causing the disease is not transferred from one country to the other.

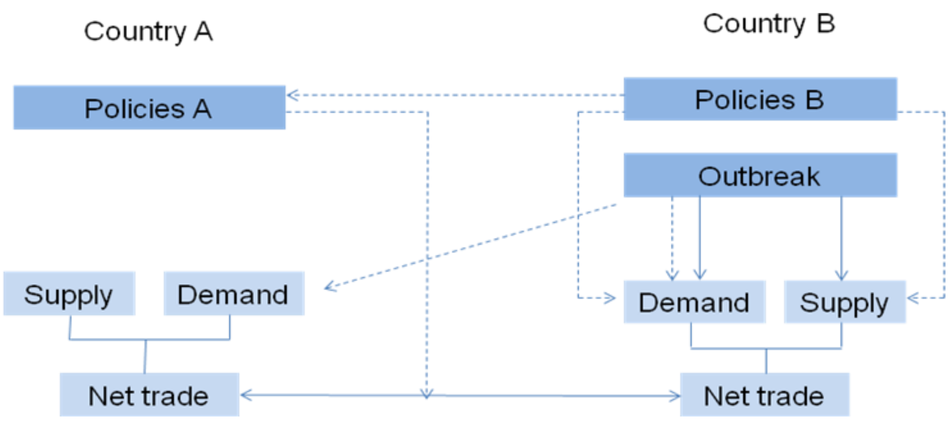
94. In the following, a situation is assumed where country A imports meat from country B and a disease outbreak occurs in the latter country.

16 In this section, a distinction between *direct* and *indirect* effects of the disease will be made. Effects caused by the virus itself, i.e. through biological action, will be called *direct effects*. All effects that are not caused by the virus itself but through non-biological reactions to its appearance will be called *indirect effects*. The impact of indirect effects is often more pronounced than the impact of direct effects.

95. On the domestic market of country B, the most directly affected variable is *supply*, either through morbidity or mortality[17]. Disease control policies applied may further affect supply indirectly, e.g. through killing and destruction of infected animals. Domestic *demand* can be directly affected too, if the animal disease in question is a zoonosis[18], affecting consumer health and reducing intake of livestock products. As it is the case for supply, the outbreak(s) might further affect demand indirectly through negative media coverage. More indirectly, demand effects can be mitigated through targeted communication policies, or by giving less ground to negative press through the control measure chosen. All effects on supply and demand will translate into the net-trade of the respective country.

96. Looking at the international level, domestic supply in the importing country A will remain unchanged, while demand can be indirectly affected through the same channels, i.e. media pictures, as in country B. But more importantly, the animal disease outbreak and the policy measures taken in the infected country will influence policy makers in country A. The measures taken by country A will have repercussions on the trade between the two countries, notably reducing imports from country B.

Figure 4



97. These general mechanisms will in the following be analysed in more detail using a comparative-static framework based on the following set of assumptions:

- The country in which the outbreak occurs is a large exporting country, shocks on the domestic market will be transmitted to the world markets. There is perfect competition on both markets, and goods are homogenous across countries.

- The outbreak is assumed to occur in region I in Figure 5 below, where the each dot represents a farm. Under a pure stamping-out policy, all animals in region I, i.e. on the farm where the outbreak occurred, are assumed to be culled. The animals in region II are seen as having a high risk of infection, and are killed and destroyed too. This situation represents the benchmark against which alternative approaches to control the disease will be analysed.

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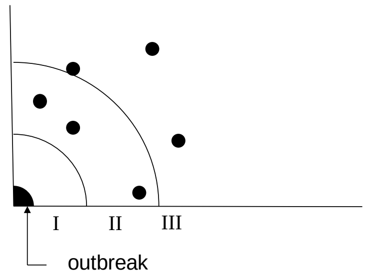
17 The term morbidity refers to losses in production that are not caused because the animals die (mortality), but because their performance decreases. This includes yield losses, losses of reproductive capacity etc. (Horst et al. 1999).

18 A zoonosis is any disease or infection which is transmissible from animals to humans (OIE 2007).

Figure 5



- It is assumed that the alternative control strategy to stamping out is a vaccination-to-*live* policy. It was chosen because the economic impact of a vaccination-to-*die* strategy can be expected to differ only marginally from a stamping-out policy as the same share of production will be taken out of the market, and the period of recovery of disease free status is almost the same as under pure stamping-out. A routine vaccination policy does not seem an attractive option for most OECD countries and was for this reason not further considered.

- Under the vaccination-to-live policy, all animals in region I will be slaughtered, but all animals in region II are assumed to be effectively vaccinated, that is, the disease is contained to region I. It is further assumed that the vaccinated animals are slaughtered at normal slaughter weight and can be introduced into the food chain.

- Movement restrictions are assumed to be implemented in regions I and II simultaneously and in direct response to the outbreak, region III is not affected by movement restrictions or by the disease.

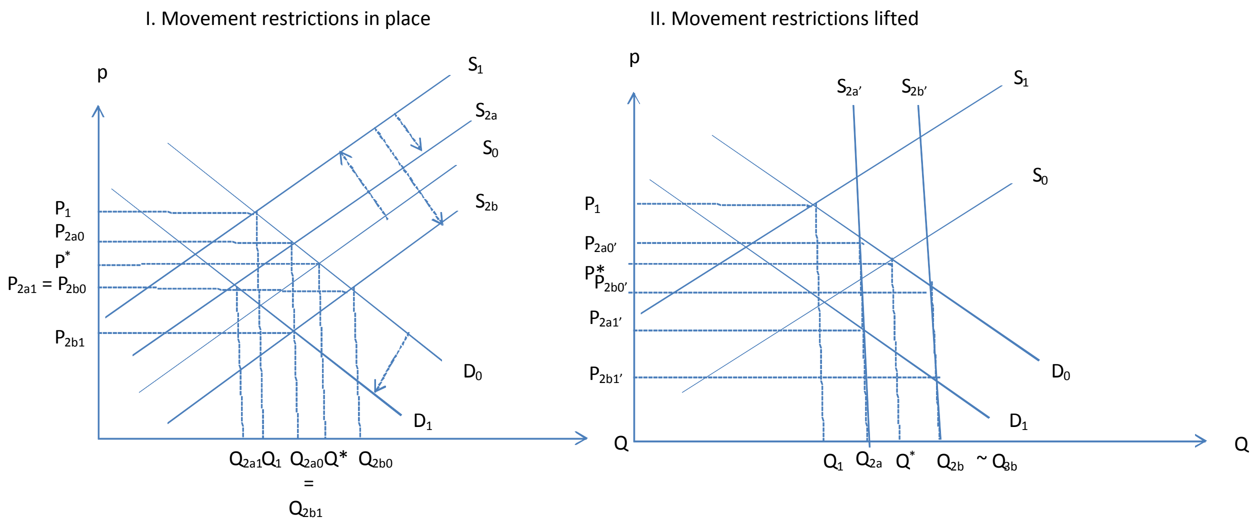
It should be kept in mind that this comparative-static analysis is restricted to one market, but FMD is a disease affecting multiple species. This means that the described effects can take place on several meat markets simultaneously. Especially trade restrictions often apply to products of all susceptible species, even if outbreaks have occurred only in one species.

Domestic supply effects

98. In first instance, an outbreak of a contagious animal disease has the potential to lead to a loss of marketable production, through stamping out, mortality and morbidity. Additionally, movement restrictions are usually put in place. These effects provoke less delivery to the slaughterhouses, which is represented in the left panel of Figure 6 as a shift of the supply curve from S_0 to S_1. In a competitive setting without any other changes in behaviour of the market participants, this would lead to an increase in prices by (P_1P^*), reaching a new (short-term) equilibrium at (Q_1, P_1). A situation of reduced supplies can persist until the issue is resolved and animal supply returns to normal.

99. It is obvious that under the assumption of a **vaccination-to-live strategy** the effect of supply shortage is reduced as not the same amounts of animals are destroyed. However, if the animals cannot be transported to the slaughter houses due to movement restrictions, the effect of a vaccination-to-live strategy is in the short run the same as the one of a stamping-out policy.

Figure 6



100. It is possible that movement restrictions are imposed only on a regional level. But despite these restrictions, and depending on the geographical distribution of the establishments, producers in regions adjoining the outbreak like region III in Figure 5, might fear the spread of the disease and consequent movement restrictions[19]. This might trigger a short-term surge in the supply of animals to slaughter houses and is depicted by a shift of the supply curve from S_1 to S_{2a}, causing a price decrease by $(P_1\text{-}P_{2a0})$. Whether this effect at national level compensates or not, or even overcompensates the initially described shock of S_0 shifting to S_1, cannot be determined a priori. The supply function might well shift to the right of the initial equilibrium, that is S_{2b}, with the respective changes in prices being $(P_1\text{-}P_{2b0})$[20].

101. Farmers rushing to slaughter their animals may meet lower willingness to pay from the side of the slaughterhouses due to non-optimal slaughter weight and carcass, reflected in a shift of the demand function from D_0 to D_1, followed by price reductions of $(P_{2a0}\text{-}P_{2b0})$ or $(P_{2b0}\text{-}P_{2b1})$ respectively

102. This short term supply increase should not be altered in their nature if the **alternative control** strategy of vaccination-to-live is applied in region II because the same supply incentives based on the fear for movement restrictions would apply.

103. The situation after movement restrictions have been lifted is depicted in the right panel of Figure 6. Supply will gradually recover its initial position. The path over time of this recovery depends on the duration of the movement restrictions, the share of animals sold early, the share of animals destroyed and the regular fattening period.

104. If the movement restriction had been imposed over a longer period of time and just a small share of animals was stamped out or marketed before reaching normal slaughter weight, many and heavier animals can be expected to arrive to the market, causing a temporary surge in supply. Again the

19 In this framework, we abstract from exceptional slaughter justified by animal welfare.

20 Of course, the supply function can also return to its initial position, but this case is not further discussed here. Additionally, the price elasticities of supply are assumed to remain unchanged for the ease of representation, despite the fact that they might become more inelastic in the short term.

slaughterhouses' willingness to pay might be reduced due to fatter animals (D_1). As farmers can hardly react to this, the supply function can be seen as totally inelastic in the short term (for example at $S_{2a'}$ and $S_{2b'}$[21]), and the demand shift will trigger pronounced price decreases, e.g. by $(P_{2a0}-P_{2a1'})$ or $(P_{2b0}-P_{2b1'})$.

105. The extent of the quality effect depends on the length of the movement restrictions, and of the regular fattening period of the species in question. Fast growing species like poultry and pigs are likely to be more affected by an extended quarantine period than cattle.

106. On the other hand, if the time of movement restrictions was relatively limited and a large share of the national herd had been either stamped out or sold early, supply might remain at levels below normal for a longer period.

107. Again, a **vaccination-to-live strategy** should not alter these effects in principle, but might dampen the total effect of loss of production through stamping out and contribute to a more pronounced short-term surge in supply after the movement restrictions are lifted. Moreover, prices for vaccinated animals might be below the prices for non-vaccinated ones.

Impacts on domestic demand

108. The analysis carried out so far ignored the impact of animal disease outbreaks on consumers' behaviour. This might not be a realistic assumption, as animal disease outbreaks are a topic of public interest, and repercussions on the behaviour of the final consumer have been observed in the past. Additionally, if the animal disease affects human health, this might also impact on their consumption levels at all prices. However, this direct impact on demand can be expected to be very limited in most cases and is not further discussed here.

109. The impact of a disease induced shift in consumer preferences can also be seen in the left hand panel of Figure 6, by interpreting the shift from D_0 to D_1 as reduced demand by consumers due to objections of consumption of the respective animal product. At any price and at any given supply curve, prices and quantities consumed are inferior to the situation without consumer's rejection of the animal product in question.[22] This consumer reaction might be mitigated by information and communication policies that counteract negative media coverage.

110. **Alternative control practices** might give less rise to negative press and might therefore facilitate stabilization of demand for the product in question.

Impacts on international markets

111. As indicated Figure 4, all changes on the domestic markets of an open economy will in some way be reflected on the world market by changes of the export supply of a net exporting country or in the import demand of a net importing country. All factors causing domestic supply and demand of a net exporting country to shift will be reflected in its excess supply. Analogously, shifts in the supply or demand of a net importing country will be reflected in its import demand.

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21 Here, the position of the inelastic supply functions $S_{2a'}$ and $S_{2b'}$ has been chosen for the convenience of a clear graphical representation. They do not necessary have to be a rotation of S_{2a} and S_{2b} around their intersection with D_0, but may also be shifted.

22 The movement of the demand curve here should not be confused with the movement of the demand curve due to quality issues it represented in the analysis of the domestic supply effects. In this case, the *intake* of the animal product is reduced at all prices, while in the former the *quality* is altered.

112. In addition to the effects caused by supply and demand changes, the international markets will be affected by trade policies implemented on both sides.

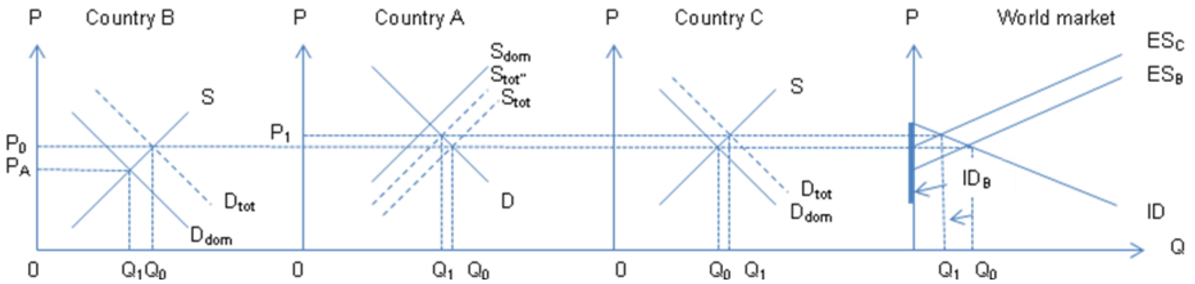
113. A three country model is depicted in Figure7. There are three countries A, B and C. In the initial situation, country B is assumed to export to country A, P_0 is the resulting world market price. Country C is in its autarky equilibrium. The world market in terms of excess supply of country B, ES_B (and later respectively for country C, ES_C) and import demand of country A is depicted on the right panel of Figure7.

114. When an outbreak of FMD occurs in country B, importing countries usually impose trade bans to one or more commodities imported from the infected region.[23] Economically, a trade ban can be interpreted as an import quota with zero quota quantity for the infected exporting country B. According to the economic theory of import quotas (see for example (Houck 1986)), this can be interpreted as a rotation of the demand for imports from country B into a totally inelastic position, as is depicted through ID_B in the right hand panel of Figure7.

115. The result of this trade ban is a reduction of supply on the world market. Country C, that at the initial equilibrium was not trading internationally, is faced with a total demand curve of D_{tot} and becomes an exporter at the new world market price P_1. Country A reduces its net-trade position. It now sources imports exclusively from country C. Total supply on A's market is reduced from S_{tot} to $S_{tot'}$, .and the market price increases from P_0 to P_1. The quantities traded on the world market decrease by (Q_0-Q_1). The new equilibrium for country B is its autarky state, with the autarky price being ad P_A.

116. Exporting countries experiencing animal disease outbreaks sometimes implement voluntary export bans. This translates into an inelastic position of the export supply at zero traded quantities, and consequently the same market reactions are brought about (not depicted).

Figure7



117. Relaxing temporarily the assumption of homogenous goods and allowing for different preferences related to the country of origin, the effects of a FMD outbreak are slightly different. Imports from the infected country B cannot be perfectly substituted by imports from country C. The equilibrium price and quantities traded after the outbreak will be inferior to the ones under the assumption of homogenous goods, if the willingness to pay for products from country C is lower than for products from country B (not depicted).

118. The impact of **alternative control strategies** on international markets can be viewed at two levels: First the impacts on supply and demand in domestic markets that are transmitted to the international markets, as was discussed earlier in this chapter. Secondly, the impact of alternative control strategies on

23 These can be applied to the entire country or to parts of it if regionalisation is applied, but this does not change the basic concept. In addition or alternative to trade bans, sanitary control measures can be imposed, but these will not be considered here.

the disease status and consequently on the policy reaction of importing countries. The period for recovering the status of FMD free without vaccination is longer when alternatives to pure stamping-out strategies are applied, prolonging the period where the infected exporting country is likely to face trade bans. It should be noted that the impact of a trade ban can be larger and more persistent than the impact of the disease itself through loss in production.

Other effects

119. The impact of animal diseases is of course not limited to the effects described in the comparative static analysis carried out above. A range of other effects might take place. Production might be further distorted in the longer term if for example the building up of a breeding herd was disrupted due to the FMD outbreak. For an exporting country it might take some time to recover the lost market shares even after it has been recognized as free from FMD. For exporting countries with a longstanding history of freedom of disease, the loss of reputation may also be a concern.

120. Spill-over effects or externalities of FMD outbreaks can be considerable. The epidemic in Great Britain is an example where in addition to the agricultural sector, rural tourism was severely affected as access to the countryside was restricted and deterred visitors from spending their holiday in the countryside. Estimates indicate that the loss to the domestic rural tourism industry amounted to a sum similar to the estimates of losses to the agriculture and the food chain (Thompson *et al.* 2002).

121. Furthermore, an FMD outbreak may imply considerable budgetary costs. Control measures are usually carried out and financed by governments. Additionally, financial assistance is often granted to farmers for the loss of income as a consequence of the epidemic. In many cases, this is done by means of a public fund that is often co-financed through the government, or other pre-agreed cost sharing mechanisms between the public and the private sector.

122. The impact of a vaccination-to-live strategy on these effects depends generally on its ability to contain the disease compared to the stamping-out strategy. In the case of the budgetary cost, the cost of vaccination must be taken into account if they are financed through the public. Estimates on the cost of emergency vaccination in OECD countries are rare. However, the cost of applying a dose of emergency vaccination has been estimated at €1 per dose and €35 per farm visit for cattle in Belgium, while the buying cost of one dose of vaccine was 32 yen in Japan 2006. In Switzerland, the cost of vaccinating one animal, including material and work of an official veterinarian, was estimated to range between CHF5 and 10[24] per dose. More detailed information for Canada, the U.S. and the Netherlands can be found in Annex A.

Quantitative assessment of FMD outbreaks and alternative control strategies

123. In this section, an attempt is made to quantify the costs arising from the trade bans related to FMD and different control strategies. Though, as described earlier in this chapter, costs will arise from national disease control measures, too, the costs related to the international trade restrictions have been found to be the most important cost items for major livestock exporting countries (see for example (Abdalla *et al.* 2005, Dijkhuizen, Huirne and Jalvingh 1995)). This especially holds true for short epidemics in countries with an important export share, where the control costs are relatively limited compared to the costs related to the trade ban that can expected to be pronounced. Moreover, any assessment of costs other than the ones related to the trade restrictions requires detailed knowledge of the

24 Using average 2006 exchange rates, this corresponds to EUR 0.22 per dose in Japan, and EUR 3.18 to EUR 6.36 in Switzerland.

characteristics of the epidemic, e.g. number of animals infected of each susceptible species and the farm structure in the infected region, information that is not available for this study. Also, the benefit of avoiding potential outbreaks through trade restrictions is not taken into account.

