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# Livestock product trade and highly contagious animal diseases

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## Abstract

An outbreak of foot and mouth disease (FMD) can distort livestock markets. In this paper we have simulated welfare effects due to the risk of a hypothetical FMD outbreak and trade distortions associated with the disease. The analysis was carried out with stochastic dynamic partial-equilibrium models characterizing the Finnish pig and cattle sectors. The models maximise the aggregate welfare of consumers, producers and taxpayers arising from the domestic and two export markets, imported goods and direct costs caused by disease eradication measures. The duration of trade distortions and the probability of occurrence of disease are stochastic and unknown beforehand. The results suggest that if a disease outbreak with trade distortions occurs, the losses are likely to be primarily by excess supply of pigmeat, butter and cheese. Consumers can occasionally benefit if a disease outbreak with a trade ban results in the saturation of the domestic markets and falling prices. Although there are limited opportunities to adjust production rapidly, the meat sector is able to reduce losses through premature slaughter and reduced insemination of animals whereas in the dairy sector the largest potential seems to be in adjusting the processing quantities of milk products.

**Keywords** Foot and mouth disease, dynamic programming, supply, price, trade, risk

**JEL codes** C61, Q11, Q17

## 1. Introduction

An outbreak of a contagious animal disease can cause heavy losses to society (e.g. Thompson *et al.*, 2002; Mangen and Burrell, 2003; Schoenbaum and Disney, 2003; Boisvert *et al.*, 2012). The losses can be particularly heavy if the outbreak is large and affect a large number of animals, or if it affects the trade of animals and products of animal origin. Due to the threat of disease to animals, livestock production, and in some cases to human health, national and international public regulations put specific attention to prevent animal diseases from spreading.

Based on the Sanitary and Phytosanitary (SPS) agreement included in the agreement establishing the World Trade Organization (GATT, 1994), countries can protect their human, animal or plant life or health from risks arising from the entry, establishment or spread of pests, diseases and disease-carrying or disease-causing organisms. One typical area of SPS measures is the prevention of diseases or pest spreading to a country (WTO, 2010). The agreement therefore allows countries to ban the import of animals and animal products from a country where foot and mouth disease (FMD) has been observed.

The number of SPS measures taken by countries has increased over time and globally more than one thousand measures were taken in the year 2010. The vast majority (94%) of specific trade concerns related to SPS measures affect the agricultural sector. SPS measures also cause trade disputes. During 2007 to 2011, 28 percent of WTO trade disputes within the agricultural sector were citing SPS measures<sup>1</sup>. In 2009, 35% of non-tariff measures taken by the European Union (EU) were related to SPS measures (WTO 2012).

In the industrialized countries, special attention is paid to mitigate non-endemic highly contagious animal diseases such as foot and mouth disease, which introduction into the country can have high-impact consequences. An outbreak of FMD typically affects the livestock market by reducing market supply of animals and derived products, and by causing trade and market disruptions. A ban on the import of animals and animal products from an infected country or region (hereafter referred to as the trade ban) causes temporary excess supply in the domestic markets. This tightens competition and is likely to decrease producer prices. Lower prices can result in producers reducing production and importers reducing imports. –While imports may be decreased significantly in the short-term, rapid adjustments in domestic livestock production and animal stock are inhibited significantly by biological lags which make large short-term fluctuations in animal stock costly, and uncertainty on the

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<sup>1</sup> Trade disputes may frequently cite more than one agreement.

extent and duration of disease outbreak and the trade ban. On the demand side, consumers may choose to increase the consumption of animal products due to falling prices. However, in developed countries where consumers spend quite small part of their income on food, domestic consumption responds sluggishly to price changes. Hence the increase in e.g. meat consumption may be marginal despite significant price reductions. Overall, studies (e.g. Lyytikäinen *et al.*, 2010; Boisvert *et al.*, 2012; Tozer and Marsh, 2012) suggest that trade distortions can result in substantial economic losses and outbreak can hit producers particularly badly in export-oriented countries. Although these aspects are well-known, studies haven't really addressed how the risk of trade disruptions contributes to the food sector overall, including both disease time and non-disease time actions and behaviour.

