Cross-border collaboration

in

contagious livestock disease management

Geralda E. Hop

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This research was conducted under the auspices of the Wageningen School of Social Sciences (WASS).

Cross-border collaboration in contagious livestock disease management

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Thesis

submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Wednesday 28 May 2014
at 4 p.m. in the Aula.

Geralda E. Hop
Cross-border collaboration in contagious livestock disease management,
286 pages

PhD thesis, Wageningen University, Wageningen, NL (2014)
With references, with summaries in English, Dutch and German

ISBN 978-94-6173-945-2

Abstract

This dissertation aimed at examining the potential gains and main challenges for further cross-border collaboration in contagious livestock disease management within the cross-border region of the Netherlands (NL) and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS). The dissertation's under- lying assertion was that further cross-border collaboration can mitigate the veterinary and, especially, the economic impacts of existing (in peacetime) and emerging (during crisis situations) borders between NL and NRW–LS, without compromising the economic advantages of cross-border trade and without increasing veterinary risk.

The cross-border region of NL-NRW-LS is a large and highly integrated livestock production area and increasingly develops towards an epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk. This dissertation shows that a further increase in the cross-border production dependency due to changes in the livestock production structure is likely. These developments change the likelihood and impact of contagious livestock diseases.

Potential gains for further cross-border collaboration in contagious livestock disease management are (i) peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade, and (ii) crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences. Main challenges for further cross-border collaboration are (i) improving the quantity, quality and speed of cross-border communication between countries' veterinary authorities and ministries, and (ii) keeping pace with the increasing globalisation of trade flows through implementing tailor-made institutional settings and harmonising organisational responsibilities.

In peacetime, both NL and Germany (GER) have several possibilities for reducing the economic impact of existing borders, i.e., through mitigating costs of additional, veterinary cross-border measures, without increasing veterinary risks. Most cost savings can be realised by relaxing measures related to slaughter broilers (GER) and slaughter pigs (NL). For crisis situations, the contagious livestock disease classical swine fever (CSF) was used as example. Only limited possibilities exist to mitigate the *veterinary impact* of CSF through further cross-border harmonisation and collaboration. This is mainly due to changes in the production structure of livestock. However, this dissertation shows that there is still a substantial scope for mitigating the *economic impact* of CSF through further cross-border collaboration, particularly the impact resulting from market disruptions. For example, CSF induced market shocks can be mitigated through the channelling of trade flows within a cross-border context.

Nevertheless, country-specific differences in contingency planning limit further cross-border harmonisation of contagious livestock disease management, implying the continuation of existing (in peacetime) and emerging (during crisis situations) borders. A common information-exchange platform, i.e., borderless information exchange, is the basis for more intensive cross-border collaboration.

Contents

1

General introduction

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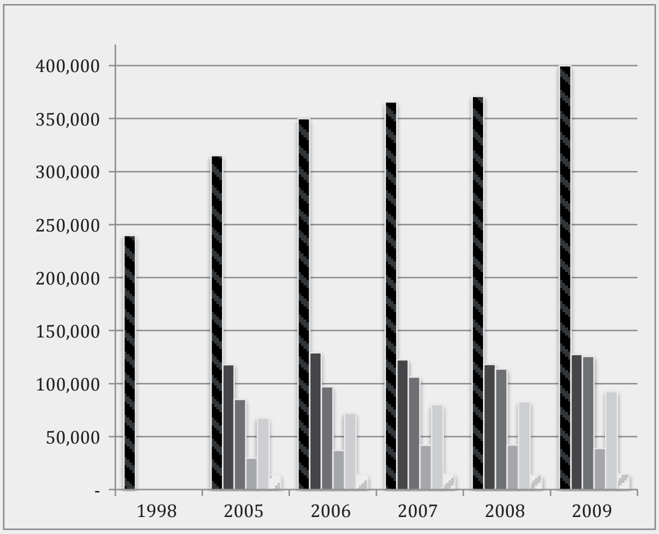
1

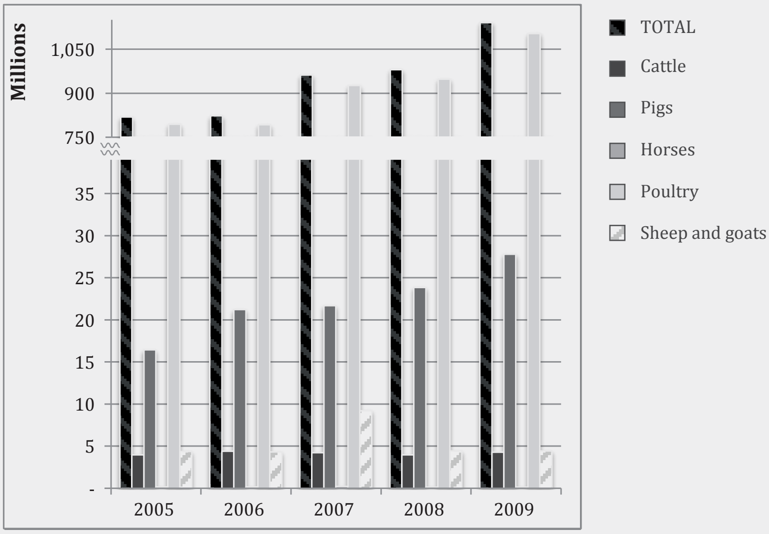
Background

In the past decades, globalisation has led to increased trade in livestock and livestock commodities. Since the General Agreement on Tariffs and Trade (GATT) came into effect in 1948, trade has been subject to international rules (Wilson and Beers, 2001). To facilitate safe trade and prevent disease spread, international animal health standards are set by the World Organisation for Animal Health (OIE) under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) of the World Trade Organisation (WTO) and documented in the OIE's Terrestrial Animal Health Code (Thomson *et al.*, 2004). The SPS Agreement's main intent is to enhance trade in agricultural products by reducing the use of SPS measures as unjustified barriers to trade (Zepeda *et al.*, 2001, 2005). This reduces the practice of governments to using food safety and quarantine requirements as unjustified trade barriers to protect domestic agriculture from import competition (Wilson and Beers, 2001).

The establishment of the European Union (EU) single market in 1992 has stimulated European trade in livestock and livestock commodities among member states (EU, 2010; PVE, 2011; Bayerische Landesanstalt für Landwirtschaft, 2011). Figure 1.1 provides an overview of the intra community trade in terms of the number of live animal consignments for the years 1998 and 2005-2009 (Figure 1.1a) and the total number of animals for the years 2005-2009 (Figure 1.1b). The intra community trade numbers presented in Figure 1.1 include import to and export from EU-27; however, EU-27's imports and exports of live animals are relatively small compared with intra community trade (Eurostat, 2013). Despite the decreasing number of animals produced across the EU (Eurostat, 2013), intra community trade has steadily increased after the establishment of the EU single market from 240,000 consignments in 1998 (McGrann and Wiseman, 2001) to almost 400,000 in 2009 (Baltussen *et al.*, 2011). In 2009, this intra community trade involved the trade in 1,140 million animals: 1,104 million poultry, 28 million pigs, 4 million cattle, 4 million sheep and goats, and a small number of horses. Main reasons for intra community trade are regional specialisation of production and increased regional production of livestock and livestock commodities (Arens *et al.*, 2010), price differentials between member states, and limited slaughter or processing capacity (Baltussen *et al.*, 2011). As a result, the imbalance between regional production and consumption has increased. Most of the intra community trade in livestock takes place between a few member states. Seven member states – Belgium, France, Germany (GER), Italy, the Netherlands (NL), Poland and Spain – account for 60% of the intra community trade in cattle and almost 70% of pigs are transported from Denmark or NL, while GER receives more than 50% of all transported pigs within the EU (CEC, 2011).



A. Number of consignments of live animals



B. Total number of animals (x 1,000,000)

Figure 1.1 Intra community trade in number of consignments of live animals (A) and total number of animals (B) for the years 1998 and 2005-2009 (intra community trade including import to and export from EU-27) (McGrann and Wiseman (2001) and Baltussen *et al.* (2011)).