124. In order to limit the scope of this paper, the range of the reported results has been restricted to the main sectors affected: Though both modelling systems go far beyond these two products, the discussion is restricted to beef and pork products unless global indicators like income are analysed.

Methodology

125. To assess the overall costs of FMD outbreaks and alternative control strategies, two approaches have been taken:

- To measure the control costs, a review of the existing literature was carried out to identify and to put an estimated figure on the most important non-market cost items like the cost of carcass disposal, vaccination and desinfection. This information is presented in Annex A.

- For consideration of the impacts of the trade ban and consequential market adjustments, however, simulations involving two different modelling systems, Aglink-Cosimo and GTAP, were carried out and then combined.

Aglink-Cosimo

126. One of the two modelling systems applied for this study is the OECD-FAO Aglink-Cosimo model. The Aglink-Cosimo model is an agricultural sector model, *i.e.* it covers the agricultural sector only, but with a considerable level of product disaggregation. The model design is recursive-dynamic with annual frequency in terms of historical observations and data projections. This means that variables may be a function of their lagged annual values, and permit an analysis of market developments over time. This is of particular interest when meat and livestock markets are of interest, since herd dynamics limit the farmers' ability to respond in the short term to price signals. One major shortcoming with the use of this model is the assumption on farmers' price expectations. In the model, production is a function of current and historic prices only; no forward-looking behaviour is taken into account. This may in some cases overestimate the models reaction. Another drawback in the context of trade analysis is that Aglink-Cosimo does not represent bilateral trade flows, i.e. trade flows between countries that are differentiated by source and origin of the product traded. On the other hand, Aglink-Cosimo is built from individual country modules that approximate specific country behaviour, characteristics and relationships as opposed to a standard template model. The simulation horizon of the model reaches out to 2017. A more comprehensive description of the model characteristics can be found elsewhere (OECD 2007a).

127. The model has been adapted to the country focus that was desired for this study. The meat markets of one European country have been broken out of the EU27 aggregate. In the expanded model version, the respective country features market clearing prices for meat products that may differ from the prices in the remaining EU member countries, as well as trade flows with the remaining European member countries and the rest of the world. More information on this issue is available from the author of this study.

GTAP

128. To complement the partial equilibrium Aglink-Cosimo modelling system, a general equilibrium modelling system, the Global Trade Analysis Project (GTAP) model was also employed in the analysis to take into account the economy wide implications of a FMD outbreak and to allow for bilateral trade

analysis. The starting point is the database and model formulation of the GTAP comparative-static general equilibrium model ((Hertel , T. W. 1997); (GTAP)). The well-known GTAP model is a multi-regional model with theoretical foundations based on neo-classical micro-economic theory.

129. Key assumptions include that all sectors produce under constant returns to scale with perfect competition in both factor markets and output markets. Firms combine intermediate inputs and primary factors such as land, labour and capital. Intermediate inputs are used in fixed proportions according to given input-output structure, but are themselves composites of domestic and foreign components. In addition, the foreign component is differentiated by region of origin according to the so-called 'Armington assumption' (Armington 1969), which permits the modelling of bilateral trade flows, depending on the ease of substitution between products from different regions.

130. For the purposes of this study the standard GTAP model is modified to focus on the short run nature of FMD. In particular, the agricultural production factors capital and land are made sector specific, which implies that they cannot move out of the sector being hit by an adverse economic shock like the FMD case modelled. This is typically a short run assumption. In the long run, and *if adverse conditions would persist*, production factors would clearly move to alternative uses and activities where they could earn a higher return. The model uses the latest GTAP data version[25], which is benchmarked to 2004 and contains 110 countries or regions and 57 sectors. To maximize the focus on trade effects of animal disease outbreaks, the database has been aggregated to 21 selected regions and 16 sectors. The country and sector listing is provided in Annex B.

Model linkage

131. The aim of combining two modelling systems for this study was not only to present results of both systems to the reader. Additionally, simulation results from GTAP have been used as an input for the simulations with Aglink-Cosimo. In particular, where the model design of Aglink-Cosimo does not allow for endogenous observation of imports, the percentage changes in the respective trade flow from GTAP, adjusted for the share of the affected commodity within the GTAP composite[26], was implemented into Aglink-Cosimo in the year of the outbreak. It should be born in mind that this procedure necessarily induces some noise:

- First, the databases of Aglink-Cosimo and GTAP are not fully compatible; differences can be expected to arise from using different data sources and aggregations.

- Second, while GTAP is based on 2004 data, the simulation of the shock with Aglink-Cosimo is for 2009, implying that changes in the relative importance of individual commodities between those years are not accounted for in the GTAP results.

- Third, for the adjustment of changes in trade in the GTAP composite to individual Aglink-Cosimo commodities it was necessary to assume that trade of the other elements of the composite remain unchanged, a somewhat strong assumption.

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25 7p6 pre-release (June 2008)

26 In the GTAP database, some products are aggregated to composite goods. Live cattle and pigs as well as the respective meat products represent only a share in the composite. For example, the share of beef products in the import value of Canada of the GTAP composite "Bovine meat products" is 82%, as this aggregate also includes other red meat products, e.g. lamb meat. A list of the product aggregation as well as the shares used for adjustment can be found in the annex.

Scenario definition and implementation

132. Outbreaks of FMD are assumed to occur alternatively in three countries: Canada, the Netherlands and the United States (US). The choice of these countries was based on economic criteria: The United States and Canada are among the world's most important meat exporting countries, with one difference being that the US has a larger domestic market for meat products as compared to Canada. The case of the US will thus provide insight on FMD outbreaks and control strategies for countries with a high share on international markets, but at the same time an important domestic market. The case of Canada can be seen as an example for a country where any disease event influencing exports will impact considerably the international markets, but also the domestic markets that have limited capacity to absorb any restricted exports. The Netherlands has been chosen as an example of a European Union country, which features a highly developed livestock industry. It ranks highest among the European countries in total meat export value (EUROSTAT), but also in terms of export share over domestic production (OECD 2007b). The Netherlands' case will allow analysis of the consequences of animal disease related restrictions in an important meat exporting country in the EU, where trade takes place predominantly in the free trade area of the EU. It should be noted that an assessment of the risk of being infected with FMD has not been carried out for any of these countries or implied in their selection.

133. Two different control strategies are simulated for each of the countries. In the first set of scenarios, the disease is exclusively fought by stamping-out. In the second set of scenarios, the stamping-out of infected herds is combined with emergency vaccination, more specifically, a vaccination-to-live strategy. It is assumed that vaccinated animals can enter the food chain without any barriers [27]. Both control strategies may or may not be combined with regionalization for trade purposes.[28] Table 4 summarizes the scenarios to be simulated.

Table 4. Scenarios

COUNTRY X			
STAMPING-OUT		VACCINATION-TO-LIVE	
NO REGIONALIZATION	REGIONALIZATION	NO REGIONALIZATION	REGIONALIZATION

134. As described, the scenarios are limited to the impact trade embargo, meaning that certain amounts that would be exported under normal conditions are diverted to the domestic market, pushing prices down. No assumptions are made on losses in production as a consequence of the disease itself or veterinary intervention (e.g. through stamping-out), nor are any consumer reactions other than through the market mechanisms assumed.[29] No explicit assumptions on the availability of the vaccine or slaughter

27 This assumption is debatable. Industry concerns may be such that meat from vaccinated animals is not accepted. However, since no assumption on consumer behaviour is made here, this aspect of vaccination strategies has been abstracted from. Moreover, there may be legal provisions requiring special treatment of meat from vaccinated animals that would increase the cost of making such meat available to the consumer.

28 Regionalization or zoning means the definition of an animal subpopulation with a distinct health status for international trade purposes (OIE, 2007). In practice, this means to delimitate the infected zone from a non-infected zone.

29 . Consumers' reaction, other than the response to prices, is a highly unpredictable issue in the context of animal diseases. Consumers' concerns may be such that they react by substituting between meat products or between different geographical origin of the same meat product, or maybe by reducing overall meat

capacity are made. It is further assumed that all trading partners resume trading after the declaration of disease free status. For the countries under study, several parameters have to be defined. In particular, these are the duration of the epidemic, the duration of the waiting period, and the products affected by the trade ban. For the scenarios including regionalization, additionally the location of the outbreak and the borders along which regionalization is applied, have to be determined. Since the assumptions on these parameters are crucial to the modeling results, the choice of each of them shall be briefly discussed in the following. A summary of the parameters can be found in Annex B.

The duration of the epidemic

135. The duration of the epidemic shall here be defined as the time that passes between the first confirmed outbreak and the last case.

136. To determine the duration of a hypothetical epidemic without applying any epidemiological model is a somewhat arbitrary decision. Other studies involving the use of epidemiological models can give some insight of the range in which the duration of the epidemic may lie. However, the outcomes of epidemiological simulation models themselves rely on a set of assumptions and vary greatly depending on the latter. Moreover, these studies may not be available for the respective country example in this analysis. Historic experience in a given country may serve as a benchmark. Yet, in light of the abundance of parameters that determine the duration of the epidemic, a replication of one single historic situation is seen to be highly unlikely, too.

137. For these reasons, the duration of the epidemic under a *stamping-out strategy* has been based on historic *averages*. Excluding the special cases of the UK 2001 epidemic and Turkey from the sample[30], the average duration of FMD outbreaks in OECD countries over the last 10 years was roughly 2 months after the first case. This is fairly in line with a recent epidemiological scenario analysis, indicating that an epidemic of FMD in the Middle West of the US may, depending on the intensity of stamping-out, take almost up to two months (Paarlberg et al. 2008). For the purpose of this study two months has been selected as the duration of the epidemic under a stamping-out strategy.

138. There is only very limited historic evidence from OECD countries for the duration of epidemics under *vaccination strategies*. Korea and the Netherlands are the only OECD countries that have vaccinated as a response to FMD in their countries in the recent past, and it seems inappropriate to extrapolate from these few experiences to determine the duration of the epidemic in the simulations. Brazil is a country that regularly vaccinates it’s livestock against FMD, but in view of the very different structure of animal production in Brazil, it was not deemed an appropriate example. Studies employing epidemiological models suggest that the duration of the epidemic with vaccination differs relatively little from a stamping-out strategy (Kobayashi et al. 2007). Nevertheless, this and other studies also show that the advantage of vaccination compared to stamping-out depends heavily on parameters as the index case (animal type and location), the radius of vaccination and slaughter around the outbreaks (Bates, Carpenter & Thurmond 2003), (Morris et al. 2001), the characteristics of the infected region (Morris et al. 2001) and the speed of spread of the disease () among others. Some studies even indicate that a comprehensive slaughter strategy can be more time efficient in containing the disease than a combination of a less comprehensive slaughter strategy with limited vaccination (Bates, Carpenter & Thurmond 2003).

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consumption. On the other hand, a well designed communication policy may mitigate negative impact on consumption that media coverage or health concerns may have.

30 In Turkey FMD is endemic, and the 2001 epidemic in the UK is deemed an outlier.

139. Given the ambiguity of the issue, and since the main purpose of this study is to analyze the impact of the trade ban arising from various control strategies, it shall be assumed that the *control strategy does not affect the duration of the epidemic, that is assumed to be 2 months.*

The duration of the waiting period

140. Historic evidence shows that the waiting period is in practice often longer than the OIE official waiting periods. This can be attributed to the administrational procedures preceding the official recognition of being free of the disease. Over the last ten years, it took OECD countries that did not vaccinate, on average 4.5 months after the last outbreak to regain disease-free status, *i.e,* on average 1.5 months longer than the official waiting period. The waiting period that is assumed for the stamping-out scenarios will therefore be 4.5 months.

141. If the measures taken to fight FMD include a vaccination-to-live strategy, the OIE guidelines state that the waiting period of 6 months starts after the last case or the last vaccination, whatever occurs last (OIE, 2007). For this study, it shall be assumed that these two events coincide. There is little historic evidence from OECD countries with regard to the administrative effort after a vaccination-to-live strategy. Hence, for the purpose of this study it is assumed that the administrative effort takes the same time no matter what the control strategy is. The total waiting period added to the duration of the epidemic is then 7.5 (6+1.5) months under the vaccination-to-live strategy.

Products affected by the trade ban

142. Many agricultural products can be subject to trade bans related to FMD outbreaks. These include not only meats from the susceptible species, but also dairy products and even non-animal products, like straw and forages. However, for this study, the range of products is limited to meat of cattle and pigs. This is justified by the relatively limited importance of international trade of meats from other susceptible species as sheep and goats as well as fresh dairy products.

Location of the outbreak and borders for regionalization

143. Defining the location of the hypothetical outbreak is necessary if regionalization is to be considered. It goes beyond the scope of this study to assess which regions within a country may be particularly at risk of experiencing FMD outbreaks *e.g.* because of high animal density, frequent animal movement *etc*. Therefore, the decision where the outbreak shall take place has been based on economic criteria and data availability. Where export data by region was available, a high share in total national exports of meat of susceptible species has been chosen, as it will serve as a benchmark for the respective country. Where this was not available, high shares in total production or even animal inventories had to be used as an approximation.

- In the case of the US, Iowa is the state with the largest share in the export value of live animals and meat. It reached 17% of the total in 2006 (United Stated Department of Agriculture 2007).[31.]

31 At the moment of drafting this note, export data by state was not available by type of meat. Slaughter production is generally available by state and type of meat. However, in the case of Iowa it is not public. For this reason, animal inventory data has been used to approximate the Iowa's share of pork and beef exports in total US exports.

- In Canada, Alberta is the province with the highest share in the national export value of beef and pork meat in 2007, accounting for 38% of the total export value of Canada for these products (Industry Canada).

- According to the most recent data available, the region in the Netherlands with the highest share in total pig and cattle inventory was North Brabant. It accounted for 37% of the total inventory of the aforementioned species (Statistics Netherlands).

144. It is left to infected countries to determine on which geographic area they want to establish the zone considered free from FMD for international trade purposes, as long as their implementation complies with the OIE guidelines. Where no contingency plans for a possible FMD event could be retrieved, assumptions on the possible borders had to be made. As for the US and the Netherlands where no information on possible regionalization was available or did not match the data availability, the decision was based on legal borders, *i.e.* states or provinces, respectively.

145. For Canada on the other hand, country experts stated that the most reasonable regionalization in case of animal disease outbreaks would, for geographic reasons, be between the provinces of Manitoba and Ontario, dividing the country into a western and an eastern part.

Scenario Implementation

146. Most FMD incidents are of relatively short duration of a number of months rather than years. The periodicity of both models used in this analysis is annual data, meaning that it is not possible to implement trade bans in months explicitly within years. Thus, the trade ban had to be translated into shares of one year. The assumption underlying this procedure is that trade flows are equally distributed over the year. Moreover, both modeling systems operate on a national basis, *i.e.* the exclusion of a region within the country from international trade can only be reflected in terms of some assumptions such as the regions' share in national exports. The export quantity in the year of the outbreak q_1 of the respective country is then calculated according to the formula

$$q_1 = q_0 \cdot (1 - t \cdot r \cdot \mu),$$

with $t, r, \mu \leq 1$

Where q_0 is the initial quantity of exports in the respective year, t is the time the country is declared as infected expressed in per cent of a year, and r is the share of the infected region in national meat exports, production or animal inventory. For the simulations in GTAP, the export quantities were additionally adjusted by the share that the affected commodity has in the GTAP composite μ. The latter is equal to one for all simulations with Aglink-Cosimo.

147. For example, for the case of beef exports from Canada under the stamping-out with regionalization, t takes the value of 0.54 (6.5 months), and r is equal 0.87 representing the share of west Canada in total exports. For the simulations with GTAP, μ takes the value 0.94.

148. The shares are presented in Annex B.

Impacts from the perspective of the infected country

149. One of the key points in the discussion of whether to vaccinate or not against FMD, is the consequence that a prolonged trade ban may have on the domestic industry. In this section, an attempt is made to quantify the losses in revenue[32] resulting from the trade ban by analyzing and comparing the outcome of the simulated scenarios. The impact of an FMD outbreak and the resulting trade ban are not limited to the year of the outbreak. Thus, the dynamic effects of an outbreak will be evaluated. Lastly, an assessment of other costs related to the different control strategies is made.

Losses in revenue

The impact of an outbreak in the United States, a leading meat exporting country

150. The US is, together with Canada, one of the world's most important meat exporting countries. In 2006, it accounted for more than 23% of global pork exports. Its share in global beef exports dropped sharply in 2004, after the detection of Bovine Spongiform Encephalitis (BSE) in North America, but is projected to recover to a level of around 12% of global exports within the next five years (OECD-FAO 2008).[33]

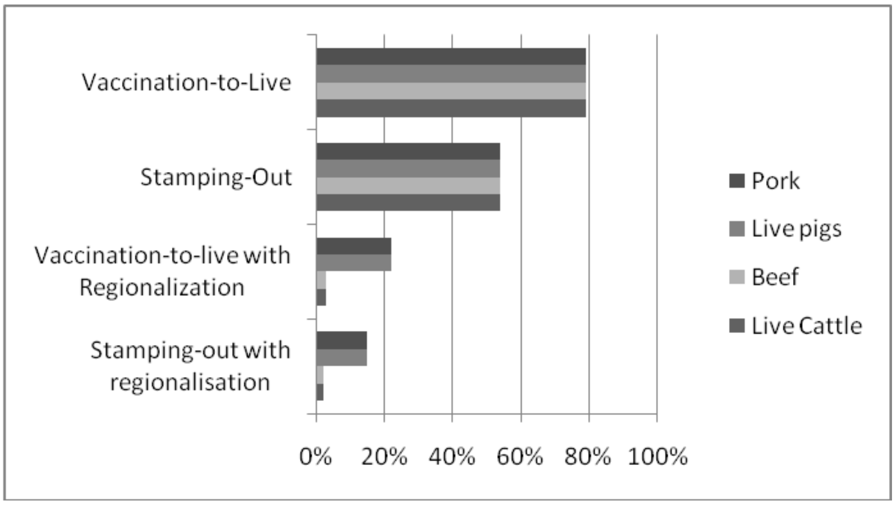
151. Figure 8 shows which share of yearly exports is assumed to be banned under each of the disease eradication scenarios.[34] Clearly, the vaccination-to-live scenario, with an assumed loss of annual exports of almost 80%, presents the largest shock to the markets. It is followed by the stamping-out scenario with over 50% export loss. Under the assumption of regionalization, the extent of the shock is more limited, especially for the beef sector. For the pork sector, it is about 20% of the pork exports that needs to be diverted to the domestic market under the vaccination-to-live scenario with regionalization. Under the assumption of stamping-out with regionalisation, the trade shocks are less marked.

32 This is not equal to changes in profit, as input costs may also adjust, though the scope to which they do is probably limited in the short term. Furthermore, only changes is revenue from the sales of pork and beef are considered here, while there may be side effects on other sectors like for example feed supply that are not accounted for. The same is true for other, competing meat products like for example poultry.