The European Union is a net exporter of pigmeat and dairy products. In the EU as well as in many individual member states cheese and butter represent an important share of exports of dairy products (e.g. Thielke *et al.*, 2013; European Commission, 2014). This is important because cheese and butter contain a lot of fat relative to protein. In the event of cheese and butter it is especially the fat component of milk that is being traded. Finland is one of the countries where this aspect is particularly important due to relatively large export share of butter among dairy products, due to low domestic consumption per capita. Similarly, the exporting of meat is concentrated to specific cuts of carcass. Moreover, it is important to take into account the structure of trade of animal products because various markets can respond differently to changes in prices and quantities traded (*cf.* Mangen and Burrell, 2003; Niemi and Lehtonen 2011).

The goal of this paper is to examine livestock markets and trade (exports, imports, domestic markets) in order to identify which products can cause trade losses to the Finnish pig, dairy and cattle sector in the event of FMD outbreak and how does the risk of trade disruptions affect returns to the sector and production in a disease-free time. The analysis was carried out with a stochastic dynamic partial-equilibrium model covering pig, dairy and beef markets in Finland at a monthly level. This large coverage of livestock products included in the monthly-level economic model-based analysis of animal disease impacts is rare in the literature. We also consider it important in terms of the realism and consistency of the economic analysis that both the duration of trade ban and the probability of introducing the disease into the country are assumed to be stochastic and unknown beforehand. Hence, our study contributed to the previous knowledge about the uncertainty related to the trade distortions associated with animal disease outbreak and the role of different export markets.

The following section describes the model and subsequent section report results and provide important conclusions.

## **2. Data and model**

### *2.1. Model overview*

The problem was studied with partial-equilibrium models characterizing the Finnish pig and cattle sectors. The models find the dynamic path of supply of milk and meat that maximises the aggregate welfare of consumers, producers and taxpayers taking account of domestic and export markets, price movements induced by the outbreak and the stochastic trade ban, and adds exogenously given direct disease control costs to tax payers. The direct costs are assumed not to influence the behaviour of producers and consumers. Effects to the pig sector were calculated using a dynamic partial-equilibrium model represented by Niemi and Lehtonen (2011). For the purposes of this study an analogous dynamic partial-equilibrium model for the Finnish beef and dairy sector was developed, to be called a cattle sector model.

In the cattle sector morel, four markets were considered for seven animal product categories:

- 1) Domestic demand for Finnish products in Finland,
- 2) Export demand for Finnish products within the EU (i.e. intra-community export),
- 3) Export demand for Finnish products outside the EU (ROW export) and
- 4) Demand for imported meat and dairy products in Finland.

The seven product categories were beef, liquid milk, cream, sour milk products, butter, cheese, milk powder. Demand equations were estimated for each market and product category with three-stage least squares method (see Lyytikäinen *et al.*, 2011). Hence, each market and product category could have specific elasticity estimates for demand.

The model is able to take into account that the trade disruptions can occur differently at different markets, their duration and occurrence is unknown beforehand, and that producers have possibilities, although very limited in the short run, to adjust production to rapidly changed market conditions (Fig. 1). In this paper, a trade ban was considered to occur as a temporary interruption of exports from Finland to non-EU markets (ROW exports), such as Russia. The exact duration of the trade ban was unknown beforehand, but an estimate for the expected duration and the probability of occurrence (if not already present) is provided. The partial equilibrium model was programmed and solved by using stochastic dynamic programming in Matlab R2013a (Mathworks Inc., Massachusetts, USA). Hence, the method

was able to address the importance of new information arriving at the market as a shock occurs. The model was calibrated to correspond to market situation in 2006, which represents an average situation on the Finnish livestock markets after 2000. Pigmeat production increased from 2000 to 2008 by almost 20% but has decreased by more than 10% after the peak year of 2008. The dairy and beef markets have been more stable, even if dairy milk production has decreased gradually by 8% from 2002 to 2012 (Niemi and Ahlstedt 2010, 2013).