Without compromising free trade within the EU single market, the EU aims at ensuring a uniform and high level of animal health throughout the EU. Hence, in 1990 a non-vaccination strategy was implemented for most contagious livestock diseases (Terpstra and de Smit, 2000), resulting in a highly susceptible livestock population (Directorate General for Health & Consumers, 2012). In spite of intensive global and national efforts to control or eradicate contagious livestock diseases, a large number of countries is still not free of such diseases (OIE, 2012). These countries present a major challenge to a worldwide, liberalised but safe trade in livestock and livestock commodities (Brückner, 2011). As a result, the EU single market poses a significant risk for the wide-spread dissemination of contagious livestock diseases, whilst at the same time being accepted as inevitable due to the allowance of free trade (Brückner, 2009). This risk was experienced in outbreaks of classical swine fever (CSF) in GER, Belgium and NL in 1997-98 (Stegeman *et al.*, 2002) and in GER in 2006 (OIE, 2012), as well as in the outbreak of foot-and-mouth disease (FMD) in the UK, Ireland, NL and France in 2001 (Bouma *et al.*, 2003).

However, to put these risks in perspective, the few countries that represent the largest share of intra community trade in live animals are very well aware of their dependence on safe and verifiable trade. In the past few decades, EU countries' veterinary status (i.e., biosecurity level) has improved and differences in veterinary status across main EU trade partners have reduced (Brückner, 2011). The intra community trade has become less complicated and less risky by increasing transparency through an EU-wide tracking and tracing system (Traces). Additionally, livestock transports proceed to just one destination farm and the loading of additional animals along the road is no longer allowed (McGrann and Wiseman, 2001). Thus, despite – or perhaps, thanks to – the establishment of the EU single market, most trade has become less risky at the same time.

Problem statement

Regional specialisation of production and increased regional production of livestock have led to an integration of EU livestock production across borders, i.e., integrated production areas, and livestock value chains have globalised in recent decades. Nevertheless, contagious livestock disease management is still a 'single country'-affair, even though it relates to and depends on other countries' livestock trade relationships and dependencies, as well as their prevention, monitoring (peacetime) and control (crisis situation) strategies. These strategies are derived from the requirements of the international bodies (e.g., OIE and WTO) and are transposed into EU directives and national veterinary contingency plans. The European Commission is responsible for ensuring that EU legislation meets the international requirements following the SPS Agreements. Although determined at EU-level, European directives leave national governments scope for implementing specific rules which makes 'beyond-country-level' contagious livestock disease management difficult (Breuer *et al.*, 2008).

Highly integrated production areas imply that disease introduction and control are a shared veterinary and economic risk and show the need for and potential of a more structural and integrated intervention to increase cross-border collaboration in contagious livestock disease management (AEBR, 2006; Breuer *et al.*, 2008; Arens *et al.*, 2010). Efficiency of cross-border prevention and control of contagious livestock diseases can be improved, as was demonstrated by Breuer *et al.* (2008) for the outbreak of CSF in GER in 2006. Effective cross-border cooperation and communication between countries' public administration, for example, veterinary authorities and ministries, is thus essential for ensuring effective and rapid animal disease control. It can be questioned whether countries' public administrations can keep pace with the strong trade globalisation as they currently lack tailor-made institutional settings and constraint effective regional specialisation (AEBR, 2006; Arens *et al.*, 2010).

Policy makers recognise this problem and are aware of the need to increase cross-border collaboration in contagious livestock disease management (MUNLV, 2007; Breuer *et al.*, 2008). Particularly during outbreaks of highly contagious livestock diseases in the past, several *ad hoc* initiatives have already been undertaken (AEBR, 2006; Brand *et al.*, 2007). For example, during the bluetongue crisis in 2006 there were cooperation initiatives between veterinary authorities of the three initially-affected countries (Belgium, GER and NL) including, e.g., the formation of a research group to provide science-based decision support for future bluetongue monitoring and surveillance (Deluyker and Reintjes, 2008). However, it can be hypothesised that, in the long run, a more structural improvement of collaboration and harmonisation can reduce the economic consequences of contagious livestock disease management, while minimising the negative consequences for trade between bordering countries and without increasing veterinary risks. Such a comprehensive framework for long-term cross-border policy development is still lacking.

Case study region

A particular example of a large and highly integrated livestock production area is the cross-border region of NL and the German states of North Rhine Westphalia (NRW) and Lower Saxony (LS). In this dissertation, this cross-border region is used as case study region (Figure 1.2). The region's veterinary authorities and livestock production sectors already have a long history in cooperating in peacetime and crisis situations and there clearly is no other area within the EU in which the production of livestock is comparably integrated (Bäurle *et al.*, 2007; Veauthier and Windhorst, 2008). It is therefore a good example for illustrating the potential difficulties and opportunities for other cross-border regions.

To illustrate the region's high level of integration, in 2010, 81% of the NL's total slaughter pig exports went to German slaughterhouses, 95% of which went to NRW and LS (PVE, 2011). Additionally, 52% of the NL's exported piglets went to GER, 84% of which went to NRW and LS (PVE, 2011). This large trade partly results from Dutch environmental legislation that caused a structural change in pig production in which farmers switched from the production of fattening pigs to the production of piglets (Silvis *et al.*, 2009). As a result of a shortage of fattening places within NL, large numbers of Dutch piglets have been exported to Germany (GER) and consequently, Dutch piglet producers and German fattening pig farmers highly depend on one another in terms of their pig production (Bayerische Landesanstalt für Landwirtschaft, 2011). Also other Dutch and German livestock sectors have increased their mutual cross-border dependency over the past decade, and a further increase is expected in the near future (Hop *et al.*, 2014). For example, 130 million of the 287 million broilers produced in NRW and LS were slaughtered in NL in 2010, and nearly 5000 veal calf transports from NRW and LS to NL were recorded (PVE, 2011).

With an overall population of more than 42 million people, the case study region is also a large consumption area (CBS, 2010; FSO, 2010). Both the production and consumption of livestock commodities have a large cross-border importance, resulting in a great social, economic, environmental and political cross-border dependence of producers and consumers.

Objective

The overall objective of this dissertation is to examine the potential gains and main challenges for further cross-border collaboration in contagious livestock disease management within the cross-border region of NL, NRW and LS. This dissertation's underlying assertion is that further cross-border collaboration can mitigate the veterinary and, especially, the economic impacts of existing (in peacetime) and emerging (during crisis situations) borders between NL and NRW–LS, without compromising the economic advantages of cross-border trade and without increasing veterinary risks. The overall objective is split into five sub objectives:

- to present a conceptual framework of the potential gains and the main challenges for further cross-border collaboration in the control of highly contagious livestock diseases within the cross-border region of NL–NRW–LS;

Figure 1.2 A map of the cross-border region of the Netherlands (NL), North Rhine Westphalia (NRW), and Lower Saxony (LS) in relation to the rest of Europe (the map of Europe was adapted from Anonymous (2013)).

- to explore changes in future production structure features within the cross-border region of NL–NRW–LS projected towards 2020, and to elaborate the findings in terms of possible implications for contagious livestock disease introduction, spread and control;
- to examine the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL–NRW–LS;
- to examine CSF control strategies' veterinary and direct economic impacts for NL,

NRW and LS given the current production structure, and to analyse CSF's cross-border causes and impacts within the NL-NRW-LS region;
- to obtain insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation (dividing the country into a diseased region with and free regions without movement and trade restrictions), vaccination, and regional specialisation of pig production, and to assess the potential for mitigating these market disruptions in a cross-border context.

Outline of the dissertation

This dissertation comprises a general introduction (chapter 1), five research chapters (chapters 2–6) and a general discussion (chapter 7). The structure of this dissertation is presented in Figure 1.3.

Chapter 2 presents a conceptual framework of the potential gains and main challenges for further cross-border collaboration in the control of highly contagious livestock diseases within the cross-border region of NL–NRW–LS. This chapter uses a general disease management framework to describe the way in which chapters 3–6 relate to and affect the epidemiological system and, consequently, how they affect the stakeholders in terms of economic consequences. The chapter discusses possibilities for future policy making in contagious livestock disease management: peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade (elaborated in chapter 4), and crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences (elaborated in chapters 5 and 6 for CSF). The chapter discusses the importance of jointly considering mitigating the impact of peacetime and crisis borders. For example, reducing the quality or quantity of peacetime information collection can affect the control strategy and information needed to eradicate livestock diseases in both short- and long-term. In addition, this chapter addresses the need for a good understanding of future developments in those features of the livestock production structure that influence the risks of disease introduction, notification and eradication. Changes in these risks can affect the consequences of strategies and the routine veterinary and disease control measures needed to regulate contagious livestock diseases. Adjusting current legislation according to the changes in risks requires a large effort and several years, i.e., changing current legislation is laborious. The livestock production structure has proven to rapidly change in the past decades and is expected to change in the next decade (EC, 2010). Therefore, it is worthwhile to take into account the implications of these changes on the potential of mitigating the veterinary and economic impacts of existing (peacetime) and emerging (crisis situations) borders between NL and NRW–LS. The findings of this chapter are based on a literature search and experts and research end-users' consultation.