33 The figures include trade of live animals.

34 These shares were calculated according to the formula presented in the section *"Scenario Implementation"*.

Figure 8. Assumed losses of annual exports for the US in the year of the epidemic



152. Despite being a large exporting country in absolute terms, its export share, defined as the share of exports over domestic production, is limited. Only around 15% of the national pork production was exported in 2006, for beef this share was only around 5% in the same year.

153. Table 5 presents the loss in farmer's revenue under the different assumptions made on the strategy taken to eradicate- the disease.

Table 5. Loss of farm revenues

	Beef		Pork	
	1000 USD	%	1000 USD	%
		year of outbreak		
Vaccination-to-Live	-4,946,818	-14%	-4,034,123	-27%
Stamping-Out	-3,255,752	-9%	-2,453,330	-16%
Vaccination-to-Live with regionalisation	-484,900	-1%	-725,653	-5%
Stamping-Out with regionalization	-329,508	-1%	-480,633	-3%
		average 2010-2017		
Vaccination-to-Live	-2,852,550	-1%	-9,580,213	-7%
Stamping-Out	-1,844,168	-1%	-6,425,071	-5%
Vaccination-to-Live with regionalisation	-243,558	0%	-2,368,008	-2%
Stamping-Out with regionalization	-159,970	0%	-1,586,755	-1%

Source: Calculations based on Aglink-Cosimo modeling results

154. The results indicate that, no matter which control strategy is taken, the relative impact of the trade ban on the pork market is more pronounced than on the beef markets. This is explained by the fact that the export share of pork is considerably higher than for beef, and that the US is a net importer of beef as opposed to their net exporter position for pork. This means that the size of the domestic market available to absorb increased supplies due to lower exports is smaller.

155. Under the standard stamping-out scenario, the losses to the pork sector in the year of the hypothetical outbreak amount to almost USD 2.5 billion[35], representing a loss of 16% in producer income when compared to the baseline. Domestic pork prices decline by 20% in the year of the epidemic, domestic

35 All results shown in this section are results from Aglink-Cosimo.

beef prices decline by approximately 10%. Though higher in absolute value terms, the revenue losses for the beef sector amount to only 9% of the initial value in the baseline.

156. If the US were to follow a vaccination-to-live strategy, the trade ban would be three months longer, and the decrease in prices therefore more pronounced. As Table 5 indicates, the losses to the pork sector would amount to almost one third of the baseline value in the year of the outbreak. The losses to the beef sector under this scenario amount to almost 14% of the baseline value.

157. Both scenarios have been repeated under the assumption that the veterinarian authorities establish a zone which is declared as free from FMD. As mentioned, the state of Iowa is assumed to be the infected zone in this exercise, while the rest of the US is declared to be free from FMD without vaccination, and the US's trading partners are presumed to accept this regionalization. For the case of Iowa, this means that only 4% of the national beef exports are affected by the ban for the respective time period, and 28% of total US pork exports. State boundaries may in reality not be appropriate for determining an animal subpopulation, but the results hold certainly true for any subpopulation accounting for these shares in the national herd.

158. Under this scenario, the impacts on beef markets are even more limited, which can be explained by Iowa's limited role in national beef production. Also for pork, the losses to the sector are smaller than under a stamping-out scenario without regionalization. The losses of producer revenue amount to around 5% of the baseline value in the year of the outbreak.

159. The stamping-out scenario has also been run in combination with the regionalisation assumption. The model results indicate that, under these assumptions, the impact of a hypothetical outbreak of FMD would be fairly limited. On average, the revenue losses at the national level by the beef sector, amount to less than one per cent in the year of the epidemic. Even for the more affected pork sector, the losses in 2009 are limited to around 3 per cent of average revenue.

160. Given the rigidities in supply response and the assumption made on farmers price expectations, the impacts of the hypothetical outbreak on revenues in the livestock sector are not limited to the year of the epidemic. The changes compared to the baseline are aggregated over the eight years following the outbreak and are shown in Table 5. Generally speaking, the dynamic effects on the pork market are more pronounced than on the beef market. This can be explained by the relative size of the disturbance on both markets. Under all scenarios, the beef market recovers comparatively swiftly, and the deviation in farm revenue from the baseline does not exceed 1%. For the pork markets, on the other hand, up to a further 7% of revenue may be lost over the 8 years following the outbreak. These differences are explained by the different relevance of exports to both markets and the resulting difference in price movements.

Canada, an important net meat exporter with high export share

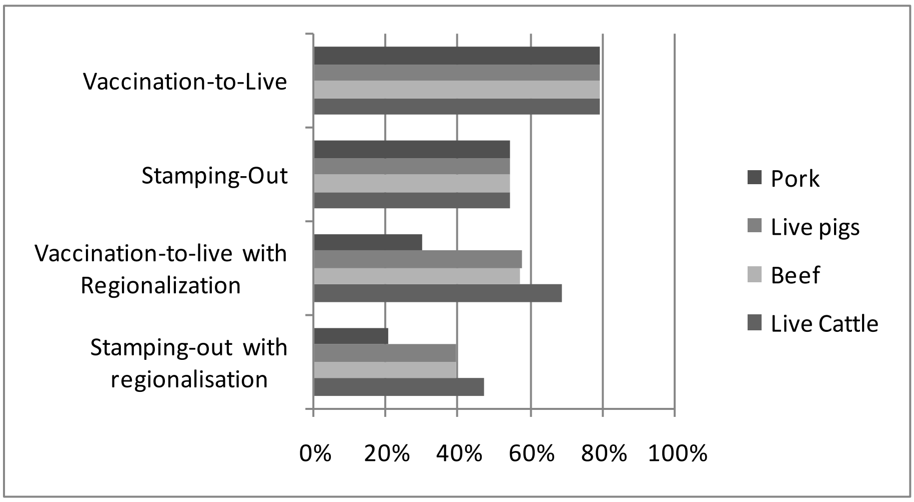
161. Canada has been chosen for this study to illustrate the effects of a hypothetical outbreak on a country which is a substantial net meat exporter in terms of the importance to the domestic industry as well as to the international meat markets. With about 25% in 2006, it has a similar share of world pork exports as the US. Almost 10% of world beef exports originated in Canada in 2006 (OECD-FAO 2008). This ranks it high among the OECD countries, where only Australia has a bigger share of world exports of beef.

162. In addition to this, Canada provides an interesting case since the export sector plays an important role to the industry. The export/production ratio of Canadian pork was almost 65% in 2006, and that of beef more than 46% in the same year. Canada is a net exporter of both beef and pork. Any event that restricts exports from Canada can therefore be expected to have significant impact on both world markets and the domestic industry.

163. Figure 9 depicts the share of Canada's annual exports that are assumed to be redirected to the domestic market under each of the FMD control scenarios[36]. Under the stamping-out scenario and the vaccination-to-live scenario, the shares of exports that are lost are the same as for the other countries in this study, *i.e.* 54% and 79% of annual exports respectively for all sectors in the year of the outbreak.

164. In the scenarios including regionalisation, however, the extent of losses of exports differs considerably between the sectors. Since pork is mainly exported from Quebec and Ontario that are assumed to be declared free of FMD in this scenario and keep exporting (these two provinces accounted for 62% of Canadian pork export value in 2007 (Industry Canada)), Canada's total exports of pork meat are relatively little affected compared to the other sectors.[37] Live cattle, on the other hand, where western Canada reached a share of total export value of 87% in 2007 (Industry Canada), does not gain much from regionalisation.

Figure 9. Assumed losses of annual exports for Canada in the year of the epidemic



36 Again, these shares were calculated according to the formula presented in the section *"Scenario Implementation"*.

37 This only holds true if the raising of animals, slaughter and export are geographically close to each other. In any case in which *e.g.* live animals from Manitoba are input for the exporting sector in Ontario, the benefit from regionalization will be more limited.

165. The first scenario to examine is the *stamping-out* scenario, where more than half of what is shipped abroad under normal circumstances must find new outlets in the domestic market. Prices for both pork and beef decrease considerably, for pork it is around 80%, for beef 65% compared to the baseline.

166. As Table 6 indicates, losses for both the beef and the pork sector are considerable and reach over 50% of the annual revenue under the standard scenario of stamping-out. At first glance, it may seem surprising that the losses in the short run are higher for beef than for pork. This can be explained by two effects. On the one hand, pork production in Canada was found to be extremely inelastic in the short run. While prices drop sharply, farmers still deliver pork to the slaughterhouses in the first year. In the case of beef, the price decrease is less pronounced, but at the same time supply to the slaughterhouses is reduced.

Table 6. Loss of farm revenues

	Beef		Pork	
	1000 USD	%	1000 USD	%
Vaccination-to-Live	-4,392,030	-88	-2,553,464	-84
Vaccination-to-Live with Regionalisation	-3,807,299	-76	-1,668,559	-55
Stamping-Out	-2,816,724	-56	-1,624,158	-53
Stamping-Out with regionalization	-2,274,097	-46	-999,434	-33
		average 2010-2017		
Vaccination-to-Live	-8,818,012	-24%	-24,463,992	-86%
Vaccination-to-Live with regionalisation	-7,189,537	-20%	-19,128,526	-67%
Stamping-Out	-4,509,717	-12%	-8,787,282	-31%
Stamping-Out with regionalization	-3,592,170	-10%	-6,463,955	-23%

Source: Calculations based on Aglink-Cosimo modeling results

167. The second reason is Canada’s less important role in world beef exports, causing the world market price for beef to increases less than in the case of pork. This in turn means that the revenue made on the international markets is higher for the remaining share of pork that can be exported than for the exportable quantities of beef.

168. Not surprisingly, these effects are even stronger under the *vaccination-to-live scenario*. Given the strong export orientation of the Canadian livestock sector, this would materialize into some 600 000 tonnes of beef and over 1 million tonnes of additional supply of pork on the domestic market. In other words, supply to the domestic market is more than doubled in the case of pork, and almost doubled in the case of beef. This represents an extreme case in many respects, and while the modeling results may serve as an indication, they should be interpreted with care given the limitation of all modeling systems when handling large shocks.

169. Under the vaccination-to-live scenario, beef prices drop by almost 97%, while pork prices decrease to almost zero. It should be reiterated that these estimates are a result of pure market mechanisms. In reality, one could expect farmers to take other offsetting measures when faced with such a decrease in price. When the selling price no longer covers variable costs, farmers may slaughter pigs prematurely, an action that would decrease supply and possibly support the average market price for the year.

170. The *vaccination-to-live scenario* has also been combined with *regionalisation*. Although lower volumes are involved, the above pattern of losses is repeated. Losses to the beef sector are higher than in the pork sector in the first year.

171. Given the high cost of an FMD outbreak already under a standard stamping-out scenario, for Canada stamping-out with regionalization may be worth a closer look. Here, the losses in revenue to the beef sector amount to over USD 2.2 billion or 46% in the year of the outbreak. This means that under the

regionalization scenario, about 20% of the losses in revenue in the beef sector could be mitigated by regionalization. In the pork sector, regionalization mitigates around 40% of the losses of revenue compared to stamping-out without regionalization.

172. Interestingly, when adjustments in following years are included, it is the pork sector where more revenue, over the medium term, is lost than in the beef sector. A stronger decrease in pork prices makes itself felt in the years following an outbreak more considerably than in the beef market, where prices fall, but not to the same degree as for pork. Another factor contributing to this outcome is the assumption on farmers' expectations. Canada would become a net importer of pork for a couple of years following the hypothetical outbreak. In those years, revenues from export have been assumed to be zero. It should be reiterated that this is the result of a pure market mechanism in combination with naïve price expectations of the livestock producer.

The Netherlands, a European Country case

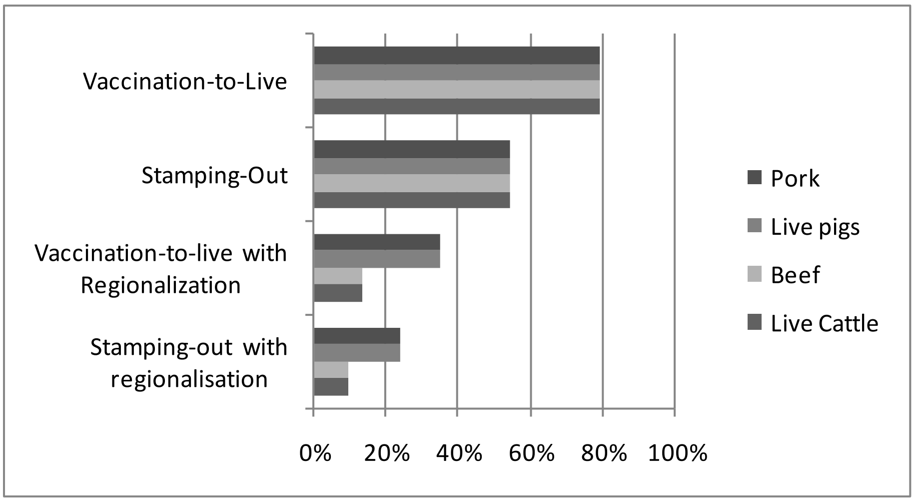
173. The Netherlands was chosen as an example for a European country. The Netherlands is, within the European Union, the most important meat exporting country. In 2007, it was leading the list of European countries with an export value of over EUR 15 billion for live animals and pork and beef meat exports (EUROSTAT).

174. In addition, the Netherlands was considered an interesting case as its market structure is also characterized by a high share of exports as a proportion of production (OECD, 2007), indicating the importance of export markets to the meat sector.

175. Figure 10 shows the shares of exports that are subject to trade restrictions in the year of the outbreak[38]. Since the time needed to recover disease-free status is the same for all countries by assumption and exports are assumed to be restricted even to other EU countries, the losses do not differ from those of the US or Canada case studies in percentage terms. In the two scenarios, including regionalization based on North Brabant, the shock to the beef sector was found to be less than half of that for the pork sector, given the composition of animal inventory in the region of North Brabant. The results of this exercise can provide an indication of what might be expected for any region in the Netherlands accounting for a similar share of the total national animal population as North Brabant.

[38] As in the previous sections, these were computed according to the formula presented in the section *"Scenario Implementation"*.

Figure 10. Assumed losses of annual exports for the Netherlands in the year of the epidemic



176. In the *stamping-out scenario*, the amount of pork that need to be sold on the domestic market is around 470 000 tonnes of pork meat, and 200 000 tonnes of live pigs. The amount of beef amounts to roughly 195 000 tonnes, most of which is meat. Following the outbreak and implementation of trade bans, domestic pork prices drop sharply by over 80%, and beef prices drop by 66%.

177. The impact on the revenue for the farming sector is presented in Table 7. In the year of the outbreak itself, the loss of revenue is more pronounced for the pork sector than for the cattle sector. The reason for this is that the Netherlands, while being a net exporter of beef, also imports considerable quantities of beef. In the case of the simulated trade restrictions, these imports are crowded out of the domestic market by domestic production, thereby alleviating some of the pressure on the domestic industry.

Table 7. Loss of farm revenues

	Beef		Pork	
	1000 USD	%	1000 USD	%
		year of outbreak		
Vaccination-to-Live	-888,018	-64%	-2,461,264	-78%
Stamping-Out	-506,295	-37%	-1,657,035	-53%
Vaccination-to-Live with regionalisation	-63,319	-5%	-919,139	-29%
Stamping-Out with regionalization	-33,434	-2%	-577,100	-18%
		average 2010-2017		
Vaccination-to-Live	-153,791	-1%	-1,753,159	-7%
Stamping-Out	-108,516	-1%	-1,429,998	-6%
Vaccination-to-Live with regionalisation	-38,044	0%	-908,688	-4%
Stamping-Out with regionalization	-25,712	0%	-637,938	-2%

Source: Calculations based on Aglink-Cosimo modeling results

178. In the stamping-out scenario, loss incurred by the pork sector amount to over USD 1.6 billion or over 52%. For the cattle sector, these values are around 37% or USD 5 million.

179. Under a vaccination-to-live scenario, almost 80% of exports need to be accommodated on the domestic market. Given the particularly high export share of production, this means almost doubling the supply on the domestic market, which has to be seen as an extreme disruption of normal business. Under

these extreme assumptions, pork prices drop by 94%, and beef prices by almost 80% in the year of the outbreak. These sharp price declines imply an 80% loss of revenue compared to the baseline results. For the beef sector, the loss of revenue amounts to almost 65% of that in the baseline.

180. If, on the other hand, the control strategy is unchanged vaccination-to-live, but, only a sub-region of the Netherlands with a share of exports equal to the share of animal inventory of North Brabant is subject to trade constraints, the losses to the meat and livestock sector are more limited. For the beef sector, it is less than 5% in the year of the outbreak. The pork sector is faced with losses in revenue of almost 30% in the year of the outbreak.

181. For the Netherlands, the stamping-out scenario has also been run with regionalisation assumption. Even under this scenario, that represents the smallest shock to the sector, the losses in farm revenue are considerable especially in the pork sector.

182. The dynamic impacts on the beef sector from adjustments in following years after an outbreak are limited, when compared to the pork sector. For beef, a deviation from the baseline of only 1% is to be expected under the vaccination-to-live and the regionalization scenarios. The dynamic effects on loss of revenue generated within the pork sector are more notable, and reach a maximum of 7% under the vaccination-to-live scenario.

International effects

183. Trade restrictions erected against any major meat exporting country will certainly have their impact beyond infected countries' domestic market. In the following sections an attempt is made to provide insight into two issues of international relevance.

184. First, how do international trade patterns change when a major seller of meat temporarily drops out of the markets due to the imposition of trade bans, i.e., how are its major trading partners, and how are its competitors affected.

185. The results are an output of the GTAP model, which does not contain quantity information (e.g. it does not report tones of meat). Instead, the model's database is formulated in values (e.g. millions of dollars of meat). The model equations decompose percent changes in values into percent changes in prices and percentage changes in volumes for bilateral trade. Since there is not initial quantity information, the bilateral quantity changes cannot be aggregated in a straightforward way. Therefore, the bilateral trade changes are reported in values. Moreover, since GTAP commodities are aggregates of different underlying products (e.g. the product group "bovine meat products" includes fresh and frozen bovine meat, sheep meat, etc.), the reported percent changes reflect changes of the aggregate, and not just one of its components.

186. A second section addresses economic impacts in a more global manner. It provides information on how border prices would rise as a consequence of the trade ban, and identifies country groups that may lose or benefit as a consequence of the trade restrictions.

Trade effects

187. In this section, both the effects of total and bilateral trade are analysed on a country-to-country basis. Only the results for the stamping-out scenario are discussed here, since across the scenarios, it is only the magnitude of the shocks that varies. The full results can be found in Annex B. Moreover, only the impact on the top three importing countries for beef and pork of each infected country are analysed in detail.

Outbreak in the United States

188. Any outbreak in the US will predominantly affect Canada, Mexico and Japan, since those are the countries that absorb large shares of US meat exports.