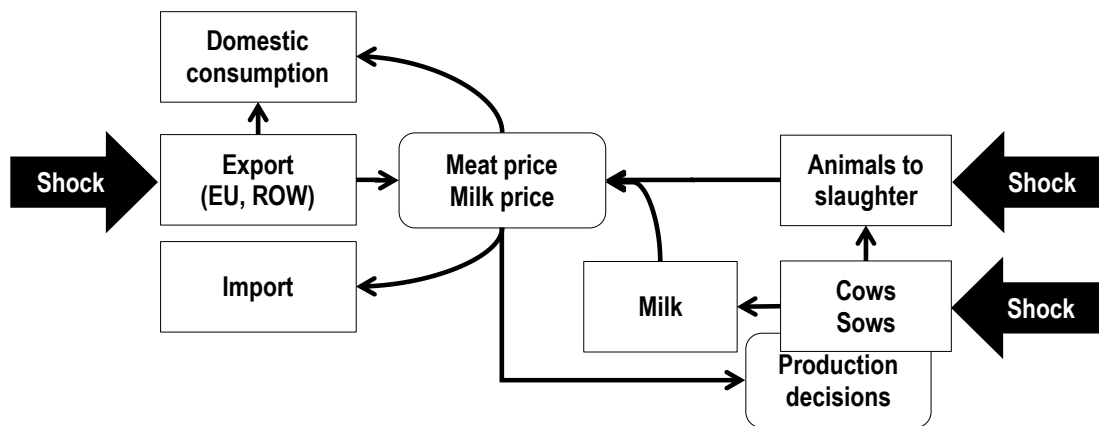


Figure 1. Partial-equilibrium model simulates simultaneous and interrelated changes in production decisions and production quantities, import, export and domestic consumption decisions and market prices over time, and the implications of disease shock on these as well as on the animal stock.

## 2.2. The Bellman equation

Adapting the specification by Niemi and Lehtonen (2011), the behaviour of competitive markets is simulated by maximising social welfare, the sum of consumer and producer surplus. In this case an “invisible” social planner maximises the value of the Bellman equation. The objective function is specified separately but analogically to both pigs and cattle with the following Bellmann equation (Bellman, 1957):

$$V_t(\mathbf{x}_t) = \max_{\{\mathbf{u}_t\}} \{R(\mathbf{x}_t, \mathbf{u}_t) + \beta E(V_{t+1}(\mathbf{x}_{t+1}))\} \text{ for } t=0, \dots, T, \quad (1),$$

subject to:

$$\mathbf{x}_{r,t+1} = g_r(\mathbf{x}_{r,t}, \mathbf{u}_{r,t}) - \delta(\mathbf{x}_{r,t}) \quad (\text{transition equation for the reproduction animal stocks}),$$

$$\mathbf{x}_{s,t+1} = g_s(\mathbf{x}_{r,t}, \mathbf{x}_{s,t}, \mathbf{u}_{r,t}, \mathbf{u}_{s,t}) - \delta(\mathbf{x}_{s,t}) \quad (\text{transition equation for the young animal stocks}),$$

$$x_{B,t+1} = \text{Pr}(x_{B,t}) \quad (\text{transition equation for the state of trade ban}),$$

where  $\mathbf{x}_{r,t}$ ,  $\mathbf{x}_{s,t}$ ,  $x_{B,t}$  and  $V_T(\mathbf{x}_T)$  are given

$$\mathbf{x}_t = \{\mathbf{x}_{s,t}, \mathbf{x}_{r,t}, x_{B,t}\}, \mathbf{u}_t = \{\mathbf{u}_{r,t}, \mathbf{u}_{s,t}\}, \text{ and}$$

The vector of state variables,  $\mathbf{x}_t = \{\mathbf{x}_{s,t}, \mathbf{x}_{r,t}, x_{B,t}\}$ , contains information on three major variables indicated by the subscripts such that  $r$  refers to the stock of lactating reproduction animals (dairy cows, beef cows),  $s$  refers to the young animals raised for meat or future reproduction (all growing cattle),  $B$  refers to the trade ban,  $\mathbf{u}_t = \{\mathbf{u}_{r,t}, \mathbf{u}_{s,t}\}$  refers to the vectors of decision variables which characterize the share of reproduction animals served in the current period, and the slaughter of growing animals extracted from the stock in the current period, respectively.  $\beta$  is the discount factor and  $R(\mathbf{x}_t, \mathbf{u}_t)$  refers to one-period net utility from the sector's activity, which includes producer's surplus, consumer's surplus and costs to the taxpayers.

Transition equations ( $g$ 's) for animal stocks take into account the biological lags involved in producing animals, starting from an insemination decision. The size of animal stock in the subsequent period depends on the earlier insemination decisions ( $\mathbf{u}_{r,t}$ ), the number of animals slaughtered ( $\mathbf{u}_{s,t}$ ) and on the number of animals removed from the stock due to exogenous disease shock ( $\delta$ 's). The expectations operator  $E$  and transition equation for the state of the trade ban highlight uncertainty about the future. In each time period, the state of the export market is either 'trade ban' or 'no trade ban'. As time elapses, the state of the export market can be switched between these two alternatives and decisions can be updated according to the state observed in each period. The expectations operator uses the parameters indicating the probability of a trade ban to simulate the distribution of the next-period state of nature. The evolution of the trade ban status over time is governed by probability parameters given by transition equations (Pr's).

