The impact of Foot-and-Mouth Disease outbreaks and alternative control strategies on agricultural markets and trade

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Abstract:

Foot and Mouth Disease (FMD) is one of the most contagious animal diseases. Because of the easy transfer between animals, FMD is of importance to the domestic market, but also to international agricultural trade. Infected countries are often confronted with rigorous measures implemented by their trading partners.
The guidelines set out by the World Organisation for Animal Health (OIE) define the waiting period after which a country that experienced an FMD epidemic can be declared as free of the disease for international trade purposes. In order to minimize the duration of this period, infected developed countries have often implemented mass slaughter strategies.
The aim of the paper is to examine the impact of alternative control strategies on the domestic market of the infected country and on international markets.
To this end, synergies between two modeling systems have been exploited: the OECD's Aglink-Cosimo model and the GTAP model. This study provides insight on the impact of FMD and alternative control practices and shows how the two models can be combined to provide quantitative estimates for a broad range of economic indicators.

Keywords

International agricultural trade, agricultural policy, livestock

Introduction

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 many countries. It causes high mortality in young animals, and decreases the performance of adult animals. Despite considerable investment of resources and effort by countries to prevent outbreaks, FMD is a recurring phenomenon in many parts of the world.

FMD is important 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: livestock product importing countries usually react 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).

There are several ways of fighting an FMD epidemic. One consists of culling infected and suspect animals in and around the confirmed outbreak, often referred to as *stamping-out*. In the past, stamping-out has been the standard approach in most OECD countries because of economic consequences of the alternative strategies including vaccination: Unless all vaccinated animals are killed and destroyed, the waiting period before the infected country regains its disease free status is virtually doubled. During the waiting period, the exporting country is likely to be faced with restrictions on its exports.

The radical approach of stamping-out has been increasingly questioned by the broad public, as alternatives to mass slaughter are at hand.

The aim of this paper is to assess the impact of different control strategies both on the domestic as well as on the international markets.

The paper is structured as follows: First, information on the international regulatory framework related to FMD is given. The different options for policy interventions and the consequences on the international disease status of the country are outlined. After a brief description of the methodology applied, results from the quantitative analysis, both from infected country and global perspectives, are presented.

Options for policy interventions and the international regulatory framework

In case of an outbreak of FMD, a variety of measures is 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, they are often deemed to be insufficient and thus complemented by stamping-out, vaccination and slaughter, or combinations of these measures.

Vaccination: successful immunisation of animals through the application of a vaccine (OIE 2007). Here, the term vaccination is used when vaccines are applied in immediate response to an outbreak in order to protect high-risk animals from being infected ("*emergency vaccination*").

Stamping-out or culling: 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 (OIE 2007).

The implementation of these measures can have significant impacts on international trade relations of the infected country, and can be controversial.

International disease status and domestic control measures

The OIE classifies countries according to their animal health status. Principally, three different classifications are distinguished: FMD free country/zone where vaccination is *not* practised, FMD free country/zone where vaccination *is* practised, and FMD infected country/zone (OIE 2007).

After an infection, a waiting period is required before the country can be recognised as free from FMD. The time that must elapse before it can regain the status of FMD free, with or without vaccination, depends on two aspects: 1. Status the country had prior to the FMD outbreak or FMD virus (FMDV) infection; 2. Control measures taken to fight the disease. Table 1summarises possible combinations of the two.

Table 1.

		Status to be recovered				
		Country or zone where vaccination is not practised			**Country or zone where vaccination is practised**	
	Control measures	**No emergency vaccination**	**Emergency vaccination**		**Emergency vaccination**	**No emergency vaccination**
			Slaughter of all vaccinated animals	No slaughter of all vaccinated animals		
	stamping out + serological surveillance	3 months after the last case (Article 2.2.10.8. 1 a)	3 months after slaughter of all vaccinated animals (Article 2.2.10.8.1 b)	6 months after the (later of) the last case or last vaccination* (Article 2.2.10.8.1 c)	6 months after last case** (Article 2.2.10.8. 2 a)	24 months after the last outbreak, 12 months after the last FMDV circulation
	no stamping out + serological surveillance	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)			18 months after last case** (Article 2.2.10.8. 2 b)	(Article 2.2.10.3.)