189. The results are presented in Table 8. In summary, imports of beef products of Japan are affected only marginally by a hypothetical FMD outbreak in the US, while Canada and Mexico decrease their aggregate imports of beef and beef products value by 4% and 7 % respectively, as a result of their strong concentration on beef imports from the US.

190. Japan intensifies its beef importation predominantly from competitor countries such as Australia and New Zealand, which are its main beef meat sources under normal conditions. Canada is hit significantly by an outbreak of FMD in the US, given its close trade relation with this country, integrated livestock rearing and fattening operations and poorly diversified trade pattern. Though being able to find substitutes for US beef in New Zealand, Australia and South America, Canada's beef imports are significantly reduced. The main reason for this sharp drop lies in the composition of the Canadian import package. About one-third of the import value from the US in this product category is generated through trade of live animals. Distance is a key trade cost factor in live animals trade, and therefore Canada cannot easily switch towards other and more distant suppliers. Mexico replaces about half of its import value from the US with beef originating in Canada, while another 15% is substituted from New Zealand and Australia. Nevertheless, the reduction in Mexico's import value of beef and beef products is shown to be not negligible.

191. The above analysis indicates that the US trading partners mainly substitute their beef from Oceania in case the US should temporarily drop out as an exporter, but at the same time this country group expands its total exports only marginally. This clearly indicates that beef exports are diverted away from other destinations. In the case of Oceania, these are predominantly the US itself, as given the low domestic beef price this destination looses its attractiveness as an export market.

192. The same three countries are the main export destinations for pork and pork products from the US. Interestingly, Japan, which in normal years leads the list of importers of pork from the US, purchasing over 30% of US exports, slightly increases its total imports of pork, indicating a net substitution away from beef products. Canada is the country that accounts for the largest drop in pork imports following an outbreak in the US, which can be explained by the extraordinary importance of US pork shipments to Canada, which sources its pork requirements almost entirely from the US. The impact on Mexico's total pork imports is limited, as it replaces imports from the US by almost doubling its imports originating in Canada, and more than doubling imports from South American countries, excluding Brazil and Argentina.

Table 8 Trade effects of an outbreak in the US fought by stamping-out[39]

	Destination	JAPAN	CANADA	MEXICO	TOTAL	JAPAN	CANADA	MEXICO	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	14	5	20	**36**	5	1	0	**13**
	%	1	11	46	1	4	16	14	1
New Zealand	ABS	3	14	25	**41**	1	3	1	**20**
	%	1	11	47	1	1	30	32	3
Japan	ABS	0	0	0	**0**	0	0	0	**3**
	%	na	13	53	1	na	41	91	3
Korea	ABS	0	0	0	**0**	1	0	0	**2**
	%	0	9	50	-1	6	39	95	2
Canada	ABS	0	0	156	**82**	13	0	62	**-28**
	%	0	na	48	4	2	na	94	-1
USA	ABS	-27	-49	-318	**-711**	-264	-140	-192	**-1040**
	%	-24	-34	-39	-35	-19	-16	-16	-14
Mexico	ABS	0	0	0	**-13**	-18	0	0	**-25**
	%	-1	11	na	-2	-9	15	na	-7
Argentina	ABS	0	0	0	**10**	1	2	0	**7**
	%	2	13	47	1	5	28	33	1
Brazil	ABS	0	0	0	**23**	41	16	0	**60**
	%	2	12	54	1	7	42	91	1
Belgium	ABS	0	0	0	**6**	1	1	0	**23**
	%	9	18	13	1	8	24	108	1
Denmark	ABS	0	0	1	**4**	88	3	2	**67**
	%	3	13	53	1	9	37	97	1
France	ABS	0	0	0	**23**	10	2	2	**72**
	%	6	15	40	1	10	36	93	2
Germany	ABS	0	1	1	**23**	1	1	1	**60**
	%	8	19	13	1	4	22	93	1
Italy	ABS	0	0	0	**9**	3	3	1	**29**
	%	4	15	40	2	10	42	73	2
Netherlands	ABS	0	0	0	**9**	5	2	0	**36**
	%	6	19	13	1	8	13	46	1
Rest of Asia	ABS	1	1	1	**26**	117	9	5	**216**
	%	5	15	38	2	8	19	37	3
Rest of South America	ABS	0	8	9	**16**	9	7	78	**86**
	%	2	11	53	1	5	40	102	10
Rest of EU	ABS	2	2	3	**51**	24	10	10	**180**
	%	5	14	48	1	9	40	86	2
Africa	ABS	0	0	1	**10**	1	1	1	**12**
	%	6	15	42	1	3	26	62	2
Rest of non-EU Europe	ABS	1	1	1	**12**	1	2	2	**23**
	%	6	16	41	1	3	20	42	2
Rest of the World	ABS	0	0	9	**10**	1	3	10	**18**
	%	-1	9	34	3	3	32	59	7
Total	ABS	**-4**	**-16**	**-91**	**-334**	**39**	**-74**	**-16**	**-167**
	%	0	-4	-7	-1	1	-7	-1	0

Source: GTAP simulation

39 Changes in export/import value. Absolute changes are in mio. 2004 USD.

Outbreak in Canada

193. Canada's trade relations with other countries are more diversified than those of the US. Whereas the US trades both beef and pork products virtually with the same three countries, Canada serves different destinations with its exports of beef and pork products. While its international beef sales are predominantly directed to the US, Mexico and, to a smaller degree, to Asia, it ships pork products mainly to the US and Japan, and to a smaller degree also to Australia.

194. For both beef and pork products, the US is the country whose aggregate meat purchases decrease most due to a disease event in Canada, by 7% or 8%, respectively. In the case of beef, this can again be attributed to the relevance of live animal trade between the two countries which can not be easily substituted from other sources, although imports from Oceania rise.

195. Mexico, despite being the second most important customer for Canadian beef, is affected only marginally, as it absorbs only around 5% of total Canadian beef exports (United Nations). The same holds true for Asia, where decreases in imports are hardly visible in percentage terms.

196. On the pork market, other importers than the US do not experience significant changes in their aggregate imports. The US, Brazil and Denmark make up for more than half of the trade value that Canadian exporters lose on Japanese markets, increasing their export value to this Asian country by around 5%. Australia sources additional pork mainly from Denmark, increasing the value of imports from this region by roughly one-fifth.

197. Denmark's total exports rise only to a limited extent. It diverts exports away from other countries - mainly European countries - to meet the new demand (data not shown).

Table 9. Trade effects of an outbreak in Canada fought by stamping-out[40]

	Destination	USA	MEXICO	Rest of ASIA	TOTAL	Australia	JAPAN	USA	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	122	4	-18	**69**	0	0	5	**7**
	%	*9*	*10*	*-1*	***1***	*na*	*0*	*21*	***1***
New Zealand	ABS	99	7	1	**65**	3	0	21	**24**
	%	*12*	*13*	*0*	***2***	*11*	*1*	*25*	***4***
Japan	ABS	1	0	0	**1**	0	0	1	**5**
	%	*14*	*16*	*2*	***4***	*19*	*na*	*24*	***4***
Korea	ABS	0	0	0	**0**	0	1	1	**3**
	%	*14*	*16*	*2*	***2***	*17*	*5*	*29*	***4***
Canada	ABS	-686	-173	-57	**-1050**	-39	-255	-821	**-1462**
	%	*-54*	*-54*	*-54*	***-54***	*-42*	*-42*	*-43*	***-43***
USA	ABS	0	123	1	**96**	2	69	0	**-15**
	%	*na*	*15*	*0*	***5***	*12*	*5*	*na*	***0***
Mexico	ABS	24	0	0	**25**	0	8	17	**26**
	%	*4*	*na*	*1*	***4***	*3*	*4*	*27*	***8***
Argentina	ABS	0	0	4	**8**	0	0	21	**16**
	%	*8*	*16*	*3*	***1***	*2*	*2*	*22*	***3***
Brazil	ABS	1	0	15	**18**	0	26	69	**46**
	%	*12*	*17*	*3*	***1***	*15*	*4*	*24*	***1***
Belgium	ABS	1	0	1	**6**	0	1	3	**22**
	%	*9*	*5*	*3*	***1***	*14*	*6*	*27*	***1***
Denmark	ABS	0	0	3	**3**	18	50	55	**74**
	%	*8*	*17*	*3*	***1***	*20*	*5*	*22*	***1***
France	ABS	2	0	1	**22**	1	7	8	**64**
	%	*12*	*14*	*2*	***1***	*18*	*8*	*28*	***2***
Germany	ABS	4	0	2	**24**	0	1	8	**58**
	%	*7*	*5*	*1*	***1***	*17*	*4*	*29*	***1***
Italy	ABS	2	0	1	**9**	0	2	13	**28**
	%	*15*	*14*	*4*	***2***	*17*	*7*	*26*	***2***
Netherlands	ABS	2	0	2	**10**	2	3	9	**42**
	%	*7*	*5*	*4*	***1***	*23*	*6*	*28*	***1***
Rest of Asia	ABS	4	0	20	**26**	1	79	160	**307**
	%	*12*	*13*	*2*	***2***	*6*	*5*	*31*	***5***
Rest of South America	ABS	45	3	2	**38**	1	10	16	**29**
	%	*14*	*17*	*2*	***4***	*19*	*6*	*28*	***3***
Rest of EU	ABS	15	1	6	**63**	3	18	65	**189**
	%	*11*	*16*	*3*	***1***	*21*	*7*	*28*	***2***
Africa	ABS	2	0	5	**10**	0	1	12	**24**
	%	*13*	*14*	*2*	***2***	*10*	*3*	*30*	***3***
Rest of non-EU Europe	ABS	3	0	1	**12**	1	1	19	**38**
	%	*13*	*14*	*2*	***2***	*11*	*3*	*30*	***3***
Rest of the World	ABS	12	3	0	**17**	0	1	4	**8**
	%	*13*	*11*	*1*	***6***	*12*	*4*	*28*	***3***
Total	ABS	**-347**	**-31**	**-12**	**-530**	**-7**	**23**	**-314**	**-470**
	%	***-7***	***-2***	***0***	***-2***	***-2***	***0***	***-8***	***-1***

Source: GTAP simulation

40 Changes in export/import value. Absolute changes are in USD 2004 mio.

Outbreak in the Netherlands

198. The Netherlands has a completely different international trade pattern than the two aforementioned North American countries. Its main export destinations are all to be found in the European Union, amongst its member states.

199. France, Germany and Italy absorb together roughly 60% of Dutch exports of beef products, each accounting for approximately 18-23%. For all three countries, meat imports rather than imports of live animals play the primary role.

200. For pork products, Germany is the leading recipient, taking about one third of Dutch export sales. Almost two thirds of Germany's import value from the Netherlands can be attributed to imports of live animals. Italy and Greece, receiving about 20% and 10% of Dutch exports of pork and pork products, purchase mainly meat products.

201. Among the top three importers of Dutch beef and beef products, the model results indicate that Germany's imports would suffer the most from an animal disease related trade ban erected against the Netherlands. This is the result of the important role that beef products from the Netherlands play in the composite of Germany's imports. According to the GTAP database, it sourced around 20% of its beef imports from the Netherlands, whereas Italy and France have a more diversified pattern of imports. Although not compensating fully for the drop-out of the market of the Netherlands during the disease outbreak, Argentina, other European countries[41] and France are countries that substitute for part of the former exports of the Netherlands.

202. Aggregate imports of beef of Italy and France decrease only slightly, because France intensifies its existing trade flows from the Rest-of-Europe aggregate, and to a smaller extent with Belgium and Germany. Italy, on the other hand, increases imports from the Rest-of-Europe aggregate, too, but also from France and Germany.

203. While some destinations, such as France and Italy, receive more German beef, trade is diverted away from other destinations. Again, it is the FMD infected country itself from which exports are diverted away, as the domestic price falls due to the impediments to export.

204. The impacts on the Netherlands main recipients of pork, again France and Germany as well as the Rest-of-Europe aggregate, are less pronounced than in the case of beef. Total imports of these three countries remain rather stable as other sources for pork can be found. An interesting observation is that Germany's imports actually increase slightly, with additional imports coming mainly from the Rest-of-Europe aggregate. France is able to cover the gap by increasing its imports also from the Rest-of-Europe region. This country group increases predominantly intra-trade, but also imports from Germany, France and Denmark.

[41] Within this country group, Poland can be expected to increase its exports given its role in the past.

Table 10. Trade effects of an outbreak in the Netherlands fought by stamping-out[42]

	Destination	FRANCE	GERMANY	ITALY	**TOTAL**	FRANCE	GERMANY	Rest EU	**TOTAL**
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	1	1	0	**13**	0	2	1	**7**
	%	*7*	*8*	*9*	***0***	*2*	*12*	*3*	***1***
New Zealand	ABS	11	15	2	**34**	0	5	2	**10**
	%	*7*	*8*	*8*	***1***	*2*	*7*	*3*	***1***
Japan	ABS	0	0	0	**1**	0	0	0	**1**
	%	*8*	*9*	*10*	***3***	*3*	*6*	*4*	***1***
Korea	ABS	0	0	0	**0**	0	0	0	**1**
	%	*8*	*9*	*10*	***2***	*3*	*8*	*4*	***1***
Canada	ABS	2	1	0	**10**	0	6	1	**24**
	%	*8*	*7*	*7*	***1***	*2*	*21*	*3*	***1***
USA	ABS	2	1	1	**19**	1	7	8	**86**
	%	*8*	*8*	*7*	***1***	*2*	*16*	*4*	***1***
Mexico	ABS	0	0	0	**7**	0	7	1	**11**
	%	*8*	*7*	*7*	***1***	*2*	*22*	*3*	***3***
Argentina	ABS	2	15	4	**15**	0	13	1	**7**
	%	*6*	*7*	*7*	***1***	*1*	*14*	*2*	***1***
Brazil	ABS	3	10	13	**25**	1	24	15	**8**
	%	*7*	*8*	*9*	***1***	*2*	*8*	*4*	***0***
Belgium	ABS	11	4	8	**-2**	5	42	15	**-26**
	%	*5*	*6*	*6*	***0***	*1*	*5*	*3*	***-1***
Denmark	ABS	1	3	6	**5**	0	52	25	**41**
	%	*4*	*6*	*6*	***1***	*0*	*6*	*1*	***1***
France	ABS	0	11	32	**61**	0	37	41	**128**
	%	*na*	*7*	*2*	***2***	*na*	*7*	*3*	***3***
Germany	ABS	23	0	34	**43**	6	0	50	**-11**
	%	*6*	*na*	*7*	***2***	*2*	*na*	*3*	***0***
Italy	ABS	8	3	0	**13**	2	16	15	**31**
	%	*6*	*7*	*na*	***2***	*1*	*5*	*2*	***2***
Netherlands	ABS	-182	-186	-236	**-1013**	-55	-367	-504	**-1322**
	%	*-55*	*-55*	*-55*	***-54***	*-26*	*-26*	*-26*	***-26***
Rest of Asia	ABS	1	2	0	**13**	2	72	21	**137**
	%	*7*	*8*	*7*	***1***	*2*	*18*	*3*	***2***
Rest of South America	ABS	1	2	1	**11**	0	10	3	**15**
	%	*8*	*9*	*8*	***1***	*2*	*13*	*3*	***2***
Rest of EU	ABS	54	17	53	**148**	19	108	107	**249**
	%	*7*	*7*	*6*	***3***	*2*	*7*	*3*	***3***
Africa	ABS	1	2	0	**12**	1	9	3	**22**
	%	*7*	*8*	*6*	***2***	*2*	*16*	*3*	***3***
Rest of non-EU Europe	ABS	1	2	4	**17**	2	24	9	**46**
	%	*6*	*7*	*5*	***2***	*3*	*19*	*3*	***3***
Rest of the World	ABS	0	0	0	**3**	0	5	1	**7**
	%	*7*	*9*	*4*	***1***	*2*	*18*	*3*	***3***
Total	ABS	**-61**	**-95**	**-76**	**-564**	**-14**	**71**	**-187**	**-528**
	%	***-3***	***-6***	***-2***	***-2***	***-1***	***1***	***-1***	***-1***

Source: GTAP simulation

42 Absolute changes in USD 2004 mio. and per cent

International economic spillovers

205. Taking a step back, a more general view on the international economic consequences shall be taken in this section.

206. The analysis of international economic spill-over effects starts by looking at the bilateral border price effects of the partial trade ban imposed by importing countries. This is followed by a decomposition of national income effects, measured as Equivalent Variation (EV) [43].

207. Table 11 presents summary information on the tariff-equivalent of the imposed trade embargo[44]. The numbers are to be understood as the average *ad valorem* tariff that would yield the same reduction of bilateral trade as the actual trade ban being simulated[45], *i.e,* by *how much* would the border price for imports of the given commodity rise to produce the same pattern as the trade ban. The *ad-valorem* equivalent can thus be interpreted as an additional cost per unit of the imported good triggered by the trade ban.

208. For each country being affected by FMD, an average ad-valorem equivalent is calculated as an average across all importing countries. It is expressed in percentage terms, making it is easily comparable across products and across the different infected countries.

Table 11. *Ad-valorem* tariff equivalents of imposed trade ban adjusted for share of disease product in GTAP composite commodity

	stamping out			stamping out with regionalisation			vaccination to live			vaccination to live with regionalisation		
GTAP sector	USA	Canada	Netherlands	USA	Canada	Netherlands	USA	Canada	Netherlands	USA	Canada	Netherlands
Cattle	32	33	38	2	27	8	47	49	52	3	41	11
Pigs	147	58	50	44	44	24	208	77	71	63	60	33
Beef products	12	18	19	1	13	3	19	28	29	1	19	5
Pork products	13	16	21	4	8	9	19	24	30	5	11	13

Source: Calculations, based on GTAP simulations

209. The first observation to make is that the size to the tariff-equivalent can be substantial. An *ad valorem* tariff larger than 50%, as occurs under several of the scenarios, implies that, in the absence of an

43 The so-called equivalent variation (EV) measures what change in income would lead to the same level of utility as the proposed policy change, here the trade embargo. In other words, instead of effectuating a certain policy change how much income should be given to (or taken away from) households to achieve the same welfare. This measure informs us about the potential welfare change, but it does not inform us about distributive effects between different types of households. In fact, if the EV is positive, we know that enough resources are mobilized such that the winners from the policy move can potentially compensate the losers.

44 These ad-valorem equivalents are a result of post-model analysis, *not* part of the implemented shock. The trade ban is modelled as a trade ban, i.e. a restrictions on quantities traded.

45 Technically, these numbers are calculated as percentage shifts of the import demand functions that are sufficient to achieve the required reduction in bilateral imports. This is equivalent to an endogenous import-using technical change, just big enough to achieve a given exogenous reduction in bilateral imports.

effective trade ban, a price rise of 50% would be needed to divert imports away from the FMD affected source.

210. Second, the direct trade cost of banning trade is smaller for the standard control strategy of stamping-out. In the vaccination-to-live scenarios, the duration of the ban is longer, and hence the trade costs are higher.