It is assumed that prices adjust and markets clear each month. Losses due to the disease outbreak are the difference in the simulated value of production between the two market states (i.e. trade ban versus no trade ban, *ceteris paribus*), added with the direct costs of controlling and eradicating the disease. Direct costs are considered exogenous to the

producers and the consumers. Therefore, since not affecting the behaviour of producers and consumers, direct costs to public funds are not shown in equation 1.

### 2.3. Parameter values

The elasticity estimates of demand for animal products were estimated with three-stage least squares as described by Niemi and Lehtonen (2011) and Lyytikäinen et al. (2011). The estimates are provided in table 1. The direct costs of eradicating disease from Finland were estimated as described by Lyytikäinen et al. (2011). Resources needed to eradicate the disease (Table 1) were based on information obtained from the Finnish authorities and data retrieved from Risk Solutions (2005). The parameters used in equation (1) are available upon request from the authors.

Table 1. Elasticity estimates of demand for animal products used in the model.

	Exports to the EU		Exports to outside the EU		Imports to Finland		Domestic demand	
	Estimate	P-value	Estimate	P-value	Estimate	P-value	Estimate	P-value
Pigmeat	-0.968	0.003	-0.512	0.001	0.872	0.295	-0.138	0.032
Beef	-1.016	0.000	-2.631	0.000	0.939	0.318	-0.376	0.052
Liquid	-6.261	0.000	-6.261	0.000	6.804	0.000	-0.157	0.060
Creams	-4.574	0.000	-4.574	0.000	0 <sup>1)</sup>	0 <sup>1)</sup>	-1.925	0.003
Butter	-1.768	0.009	-0.249	0.506	0 <sup>1)</sup>	0 <sup>1)</sup>	-0.168	0.874
Yoghurt	-0.327	0.281	-0.327	0.281	0 <sup>1)</sup>	0 <sup>1)</sup>	-0.464	0.013
Cheese	-2.326	0.000	-0.154	0.838	0.555	0.375	-1.594	0.001
Milk powder	-1.300	0.288	-1.866	0.017	0.009	0.981	-1.523	0.005

1) The parameter was restricted at zero.

Source: Estimated with three-stage least squares regression model (Lyytikäinen *et al.*, 2011; Niemi and Lehtonen,

Table 2. Parameters regarding the direct costs of disease eradication as used in the model.

Unit of measure	€ per unit <sup>1)</sup>
Infected farm, maximum for a farm-type dependent fixed cost	119 576
Per fattening pig in an infected farm	175
Per sow in an infected farm	572
Per dairy cow in an infected farm	1 550
Per heifer in an infected farm	1 211
Per suckler cow in an infected farm	1 296
Per growing cattle in an infected farm	1 726
Per farm in a protection zone	638+6 028*duration in months
Per farm in a surveillance zone	425+468*duration in months
Per contacts farm	1 130
Vaccination, excluding the cost of culling vaccinated animals	892 per farm+8.53 per animal

1) Including the value of culled animal, if applicable.

Source: Lyytikäinen *et al.* (2011)

### 2.4. Scenarios

The model was applied in four hypothetical scenarios. The scenarios differed in the magnitude of disease outbreaks (affecting e.g. the extent of disease eradication measures), the expected duration of trade ban and the probability of introduction of disease and trade ban is



not currently observed. In the first two scenarios, it was compared how one disease outbreak with associated trade ban epidemic jointly affects the welfare of livestock producers (including the food processing industry), consumers (including retail sector), public funds and these all taken together:

- *Scenario 1.* ROW trade ban which expected duration is four months, and disease losses are caused by a “medium-sized” disease outbreak in Finland.
- *Scenario 2.* ROW trade shock which expected duration is seven months, and disease losses are caused by a “large” disease outbreak in Finland.

In this case, the results of two scenarios were compared to the situation in disease-free time. “Medium-sized outbreak” represents a case where 0.2 per cent of pigs and cattle in Finland are culled due to the farms being infected farms whereas “large outbreak” represent culling rate of 2. Based on the results of Lyytikäinen *et al.* (2010), our medium-sized epidemic actually represents quite large outbreak. It is the average of 9% the most severe FMD outbreaks, and large disease outbreak represents an extreme case which probability of occurrence is less than one in ten thousand.