* if FMDV is proven to be absent in the remaining vaccinated population
** if FMDV circulation is proven to be absent

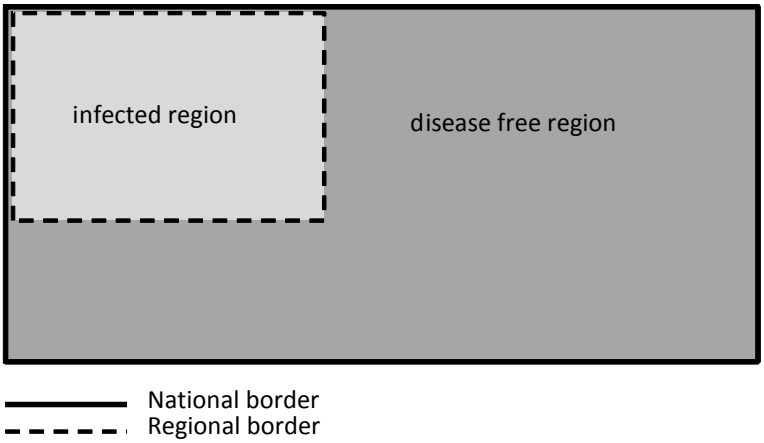
Source:(OIE 2007).

This overview reveals that the waiting period is shortest when a pure stamping-out strategy is followed. It is the main reason for choosing this option. The waiting period after a vaccination-to-die strategy is only slightly longer, as its counting starts after slaughter of vaccinated animals, not after the last case. A vaccination-to-live strategy ranges in between the 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.

The principle of zoning for international trade purposes

Countries can define a subpopulation – zone/region - with a different animal health status inside the national boundaries, for example an FMD free zone within an infected country (OIE 2007) as in Figure1. Zoning has been widely applied by countries affected by FMD and allowed to maintain exports while being infected with FMD in some parts of the country.

Figure 1. Zoning



Methodology

To analyse the impacts of the trade ban and consequential market adjustments, simulations involving two different modelling systems, Aglink-Cosimo and GTAP, were combined.

Aglink-Cosimo

Aglink-Cosimo is an agricultural sector model with a considerable level of product disaggregation. The model design is recursive-dynamic with annual frequency, and permits an analysis of market developments over time. This is of particular interest when meat and livestock markets are considered, since herd dynamics limit the farmers' ability to respond in the short term to price signals. One shortcoming of this model is the assumption on farmers' price expectations. Production is defined as a function of current and historic prices only; no forward-looking behaviour is taken into account. This may in some cases overestimate the model's reaction. Another drawback, in the context of trade analysis, is that Aglink-Cosimo does not represent bilateral trade flows.

Aglink-Cosimo, however, is built from individual country modules that approximate specific country characteristics and relationships contrary to a standard template model. The simulation horizon reaches out to 2017. A more comprehensive description of the model can be found in (OECD 2007).

GTAP

The partial equilibrium Aglink-Cosimo model was complemented by a general equilibrium model - the Global Trade Analysis Project (GTAP), to take into account the economy wide implications of FMD and to allow for bilateral trade analysis.

In this study the standard GTAP model (Hertel , T. W. 1997; GTAP)) was 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, *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[2], which is benchmarked to 2004. To

[2] 7p6 pre-release (June 2008)

maximize the focus on trade effects of animal disease outbreaks, the database has been aggregated to 21 selected regions and 16 sectors.

Model linkage

In order to make the two models consistent, 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[3], was implemented into Aglink-Cosimo in the year of the outbreak.

Scenario definition and implementation

Outbreaks of FMD are assumed to occur alternatively in three countries: Canada, the Netherlands and the United States (US). The choice was based on economic criteria: the US and Canada are among the world's most important meat exporting countries, though 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.

Canada is an example of 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.

Finally, the Netherlands' case allows analysis of the consequences of animal disease related restrictions in an important meat exporting country of the European Union, where trade takes place predominantly within the free trade area of the EU.

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, stamping-out is combined with a vaccination-to-live strategy, and it is assumed that vaccinated animals can enter the food chain without any barriers. Both control strategies may be combined with regionalization for trade purposes (Table 2).

Table 2.

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

Scenarios are limited to the impact of trade embargo: 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. It is further assumed

[3] In the GTAP database, some products are aggregated to composite goods. 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.

that all trading partners resume trading after the declaration of disease free status. The following parameters have to be defined:

- The duration of the epidemic.
  It assumed to be 2 months, based on the average of OECD countries over the last 10 years.