211. Third, if regionalization is implemented and accepted by trading patterns, the additional cost of imports are reduced under both control strategies, as a smaller portion of total exports is affected by the ban and the disturbance of international markets is less marked.

212. Fourth, the average direct trade costs do not differ very much according to the country where the FMD outbreak occurs, but there are of course some differences in the bilateral cost that are hidden by averaging.[46] For example, Mexico sources over 60%[47] of its beef imports from the US and will therefore incur a higher cost than, say Belgium that imports virtually no beef from the US. For illustration, the adjusted tariff equivalent that would result in the same reduction of beef trade from the US to Mexico would be, in the case of stamping-out, about 19% for Mexico, compared to 12% on average.

213. The GTAP modeling system also provides insight into the economy-wide incomes effects, measured in terms of the EV. These are given in Table 12 in USD 2004 million, for each country, resulting from the chosen control strategy following the FMD outbreak. For the standard control strategy stamping-out the table shows the total EV and also isolates the terms-of-trade effect. GTAP provides information to which adjustment in the economy the welfare change can be attributed. The terms-of-trade effect is the component of EV that is attributable to changes in the ratio of export prices to import prices, weighted by export and import volumes. If the price of a country's export package increases relative to the price of its bundle of imports, the terms-of-trade improve, and they decline in the reverse situation[48].

214. Table 12 shows that there are losers as well as winners from a FMD outbreak. Taking the example of an FMD outbreak in the US, it can be seen that the biggest loser is the US itself. However, countries that import livestock products from the US are also adversely affected: for example Japan and Mexico would have to purchase their imports from other sources at higher prices and this would lead to a deterioration of their terms of trade. On the other hand, producers in countries that compete with US meat exports to these destinations and elsewhere would see an improvement in their terms of trade because of an increased demand for their products from countries that switch to them as import sources and because of the reduced meat supplies available on international markets.

215. A similar pattern can be observed in case of disease outbreaks in Canada and in the Netherlands, although the regional distribution of welfare effects differs because of differing existing trade patterns. The Netherlands export primarily to other EU member states, and therefore the welfare impact is mostly felt inside the EU. However some non-EU suppliers of livestock products would also in this case face improved terms of trade and concomitant positive income effects.

46 The one outlier is 'Other Animal Products'- composite that contains pigs from the USA. The reason is that pigs actually constitute a very small fraction (3%) of the GTAP composite, which is the aggregation level at which the calculations are performed. Since the fraction of pigs in the composite is in the dominator, the resulting tariff equivalent is large.

47 This figure corresponds to the GTAP base year, which is 2004. The share of imports that Mexico sources from the US has been rising since.

48 . As the welfare change attributable to the term-of-trade effect is only *one* of several components in the total welfare change, a positive terms-of-trade effect can be outweighed by negative effects in the other components, for example arising from inefficient resource allocation.

216. Another observation is that there are countries that have unambiguously negative total income effects, no matter in which country the outbreak takes place. Among this group, many net importers of beef and pork can be found, as for example Japan, Mexico[49] and Korea. A second country group can be identified that has unambiguously positive income effects. Large meat exporting countries like Australia and Brazil can be found in that country group, that experience positive changes in their terms-of-trade.

Box 3. Costs and benefits of zoning

Comparison of the welfare effects across scenarios provides some interesting insight on the economic benefits of zoning. For Canada, a pessimistic estimate of the costs of implementing regionalization is 76.8 million USD (Canadian Animal Health Coalition 2002). The national income losses that can be avoided through zoning are more than three times higher the cost of this administrational effort.

217. The calculated welfare effects in the country of the FMD outbreak are smaller than the estimated producer revenue losses presented above. One reason for this difference is that in the welfare calculations all direct and indirect market effects are taken into account. For example, while producers lose revenues, consumers and industry customers gain because of lower domestic prices. Another contributing factor is the so-called allocative efficiency effects. If the sector that is hit by an FMD outbreak is receiving output- or input-linked support, a decrease in production will be counted as an allocative gain, because it leads to lower deadweight losses associated with this kind of support.

218. Finally, it should be reiterated that the welfare assessment provided here is only partial as it does not take into account the benefit of avoiding production losses through exported contamination to the importing country.

49 Mexico was a net exporter of beef in 2007, but is projected to become a net importer again in 2008 (OECD-FAO 2008).

Table 12. Equivalent variation, stamping-out scenario (mio 2004 USD)

	USA		Canada		Netherlands	
	Total	of which Terms-of-Trade	Total	of which Terms-of-Trade	Total	of which Terms-of-Trade
Argentina	11	12	9	13	11	15
Australia	58	48	84	88	18	18
Belgium	8	10	3	6	-45	43
Brazil	63	67	48	56	23	28
Canada	-44	130	-945	-818	15	19
Denmark	45	43	50	50	52	60
France	45	28	6	15	82	114
Germany	2	2	-36	-4	-195	113
Italy	-12	-9	-32	-13	-33	66
Japan	-263	-35	-281	-44	-57	-22
Korea	-94	-20	-40	-19	-9	-3
Mexico	-308	-7	-88	-8	-7	-1
Netherlands	13	20	9	18	-888	-822
New Zealand	37	35	48	47	23	22
USA	-612	-437	-122	563	3	16
Africa	-2	3	-9	-1	-10	10
Rest of Asia	-107	6	-234	15	-56	13
Rest of South America	10	28	-2	10	1	5
Rest of European Union	-7	47	-52	27	111	293
Rest of Europe	-76	6	-42	-4	-29	11
Rest of the world	-16	23	-21	3	-2	1
World	-1248	0	-1647	-2	-990	-1

(dark grey) : Countries where EV is unambigously **negative**, to matter where epidemic
(light grey) : Countries where EV is unambigously **positive**, to matter where epidemic
(white) : Countries with mixed effect on EV

Source: GTAP simulation

Discussion of results

219. Models necessarily abstract from reality, so certain adjustment processes that can take place in reality are not taken into account. Premature slaughtering of animals in times where prices are extremely low, as mentioned earlier, could be one of these mechanisms. Governments could intervene, taking livestock products from the market and thereby alleviating the downward pressure on prices. Increased amounts of meat could be heat treated and thereby made a "safe" product to export, or conserved for later outlet to the market. However, in how far this would stabilize prices depends critically on the industry's capacity to expand processing and storage of a perishable and quality-wise highly sensitive good.

Box 4. Sensitivity to input parameters

As for any deterministic simulation exercise, the output depends crucially on the input parameters. The choice of these parameters has been outlined earlier in this section. But what if any of these parameters varied? Recalling the equation used to calculate exports in the year of the outbreak, it becomes clear the shock to exports is a function of two variables: The duration of the trade restrictions *t*, and the coefficient accounting for the region infected *r*. Varying these parameters, an infinite number of combinations can be found that would lead to the same shock on exports, and hence to the same model results as the ones presented earlier in this study.

An alternative approach was taken here to provide some indication how the most global variable, the global and national income loss evolves with the severity of the epidemic. The national and global income effects of the simulated outbreaks are presented in Figure 1. The four observations correspond to the four scenarios that have been simulated. For the scenarios including regionalization, the shocks imposed on the different livestock products were translated into a standardized indicator of the shock to meat exports.[50]. The indicator facilitates cross-country comparison, and is bounded from below by zero (no export effect).

Figure 1. Variation of income losses

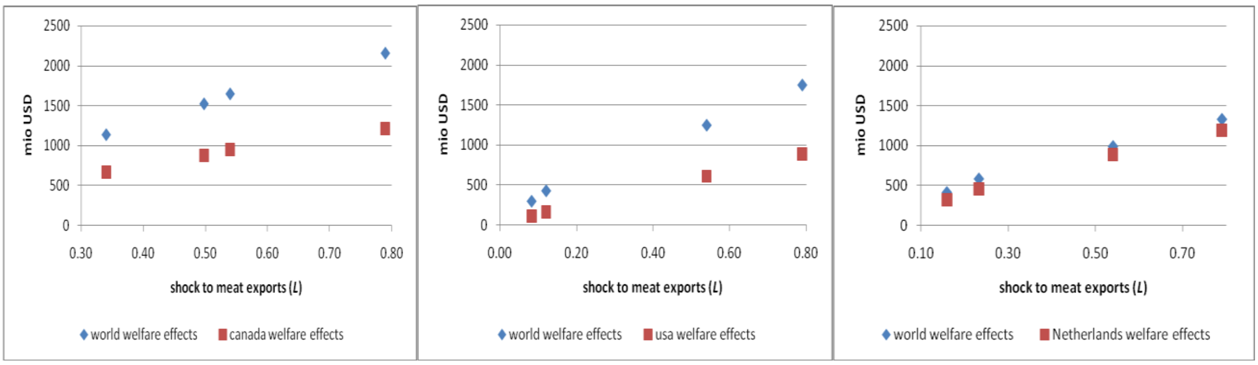


Figure 1 shows that the losses of national and global income exhibit a rather linear relation with the loss of export opportunities. Keeping in mind that the relationship is not perfectly linear, this allows extrapolation from the scenario results here. If any of the parameters used to determine the duration of the trade restrictions, i.e. the duration of the epidemic, the needed for compilation of documents and the waiting period changed (ceteris paribus), income losses would change almost linearly.

220. Another uncertainty in comparing the two strategies chosen here is the feasibility of vaccination and regionalization in a disease event. Both measures could be competing for limited resources in the veterinarian and related institutions. Vaccines or veterinarian staff could be a limiting factor in large epidemics. With regards to regionalization, concentrating resources on a swift control of the disease may have priority over establishing and controlling a disease-free zone.

221. The limited availability of information on the epidemiological development and the implied direct control costs made it impossible to carry out a full cost benefit analysis. Any ranking of control strategies given in the quantitative analysis relates to economic losses from the trade ban only. Though

50 This was done according to the following formula: $L = t \cdot (\sum_i ex_i^0 \cdot r_i) / \sum_i ex_i^0$ where L represents the "average" shock, *t* the duration of the trade ban, ex_1^0 the exports of a certain meat product in the base year, and *r* the share of that region in national exports (*r* is equal to one in all scenarios without regionalisation). The index *i* stands for different livestock products considered in this study.

these have been deemed to be the most important ones for large exporting countries, the order could theoretically be altered in a full cost analysis.

222. Simulating trade bans of less than one year with models relying on annual data as well simulating trade restrictions that concern only parts of a country in models that operate on a national basis necessarily introduces some approximation errors into the results. The approach that had to be taken to reflect zoning does not take into account that exporters from non-infected regions may increase their exports, thereby overestimating the impact of the trade restrictions. Similarly, the way the temporary export ban was implemented tends to overestimate the shock as exporters may be able to compensate for reduced exports as soon as the trade bans have been lifted. Also, the abstraction from slaughter for disease control purposes leads to an overestimation of the impacts of the trade ban, though this may not be highly relevant for the countries under study.

Conclusions

223. FMD is a wide spread phenomenon, and eradication is a goal for many countries in the world. Governments have a variety of tools at hand to fight FMD, whose application can be controversial under some circumstances. For most OECD countries, the discussion has been whether to vaccinate or not in response to FMD outbreaks. The motivation behind not vaccinating is an economic one: Unless all vaccinated animals are slaughtered and destroyed, vaccination will bring about a remarkably longer waiting period compared to the one when only stamping-out is applied.

224. The historical overview of FMD outbreaks in OECD and selected non member economies revealed two main points. First, with the exception of three countries, Turkey, Korea and the Netherlands, all infected OECD countries responded with stamping-out only. The Netherland applied a Vaccination-to-Die strategy more as an ad-hoc response to the lack of slaughtering facilities than as a general approach to follow. However, the permission of vaccination during the 2007 epidemic in the UK may indicate an increasing acceptance of vaccination against FMD.

225. The qualitative economic analysis carried out revealed the economic impacts of a vaccination-to-live strategy compared to stamping-out. Under some circumstances, vaccination-to-live can help to mitigate some of the domestic market turbulences caused by stamping-out. Less production may be lost, and consumers' reactions might be dampened. However, alternative control strategies, understood as alternatives to pure stamping-out, will in practice always extend the period until the disease-free status is regained. As mentioned earlier, this means that the period where the exporting country is likely to be faced with trade restrictions by trading partners is longer. In the past, the economic losses due to international trade have often been judged to be the most important ones in the context of animal disease outbreaks.

226. Three case studies have been carried out to quantify the economic impact of FMD related trade bans triggered by different control strategies in countries with different characteristics on both the domestic and the international market. Four scenarios have been simulated, a stamping-out strategy and a vaccination-to-live strategy, that differ by the length of the trade ban. Both control strategies have been combined with regionalization in order to quantify the possible gains of this additional administrative effort. Although an attempt has been made to provide insight on the non-markets cost of either control strategy, it was beyond the scope of this study to fully include these into the cost analysis. The same holds true for spill-over effects to other sectors that have been deemed to be important in the past, e.g. the impact on rural tourism (Thompson et al. 2002). The focus is thus on the direct meat product market costs related to the trade restrictions.

227. Not surprisingly, the shorter the trade ban triggered by the epidemic and control strategy chosen, the lower the disturbance on the market. For all countries, the lowest impact was found for a stamping-out

strategy with regionalization, and the highest one for a vaccination-to-live strategy without regionalization. However, the magnitude of the effect differs considerably across countries:

- For a country with a strong export orientation and pronounced net exporting position, any FMD outbreak, no matter the control strategy selected, causes severe damage to the industry.
- For a country with large exports, but at the same time a large domestic market, the disturbance to domestic markets is less pronounced as capacity exists to absorb redirected export product.
- Another crucial factor is the net-trade position of the country. If both imports and exports of the same commodity take place in significant scope, the cost of prolonging the trade ban to the domestic industry is less pronounced as imports are crowded out and part of the effect is exported.

228. With regards to regionalization it can be said that it always alleviates the cost to the industry conceivably, and the cost for implementing this regionalization has been found to be well below the figures of lost revenue to the sector in the case of Canada. Regionalization is the more interesting if the infected zone can be kept small. This may leave policy makers with a greater choice with regards to the control strategy chosen, since any adverse impact will be restricted to a small share of exports. However, this conclusion is only valid if regionalization completely insures a trade partner against the risk of imported infection and is accepted by them as satisfying this essential requirement

229. From an international perspective, the picture is more differentiated. While the infected country itself unarbitrarily loses in case of an outbreak, the welfare analysis shows that some countries can benefit from disease events and the resulting trade embargo. They will do so the more, the longer trade restrictions are in place. On the other hand, countries that import either from the infected country itself or from other sources are hit by the drop out of a main supplier and the consequent increase in international prices. For these importing countries, everything that speeds up the process of resuming trade with their main supplier is of interest. While the official declaration of disease free status is in the hand of the exporting country and the OIE, mutual agreements between trading partners may be worthwhile a consideration.

230. However, all statements with regards to the international impacts made here rely on the assumption that the importing country is not infected through trade of livestock products, *i.e.*,the benefit of an avoided outbreak is not taken into consideration. Accepting regionalization for example is unlikely to be beneficial for an importing country if it comes along with an epidemic of FMD in the own country. Moreover, no assumptions on consumers' reaction other than to market signals have been made. The picture may change if in addition to this, consumers' preferences are changed through the appearance on the disease or may even through the control strategy taken.

231. Finally, it should be kept in mind that in this analysis, the total trade embargo is a sum of the duration of the epidemic and the period before declaration of freedom of the disease. The total cost to the economy (measured through the income effects of the trade ban) exhibits an almost linear relationship with the length of the trade embargo. In other words, any change in either the duration of the epidemic or the duration of the trade restrictions would cause almost linear changes in national and global income.

ANNEX A.

CONTROL COSTS

Control cost in the US

232. For the U.S, the control costs whose order of magnitude could be gauged from existing studies are essentially the cost of cleansing and disinfection after slaughtering the infected herd, and the cost of destroyed feed. For vaccination, estimates for the cost of the vaccine as well as the labour required to administer it could be identified.

233. Cleaning and disinfection costs are to be understood as cleaning all contaminated material in a depopulated premise, including removing manure from corrals, haul carcasses and material to be burned, carcass disposal and labor costs (Ekboir 1999).

234. The estimated cost of quarantine enforcement around any infected premises is included too, though this particular cost can not be attributed to any specific control strategy. It is an additional cost arising from the establishment of check points and quarantine barriers around any infected farm.

Annex Table A.1. Control costs US

Cost Item	Region	Amount
Cleaning and Desinfection Cost[a]	Dairy Premise (USD)	82 246-136 740
	Feedlot (USD)	134 780
	Commercial hog operation (USD)	92 916
Destroyed Feed[a]	Dairy Premise (USD)	136 971-561 539
	Feedlot (USD)	908 693
	Commercial hog operation (USD)	25 000
Dose of Vaccine[b]	USD	1
Cost of Vaccination Team per day[b]	USD per day	2656
Quarantine Enforcement[a]	USD per day and checkpoint	5591
Zoning enforcement		n.a.

a) (Ekboir 1999)

b) (Bates, Carpenter & Thurmond 2003)

235. No estimates for the cost of enforcing zoning where available for the US. Most of the information available on costs related to FMD control strategies has been made for the State of California. It is questionable in how far these numbers are valid for regions with a different infrastructure and herd composition. Nevertheless, they may serve as an indication of the rank order and range of other costs involved in such outbreaks.

Control costs in the Netherlands

236. Other control costs for the Netherlands have been extracted from (Tomassen, F. H. M. et al. 2002)and are summarized in Table A.2. The cost items are given on a per animal basis.

237. The stamping-out organization costs refer to the cost related to diagnosing, valuing and killing the animal, cleansing and disinfection of the premise and the surveillance of the protection zone.

Annex Table A.2. Control Costs Netherlands

Cost Item[a]	Amount	
Stamping-out Organisation Cost	Dairy Cow (EUR)	136
	Sow (EUR)	68
	Fattening Pig (EUR)	18
Vaccination cost	Dairy Cow (EUR)	9
	Sow (EUR)	7
	Fattening Pig (EUR)	2
Movement restriction	Dairy Cow (EUR per day)	0.07
	Sow (EUR per day)	0.15
	Fattening Pig (EUR per day)	0.02
Zoning enforcement		n.a.

a) (Tomassen, F. H. M. et al. 2002)

238. The vaccination costs include labor and material for the vaccination teams.

The cost of movement restrictions refers to the cost for additional feed for maintenance, and other costs related to delayed delivery. No estimates of the cost of implementing zoning in the Netherlands could be found in the literature reviewed.

Control costs in Canada

239. A recent study carried out for the Canadian Animal Health Coalition (Canadian Animal Health Coalition 2002) provides information on the costs of a hypothetical outbreak of FMD in central Alberta. Three scenarios are considered, varying by the size of the outbreak, but not for the control strategy. While none of these matched directly the assumptions made in this study, extrapolations were made from the study, viewing the size and the duration as a continuum. The cost items are presented in Table A.3.

240. Some CAD 21 million are estimated for control and disposal of infected animals under a stamping-out strategy, including slaughter, cleaning and disinfection of premises, as well as disposing of feed and other contaminated material. The latter figure corresponds to about 30 000 animals stamped out and another 330 000 animals slaughtered for welfare reasons.[51] The authors find a total cost of detection and surveillance of the infected zone (including cost of inspection and control of livestock movements and administrative overheads) for an epidemic of 2 months of CAD 108 million.