Two further scenarios simulated how constant risk of observing a new case of trade ban and disease affects the value of sector over 30 years period. Hence, the comparison was made to the situation where the probability of trade ban and disease outbreak to occur is zero:

- *Scenario 3.* ROW trade ban which expected duration is four months, and disease losses are caused by a “medium-sized” disease outbreak in Finland, which both are expected to arrive on average once in a decade.
- *Scenario 4.* ROW trade shock which expected duration is five months, and disease losses caused by a “large” disease outbreak in Finland, which both are expected to arrive on average once in a decade.

### **3. Results and discussion**

#### *3.1. Impacts of disease shock*

The introduction of a disease outbreak which causes 0.2 percent instantaneous reduction in the supply and distorts the export of animal products (scenario 1) was simulated to cause welfare losses worth €37 million to the society. Almost half of the losses were borne by the pig sector and the remaining were mainly borne by the dairy sector. Beef production did not cause major market losses due to small amount of beef exports (Figure 2).

The total losses to producers were simulated at €101 million. However, there were differences in the composition of losses between the sectors. In the pig sector the losses were mainly due to temporary excess supply in the domestic markets due trade distortions. Also dairy producers were simulated to suffer substantial losses due to trade distortions, but these losses were somewhat smaller when compared to the size of the market than in the pig sector.

Direct cost of disease eradication measures were simulated at €10.5 million per outbreak. In the cattle sector the costs of disease eradication measures were more prominent than in the pig sector as the cattle sector is larger in size than the pig sector. Temporary excess supply was simulated to reduce the prices of livestock products. Consumers were simulated to benefit from the disease outbreak. The market shock therefore resulted in an income transfer between consumers and producers. Particularly the benefits due to falling dairy product prices to consumers were substantial.

In the event of a (very) large (scenario 2) outbreak presented in Figure 3, the total losses were simulated at € 163 million per outbreak. In particular, direct losses for the dairy sector due to disease eradication measures were increased when compared to the results presented in Figure 2. While the benefits to consumers were virtually the same in scenarios 1 and 2, the losses to producers were increased substantially in scenario 2 where they amounted almost €140 million. The difference in producer's losses between scenarios 1 and 2 was mainly due to prolonged trade ban, but to some extent also due to the loss of animals and production capacity following disease eradication measures. Hence, trade distortions were simulated to cause major losses to the producers. In addition, the costs to public funds were simulated to increase substantially due to this extremely large disease outbreak.

The results suggest that trade distortions on non-EU markets (ROW) faced by Finnish pig, beef and dairy sectors could be larger in the pig sector than in the dairy and beef sectors. In the event of a medium-sized shock realizing, producer prices of pig meat were simulated to fall by 16-20 % whereas producer price of beef fell only modestly, generally less than 5%. This is due to a small share of beef exported, out of the domestic beef production, while beef imports cover 20% of total consumption. The decrease of milk price was -18%. In monetary terms, the most important contributor was dairy sector, although relative losses (losses compared to the value of production) were larger in the pig sector than in the dairy sector. The importance of dairy production was mainly because of large size of dairy sector when compared to pig or beef sectors, and because of export orientation of milk production. While domestic milk production, in terms of milk equivalent, is close to the domestic consumption, approximately 40% of total cheese consumption was covered by imported cheese, and

approximately 35% of domestic cheese production was concurrently exported. In 2012 already 48% of cheese consumed was imported while the share of exports out of the total domestic cheese production was over 40% (Niemi and Ahlstedt, 2013).