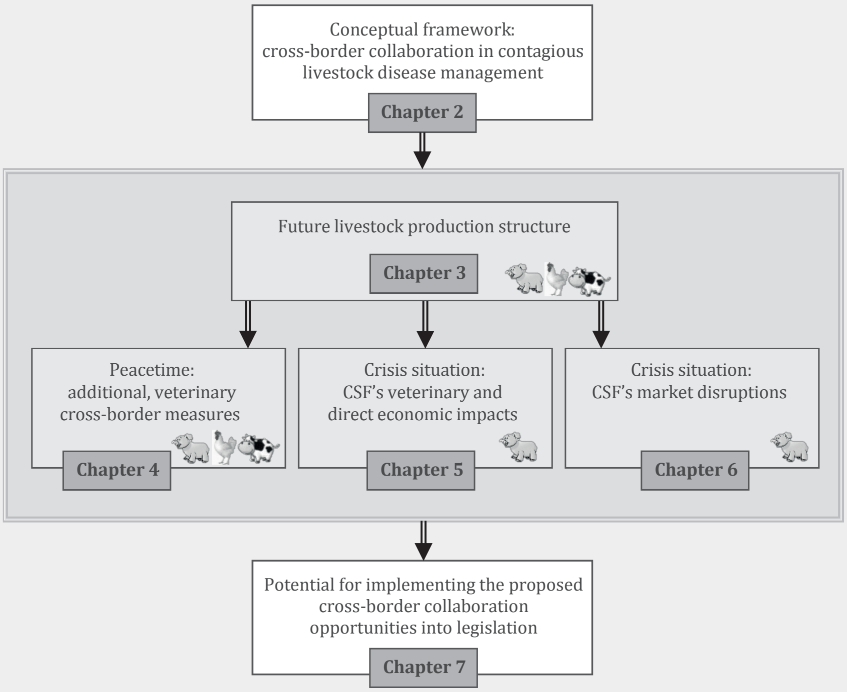


Figure 1.3 Structure of the dissertation.

Chapter 3 explores changes in future production structure features within the cross-border region of NL–NRW–LS projected towards 2020, and elaborates the findings of this chapter in terms of possible implications for contagious livestock disease introduction, spread and control. This chapter identifies the main driving forces that are likely to impact the future structure of livestock production (pig, poultry and dairy sectors), quantitatively assesses their impact on the future structure of livestock production, and explores possible implications for contagious livestock disease management. The chapter explores these expected structural developments through a literature search, through a Policy Delphi study, by organising workshops and by carrying out interviews. The outcomes are used as input for chapters 4 (for peacetime), 5 and 7 (for crisis situations as discussed in chapters 5 and 6).

Chapter 4 hypothesises that relaxing additional cross-border measures may be well-justified from a veterinary perspective, i.e., without increasing veterinary risks, and can generate cost savings, especially for neighbouring countries with similar veterinary status that are characterised by large cross-border trade. This chapter, therefore, examines the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL–NRW–LS. Chapter 4 constructs a deterministic spread-sheet cost model to calculate the costs of both routine veterinary measures (standard measures that apply to both domestic and cross-border transport) and additional cross-border measures (extra measures that only apply to cross-border transport) as applied in 2010. This model determines costs by stakeholder, region and livestock sector, and studies the prospects for cost reduction by calculating the costs after the relaxation of additional cross-border measures. Several additional cross-border measures are selected for relaxation because they have a low expected added value on preventing contagious livestock diseases, have no expected additional veterinary risks and generate reasonable cost-saving possibilities.

Chapters 5 and 6 use the example of CSF to elaborate crisis time cross-border harmonisation of, and collaboration in current contagious livestock disease control strategies to mitigate these strategies' economic consequences. **Chapter 5** examines CSF control strategies' veterinary and direct economic impacts for NL, NRW and LS given the current production structure, and analyses CSF's cross-border causes and impacts within the NL-NRW-LS region. The stochastic, dynamic and spatially explicit simulation model Interspread Plus is parameterised for CSF epidemics in the cross-border region of NL-NRW-LS. The epidemiological outputs are used as input for a conversion model programmed in SPSS, which analyses the output and calculates direct costs and costs directly resulting from the control measures applied. Three veterinary control strategies are considered: a strategy based on the minimum EU requirements, and a vaccination and non-vaccination strategy based on NL and GER's contingency plans.

Chapter 6 obtains insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation, vaccination, and regional specialisation of pig production, and assesses the potential for mitigating these market disruptions in a cross-border context. Expert workshops and spread-sheet models are used to semi-quantitatively estimate the magnitude of CSF induced market disruptions in terms of changes in trade volumes and prices.

Chapter 7 synthesises the results of the different chapters, elaborates the implications for future research, discusses the (im)possibilities and further action needed to implement the proposed cross-border collaboration opportunities from chapters 2-6 into national and EU legislation, reflects on the applied research approach and methods, and ends with a summary of this dissertation's main conclusions.

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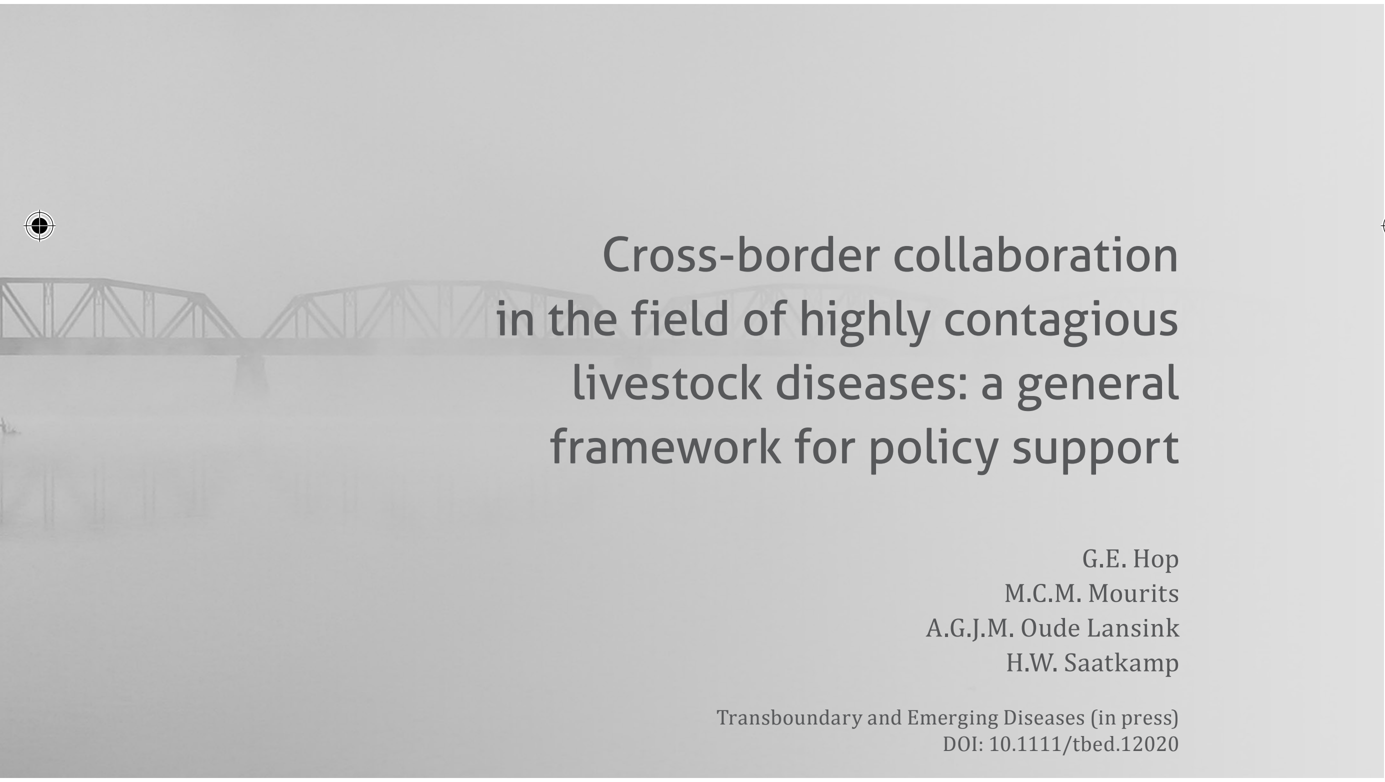