- The duration of the waiting period.
  It is assumed to be 4.5 months for stamping-out, 7.5 months for vaccination-to-live. These figures are based on the official waiting period required by the OIE plus 1.5 months representing the additional time it took OECD countries on average to regain disease free status over the last 10 years.

- The products affected by the trade ban.
  Live pigs and pork products, live cattle and beef products.

For scenarios including regionalization, additionally the location of the outbreak and the borders along which regionalization is applied, have to be determined (USA: Iowa, infected region Iowa; Canada: Alberta, infected region West Canada; Netherlands: North Brabant, infected region North Brabant).

Results

Impacts from the perspective of the infected country

United States

The US is 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).

Despite being a large exporting country in absolute terms, only around 15% of the national pork production was exported in 2006 and for beef this share was only around 5% in the same year.

Table 3. 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

As Table 3 shows, no matter which control strategy is taken, the relative impact of the trade ban on the pork market is more pronounced than on beef market. This is because the export share of pork is considerably higher than of beef, and the US is a net importer of beef, while net exporter of pork.

Losses of revenue are highest under the vaccination-to-live scenario, due to the length of the waiting period. The smallest impact is found under the stamping-out scenario with regionalization, as it is the smallest shock to the economy both in terms of the waiting period and the regional extent.

Given the rigidities in supply response and the assumption made on farmers' price expectations, the impacts on revenues in the livestock sector are not limited to the year of the epidemic. Generally, the dynamic effects on the pork market are more pronounced than on the beef market due to the relative size of the disturbance on both markets.

Canada

Given the strong export orientation of the Canadian livestock sector, losses for both beef and pork sectors are considerably higher than for the US. At a first glance, it may seem surprising that the losses in the short run are higher for beef than for pork. However, 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 case of beef, the price decrease is less pronounced, but at the same time supply to the slaughterhouses is reduced.

Table 4. 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

Moreover, Canada's less important role in world beef exports, causing the world market price for beef to increase less than in 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.

It should be noted that the *vaccination-to-live scenario* supply to the *domestic* market is more than doubled compared to the baseline in case of pork, and almost doubled in case of beef as the produced meat cannot be readily exported. This is at the extreme 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. Moreover, in reality farmers can be expected to take offsetting measures that are not captured in the modeling framework.

Since for Canada the cost of an FMD outbreak is already high under a standard stamping-out scenario, regionalization is worth a closer look. Comparing the stamping-out scenario to stamping-out with regionalization, about 20% of the losses in revenue in the beef sector and around 40% in the pork sector could be mitigated by regionalization. When adjustments in following years are included, it is the pork sector where more revenue is lost. A stronger decrease in pork prices persists in the years following the outbreak considerably more than in the beef market. Beef prices fall, but to a lesser degree. 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 outbreak. In those years, revenues from export have been assumed to be zero.

The Netherlands

The Netherlands is the most important meat exporting country of the EU. 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.

Given the market structure of the Netherlands, the impact of the trade ban is higher than for the US, but lower than for Canada. In the year of the outbreak itself, the loss of revenue is more pronounced for the pork sector than for the cattle sector under all scenarios. The reason for this is that the Netherlands, while being a net exporter of beef, also imports considerable quantities of beef. These imports are then crowded out by domestic production, thereby alleviating some of the pressure on the domestic industry.

Table 5. 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

Regionalization benefits primarily the beef sector, where it mitigates more than 90% of the revenue losses as opposed to less than 40% in the pork sector, because of the limited importance of beef in the infected region.

The dynamic impacts from adjustments in years following an outbreak, on beef sector are limited comparing to the pork sector, where they reach a maximum of 7% under the vaccination-to-live scenario.

Trade effects

This section summarises total and bilateral trade effects of FMD outbreaks[4]. The results are discussed for the stamping-out scenario only, since across the scenarios, it is only the magnitude of shocks that varies.

In tables 6 – 8 the trade effects on the three most important destinations for exports from the infected countries are presented.