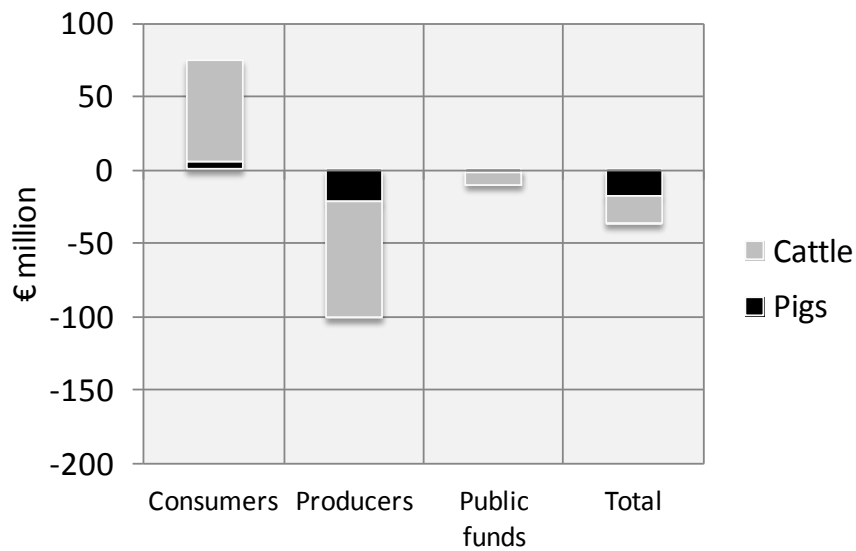


Figure 2. Simulated welfare effects of a medium-sized foot and mouth disease outbreak (scenario 1) in Finland.

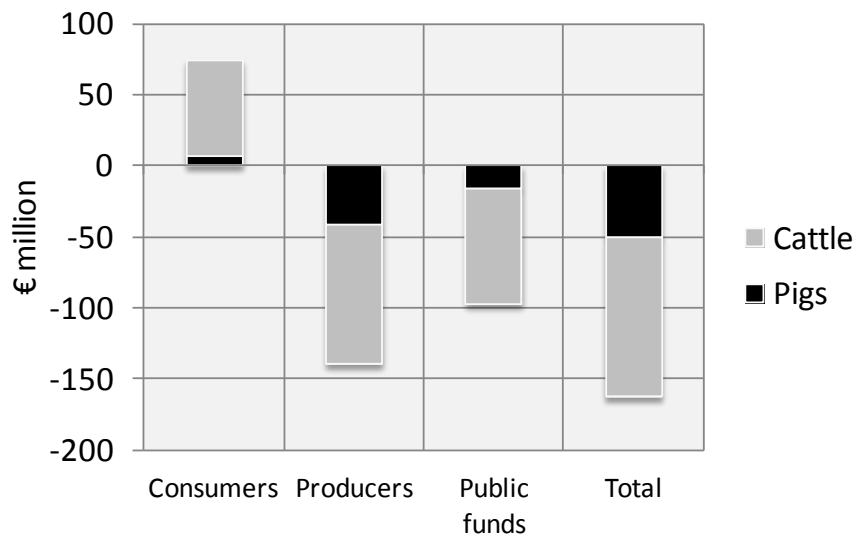


Figure 3. Simulated welfare effects of a large foot and mouth disease outbreak (scenario 2) in Finland.

The quantities supplied differ between the scenarios. While milk production is quite constant across scenarios, producers choose to market more beef already during the first months after having information about the occurrence of disease. This reduces excess supply in the markets in two ways. Firstly, if trade distortions will be prolonged (a possibility that producers need to take into account while the duration of the trade ban is unknown beforehand), early increase in the slaughter of animals lead to a smaller excess supply and to a better market situation over entire time period, compared to later increase of the slaughtering. Thus slaughterings and excess supply will be relatively balanced over time in this way. In fact, instantaneous increase in the supply is the larger the longer trade distortions are expected to last. Secondly, the average slaughter weight of animals is the lower the higher share of current animal stock is slaughtered, because extra animals that are slaughtered have not yet reached their typical slaughter weight.

The rigidity of milk supply is also rational because it is costly to decrease the number of dairy cows prematurely. If their culling is substantially increased, milk production cannot be recovered immediately after export markets have recovered. Rational producers are thus taking into account the recovery period after the trade ban as well already when in the early stages of the disease outbreak, even if the length of the trade ban is unknown. Moreover, the model allows the adjustment of milk processing which is more flexible than biologically determined dairy farm production process. An important observation which is supported also by previous studies (e.g. Mangen and Burrell, 2003; Niemi and Lehtonen, 2011) is that although producer prices are to decrease during the trade ban, the prices of meat can recover over time and if the disease outbreak results in an exogenous fall in the animal stock, and hence fall in the supply, producer prices can in fact temporarily increase after the export markets have recovered.

The results are in line with previous studies conducted in industrialised countries. These studies (e.g. Mangen and Burrell, 2003; Schoenbaum and Disney, 2003; Boisvert *et al.*, 2012; Tozer and Marsh, 2012) have noted that stakeholder groups can be affected differently by highly contagious animal diseases. Also the importance of export orientation and the size of disease outbreak on estimated losses have been highlighted in previous studies. However, previous studies have typically taken the duration of trade ban as exogenously given and not considered it as a stochastic process which contributes to the production decisions made by producers. We have addressed this aspect in our model.