Cross-border collaboration in the field of highly contagious livestock diseases: a general framework for policy support

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Transboundary and Emerging Diseases (in press)
DOI: 10.1111/tbed.12020

Abstract

This chapter presents a conceptual framework of the potential gains and the main challenges for further cross-border collaboration in the control of highly contagious livestock diseases in regions with cross-border reliance on production and consumption of livestock commodities. The aim of this intensification of cross-border collaboration is to retain the economic advantages of cross-border trade in livestock and livestock commodities while maintaining a low risk of highly contagious livestock diseases.

From these two foci, possibilities for future policy making with respect to highly contagious livestock diseases are discussed: peacetime cross-border cooperation to improve the cost-effectiveness of routine veterinary measures and crisis time cross-border harmonisation of, and collaboration in current disease control strategies. A general disease management framework was used to describe the way in which these two fields are related to and affect the epidemiological system and, consequently, how they impact the stakeholders. In addition to this framework, the importance of a good understanding of influencing factors, that is, the production structure of livestock, was stressed because these factors are important determinants of the frequency and magnitude of highly contagious livestock diseases and their economic impact. The use of the suggested integrated approach was illustrated for the extended cross-border region of the Netherlands and Germany, that is, North Rhine Westphalia and Lower Saxony. For this region, current difficulties in cross-border trade in livestock and livestock commodities and possibilities for future cross-border collaboration were examined. The concepts and ideas presented in this chapter should foster future development of cross-border collaboration in animal health control.

Introduction

In the past decades, globalisation has led to more and intensified trade in livestock and livestock commodities. To facilitate safe trade and prevent disease spread, international animal health standards are set by the World Organisation for Animal Health (OIE) under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) of the World Trade Organisation (WTO) and documented in the OIE's Terrestrial Animal Health Code (Thomson *et al.*, 2004). The SPS Agreement's main intent is to allow increased trade of agricultural products by avoiding the use of SPS measures as unjustified barriers to trade (Zepeda *et al.*, 2001, 2005). Veterinary services and private professionals are essential to fulfil and comply with the SPS agreement, i.e., in demonstrating a country's health status through, for example, surveillance and veterinary risk assessment (Zepeda *et al.*, 2005).

Trade globalisation has led to regional specialisation and intensified production of livestock and livestock commodities (Arens *et al.*, 2010) and, consequently, mutual dependencies between livestock producers and consumers across borders due to large cross-border trade. For example, during the last decade, the Netherlands (NL) increased the production of piglets. Increasingly more Dutch piglets have been exported to German fattening farms (Silvis *et al.*, 2009; Bayerische Landesanstalt für Landwirtschaft, 2011). This mutual dependency is expected to increase even further in the near future (Hop *et al.*, 2014).

An important consequence of increased cross-border trade is the higher likelihood of introducing contagious livestock diseases into bordering countries. Outbreaks of classical swine fever (CSF) in Germany (GER), Belgium and NL in 1997–1998 (Stegeman *et al.*, 2002) and in GER in 2006 (OIE, 2012) showed that control of highly contagious livestock diseases is a cross-border problem. Efficiency of cross-border prevention and control of these diseases can be improved, as was demonstrated by Breuer *et al.* (2008) for the outbreak of CSF in GER in 2006. Effective cross-border cooperation and communication between countries' public administration, for example, veterinary authorities and ministries, is thus essential to ensure efficient animal disease control. It can be questioned whether countries' public administrations can keep pace with the strong trade globalisation as they currently lack tailor-made institutional settings and constraint effective regional specialisation (Arens *et al.*, 2010).

Policy makers recognise this problem and are aware of the opportunities to harmonise disease control (Breuer *et al.*, 2008). Particularly during outbreaks of highly contagious livestock diseases, several *ad hoc* initiatives have already been undertaken (AEBR, 2006; Brand *et al.*, 2007). For example, there were cooperation initiatives between NL and GER during the bluetongue crisis in 2006 (Deluyker and Reintjes, 2008). However, it can be hypothesised that, in the long run, a more

structural improvement of collaboration and harmonisation can reduce the economic consequences of disease control without compromising the economic advantages of cross-border trade and without increasing veterinary risk. Such a comprehensive framework for long-term cross-border policy development is still lacking.
The objective of this chapter was, therefore, to present a conceptual framework of the potential gains and the main challenges for further cross-border collaboration in the field of highly contagious livestock disease control. A general framework was defined and applied to present the current difficulties in cross-border trade in livestock and livestock commodities and possibilities for future cross-border collaboration and harmonisation for the extended cross-border region of NL and GER, that is, North Rhine Westphalia (NRW) and Lower Saxony (LS). The concepts and ideas presented in this chapter should foster future development of cross-border collaboration in animal health control.

General framework

The aim of intensification of cross-border cooperation in highly contagious livestock disease control is to retain the economic advantage of cross-border trade while maintaining a low risk of highly contagious livestock diseases. From these two foci, two fields of future policy making are identified: (i) peacetime cross-border cooperation to improve the cost-effectiveness of routine veterinary measures, and (ii) crisis time cross-border harmonisation of, and collaboration in veterinary disease control strategies. Due to their mutual dependency, it is important to consider these two fields jointly. For example, budget cuts in veterinary services can reduce the quality of, for example, surveillance and monitoring systems and risk assessment. Such changes in routine veterinary measures most likely reduce the quality of information collection and can affect the control strategy and information needed to eradicate livestock diseases in both short- and long-term.
In Figure 2.1, the two fields of policy making are included in a general disease management framework. The original framework was developed by Longworth and Saatkamp (2006) and outlines the overall management for prevention, monitoring and control of avian influenza (AI). In our figure, the original framework has been extended with our identified fields of policy making, resulting in a framework that includes the main challenges for cross-border collaboration related to highly contagious livestock disease control. The framework uses a similar qualitative conceptual approach as described and used by Dresner (2008), EFSA (2009) and Thulke and Grimm (2010).
The framework's four key elements are states, events, influencing factors and actions, as listed on the left of Figure 2.1. Domestic commercial populations of a region or