51 The number of animals submitted to welfare slaughter is a result of the modelling exercise ((Canadian Animal Health Coalition 2002)p. ii).

Annex Table A.3. Control Costs Canada

Cost Item[a]		Amount
Control and disposal Cost	(CAD)	21,942,857
Detection and Surveillance	(CAD)	108,571,429
Vaccination cost		n.a.
Zoning enforcement	(CAD)	75,000,000 -100,000,000

a) (Canadian Animal Health Coalition 2002)

241. There is no analysis of costs of vaccination, but an estimate of the costs of zoning is given. They include, among others, the enforcement of border controls, adequate veterinary infrastructure by international standards, and the cost of establishing a system for tracking and tracing animal movements on national level (Canadian Animal Health Coalition 2002).

ANNEX B.

Annex Table B.1. Scenario parameters

USA	Stamping-Out Scenario	Vaccination-to-live Scenario
Location of Outbreak	IOWA	IOWA
Duration of the Epidemic (Months)	2	2
Duration of waiting period (Months)	3+1.5 = 4.5	6+1.5 = 7.5
Total duration of trade ban (Months)	2+4.5 = 6.5 (= 0.54 years)	2+7.5 = 9.5 (= 0.79 years)
Borders along which regionalisation is applied	IOWA	IOWA
Products affected by Trade ban	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals
CANADA	Stamping-Out Scenario	Vaccination-to-live Scenario
Location of Outbreak	ALBERTA	ALBERTA
Duration of the Epidemic (Months)	2	2
Duration of waiting period (Months)	3+1.5 = 4.5	6+1.5 = 7.5
Total duration of trade ban (Months)	2+4.5 = 6.5 (= 0.54 years)	2+7.5 = 9.5 (= 0.79 years)
Borders along which regionalisation is applied	MANITOBA-ONTARIO BORDER	MANITOBA-ONTARIO BORDER
Products affected by Trade ban	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals
NETHERLANDS	Stamping-Out Scenario	Vaccination-to-live Scenario
Location of Outbreak	North Brabant	North Brabant
Duration of the Epidemic (Months)	2	2
Duration of waiting period (Months)	3+1.5 = 4.5	6+1.5 = 7.5
Total duration of trade ban (Months)	2+4.5 = 6.5 (= 0.54 years)	2+7.5 = 9.5 (= 0.79 years)
Borders along which regionalisation is applied	North Brabant	North Brabant
Products affected by Trade ban	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals	Meat of Bovine and Porcine Animals, Live bovine and porcine Animals

Annex Table B.2. GTAP regional aggregation

GTAP region	Countries included
Australia	Australia
New Zealand	New Zealand
Japan	Japan
Korea	Korea
Canada	Canada
United States of America	United States of America
Mexico	Mexico
Argentina	Argentina
Brazil	Brazil
Belgium	Belgium
Denmark	Denmark
France	France
Germany	Germany
Italy	Italy
Netherlands	Netherlands
Rest of Asia	China, Hong Kong, Chinese Taipei, Rest of East Asia, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Rest of Southeast Asia, Bangladesh, India, Pakistan, Sri Lanka, Rest of South Asia, Kazakhstan, Kyrgyzstan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Iran Islamic Republic of, Rest of Western Asia
Rest of South America	Bolivia, Chile, Colombia, Ecuador, Paraguay, Peru ,Uruguay, Venezuela, Rest of South America
rest of EU	Austria ,Cyprus ,Czech Republic, Estonia, Finland ,Greece, Hungary ,Ireland, Latvia, Lithuania ,Luxembourg ,Malta ,Poland Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Switzerland ,Norway
Africa	Egypt, Morocco Tunisia Rest of North Africa Nigeria Senegal Rest of Western Africa Central Africa South Central Africa Madagascar Malawi Mauritius Mozambique Tanzania Uganda Zambia Zimbabwe Rest of Eastern Africa Botswana South Africa Rest of South African Customs
Rest of Europe	Rest of EFTA, Albania, Bulgaria, Belarus, Croatia, Romania, Russian Federation ,Ukraine, Rest of Eastern Europe, Rest of Europe, Turkey
Rest of the World	Rest of Oceania, Rest of North America, Costa Rica, Guatemala, Nicaragua, Rest of Central America, Caribbean

Annex Table B.3. GTAP sector aggregation[52]

Aggregate	GTAP sectors included
Wheat	Wheat
Cereal grains nec	Cereal grains nec
Oil seeds	Oil seeds
Bovine Cattle, sheep and goats, horses	Bovine Cattle, sheep and goats, horses
Animal products nec	Animal products nec
Raw milk	Raw milk
Bovine Meat Products	Bovine Meat Products
Meat products nec	Meat products nec
Dairy products	Dairy products
Trade	Trade
Recreational and other services	Recreational and other services
other primary agriculture	Paddy rice; Vegetables, fruit, nuts; Sugar cane, sugar beet; Plant-based fibers; Crops nec; Wool, silk-worm cocoons; Forestry; Fishing
other processed agriculture	Vegetable oils and fats; Processed rice; Sugar; Food products nec; Beverages and tobacco products
manufactures	Coal; Oil; Gas; Minerals nec; Textiles; Wearing apparel; Leather products; Wood products; Paper products, publishing; Petroleum, coal products; Chemical, rubber, plastic products; Mineral products nec; Ferrous metals; Metals nec; Metal products; Motor vehicles and parts; Transport equipment nec; Electronic equipment; Machinery and equipment nec; Manufactures nec
other services	Electricity; Gas manufacture, distribution; Water; Construction; Communication; Financial services nec; Insurance; Business services nec; Public Administration, Defense, Health, Education; Dwellings
transportation	Transport nec; Sea transport; Air transport

52 More detailed information is available at https://www.gtap.agecon.purdue.edu/databases/contribute/detailedsector.asp

Annex Table B.4. Shares of beef and pork exports in GTAP aggregate exports (*μ*)

Country	GTAP aggregate	Share of beef/pork exports in aggregate exports (μ)
USA	Bovine cattle, sheep and goats, horses	23%
	Animal products nec	3%
	Bovine meat products	72%
	Meat products nec	35%
Canada	Bovine cattle, sheep and goats, horses	92%
	Animal products nec	67%
	Bovine meat products	94%
	Meat products nec	72%
Netherlands	Bovine cattle, sheep and goats, horses	71%
	Animal products nec	44%
	Bovine meat products	96%
	Meat products nec	41%

Annex Table B.5. Factors used for shock calculations

r	USA	Canada	Netherlands
Cattle	4%	87%	17%
Pork	28%	38%	44%
Pigs	28%	73%	44%
Beef	4%	73%	17%
t			
stamping-out	54%	54%	54%
vaccination-to-live	79%	79%	79%

Annex Table B.6. Shares of beef and pork imports in GTAP aggregate imports

Country	GTAP aggregate	Share of beef/pork in aggregate imports
USA	Bovine cattle, sheeps and goats, horses	88%
	Animal products nec	68%
	Bovine meat products	88%
	Meat products nec	50%
Canada	Bovine cattle, sheeps and goats, horses	25%
	Animal products nec	1%
	Bovine meat products	82%
	Meat products nec	27%
Netherlands	Bovine cattle, sheeps and goats, horses	86%
	Animal products nec	18%
	Bovine meat products	90%
	Meat products nec	25%

Annex Table B.7. Trade effects of an outbreak in the U.S. fought by stamping-out with regionalization[53]

	Destination	JAPAN	CANADA	MEXICO	TOTAL	JAPAN	CANADA	MEXICO	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	3	0	1	**3**	2	0	0	**4**
	%	*0*	*1*	*2*	***0***	*1*	*4*	*3*	***0***
New Zealand	ABS	0	1	1	**1**	0	1	0	**6**
	%	*0*	*1*	*2*	***0***	*0*	*8*	*8*	***1***
Japan	ABS	0	0	0	**0**	0	0	0	**1**
	%	*na*	*1*	*2*	***0***	*na*	*10*	*25*	***1***
Korea	ABS	0	0	0	**0**	0	0	0	**1**
	%	*0*	*0*	*3*	***0***	*2*	*10*	*26*	***1***
Canada	ABS	0	0	7	**-1**	4	0	18	**-6**
	%	*0*	*na*	*2*	***0***	*1*	*na*	*26*	***0***
USA	ABS	-1	-2	-13	**-29**	-74	-39	-54	**-291**
	%	*-1*	*-1*	*-2*	***-1***	*-5*	*-4*	*-4*	***-4***
Mexico	ABS	0	0	0	**-1**	-6	0	0	**-9**
	%	*0*	*0*	*na*	***0***	*-3*	*4*	*na*	***-3***
Argentina	ABS	0	0	0	**1**	0	1	0	**2**
	%	*0*	*0*	*3*	***0***	*1*	*7*	*8*	***0***
Brazil	ABS	0	0	0	**-1**	12	4	0	**18**
	%	*0*	*0*	*2*	***0***	*2*	*11*	*25*	***0***
Belgium	ABS	0	0	0	**0**	0	0	0	**6**
	%	*0*	*1*	*1*	***0***	*2*	*6*	*28*	***0***
Denmark	ABS	0	0	0	**0**	25	1	1	**18**
	%	*0*	*1*	*2*	***0***	*2*	*9*	*26*	***0***
France	ABS	0	0	0	**2**	3	0	1	**19**
	%	*0*	*1*	*2*	***0***	*3*	*9*	*24*	***0***
Germany	ABS	0	0	0	**2**	0	0	0	**16**
	%	*0*	*1*	*1*	***0***	*1*	*6*	*25*	***0***
Italy	ABS	0	0	0	**1**	1	1	0	**8**
	%	*0*	*1*	*2*	***0***	*3*	*10*	*19*	***0***
Netherlands	ABS	0	0	0	**0**	1	1	0	**10**
	%	*0*	*1*	*1*	***0***	*2*	*4*	*12*	***0***
Rest of Asia	ABS	0	0	0	**2**	32	2	1	**60**
	%	*0*	*1*	*2*	***0***	*2*	*5*	*9*	***1***
Rest of South America	ABS	0	0	0	**0**	3	2	21	**24**
	%	*0*	*0*	*2*	***0***	*2*	*10*	*28*	***3***
Rest of EU	ABS	0	0	0	**4**	7	2	3	**49**
	%	*0*	*1*	*2*	***0***	*3*	*10*	*23*	***1***
Africa	ABS	0	0	0	**1**	0	0	0	**3**
	%	*0*	*1*	*2*	***0***	*1*	*6*	*16*	***0***
Rest of non-EU Europe	ABS	0	0	0	**1**	0	0	0	**6**
	%	*0*	*1*	*2*	***0***	*1*	*5*	*11*	***0***
Rest of the World	ABS	0	0	0	**0**	0	1	3	**5**
	%	*0*	*0*	*2*	***0***	*1*	*8*	*16*	***2***
Total	ABS	**3**	**0**	**-3**	**-16**	**10**	**-22**	**-5**	**-49**
	%	***0***	***0***	***0***	***0***	***0***	***-2***	***0***	***0***

Source: GTAP simulation

53. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.8. Trade effects of an outbreak in the U.S. fought by vaccination-to-live with regionalization[54]

	Destination	JAPAN	CANADA	MEXICO	TOTAL	JAPAN	CANADA	MEXICO	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	4.3	0.4	1.4	**3.8**	2.2	0.3	0.1	**5.2**
	%	*0*	*1*	*3*	***0***	*2*	*6*	*5*	***1***
New Zealand	ABS	0.7	1.2	1.7	**2.2**	0.2	1.1	0.2	**9.3**
	%	*0*	*1*	*3*	***0***	*0*	*11*	*12*	***1***
Japan	ABS	0.0	0.0	0.0	**0.0**	0.0	0.1	0.0	**1.5**
	%	*na*	*1*	*4*	***0***	*na*	*15*	*36*	***1***
Korea	ABS	0.0	0.0	0.0	**0.0**	0.4	0.1	0.0	**0.8**
	%	*0*	*0*	*3*	***-1***	*3*	*15*	*38*	***1***
Canada	ABS	0.0	0.0	9.9	**-1.3**	5.9	0.0	25.5	**-8.0**
	%	*0*	*na*	*3*	***0***	*1*	*na*	*38*	***0***
USA	ABS	-1.7	-3.0	-19.1	**-43.0**	-107.9	-57.5	-78.8	**-426.1**
	%	*-2*	*-2*	*-2*	***-2***	*-8*	*-6*	*-7*	***-6***
Mexico	ABS	-0.1	0.0	0.0	**-1.8**	-8.8	0.1	0.0	**-11.9**
	%	*0*	*0*	*na*	***0***	*-5*	*6*	*na*	***-4***
Argentina	ABS	0.0	0.0	0.0	**1.1**	0.2	0.8	0.0	**2.9**
	%	*0*	*1*	*3*	***0***	*2*	*10*	*12*	***1***
Brazil	ABS	0.0	0.0	0.0	**-1.7**	17.2	6.2	0.1	**26.2**
	%	*0*	*1*	*3*	***0***	*3*	*16*	*36*	***1***
Belgium	ABS	0.0	0.0	0.0	**0.7**	0.6	0.2	0.1	**9.1**
	%	*1*	*1*	*1*	***0***	*3*	*9*	*42*	***0***
Denmark	ABS	0.0	0.0	0.1	**0.2**	35.7	1.0	0.7	**26.9**
	%	*0*	*1*	*4*	***0***	*3*	*14*	*38*	***1***
France	ABS	0.0	0.0	0.0	**2.7**	3.8	0.6	0.9	**28.2**
	%	*1*	*1*	*3*	***0***	*4*	*13*	*36*	***1***
Germany	ABS	0.0	0.0	0.1	**2.9**	0.2	0.4	0.2	**23.3**
	%	*1*	*1*	*1*	***0***	*2*	*8*	*36*	***1***
Italy	ABS	0.0	0.0	0.0	**1.0**	1.2	1.0	0.5	**11.2**
	%	*1*	*1*	*3*	***0***	*4*	*15*	*28*	***1***
Netherlands	ABS	0.0	0.0	0.0	**0.5**	1.9	0.8	0.1	**14.3**
	%	*1*	*1*	*1*	***0***	*3*	*5*	*18*	***0***
Rest of Asia	ABS	0.1	0.0	0.0	**2.3**	47.1	3.5	1.9	**86.6**
	%	*1*	*1*	*3*	***0***	*3*	*7*	*14*	***1***
Rest of South Ar	ABS	0.0	0.5	0.6	**-0.7**	3.8	2.8	31.2	**35.2**
	%	*0*	*1*	*3*	***0***	*2*	*15*	*41*	***4***
Rest of EU	ABS	0.2	0.1	0.2	**5.4**	9.6	3.7	4.0	**71.5**
	%	*1*	*1*	*3*	***0***	*4*	*15*	*33*	***1***
Africa	ABS	0.0	0.0	0.0	**0.8**	0.3	0.4	0.4	**4.9**
	%	*1*	*1*	*3*	***0***	*1*	*10*	*24*	***1***
Rest of non-EU E	ABS	0.1	0.0	0.1	**0.8**	0.3	0.7	0.7	**9.2**
	%	*1*	*1*	*3*	***0***	*1*	*8*	*16*	***1***
Rest of the Worl	ABS	0.0	0.0	0.6	**0.2**	0.3	1.1	4.0	**7.5**
	%	*0*	*0*	*2*	***0***	*1*	*12*	*23*	***3***
Total	ABS	3.8	-0.6	-4.3	**-23.9**	14.3	-32.6	-8.2	**-72.3**
	%	***0***	***0***	***0***	***0***	***0***	***-3***	***-1***	***0***

Source: GTAP simulation

54. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.9. Trade effects of an outbreak in the U.S. fought by vaccination-to-live[55]

	Destination	JAPAN	CANADA	MEXICO	TOTAL	JAPAN	CANADA	MEXICO	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	20	8	30	**53**	8	1	0	**18**
	%	*1*	*16*	*68*	***1***	*6*	*24*	*20*	***2***
New Zealand	ABS	4	21	37	**60**	1	4	1	**28**
	%	*2*	*16*	*70*	***2***	*1*	*46*	*47*	***4***
Japan	ABS	0	0	0	**0**	0	1	0	**5**
	%	*na*	*19*	*80*	***1***	*na*	*63*	*135*	***4***
Korea	ABS	0	0	0	**0**	1	0	0	**2**
	%	*0*	*13*	*75*	***-1***	*9*	*60*	*141*	***3***
Canada	ABS	0	0	230	**124**	19	0	90	**-37**
	%	*0*	*na*	*71*	***6***	*3*	*na*	*135*	***-1***
USA	ABS	-39	-72	-464	**-1036**	-385	-205	-281	**-1517**
	%	*-35*	*-49*	*-56*	***-50***	*-27*	*-23*	*-23*	***-20***
Mexico	ABS	0	0	0	**-19**	-22	0	0	**-31**
	%	*-1*	*18*	*na*	***-3***	*-11*	*24*	*na*	***-9***
Argentina	ABS	0	0	0	**15**	1	3	0	**11**
	%	*3*	*20*	*70*	***1***	*7*	*42*	*48*	***2***
Brazil	ABS	0	0	0	**34**	59	25	0	**87**
	%	*3*	*17*	*80*	***2***	*9*	*65*	*134*	***2***
Belgium	ABS	1	0	1	**8**	2	1	1	**34**
	%	*13*	*27*	*19*	***1***	*11*	*36*	*162*	***1***
Denmark	ABS	0	0	2	**6**	128	4	3	**97**
	%	*4*	*19*	*80*	***1***	*12*	*56*	*143*	***2***
France	ABS	1	0	1	**34**	14	3	3	**105**
	%	*9*	*22*	*59*	***1***	*15*	*55*	*139*	***3***
Germany	ABS	1	1	1	**34**	1	2	1	**87**
	%	*12*	*28*	*19*	***1***	*6*	*33*	*140*	***2***
Italy	ABS	0	0	1	**13**	4	4	2	**42**
	%	*6*	*22*	*59*	***2***	*15*	*65*	*109*	***2***
Netherlands	ABS	0	0	0	**14**	7	3	0	**52**
	%	*9*	*28*	*19*	***1***	*12*	*20*	*69*	***1***
Rest of Asia	ABS	1	1	1	**38**	170	14	7	**313**
	%	*8*	*23*	*57*	***3***	*11*	*28*	*54*	***5***
Rest of South America	ABS	0	11	14	**24**	12	11	113	**126**
	%	*2*	*17*	*79*	***2***	*7*	*61*	*148*	***15***
Rest of EU	ABS	3	3	4	**75**	35	15	16	**263**
	%	*8*	*21*	*72*	***2***	*14*	*62*	*129*	***3***
Africa	ABS	1	1	1	**14**	1	2	1	**18**
	%	*8*	*23*	*62*	***2***	*5*	*39*	*92*	***2***
Rest of non-EU Europe	ABS	1	1	1	**17**	1	3	3	**33**
	%	*8*	*23*	*61*	***2***	*4*	*30*	*62*	***2***
Rest of the World	ABS	0	0	13	**15**	1	4	15	**27**
	%	*-1*	*14*	*50*	***5***	*5*	*48*	*86*	***10***
Total	ABS	**-6**	**-23**	**-127**	**-478**	**58**	**-104**	**-24**	**-239**
	%	***0***	***-5***	***-10***	***-1***	***1***	***-9***	***-2***	***0***