### 3.2. Impacts by product category

To compare the effects of different product categories we simulated the welfare effects due to trade distortions by product category per one month of trade distortion (Figure 4). Effects to the pig sector are reported in Figures 2 and 3. Decrease in domestic prices resulted in a rapid decrease in imports of meat and dairy production. Hence, they were substituted by domestic products. Disaggregating the losses by products revealed interesting aspects. The losses in the dairy sector were mainly due to distortions in the trade of high-fat-content milk products such as cheese or butter. Especially butter markets were characterized by inelastic domestic demand and high share of production being exported which resulted in large losses to the sector. In fact, the consumption of protein component of milk is close to the domestic production of milk protein and thus the excess supply of protein is much smaller, compared to butter. Somewhat similar impact could be found in the pig sector where different cuts of carcass are imported than exported.

Since there is limited stock capacity in the food sector, all milk and meat produced in excess of typical domestic consumption cannot be stored. However, stakeholders were able to adjust dairy production according to trade ban situation. The trade of milk powder and cream increased by more than ten percent whereas less butter and cheese was traded after than before observing the trade ban. While the model can allocate the protein and milk fat in different dairy products, this implies that milk fat was sold as a component in fresh products, or was stored and marketed as milk powder (Figure 5).

Also these results are in line with previous studies (e.g. Mangen and Burrell, 2003; Paarlberg *et al.*, 2008) in the sense that a highly contagious animal disease such as FMD is known to affect differently different product categories such as beef or pigmeat, which can suffer differently from trade distortions. However, previous reports have paid little attention to specific dairy product categories. The results suggest that taking into account several product categories can unveil substantial adjustment potential in the food industry, which can further reduce economic losses caused by FMD.



Figure 4. Economic welfare effects (€ million per month, excluding direct costs due to disease eradication measures) due to a trade ban imposed on products of cattle origin on producers, consumers and in total.

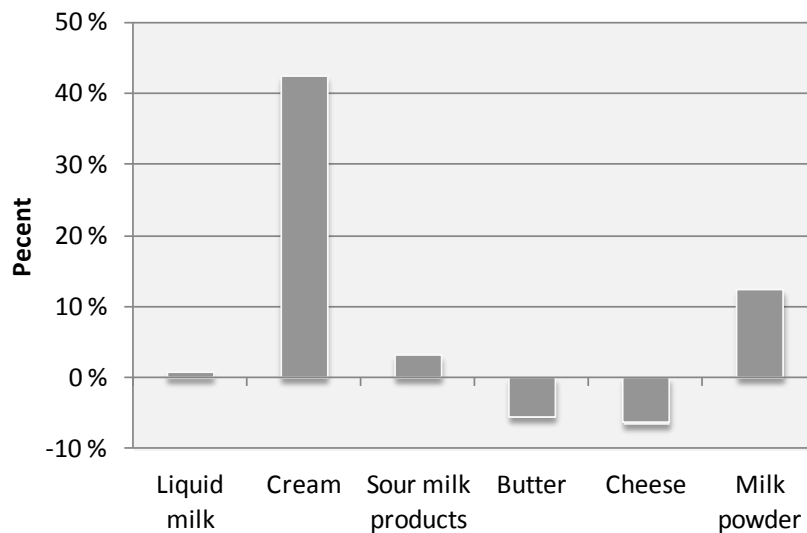


Figure 5. Disaggregation of the impact (change in the production of each product %) of trade distortions per dairy product category in Finland.

### 3.3. Impacts of the risk of re-introduction of disease and trade shock

Next, we simulated how the risk of re-occurrence of trade distortions and a disease outbreak in the future could affect the value of livestock sector (Figure 5). Welfare losses due to the risk of introduction of a trade ban and associated with medium-sized (scenario 3) or (very) large (scenario 4) foot and mouth disease outbreak were simulated at €38 million. Welfare losses due to the risk of re-introduction of large outbreak and a five months trade ban were four-fold over a 30-year period, due to a lower steady state (equilibrium) supply. Calculated

per year, this welfare reduction is approximately €5 million. In both cases, the losses were higher in the cattle sector than in the pig sector.

In the pig sector the risk of shock reduced the quantity of traded pigmeat decreased by less than one percent (Niemi and Lehtonen, 2011) whereas in the cattle sector the impact was almost negligible. This was due to the result that it was possible to reduce net trade losses in the dairy sector quite efficiently by adjusting the supply of different dairy products as highlighted in Figure 5 above. The losses were larger in relation to the size of the industry in the pig sector than in the cattle sector and therefore the impact on production was simulated to be larger in the cattle sector than in the pig sector.