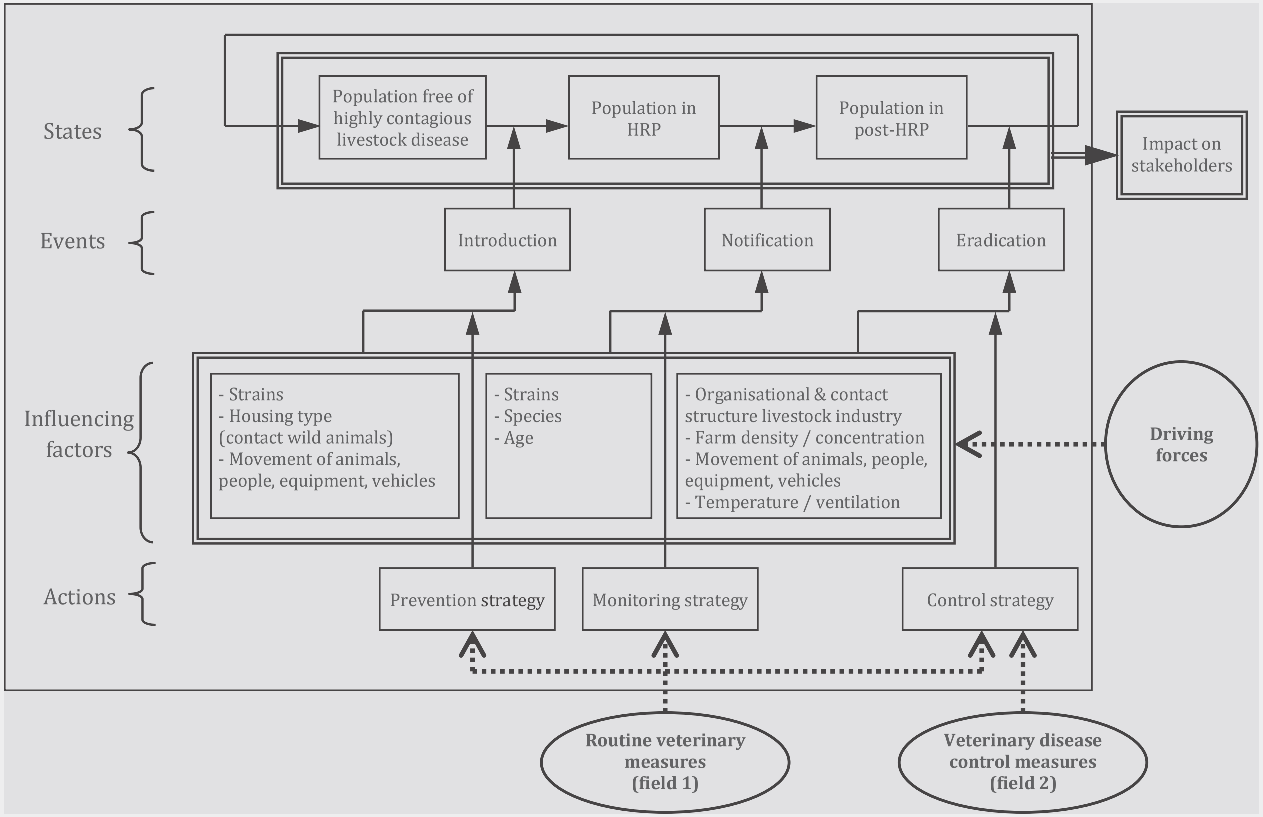

Figure 2.1 Conceptualisation of the decision-making problem regarding cross-border collaboration in the field of highly contagious livestock diseases (adapted from Longworth and Saatkamp, 2006).

country can fall into one of three mutually exclusive states at any time: (i) free of highly contagious livestock disease, (ii) the high-risk period (HRP) or (iii) the post-HRP. Transitions between these states occur following the event's introduction, notification and eradication, respectively. In peacetime, populations are free of highly contagious livestock diseases. After virus introduction, the population enters the HRP. During this period, the virus is present but not notified to be in the population; thus, it can spread freely. The length of the HRP is therefore an important factor in the epidemic's subsequent development. The population enters the post-HRP following notification of the disease. After the disease's eradication by veterinary control measures, the population re-enters the state of being free of highly contagious livestock diseases. The likelihood of events and, therefore, the length of time that a population stays in each state are affected by several influencing factors. The likelihood of events can be influenced by actions including prevention, monitoring and control strategies, as shown in Figure 2.1. The prevention strategy includes all measures aimed at reducing the likelihood of disease introduction into the domestic population. The monitoring strategy includes all measures related to the surveillance of the domestic population aimed at reducing the HRP. The control strategy includes all measures aimed at controlling disease spread and eradicating the disease as quickly as possible (De Vos *et al.*, 2003; Longworth *et al.*, 2008).

The two fields of policy making that are connected to the general framework (Figure 2.1) affect the epidemiological system and the stakeholders as follows.

1. The impact of cross-border cooperation to improve the cost-effectiveness of routine veterinary measures: Routine measures, for example collecting essential information for disease eradication, influence the prevention, monitoring and control strategy, as presented in Figure 2.1. These strategies affect the events of introduction, notification and eradication, which, in turn, affect the three different states in which a population can exist. To illustrate this point, an improvement in the cost-effectiveness of routine measures affects the following: (i) the actions of prevention, monitoring and control, (ii) the likelihood of virus introduction, (iii) the time before notifying the disease (the population is in HRP for a longer/shorter period), (iv) the eradication that is needed to control the disease and (v) the impact on the stakeholders.
2. The impact of cross-border harmonisation of, and collaboration in current veterinary disease control strategies: Harmonising the control strategy, for example sharing essential information for cross-border disease eradication, and collaborating within a cross-border region affects how livestock diseases are eradicated. Eradication influences the time in which a population stays in post-HRP; as a result, it determines the impact on the stakeholders.

In addition, it is essential to have a good impression of future developments in those features of the livestock production structure that influence the risks of disease introduction, notification and eradication. Changes in these risks can affect the consequences of strategies (actions in Figure 2.1) and the routine veterinary and disease control measures needed to regulate diseases. In Figure 2.1, these features are presented as influencing factors, which include, for example, movements of animals and the structure of livestock production. In addition to structurally increasing cross-border collaboration, it is also important to reduce the economic consequences of highly contagious livestock disease control measures. The total impact of the implemented measures on the different stakeholders depends on, for example, the epidemiological, economic, social–ethical, human health and environmental impacts (Longworth and Saatkamp, 2006; Mourits *et al.*, 2010).

The framework can be used to address specific issues related to the economic impact, for example, we can map asymmetries in impact and costs among (specific species within) livestock sectors and among stakeholders in the cross-border region. To lower the economic impact on stakeholders, economic instruments can be added to the current disease control strategy. Adding these instruments does not change the processes within the epidemiological system of Figure 2.1. However, it does influence the total control strategy and, consequently, the total economic impact on the stakeholders. Examples of these economic instruments include channelling animals and animal products to a lower quality and/or price segment of the market, or the storage of products to buffer and/or mitigate market disruptions.

In the following sections, the two fields of policy making and the future developments in influencing factors caused by driving forces are explained in more detail for the case study of the cross-border region of NL–NRW–LS. The rationale for choosing this region as a case study is explained in more detail in the next section.

Case study region NL–NRW–LS

In this chapter, the extended cross-border region of NL–NRW–LS is used as case study. This region is part of the European Union (EU) single market, which was established in 1992 (EU, 2010). The European Commission, advised by, for instance, the European Food Safety Authority (EFSA), is responsible for ensuring that EU legislation meets the SPS Agreements' international obligations.

The cross-border region of NL–NRW–LS is a large and highly entangled livestock production area, including, for example, a total pig population of approximately 11.7 million, 8.2 million and 6.4 million in NL, LS and NRW, respectively, in 2008 (Eurostat, 2010). To give an example of this entanglement, 81% of NL's total exported fattening pigs went to GER in 2010, and 95% of these fattening pigs were exported to NRW and

LS (PVE, 2011). In addition, 52% of NL's exported piglets went to GER in 2010, and 84% of these piglets were exported to NRW and LS (PVE, 2011). Also other livestock sectors show a large cross-border trade. For example, 130 million of the 287 million broilers produced in NRW and LS were slaughtered in NL in 2010, and nearly 5000 veal calf transports from NRW and LS to NL were recorded (PVE, 2011).

With an overall population of more than 42 million people, the case study region is also a large consumption area (CBS, 2010; FSO, 2010). Both the production and consumption of livestock commodities have a large cross-border importance, resulting in a great social, economic, environmental and political cross-border dependence of producers and consumers.

The cross-border region already has a long history in cooperating with respect to livestock production. It is therefore a good example for illustrating the potential difficulties and opportunities for other cross-border regions.

Routine veterinary measures

To prevent, monitor and control highly contagious livestock diseases, various routine veterinary measures are implemented to minimise the impact of such diseases. Examples of routine measures include the cleansing and disinfection of livestock trucks, veterinary controls and health declarations of animals for live use and certification of slaughter animals prior to intra community trade across the EU, and the identification and registration of animals.

The routine veterinary measures are derived from the requirements of the international bodies (e.g., OIE and WTO) and transposed into EU directives and national legislation. However, implemented routine measures may differ between countries such that some countries implement more stringent rules (Madec *et al.*, 2001). In general, differences in the implemented routine measures between countries can be explained by two factors: (i) the different health statuses between trade partners and (ii) the protection of countries' export statuses.

Different health statuses between trade partners may require a different certification system of animals and animal products and trade exemptions and quarantine measures. A region with a lower status cannot export directly to a region with a higher status without extra certifications and trade exemptions.

To protect their export status, countries can give extra guarantees to importing countries with respect to the health status of their animals and animal products.