Source: GTAP simulation

55. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.10. Trade effects of an outbreak in Canada fought by stamping-out with regionalization[56]

	Destination	USA	MEXICO	Rest of ASIA	TOTAL	Australia	JAPAN	USA	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTs			
Australia	ABS	90	3	-13	**49**	0	0	3	**7**
	%	*6*	*7*	*-1*	***1***	*na*	*0*	*12*	***1***
New Zealand	ABS	72	5	1	**48**	1	0	11	**13**
	%	*9*	*10*	*0*	***2***	*5*	*0*	*14*	***2***
Japan	ABS	1	0	0	**1**	0	0	1	**3**
	%	*10*	*12*	*2*	***3***	*8*	*na*	*12*	***3***
Korea	ABS	0	0	0	**0**	0	0	1	**2**
	%	*10*	*13*	*1*	***1***	*7*	*2*	*19*	***3***
Canada	ABS	-511	-128	-43	**-783**	-16	-108	-453	**-794**
	%	*-40*	*-40*	*-40*	***-40***	*-18*	*-18*	*-24*	***-23***
USA	ABS	0	90	1	**70**	1	25	0	**-34**
	%	*na*	*11*	*0*	***3***	*5*	*2*	*na*	***0***
Mexico	ABS	18	0	0	**19**	0	4	11	**15**
	%	*3*	*na*	*0*	***3***	*2*	*2*	*17*	***4***
Argentina	ABS	0	0	3	**6**	0	0	10	**8**
	%	*6*	*11*	*2*	***1***	*2*	*1*	*10*	***2***
Brazil	ABS	1	0	11	**15**	0	11	37	**22**
	%	*8*	*13*	*2*	***1***	*6*	*2*	*13*	***0***
Belgium	ABS	1	0	1	**4**	0	1	2	**13**
	%	*7*	*4*	*2*	***0***	*6*	*3*	*14*	***0***
Denmark	ABS	0	0	2	**2**	8	23	24	**36**
	%	*6*	*13*	*2*	***0***	*8*	*2*	*10*	***1***
France	ABS	2	0	1	**16**	0	3	5	**37**
	%	*9*	*10*	*1*	***1***	*8*	*4*	*16*	***1***
Germany	ABS	3	0	1	**17**	0	0	5	**35**
	%	*6*	*4*	*1*	***1***	*7*	*2*	*18*	***1***
Italy	ABS	1	0	0	**7**	0	1	6	**14**
	%	*11*	*10*	*3*	***1***	*7*	*3*	*11*	***1***
Netherlands	ABS	2	0	1	**8**	1	2	5	**25**
	%	*5*	*4*	*3*	***0***	*9*	*3*	*16*	***0***
Rest of Asia	ABS	3	0	15	**19**	1	35	116	**195**
	%	*9*	*9*	*1*	***2***	*3*	*2*	*22*	***3***
Rest of South America	ABS	33	2	1	**27**	0	4	10	**16**
	%	*10*	*12*	*1*	***3***	*8*	*2*	*18*	***2***
Rest of EU	ABS	11	1	4	**45**	1	9	35	**107**
	%	*8*	*12*	*2*	***1***	*9*	*3*	*15*	***1***
Africa	ABS	2	0	3	**7**	0	0	8	**16**
	%	*10*	*10*	*1*	***1***	*5*	*2*	*21*	***2***
Rest of non-EU Europe	ABS	3	0	1	**9**	0	0	13	**25**
	%	*10*	*10*	*1*	***1***	*5*	*2*	*21*	***2***
Rest of the World	ABS	8	2	0	**12**	0	0	3	**5**
	%	*10*	*8*	*1*	***4***	*5*	*2*	*18*	***2***
Total	ABS	**-261**	**-23**	**-9**	**-403**	**-3**	**11**	**-148**	**-235**
	%	***-5***	***-2***	***0***	***-1***	***-1***	***0***	***-4***	***0***

Source: GTAP simulation

56. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.11. Trade effects of an outbreak in Canada fought by vaccination-to-live with regionalization[57]

	Destination	USA	MEXICO	Rest of ASIA	TOTAL	Australia	JAPAN	USA	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	129	5	-18	**71**	0	0	4	**10**
	%	*9*	*10*	*-1*	***1***	*na*	*0*	*17*	***1***
New Zealand	ABS	104	7	1	**70**	2	0	16	**18**
	%	*13*	*14*	*0*	***2***	*7*	*0*	*19*	***3***
Japan	ABS	1	0	0	**1**	0	0	1	**4**
	%	*14*	*18*	*2*	***5***	*12*	*na*	*17*	***4***
Korea	ABS	0	0	0	**0**	0	0	1	**2**
	%	*15*	*19*	*2*	***2***	*10*	*3*	*26*	***4***
Canada	ABS	-729	-183	-61	**-1118**	-23	-153	-634	**-1113**
	%	*-57*	*-57*	*-57*	***-57***	*-25*	*-25*	*-33*	***-32***
USA	ABS	0	129	1	**103**	1	36	0	**-38**
	%	*na*	*16*	*0*	***5***	*7*	*3*	*na*	***-1***
Mexico	ABS	26	0	0	**27**	0	5	15	**21**
	%	*5*	*na*	*0*	***5***	*3*	*3*	*24*	***6***
Argentina	ABS	1	0	4	**8**	0	0	14	**11**
	%	*9*	*16*	*3*	***1***	*3*	*2*	*14*	***2***
Brazil	ABS	1	0	16	**21**	0	15	53	**31**
	%	*12*	*19*	*3*	***1***	*9*	*2*	*18*	***1***
Belgium	ABS	1	0	1	**6**	0	1	2	**18**
	%	*10*	*6*	*3*	***1***	*9*	*4*	*20*	***1***
Denmark	ABS	0	0	3	**4**	11	33	34	**50**
	%	*9*	*18*	*3*	***1***	*12*	*3*	*14*	***1***
France	ABS	2	0	1	**22**	0	5	7	**52**
	%	*12*	*14*	*2*	***1***	*11*	*5*	*23*	***1***
Germany	ABS	4	0	2	**24**	0	0	7	**49**
	%	*8*	*6*	*1*	***1***	*11*	*3*	*25*	***1***
Italy	ABS	2	0	1	**9**	0	1	8	**20**
	%	*16*	*15*	*4*	***2***	*11*	*5*	*16*	***1***
Netherlands	ABS	3	0	2	**11**	1	2	8	**36**
	%	*8*	*5*	*4*	***1***	*14*	*4*	*22*	***1***
Rest of Asia	ABS	4	0	21	**27**	1	50	162	**273**
	%	*13*	*13*	*2*	***2***	*5*	*3*	*31*	***4***
Rest of South Ar	ABS	48	3	2	**41**	1	6	14	**23**
	%	*15*	*18*	*2*	***4***	*11*	*3*	*26*	***3***
Rest of EU	ABS	16	1	6	**66**	2	12	49	**151**
	%	*12*	*17*	*3*	***1***	*13*	*5*	*21*	***2***
Africa	ABS	3	0	5	**11**	0	1	12	**23**
	%	*14*	*15*	*2*	***2***	*7*	*3*	*29*	***3***
Rest of non-EU E	ABS	4	0	1	**12**	1	1	18	**35**
	%	*14*	*15*	*2*	***2***	*7*	*2*	*29*	***3***
Rest of the Worl	ABS	12	3	0	**18**	0	1	4	**7**
	%	*14*	*11*	*1*	***6***	*7*	*3*	*26*	***2***
Total	ABS	**-370**	**-32**	**-13**	**-564**	**-4**	**16**	**-207**	**-318**
	%	***-8***	***-2***	***0***	***-2***	***-1***	***0***	***-5***	***-1***

Source: GTAP simulation

57. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.12. Trade effects of an outbreak in Canada fought by vaccination-to-live[58]

	Destination	USA	MEXICO	Rest of ASIA	TOTAL	Australia	JAPAN	USA	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	174	6	-25	**99**	0	0	7	**9**
	%	*12*	*14*	*-2*	***2***	*na*	*0*	*30*	***1***
New Zealand	ABS	141	10	0	**95**	4	1	29	**33**
	%	*18*	*18*	*0*	***3***	*16*	*1*	*35*	***5***
Japan	ABS	1	0	0	**1**	0	0	2	**6**
	%	*20*	*24*	*3*	***6***	*28*	*na*	*35*	***5***
Korea	ABS	0	0	0	**0**	0	1	1	**4**
	%	*20*	*25*	*3*	***2***	*25*	*7*	*40*	***6***
Canada	ABS	-972	-245	-81	**-1488**	-55	-363	-1146	**-2045**
	%	*-76*	*-76*	*-76*	***-76***	*-60*	*-60*	*-60*	***-60***
USA	ABS	0	174	1	**141**	3	100	0	**0**
	%	*na*	*21*	*0*	***7***	*17*	*7*	*na*	***0***
Mexico	ABS	34	0	0	**36**	0	12	24	**37**
	%	*6*	*na*	*1*	***6***	*4*	*6*	*38*	***11***
Argentina	ABS	1	0	5	**11**	0	0	30	**24**
	%	*12*	*22*	*5*	***1***	*3*	*3*	*32*	***5***
Brazil	ABS	1	0	21	**26**	0	37	99	**65**
	%	*17*	*25*	*4*	***1***	*21*	*6*	*34*	***1***
Belgium	ABS	2	0	2	**9**	0	1	4	**31**
	%	*13*	*7*	*5*	***1***	*21*	*8*	*39*	***1***
Denmark	ABS	1	0	4	**5**	26	71	80	**106**
	%	*12*	*25*	*5*	***1***	*28*	*7*	*33*	***2***
France	ABS	3	0	2	**31**	1	10	12	**90**
	%	*17*	*20*	*2*	***1***	*27*	*11*	*40*	***2***
Germany	ABS	6	0	2	**34**	0	1	11	**82**
	%	*11*	*7*	*2*	***1***	*24*	*5*	*41*	***2***
Italy	ABS	2	0	1	**13**	0	3	19	**40**
	%	*22*	*20*	*6*	***2***	*24*	*10*	*38*	***2***
Netherlands	ABS	3	0	3	**15**	2	5	13	**59**
	%	*10*	*7*	*5*	***1***	*33*	*9*	*40*	***1***
Rest of Asia	ABS	5	0	29	**38**	2	112	221	**428**
	%	*18*	*18*	*3*	***3***	*9*	*7*	*42*	***7***
Rest of South America	ABS	65	4	3	**57**	1	14	22	**41**
	%	*21*	*24*	*2*	***5***	*28*	*8*	*39*	***5***
Rest of EU	ABS	22	1	8	**90**	4	25	93	**268**
	%	*16*	*23*	*4*	***2***	*30*	*10*	*40*	***3***
Africa	ABS	3	0	7	**15**	0	1	17	**34**
	%	*19*	*20*	*3*	***2***	*14*	*4*	*42*	***4***
Rest of non-EU Europe	ABS	5	0	2	**17**	1	1	26	**52**
	%	*19*	*20*	*2*	***2***	*15*	*4*	*42*	***4***
Rest of the World	ABS	17	4	0	**24**	1	1	6	**11**
	%	*19*	*15*	*1*	***8***	*17*	*6*	*39*	***4***
Total	ABS	**-485**	**-43**	**-17**	**-732**	**-9**	**34**	**-430**	**-626**
	%	***-10***	***-3***	***0***	***-2***	***-3***	***1***	***-11***	***-1***

Source: GTAP simulation

58. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.13. Trade effects of an outbreak in the Netherlands fought by stamping-out with regionalization[59]

	Destination	FRANCE	GERMANY	ITALY	TOTAL	FRANCE	GERMANY	Rest EU	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	0.0	0.0	0.0	**3.8**	-0.2	-0.2	-0.1	**5.2**
	%	0	0	0	**0**	-1	-1	0	**1**
New Zealand	ABS	-0.3	-0.2	0.0	**2.2**	-0.1	-0.1	-0.2	**9.3**
	%	0	0	0	**0**	0	0	0	**1**
Japan	ABS	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	**1.5**
	%	0	0	0	**0**	0	-1	-1	**1**
Korea	ABS	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	**0.8**
	%	-1	-1	-1	**-1**	-1	-1	-1	**1**
Canada	ABS	-0.1	0.0	0.0	**-1.3**	-0.1	-0.1	-0.3	**-8.0**
	%	-1	0	0	**0**	-1	0	-1	**0**
USA	ABS	-0.4	-0.3	-0.2	**-43.0**	-1.1	-1.5	-10.0	**-426.1**
	%	-2	-2	-2	**-2**	-2	-3	-6	**-6**
Mexico	ABS	0.0	0.0	0.0	**-1.8**	0.0	0.0	0.0	**-11.9**
	%	-1	0	0	**0**	0	0	0	**-4**
Argentina	ABS	0.0	0.0	0.0	**1.1**	0.0	0.0	-0.1	**2.9**
	%	0	0	0	**0**	0	0	0	**1**
Brazil	ABS	-0.1	-0.3	-0.4	**-1.7**	-0.4	-3.4	-5.1	**26.2**
	%	0	0	0	**0**	-1	-1	-1	**1**
Belgium	ABS	0.1	0.0	0.0	**0.7**	0.1	1.2	0.6	**9.1**
	%	0	0	0	**0**	0	0	0	**0**
Denmark	ABS	0.0	0.0	-0.1	**0.2**	-1.0	-4.9	-11.4	**26.9**
	%	0	0	0	**0**	-1	-1	-1	**1**
France	ABS	0.0	0.2	0.6	**2.7**	0.0	1.5	3.2	**28.2**
	%	na	0	0	**0**	na	0	0	**1**
Germany	ABS	0.3	0.0	0.4	**2.9**	0.9	0.0	5.4	**23.3**
	%	0	na	0	**0**	0	na	0	**1**
Italy	ABS	0.1	0.1	0.0	**1.0**	0.6	1.1	1.9	**11.2**
	%	0	0	na	**0**	0	0	0	**1**
Netherlands	ABS	0.0	0.1	-0.1	**0.5**	0.0	2.3	1.2	**14.3**
	%	0	0	0	**0**	0	0	0	**0**
Rest of Asia	ABS	0.0	0.0	0.0	**2.3**	0.1	0.5	0.0	**86.6**
	%	0	0	0	**0**	0	0	0	**1**
Rest of South America	ABS	-0.1	-0.1	0.0	**-0.7**	-0.2	-0.7	-1.2	**35.2**
	%	0	0	0	**0**	-1	-1	-1	**4**
Rest of EU	ABS	0.5	0.3	0.5	**5.4**	2.6	5.2	10.8	**71.5**
	%	0	0	0	**0**	0	0	0	**1**
Africa	ABS	0.0	0.0	0.0	**0.8**	0.2	0.2	0.2	**4.9**
	%	0	0	0	**0**	0	0	0	**1**
Rest of non-EU Europe	ABS	0.0	0.0	0.0	**0.8**	-0.3	0.2	-0.2	**9.2**
	%	0	0	0	**0**	0	0	0	**1**
Rest of the World	ABS	0.0	0.0	0.0	**0.2**	-0.1	-0.1	-0.3	**7.5**
	%	-1	0	0	**0**	-1	-1	-1	**3**
Total	ABS	-0.1	-0.2	0.6	**-23.9**	0.9	1.0	-5.5	**-72.3**
	%	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Source: GTAP simulation

59. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.14. Trade effects of an outbreak in the Netherlands fought by vaccination-to-live with regionalization[60]

	Destination	FRANCE	GERMANY	ITALY	TOTAL	FRANCE	GERMANY	Rest EU	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	0.3	0.1	0.0	**4.2**	0.3	1.4	0.4	**5**
	%	*2*	*2*	*2*	***0***	*1*	*8*	*2*	***0***
New Zealand	ABS	2.8	3.9	0.6	**8.9**	0.3	3.3	1.1	**7**
	%	*2*	*2*	*2*	***0***	*1*	*5*	*2*	***1***
Japan	ABS	0.0	0.1	0.0	**0.1**	0.0	0.1	0.1	**1**
	%	*2*	*2*	*2*	***1***	*2*	*4*	*3*	***1***
Korea	ABS	0.0	0.0	0.0	**0.0**	0.0	0.1	0.1	**1**
	%	*2*	*2*	*3*	***0***	*2*	*5*	*3*	***1***
Canada	ABS	0.5	0.2	0.1	**1.9**	0.1	3.7	0.8	**16**
	%	*2*	*2*	*2*	***0***	*1*	*14*	*2*	***0***
USA	ABS	0.4	0.3	0.2	**5.9**	0.9	4.7	4.9	**57**
	%	*2*	*2*	*2*	***0***	*2*	*11*	*3*	***1***
Mexico	ABS	0.0	0.0	0.0	**1.9**	0.0	4.9	0.3	**7**
	%	*2*	*2*	*2*	***0***	*2*	*15*	*2*	***2***
Argentina	ABS	0.5	4.1	1.1	**4.2**	0.1	8.3	0.7	**5**
	%	*2*	*2*	*2*	***0***	*1*	*9*	*1*	***1***
Brazil	ABS	0.7	2.6	3.4	**5.0**	0.5	15.7	9.9	**8**
	%	*2*	*2*	*2*	***0***	*1*	*5*	*2*	***0***
Belgium	ABS	3.2	1.1	2.2	**-1.0**	2.4	26.4	8.8	**-13**
	%	*1*	*2*	*2*	***0***	*1*	*3*	*2*	***0***
Denmark	ABS	0.2	0.8	1.6	**1.3**	0.1	34.7	16.0	**28**
	%	*1*	*1*	*2*	***0***	*0*	*4*	*1*	***1***
France	ABS	0.0	3.0	8.8	**16.8**	0.0	24.4	26.2	**86**
	%	*na*	*2*	*1*	***1***	*na*	*5*	*2*	***2***
Germany	ABS	6.4	0.0	9.3	**11.0**	3.4	0.0	30.8	**0**
	%	*2*	*na*	*2*	***0***	*1*	*na*	*2*	***0***
Italy	ABS	2.2	0.9	0.0	**3.5**	1.6	10.6	9.6	**21**
	%	*2*	*2*	*na*	***1***	*1*	*3*	*1*	***1***
Netherlands	ABS	-49.1	-50.1	-63.5	**-273.5**	-35.8	-239.3	-327.4	**-861**
	%	*-15*	*-15*	*-15*	***-15***	*-17*	*-17*	*-17*	***-17***
Rest of Asia	ABS	0.2	0.4	0.1	**3.7**	1.4	47.8	13.6	**91**
	%	*2*	*2*	*2*	***0***	*2*	*12*	*2*	***1***
Rest of South America	ABS	0.3	0.6	0.2	**2.9**	0.2	6.6	2.0	**10**
	%	*2*	*2*	*2*	***0***	*1*	*9*	*2*	***1***
Rest of EU	ABS	14.2	4.4	13.9	**37.2**	12.5	72.6	69.9	**170**
	%	*2*	*2*	*2*	***1***	*1*	*5*	*2*	***2***
Africa	ABS	0.3	0.5	0.1	**3.2**	0.9	6.3	2.2	**15**
	%	*2*	*2*	*1*	***0***	*1*	*11*	*2*	***2***
Rest of non-EU Europe	ABS	0.3	0.5	1.0	**4.5**	1.3	16.3	5.7	**31**
	%	*2*	*2*	*1*	***1***	*2*	*13*	*2*	***2***
Rest of the World	ABS	0.0	0.1	0.1	**0.8**	0.1	3.0	0.7	**5**
	%	*2*	*2*	*1*	***0***	*2*	*12*	*2*	***2***
Total	ABS	**-17**	**-26**	**-21**	**-157**	**-10**	**52**	**-123**	**-310**
	%	***-1***	***-2***	***-1***	***0***	***0***	***1***	***-1***	***-1***