The risk of a new disease outbreak and trade ban harmed producers, but also consumers and taxpayers as it affected the quantity of trade and increased expected costs of disease eradication measures. The risk of a new market shock reduced the value of livestock sector, but the results suggest that it can also reduce disease losses. This result is related to the changes in market prices, expected market revenues and quantities traded. The recovery of the animal stock is more rapid in the case of trade ban which is expected to be short, compared to a case where a renewed trade ban is considered possible

Structural change in the livestock sector has resulted in fewer but larger companies and farms to operate in the sector. This may have increased the risk of more costly disease outbreaks. Increased trade flows may also have affected the risk of animal diseases spreading across countries. The results suggest that a well-perceived possibility of taking into account the risks can reduce the quantity of domestic products' trade a little and thus harm the society. However, we have not assessed whether the gains from international trade exceed these costs.

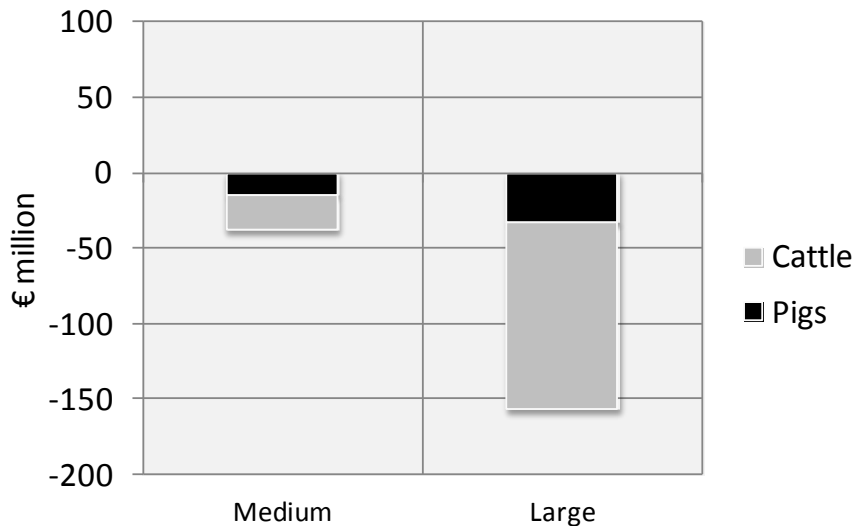


Figure 5. Simulated welfare effects due to the risk of re-introduction of a trade ban and associated with medium-sized (scenario 3) or large (scenario 4) foot and mouth disease outbreak over 30-years-period.

#### 4. Concluding remarks

In this paper we have simulated welfare effects due to a hypothetical foot and mouth disease outbreak and trade ban associated with the disease. Our results suggest that if a trade shock occurs, the market losses are likely to be borne primarily by excess supply of pigmeat, butter and cheese. The trend towards the consumption of low-fat products is one of the factors which have increased potential impacts of trade disruptions in the Finnish beef and cattle sector. If expected size of the epidemics and the duration of the trade shock are likely to increase for instance due to structural change in the livestock sector, this can reduce incentives of farmers to invest dairy or pig production.

However, there can be situations in which some stakeholder groups can occasionally benefit from a disease outbreak. Consumers can occasionally benefit if a disease outbreak with a trade ban results in the saturation of domestic markets and falling prices. Because livestock production process is rigid, producers might also be able to offset some part of their losses after the trade ban has been lifted, if the disease and the adjustment of animal stock have removed a lot of animals from the markets.

The results highlight the fact that there is a limited scope to adjust livestock production rapidly to exogenous and unexpected trade shock. Drastic adjustments in the animal stock are expensive and not likely to realise as a result of rational economic behaviour under



uncertainty about the duration of the disease outbreak and the trade ban. However, the results also show that there are some possibilities to adjust production do exist, and they are worth to be considered. When the duration of trade distortion is unknown beforehand, the meat sector is able to reduce losses through premature slaughter of meat animals and reduced insemination of reproduction animals whereas in the dairy sector the largest potential seems to be in adjusting the processing quantities of milk products. Also meat processing is likely to have some potential for adjustment in their product categories. Hence, taking into account several product categories can unveil substantial adjustment potential in the food industry, which can further be used to reduce economic losses caused by highly contagious animal diseases.

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