Routine veterinary measures in the region of NL–NRW–LS

Table 2.1 shows the current routine veterinary measures for the three main animal species: pigs, poultry and cattle. The measures are grouped into those implemented for domestic and cross-border trade, and those implemented additionally for cross-border trade from NL to NRW–LS and vice versa. All three species are split into the categories of animals for live use (L) and animals for slaughter (S). In this table, products from animal origin are not considered because EU legislation is identical for transport within and among EU countries. Execution of routine veterinary measures is the prime responsibility of veterinary services, such as the Food Safety Authorities (NVWA in NL and BVL in GER) and the Dutch Product Boards for Livestock, Meat and Eggs (PVE).

Table 2.1 suggests several ways to improve the cost-effectiveness of routine veterinary measures.

First, the majority of the additional, veterinary cross-border measures are mandatory for the transport of both animals for live use and animals for slaughter. If one considers the aim of these measures, however, measures taken with respect to slaughter animals are to some extent overdone because these animals reach their final destination once they enter the slaughterhouse, so-called dead-end hosts. Therefore, the veterinary risk of introducing highly contagious diseases into a country's livestock population by importing slaughter animals is likely to be low. Compared to transporting slaughter animals unhindered within one's own country over a long distance, a short transport just across the border requires many additional measures for no other reason than because it is part of EU legislation.

Second, in some cases, comparable measures are implemented on both sides of the border. For example, the clinical examination of slaughter animals happens before (in country of origin) and after transportation (in country of destination).

Third, and most importantly, there are almost no differences between routine measures implemented in GER and NL. The lack of differences is reasonable because all measures are based on EU legislation. However, this lack also indicates that hardly any additional routine measures are imposed by GER and NL themselves. There are two possible explanations for this finding: (i) current measures are adequate and to some extent overdone in preventing, monitoring and controlling highly contagious livestock diseases and/or (ii) the countries are not willing to implement any additional measure, likely due to high costs.

The measures described above cause administrative inconvenience. Improving the cost-effectiveness of routine measures is therefore a desired option, which can either maintain or increase veterinary risks.

While *maintaining* veterinary risks, improving the cost-effectiveness of routine veterinary measures only results in lower costs for the affected stakeholders. It is unlikely that it affects primary and secondary stakeholders in a negative way, although it may result in less work for the executing authorities. So the veterinary impact, which is the likelihood of introduction times the consequences, stays the same.

Table 2.1 Routine veterinary measures and additional cross-border measures implemented in the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (LS) for transport of animals for live use (L) and for animals for slaughter (S) for the three main animal species of pigs, poultry and cattle.

Measures	Poultry	
	Export from NL to NRW-LS	
	L	S
Routine veterinary measures (for domestic and cross-border trade)		
General		
Check (standards) load of transport	x	x
Cleansing and disinfection of truck (checked by farmer; note of farmer in logbook)	x	x
Transport >65 km and <8 h: permit for short journey	x	x
Transport >65 km: driver has certificate of competence	x	x
Transport >8 h: certificate truck, permit for long journey, logbook	x	x
Compliance with animal welfare regulations during transport	x	x
Food Chain Information (VKI) report present before slaughter		x
Clinical examination of animals by farmer during loading truck	x	x
Clinical examination of animals at arrival slaughterhouse; check documents		x
Report births, deaths, and changes in location of animals to identification and registration system	x	x
Pig-specific		
Add and check presence of metal slaughter tags		
Poultry-specific		
Annual LPAI check on farm	x	
Check results test Salmonella Gallinarum-Pullorum (parent stock of hatching eggs / one day chicks)	x	
Check results test Salmonella hader, Salmonella infantis, and Salmonella virchow (parent stock of hatching eggs / one day chicks)	x	
Check results Salmonella SE and ST	x	x
Check results Mycoplasma Gallisepticum (MG) test (parent stock of hatching eggs / one day chicks; once per 12 weeks)	x	
Additional, veterinary cross-border measures		
General		
Request export and certification animals	x	x
Time of stay of animals at farm of origin:		
• Own declaration farmer		
• Passport		
• Database		
Check animal category/type/status	x	x
Animal health status farms of origin (notifiable diseases)	x	x
Identification transport vehicle		

		Pigs				Cattle			
Export from NRW-LS to NL		Export from NL to NRW-LS		Export from NRW-LS to NL		Export from NL to NRW-LS		Export from NRW-LS to NL	
L	S	L	S	L	S	L	S	L	S
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
		x	x			x	x		
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
	x		x		x		x		x
x	x	x	x	x	x	x	x	x	x
	x		x		x		x		x
x	x	x	x	x	x	x	x	x	x
			x		x				
x									
x									
x									
x	x								
x									
x	x	x	x	x	x	x	x	x	x
		x		x	x				
						x	x	x	x
x	x			x	x			x	x
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
		x	x	x	x	x	x	x	x

Table 2.1 Continued.

Measures	Poultry	
	Export from NL to NRW-LS	
	L	S
Proof of travel time by print-out route[1]	x	x
Clinical examination of animals by a veterinarian during loading truck (check clinical syndromes of diseases / other abnormalities)	x	x
Animal health certificate (export certificate) in TRACES[2]	x	x
Pig- and cattle-specific		
Export via gathering place: approved protocol of business		
Transport document regulation on pig deliveries (VVL) containing certificate of Aujeszky's disease and SVD monitoring		
Check presence of ear tags		
Random sampling to match ear tags with farm identification number or passport		
Add and check presence of metal slaughter tags		
For veal calves: pre-announcement of transport and destination farm to prevent additional loading during transport (checked by Dutch authorities)		
Documents / blood results Infectious Bovine Rhinotracheitis (IBR)		
Insemination dates / vet declaration to check time-in-calf of pregnant cows		
Poultry-specific		
Annual check farm's compliance with export conditions	x	
Random sampling (2%) physical check day-old chicks / hatching eggs	x	
Clinical examination parent stock of day-old chicks / hatching eggs (once per 30 days)	x	x
Report changes in number of animals on farm due to transports (KIP-database)	x	x
Proof of vaccination / exemption Newcastle Disease (NCD)	x	x

[1] NL uses Routenet, whereas GER uses TRACES[2] for determining the travel time. Note that the systems use a different average speed for determining the travel time.

[2] TRACES is an intra-trade system for the cross-border trade of animals. TRACES allows the competent authorities of the different member states to inform each other of cross-border movements of animals submitted to veterinary certification.

Improving the cost-effectiveness of the current routine measures in a way that veterinary risks *increase*, results in the trade-off between the lower costs of executing routine measures on the one hand, and an increased risk of major costs in the case of an outbreak on the other hand. It can also lead to a different distribution of the costs among the various stakeholders, resulting in disproportionately large costs for some stakeholders. Thus, some countries can be affected more than others, most likely based on their dependency on trade.

		Pigs				Cattle			
Export from NRW-LS to NL		Export from NL to NRW-LS		Export from NRW-LS to NL		Export from NL to NRW-LS		Export from NRW-LS to NL	
L	S	L	S	L	S	L	S	L	S
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x
		x	x			x	x		
		x							
		x	x	x	x	x	x	x	x
		x	x	x	x	x	x	x	x
			x		x				
								x	
						x			
						x	x		
x									
x	x								
x									
x	x								

Improving the cost-effectiveness of routine veterinary measures must be performed in accordance with (inter)national requirements. Therefore, improving the cost-effectiveness requires an appropriate institutional and legal setting, including agreements on different levels, for example, within NL and GER, and on the EU and WTO levels.

Veterinary disease control measures

Veterinary disease control measures are aimed at controlling the spread of highly contagious livestock diseases and eventually eradicating the disease as quickly as possible, that is, reducing the presence of spread mechanisms via movement standstills and the stamping-out of infected premises (De Vos *et al.*, 2003). Eradicating the disease as quickly as possible assumes that the veterinary impact is minimised along with the economic impact.