If an outbreak occurs in the US, it will be Canada, Mexico and Japan that will be the most concerned since these countries absorb large shares of US meat exports. Japan's meat imports would change only marginally as it intensifies trade with New Zealand and Australia. It would slightly increase its total imports of pork, indicating a net substitution away from beef products. Mexico's total beef imports would decrease by 7%. Half of its imports from the US would be replaced by Canadian beef and another 15% by Australian and New Zealand's beef. Imports of pork would not change much due to intensified trade with Canada and many South American countries. While Canada would decrease its aggregate imports only by 4%, it would still be affected the most by FMD outbreaks in the US, given their close trade relationship, integrated livestock rearing and fattening operations and its poorly diversified trade pattern. US – Canada trade is mostly in live animals and Canada cannot switch easily towards other, more distant partners. The

[4] The results shown here are changes in the GTAP composite commodities. They must thus be understood as the average changes inside the aggregate, which are likely to differ from the impact on one specific product, especially when the share of the commodity of interest inside the composite is small.

US trade pattern would also change as, due to the export ban, increased domestic meat supply would dampen meat price and therefore reduce the attractiveness of the market as an export destination.

Similar mechanisms govern if the outbreak occurs in Canada, though more countries would be involved as Canadian beef serves different destinations than Canadian pork. While the former is predominantly directed to the US, Mexico and, to a smaller degree, Asia, the latter goes to the US, Japan and small amounts also to Australia. Again, affected countries would substitute away their imports from FMD infected country towards other partners' meat. The US total imports would decrease the most, due to aforementioned close live-animals trade relationship with Canada.

An outbreak in the Netherlands will impact mostly the EU countries as all its main destinations are amongst the member states. The most importers of Dutch meat are France, Germany, Italy and the Rest-of-EU. These countries would decrease their meat imports, mostly beef. To cover the gap, they intensify trade among themselves and search other source of meat imports, predominantly among the Rest-of-EU countries.

Overall, countries will be the more affected by an FMD outbreak, the larger their imports from infected country, the more integrated livestock/meat production and the less diversified their import partners.

Table 6. Trade effects of an outbreak in the US: stamping-out

	Destination	JAPAN	CANADA	MEXICO	TOTAL	JAPAN	CANADA	MEXICO	TOTAL
Source		BEEF				PORK			
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

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Table 7. Trade effects of an outbreak in Canada:stamping-out[5]

	Destination	USA	MEXICO	Rest of ASIA	TOTAL	Australia	JAPAN	USA	TOTAL
Source		BEEF				PORK			
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

[5] Changes in export/import value. Absolute changes are in mln. 2004 USD.

Table 8. Trade effects of an outbreak in the Netherlands: stamping-out[6]

	Destination	FRANCE	GERMANY	ITALY	TOTAL	FRANCE	GERMANY	Rest EU	TOTAL
Source		BEEF				PORK			
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

6 Absolute changes in mln. 2004 USD and per cent

International income effects

GTAP also provides insight into the economy-wide incomes effects, measured in terms of the Equivalent Variation (EV). Table 9 shows the total EV resulting from the stamping-out scenario, and isolates the terms-of-trade effect. The terms-of-trade effect is a component of EV that is attributable to changes in the ratio of export prices to import prices, weighted by export and import volumes[7].

There are losers as well as winners from an FMD outbreak. If an FMD outbreak occurs in the US, the biggest loser is the US itself. However, countries that import livestock products from the US are also adversely affected: 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 and because of the reduced meat supplies available on international markets.

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.

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, like Japan, Mexico 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.

[7]. 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, e.g. arising from inefficient resource allocation.

Table 9. Equivalent variation: stamping-out (mln 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

: Countries where EV is unambigously **negativ**e, to matter where epidemic

: Countries where EV is unambigously **positive**, to matter where epidemic

: Countries with mixed effect on EV

Source: GTAP simulation

Conclusions

Governments have a variety of tools at hand to fight FMD. For most OECD countries, the discussion has been whether to vaccinate or not in response to FMD. Three case studies have been carried out to analyse the impact of FMD outbreaks and different control strategies in countries with different characteristics on both the domestic and the international market.

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 costs related to trade restrictions. Estimates suggest that the cost of implementing regionalization is well below the gains that can be made through this effort (Canadian Animal Health Coalition 2002).

- 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.

Two modelling systems were employed in the analysis, the Aglink-Cosimo model and the GTAP modelling system. The combination of the two allows for putting numbers on a broad range of economic indicators.

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