Source: GTAP simulation

60. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.15. Trade effects of an outbreak in the Netherlands fought by vaccination-to-live[61]

	Destination	FRANCE	GERMANY	ITALY	TOTAL	FRANCE	GERMANY	Rest EU	TOTAL
Source		BEEF and BEEF PRODUCTS				PORK and PORK PRODUCTS			
Australia	ABS	3	1	0	**432**	2	4	3	**97**
	%	*16*	*18*	*17*	***8***	*8*	*23*	*13*	***9***
New Zealand	ABS	24	32	5	**227**	2	12	6	**74**
	%	*15*	*16*	*16*	***7***	*9*	*18*	*12*	***11***
Japan	ABS	0	0	0	**1**	0	0	0	**10**
	%	*12*	*16*	*16*	***7***	*12*	*16*	*12*	***8***
Korea	ABS	0	0	0	**0**	0	0	0	**4**
	%	*11*	*13*	*14*	***5***	*5*	*11*	*9*	***7***
Canada	ABS	4	1	1	**52**	1	11	4	**135**
	%	*15*	*14*	*13*	***3***	*11*	*41*	*9*	***4***
USA	ABS	3	2	1	**111**	6	13	23	**492**
	%	*14*	*13*	*13*	***5***	*12*	*31*	*13*	***7***
Mexico	ABS	0	0	0	**16**	0	16	2	**39**
	%	*13*	*11*	*10*	***3***	*5*	*48*	*14*	***12***
Argentina	ABS	4	34	9	**86**	2	30	8	**56**
	%	*13*	*16*	*16*	***8***	*13*	*33*	*12*	***11***
Brazil	ABS	6	22	30	**176**	3	51	43	**233**
	%	*15*	*18*	*20*	***8***	*8*	*16*	*10*	***5***
Belgium	ABS	18	6	13	**14**	11	72	30	**8**
	%	*8*	*10*	*9*	***2***	*3*	*8*	*5*	***0***
Denmark	ABS	1	6	9	**22**	2	82	66	**186**
	%	*7*	*10*	*9*	***4***	*1*	*9*	*4*	***4***
France	ABS	0	18	56	**124**	0	60	77	**276**
	%	*na*	*10*	*4*	***4***	*na*	*11*	*6*	***7***
Germany	ABS	36	0	51	**111**	15	0	102	**81**
	%	*10*	*na*	*11*	***5***	*4*	*na*	*6*	***2***
Italy	ABS	13	5	0	**31**	10	30	35	**92**
	%	*10*	*11*	*na*	***6***	*4*	*9*	*5*	***5***
Netherlands	ABS	-256	-261	-332	**-1421**	-77	-511	-697	**-1824**
	%	*-77*	*-77*	*-78*	***-76***	*-36*	*-37*	*-36*	***-36***
Rest of Asia	ABS	1	3	1	**301**	6	123	52	**478**
	%	*12*	*13*	*10*	***24***	*7*	*31*	*9*	***8***
Rest of South America	ABS	3	5	1	**93**	2	21	11	**79**
	%	*16*	*18*	*15*	***9***	*12*	*29*	*12*	***9***
Rest of EU	ABS	95	27	88	**312**	40	175	226	**601**
	%	*12*	*11*	*10*	***7***	*4*	*12*	*7*	***6***
Africa	ABS	2	4	1	**138**	6	17	11	**77**
	%	*14*	*15*	*9*	***22***	*9*	*29*	*10*	***10***
Rest of non-EU Europe	ABS	4	3	27	**127**	6	44	25	**148**
	%	*24*	*11*	*31*	***16***	*8*	*34*	*10*	***11***
Rest of the World	ABS	0	1	1	**17**	0	9	3	**27**
	%	*11*	*12*	*7*	***6***	*7*	*37*	*10*	***10***
Total	ABS	**-39**	**-91**	**-38**	**971**	**37**	**261**	**30**	**1367**
	%	***-2***	***-6***	***-1***	***3***	***1***	***4***	***0***	***2***

Source: GTAP simulation.

61. Changes in export/import value. Absolute changes are in mio. 2004 USD.

Annex Table B.16. Equivalent variation, stamping-out scenario (mio 2004 USD)

	outbreak in USA					outbreak in Canada					outbreak in the Netherlands				
	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**
Argentina	1	0	12	-2	**11**	1	0	13	-4	**9**	0	0	15	-4	**11**
Australia	4	-1	48	7	**58**	5	-13	88	4	**84**	0	-1	18	0	**18**
Belgium	-2	-1	10	1	**8**	-1	-2	6	0	**3**	2	-89	43	-1	**-45**
Brasil	6	-2	67	-8	**63**	5	0	56	-12	**48**	2	-1	28	-7	**23**
Canada	-54	-122	130	2	**-44**	-184	0	-818	57	**-945**	3	-4	19	-3	**15**
Denmark	3	-1	43	-1	**45**	4	-1	50	-4	**50**	18	-23	60	-3	**52**
France	12	-3	28	7	**45**	1	-7	15	-3	**6**	41	-72	114	0	**82**
Germany	-7	-3	2	9	**2**	-11	-13	-4	-8	**-36**	23	-327	113	-4	**-195**
Italy	-6	-3	-9	5	**-12**	-8	-8	-13	-2	**-32**	28	-127	66	0	**-33**
Japan	-128	-127	-35	27	**-263**	-95	-133	-44	-9	**-281**	-19	-10	-22	-7	**-57**
Korea	0	-92	-20	18	**-94**	-3	-17	-19	0	**-40**	0	-3	-3	-2	**-9**
Mexico	-60	-245	-7	4	**-308**	-23	-57	-8	-1	**-88**	-4	-1	-1	-1	**-7**
Netherlands	-7	-1	20	2	**13**	-6	-1	18	-2	**9**	-118	0	-822	52	**-888**
New Zealand	3	-1	35	0	**37**	4	-2	47	-2	**48**	2	0	22	-1	**23**
USA	-24	0	-437	-151	**-612**	2	-723	563	35	**-122**	-8	-13	16	8	**3**
Africa	-1	-7	3	2	**-2**	-2	-4	-1	-3	**-9**	-2	-15	10	-2	**-10**
Rest of Asia	-62	-97	6	47	**-107**	-44	-174	15	-30	**-234**	-15	-36	13	-19	**-56**
Rest of South America	-3	-8	28	-7	**10**	-1	-3	10	-7	**-2**	0	-1	5	-4	**1**
Rest of European Union	-58	-21	47	24	**-7**	-46	-25	27	-8	**-52**	66	-247	293	0	**111**
Rest of Europe	-43	-45	6	6	**-76**	-21	-13	-4	-4	**-42**	-17	-20	11	-3	**-29**
Rest of the World	-9	-35	23	6	**-16**	-10	-16	3	2	**-21**	-1	-3	1	1	**-2**
World	-433	-815	0	0	**-1248**	-434	-1211	-2	0	**-1647**	3	-992	-1	0	**-990**

* change in effective border price

Source: GTAP simulation

Annex Table B.17. Equivalent variation, stamping-out scenario with regionalisation (mio 2004 USD)

	outbreak in USA					outbreak in Canada					outbreak in the Netherlands				
	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**
Argentina	0	0	2	0	**2**	0	0	8	-2	**6**	0	0	5	-1	**4**
Australia	0	0	6	1	**7**	4	-7	63	3	**63**	0	0	6	0	**6**
Belgium	0	0	2	0	**2**	-1	-2	4	0	**2**	0	-37	16	0	**-21**
Brasil	2	0	15	-2	**15**	3	0	33	-7	**28**	1	0	11	-2	**9**
Canada	-17	-32	24	1	**-25**	-127	0	-571	37	**-660**	1	-2	8	-1	**6**
Denmark	1	0	11	0	**12**	2	0	27	-2	**27**	6	-8	25	-1	**23**
France	2	-1	6	1	**9**	1	-5	11	-2	**5**	11	-21	37	0	**27**
Germany	-1	0	-1	2	**-1**	-6	-10	0	-5	**-22**	1	-145	37	0	**-108**
Italy	-1	-1	-2	1	**-2**	-5	-6	-9	-1	**-21**	5	-43	23	0	**-16**
Japan	-34	-33	-9	5	**-71**	-46	-77	-24	-7	**-155**	-7	-4	-8	-3	**-22**
Korea	1	-28	-6	5	**-28**	-2	-12	-13	0	**-27**	0	-2	-1	-1	**-4**
Mexico	-16	-54	-2	1	**-71**	-16	-42	-2	0	**-60**	-2	0	-1	0	**-3**
Netherlands	-1	0	4	0	**3**	-3	-1	12	-2	**6**	-40	0	-298	17	**-321**
New Zealand	1	0	5	0	**5**	3	-1	33	-1	**34**	1	0	6	0	**6**
USA	-3	0	-80	-28	**-111**	2	-529	386	23	**-118**	-2	-4	9	5	**8**
Africa	-1	-1	0	0	**-1**	-1	-3	0	-2	**-6**	0	-6	4	-1	**-4**
Rest of Asia	-14	-22	4	8	**-24**	-29	-131	15	-20	**-166**	-6	-14	6	-8	**-22**
Rest of South America	0	-1	6	-2	**3**	-1	-2	6	-5	**-1**	0	0	2	-1	**1**
Rest of European Union	-9	-3	8	4	**1**	-31	-19	20	-5	**-35**	20	-99	109	0	**29**
Rest of Europe	-11	-11	1	1	**-19**	-13	-8	-2	-3	**-26**	-6	-8	5	-1	**-11**
Rest of the World	-2	-7	4	1	**-4**	-5	-11	3	1	**-12**	0	-1	0	0	**0**
World	-102	-196	0	0	**-298**	-269	-868	-1	0	**-1138**	-18	-395	0	0	**-413**

* change in effective border price

Source: GTAP simulation

Annex Table B.18. Equivalent variation, vaccination-to-live scenario (mio 2004 USD)

	outbreak in USA					outbreak in Canada					outbreak in the Netherlands				
	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**
Argentina	1	0	17	-2	**16**	1	-1	18	-5	**13**	0	-1	21	-5	**16**
Australia	6	-2	69	10	**84**	8	-17	124	5	**120**	0	-1	26	0	**25**
Belgium	-3	-2	14	2	**11**	-2	-3	9	1	**5**	3	-120	57	-1	**-61**
Brasil	9	-3	98	-12	**92**	6	-1	78	-16	**68**	3	-1	39	-9	**32**
Canada	-77	-170	188	4	**-56**	-228	0	-1063	78	**-1213**	4	-5	26	-4	**22**
Denmark	4	-1	63	-1	**65**	6	-1	71	-5	**71**	25	-31	84	-4	**74**
France	18	-5	41	11	**65**	0	-9	20	-4	**7**	57	-96	156	-1	**116**
Germany	-10	-4	4	14	**3**	-16	-17	-8	-10	**-51**	34	-441	150	-6	**-262**
Italy	-8	-4	-13	8	**-17**	-12	-11	-20	-3	**-45**	40	-170	85	-1	**-46**
Japan	-185	-180	-52	40	**-377**	-140	-175	-71	-11	**-397**	-27	-13	-34	-8	**-83**
Korea	-1	-123	-27	25	**-126**	-4	-23	-29	0	**-55**	0	-5	-5	-2	**-12**
Mexico	-80	-327	-8	6	**-410**	-32	-74	-15	-1	**-122**	-6	-1	-2	-1	**-10**
Netherlands	-10	-2	29	3	**19**	-8	-1	24	-3	**12**	-158	0	-1111	73	**-1196**
New Zealand	5	-2	51	-1	**54**	6	-2	68	-3	**70**	3	0	31	-1	**33**
USA	-34	0	-637	-220	**-891**	7	-928	740	47	**-135**	-11	-17	21	8	**0**
Africa	-1	-10	4	3	**-3**	-2	-5	-2	-4	**-13**	-3	-21	12	-3	**-14**
Rest of Asia	-90	-140	8	68	**-153**	-62	-226	7	-41	**-321**	-21	-49	15	-26	**-80**
Rest of South America	-4	-11	41	-10	**16**	-2	-4	13	-10	**-2**	0	-1	7	-5	**1**
Rest of European Union	-84	-30	68	36	**-10**	-66	-33	37	-11	**-73**	94	-338	404	0	**159**
Rest of Europe	-63	-64	8	9	**-111**	-29	-16	-8	-6	**-59**	-24	-27	14	-4	**-41**
Rest of the World	-13	-50	33	8	**-21**	-15	-21	4	2	**-30**	-2	-4	1	1	**-3**
World	-620	-1130	0	0	**-1750**	-584	-1566	-3	0	**-2153**	12	-1341	-2	0	**-1331**

* change in effective border price

Source: GTAP simulation

Annex Table B.19. Equivalent variation, vaccination-to-live scenario with regionalization (mio 2004 USD)

	outbreak in USA					outbreak in Canada					outbreak in the Netherlands				
	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**	contribution of changes in allocation efficiency	contribution of changes in import technology*	contributions of Terms-of-Trade effect	Other	**Total**
Argentina	0	0	3	0	**3**	0	-1	11	-3	**8**	0	0	7	-2	**6**
Australia	1	0	8	2	**10**	6	-10	90	4	**90**	0	0	8	0	**8**
Belgium	0	0	3	0	**3**	-1	-2	5	0	**2**	1	-52	22	-1	**-30**
Brasil	2	-1	23	-3	**21**	4	0	46	-10	**39**	1	0	15	-3	**13**
Canada	-25	-47	35	1	**-36**	-163	0	-760	52	**-871**	2	-2	11	-1	**9**
Denmark	2	0	17	-1	**18**	3	-1	38	-3	**38**	9	-11	36	-2	**33**
France	4	-1	8	2	**13**	1	-7	14	-2	**6**	16	-30	54	0	**39**
Germany	-2	-1	-1	3	**-1**	-9	-13	-2	-7	**-31**	1	-204	52	-1	**-151**
Italy	-1	-1	-2	1	**-3**	-7	-8	-13	-2	**-30**	7	-62	32	0	**-23**
Japan	-49	-48	-14	8	**-102**	-68	-104	-39	-9	**-219**	-10	-6	-11	-4	**-31**
Korea	1	-39	-8	6	**-39**	-3	-16	-19	0	**-38**	0	-2	-2	-1	**-5**
Mexico	-22	-76	-2	1	**-99**	-22	-57	-5	0	**-84**	-2	0	-1	0	**-4**
Netherlands	-2	0	6	1	**4**	-5	-1	16	-2	**8**	-57	0	-424	24	**-457**
New Zealand	1	0	7	0	**7**	5	-1	48	-2	**49**	1	0	8	0	**9**
USA	-5	0	-117	-41	**-163**	5	-700	518	31	**-147**	-3	-6	13	7	**11**
Africa	-1	-2	0	1	**-2**	-1	-4	-1	-3	**-8**	-1	-9	5	-1	**-5**
Rest of Asia	-21	-32	6	12	**-35**	-40	-175	13	-28	**-230**	-9	-21	9	-11	**-32**
Rest of South America	0	-1	8	-2	**5**	-1	-3	9	-7	**-2**	0	0	3	-2	**1**
Rest of European Union	-13	-4	11	7	**1**	-44	-26	27	-7	**-50**	29	-141	155	0	**43**
Rest of Europe	-15	-16	2	2	**-28**	-18	-11	-3	-4	**-36**	-9	-11	6	-2	**-15**
Rest of the World	-3	-11	6	1	**-6**	-7	-15	3	2	**-17**	0	-1	1	1	**-1**
World	-148	-280	0	0	**-428**	-366	-1155	-1	0	**-1522**	-24	-559	0	0	**-584**

* change in effective border price

Source: GTAP simulation.

GLOSSARY OF TERMS

animal health status	"*Means the status of a country or a zone with respect to an animal disease, according to the criteria listed in the relevant chapter of the Terrerestrial code dealing with the disease*" (OIE 2007) The OIE classifies countries and zones into 3 groups according to their FMD status: 1. FMD free country/zone where vaccination is not practiced 2. FMD free country/zone where vaccination is practiced 3. FMD infected country/zone
containment zone	is a particular application of the concept of zoning. A containment zone is established as a rapid response to an FMD outbreak
culling	see *stamping-out*
direct costs	costs arising from the disease and control measures, e.g. value of dead/killed animals, cost of vaccination, cost of cleaning and disinfection,
emergency vaccination	here, the term *emergency vaccination* will be used when vaccines are applied in immediate response to an outbreak in order to protect high-risk animals from being infected.
epidemiological unit	means a group of animals with a defined epidemiological relationship that share approximately the same likelihood of exposure to a pathogen (OIE 2007).
indirect cost	costs that arise as an indirect consequence of the disease e.g. through trade restrictions, disruption of business relations, idle production capacities etc.
modified stamping-out	means any incomplete implementation of stamping out (OIE 2007).
outbreak	means the occurrence of one or more cases of a disease {{6 OIE 2007}}.
regionalisation	means the separation of an animal sub-population with a distinct health status, primarily on the basis of geographical criteria {{6 OIE 2007}}.
routine vaccination	shall be related to preventive, on-going vaccination programmes that are carried out on a regular basis.
slaughter	shall here be related to the killing of animals for disease control purposes. As opposed to stamping-out, there are no further restrictions on the handling of the carcass or of the slaughter products

stamping-out	means the killing of all infected and potentially contaminated vaccinated or unvaccinated animals. The carcasses are not introduced into the food chain, but disposed of by incineration, burying etc.. The premises in which the animals were kept are cleaned and disinfected (OIE 2007).
trade cost	costs arising from export restrictions
vaccination	means the successful immunisation of animals through the application of a vaccine (OIE 2007).
vaccination-to-die	vaccination in response to an outbreak, *all* vaccinated animals are subsequently killed
vaccination-to-live	vaccination in response to an outbreak, *without* killing of the vaccinated animals
zoning	see *regionalisation*

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