The economic impact of disease outbreaks among livestock can be extensive (see e.g., Meuwissen *et al.*, 1999; Thompson *et al.*, 2002; Longworth *et al.*, in press). The total economic impact includes the specific categories of direct, consequential and aftermath costs. Direct costs consist of costs associated with the control of the disease, including costs for culling, compensation to farmers, and control measures. Consequential costs result from the disease control and can be divided into (i) direct consequential costs, which directly result from the disease control (e.g. idle production factors), and (ii) indirect consequential costs, which result from shocks in supply of and/or demand for livestock commodities (i.e. price effects). Aftermath costs are a direct or indirect result of the disease but occur after controlling the disease, for example, under-capacity due to restocking problems and price effects due to extended trade bans. Extended trade bans result in a loss of access to regional and international markets, which often have much larger economic implications than local production losses alone. The size of the economic damage depends upon the volume of exports from the affected area. Thus, the impact can be severe for areas that had an important and established export market before the outbreak.

Within the EU, governments generally bear the largest part of the direct costs. The EU refunds in most cases 50% of the organisational costs, 50% of the costs of compulsory and pre-emptive slaughter and 70% of the costs of welfare slaughter. National compensation of direct costs varies among member states. Most member states have set up a statutory system to co-finance the direct costs (e.g. NL and GER), whereas some states finance the direct costs from the national budget (e.g. Denmark and UK). In NL and GER, farmers contribute to the national animal health fund by paying a fixed levy per animal or animal product (van Asseldonk *et al.*, 2005; Bergevoet *et al.*, 2011).

In NL, the national government only carries those direct costs that exceed a certain, in advance agreed level, a so-called non-proportional contract. If the fund's capital is not available as a result of the fact that most capital is gathered through assessment payments after an epidemic, the national government gives an advance for direct costs. The Dutch fund is a form of private bank guarantee system in which the government can withdraw capital without prior approval of the livestock sector. Capital is paid back with interest by the primary sector over a certain time horizon (van Asseldonk *et al.*, 2005; Bergevoet *et al.*, 2011).

In GER, the amount that is financed by the sector is proportional, that is, risks are shared between the sector and the national government, a so-called pro-rata contract in which levies are specified as a fraction of the coverage. The fund is established by the different Bundeslander (such as NRW, LS and others), and detailed rules of the application are determined by the Bundeslander themselves. The Bundeslander and the levy fund each pay half of the non-EU compensated part. Levies are only used to co-finance EU veterinary measures following a disease outbreak, that is, no compensation is paid to farmers in surveillance zones (Bergevoet *et al.*, 2011).

With respect to covering consequential costs from livestock epidemics, only a few private insurance schemes exist within the EU. In NL, additional coverage is only available for cattle, whereas for GER, coverage is available for cattle and pigs (the so-called Ertragsschaden-versicherung). Participation level of farmers is usually low (van Asseldonk *et al.*, 2005).

Hence, for both compensation of direct and consequential costs, differences exist between NL and GER and harmonisation and collaboration possibilities are present.

Veterinary disease control measures in the region of NL–NRW–LS

The current veterinary control measures for AI, CSF and FMD for NL and GER are shown in Table 2.2. Mandatory control measures (x), optional measures (o) and non-applicable measures (–) are given. These measures are derived from the requirements of the international bodies and are transposed into EU directives and national veterinary contingency plans. Other EU countries have similar measures, although there are slight differences with respect to time periods (e.g. the time period of transport standstill) and distances (e.g. zoning). Execution of veterinary control measures is the prime responsibility of veterinary services, such as the Food Safety Authorities (NVWA in NL and BVL in GER).

Table 2.2 shows that NL and GER have similar veterinary disease control measures. NL has more optional measures (more stringent measures) laid down in laws, whereas GER decides more on an *ad hoc* basis. Especially with respect to animal welfare, NL has more optional measures available. These measures are a direct consequence of the rigid transport standstill in the compartments involved. In GER, less welfare measures are needed because only export from the protection and surveillance zones is prohibited. A plausible reason for this difference in measures may be the population density. In contrast to GER, NL contains several densely populated areas; therefore, rigid measures are needed in the event of an epidemic to avoid further dissemination of the virus. As a consequence, these welfare measures, in particular the buying-out of overweight animals, account for a substantial part of an epidemic's direct costs.

Table 2.2 Veterinary disease control measures implemented in the Netherlands (NL) and North Rhine Westphalia (NRW) – Lower Saxony (LS) for eradication of the highly contagious livestock diseases AI, CSF and FMD (mandatory control measures (x), optional measures (o) and non-applicable measures (–)).

Veterinary disease control measures	AI		CSF		FMD	
	NL	NRW-LS	NL	NRW-LS	NL	NRW-LS
General (EU)[1]						
Culling animals of affected farm	x	x	x	x	x	x
Culling animals of contact farms	o[3]	o	o[3]	o	o[3]	o
3 km protection zone around each detected farm, incl. movement standstill	x	x	x	x	x	x
10 km surveillance zone around each farm, incl. movement standstill	x	x	x	x	x	x
No export of live animals and animal products from compartment	x	x[9]	x	x[9]	x	x[9]
Additional[2]						
Whole country						
Movement standstill of 72 h	x	o[5]	x	o[5]	x	o[5]
Zoning						
Implementation of buffer zone[4]	x	x	-	-	-	-
1 km pre-emptive culling zone around each detected farm	o	x/o[10]	o	o	o	o
Culling all animals of buffer zone / compartment	o	o	-	o	-	o
Activating / changing compartmentalisation[5]	x	o	x	o	x	o
Welfare measures						
Buying-out of animals	o	-	o	-	o	-
Slaughter of animals in surveillance zone	-	o	o	o	o	-
Slaughter of newly born animals in surveillance zone	-	-	o	-	o	-
Transport of highly pregnant animals allowed	-	-	o	o	o	-
Transport of newly born animals allowed	-	-	o	o	o	-
Farm-to-farm transport allowed	-	-	o	o	o	-
Insemination ban	-	-	o	-	o	-
Cleansing and Disinfection						
Cleansing and disinfection of animal feed- and milk trucks	x	x	x	x	x	x
Cleansing and disinfection of livestock trucks and equipment	x	x	-	x	x	x

Vaccination						
Temporary radial or explicit vaccination zone around each detected farm	o	o	o	o	o	o
Radial or explicit surveillance zone around vaccination zone	-	-	o	o	o	o
Testing vaccinated animals	-	x	x	x	x	x
Culling all animals of farms with vaccinated positive animals	-	x	x	x	o	x
Vaccination of zoo animals[6]	o	o	-	-	o	-
Vaccination non-commercial (hobby) animals	o	o	-	-	o	-
Vaccination free-range commercial animals	o	o	-	-	-	-
Wildlife measures[7]						
Confinement of animals	x	-	-	-	-	-
Hunting prohibited	o	o	o	o	o	o
Monitoring wild animals	o	o	o	o	o	o
Various other measures[8]	o	o	o	o	o	o
Miscellaneous measures						
Informing and/or advising sector / zoos	x	x	x	x	x	x
Prohibited exhibitions/ fairs of						
• pigs	-	-	x	x[11]	-	-
• even-toed ungulates	-	-	-	-	x	x[11]
• poultry / birds	x	x[11]	-	-	-	-
Restricted manure movements	x	x	x	-	x	x

1 General control measures as laid down in the EU Directives 2005/94/EC (AI), 2001/89/EC (CSF) and 2003/85/EC (FMD) (CEC, 2006; CEC, 2001; and CEC, 2003; respectively)
2 Additional control measures as laid down in the national veterinary contingency plans.
3 Depending on the epidemiological risk assessment, although the measure has always been applied in NL.
4 As laid down in the EU Directive 2006/415/EG (CEC, 2006).
5 A compartment is defined in the Terrestrial Animal Health Code of the OIE as "one or more establishments under a common bio-security management system containing an animal subpopulation with a distinct health status with respect to a specific disease or specific diseases for which required surveillance, control and bio-security measures have been applied for the purpose of international trade" (OIE, 2009). This legislation offers the opportunity to continue trading from free compartments during periods of disease outbreak in a country or zone.
6 Vaccination of zoo animals is optional throughout the whole country, whereas vaccination of (non)commercial animals is optional in the temporary radial or explicit vaccination zone (only optional if requested by the EU).
7 Measures to prevent (in)direct virus introduction from wildlife to commercial animals.
8 For example, buffer zones between grazing animals and measures concerning nature and tourists.
9 In GER, no export of live animals and animal products from protection- and surveillance zones instead of from compartments.
10 Optional measure in GER except for LS where it is mandatory (laid down in ministerial order).
11 In GER, exhibitions / fairs are prohibited in *ad hoc* determined areas.

With respect to vaccination measures, at first sight there are almost no differences between the countries. However, in contrast to GER, the Dutch control strategy emphasises protective vaccination to prevent animals from being culled instead of suppressive vaccination to delay the culling of animals (K. Kardinal, Dutch Ministry of Agriculture, personal communication, 2010). By applying the first option, products from vaccinated animals can be sold at the national and/or European market under certain conditions (for conditions of, for example, FMD, see CEC, 2003).
From the above, it is observed that NL and GER hardly differ in their specific control measures. However, their overall control strategy can benefit from collaborating on several points, for example through (increased) information and capacity sharing. This may reduce the epidemic's economic impact by improving the quality of disease notification and by decreasing the HRP and post-HRP. Another method to reduce the economic impact is the implementation of new economic instruments on top of the previously described control measures. Both methods are explained in more detail in the next two sections.

Cross-border collaboration in disease control

Breuer *et al.* (2008) have observed a potential to improve collaboration in veterinary disease control among countries, for example in controlling outbreaks. The outbreak of CSF in NRW in 2006 showed that a lack of harmonisation in European contingency planning and insufficient information sharing wasted valuable time in controlling the epidemic (Breuer *et al.*, 2008). This directly affected the HRP and indirectly the post-HRP and resulted in higher spending to control the outbreak and more losses in trade and animals. Breuer *et al.* (2008) suggested implementing a more efficient information and communication structure between the countries to improve the quality of disease surveillance and notification and, consequently, to decrease the HRP and post-HRP in an outbreak.
In addition to improving information sharing between the two countries, countries can minimise an epidemic's economic impact via the sharing of capacity and resources. As Longworth and Saatkamp (2006) mentioned, successful control strategies mainly depend on the availability of sufficient resources. Examples of opportunities in sharing resources and capacity are within the stocking of vaccines, performance of diagnostic tests and the destruction of animals.

Reducing the economic impact of livestock diseases

In addition to harmonising control measures, the economic impact may be mitigated by adding new economic instruments. Saatkamp *et al.* (2010) have developed a general framework to describe the conceptual approach for the economic management of highly contagious livestock diseases (Figure 2.2). We used this framework to illustrate the impact of implementing economic instruments in

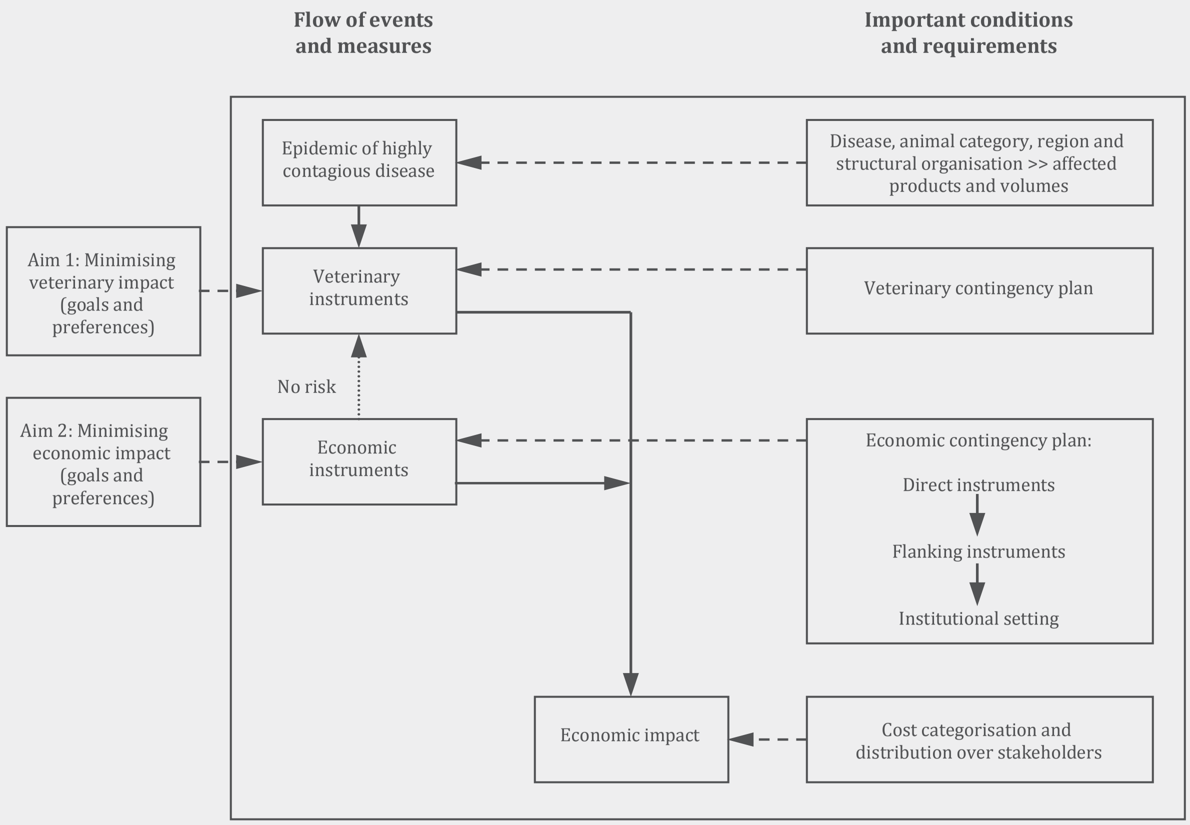

Figure 2.2 Conceptual approach for the economic management of highly contagious livestock diseases (developed by Saatkamp *et al.*, 2010).

addition to current veterinary control measures on the described epidemiological system (Figure 2.1).

The economic management of an epizootic consists of three parts: (i) direct economic instruments, (ii) flanking instruments and (iii) the institutional and legal setting of both the direct and flanking instruments.

Direct economic instruments can be implemented during the epizootic's control phase, and the ideal combination of these instruments depends on, for example, the type of the disease, the size of the outbreak and the population density of the affected area. Examples of direct instruments for the joint region of NL–NRW–LS include (i) creating extended economic zones around movement restriction zones, that is, zones in which sale of (vaccinated) animals is allowed as a solution to animal welfare problems due to transport restrictions, (ii) channelling animals and animal products, such as channelling products to lower quality and price segments of the market, (iii) storage to buffer and mitigate market disruption, and (iv) postponed and controlled restocking after the epizootic.

To facilitate the implementation of these direct instruments, flanking instruments are required to increase the willingness to cooperate among the different stakeholders. These flanking instruments include (i) compensation for stakeholders who are negatively affected by the execution of direct economic measures, and (ii) certification and/or guarantees to EU and non-EU countries (the so-called third countries). The first instrument is important because changing control measures can result in altering the distribution of the total costs of an epizootic over the various cost categories. Changing control measures can also lead to a different distribution of the total costs over the various stakeholder groups, resulting in disproportionately larger costs for some stakeholders. Therefore, it is essential to consider the distribution of the total economic impact. The second group of flanking instruments is essential for both exporting and importing countries. Importing countries need to be guaranteed that the imported animals (products) are free of highly contagious diseases, whereas exporting countries are afraid of (partly) losing their export market. Furthermore, flanking instruments also aim to control the execution of the direct economic instruments to ensure that additional veterinary and/or market risks will not emerge, that is, additional risks of increasing the epizootic should be excluded.

Comparable to the previous section on changing routine veterinary measures, both the direct and flanking instruments need to be in agreement with the requirements of international and national legislation. Therefore, implementing these instruments requires an appropriate institutional and legal setting, including agreements on different levels, for example, within NL and GER and on the EU level, and agreements with important non-EU trading countries.

Future developments in influencing factors caused by driving forces

Policy makers' negotiations to improve the cost-effectiveness of routine veterinary measures and to harmonise the current disease control strategy may require a large effort and several years. Therefore, as the production structure of livestock has proven to rapidly change in the past decades and is expected to change in the next decade (Hop *et al.*, 2014), it is worthwhile to take implications of these changes on the risks of disease introduction, notification and eradication into account as well.

The production structure of livestock is an important determinant of the frequency and magnitude of highly contagious livestock diseases and, consequently, their economic impact. In Figure 2.1, these features are presented as influencing factors.

Several studies have shown that influencing factors, like farm density and contact structure, affect the risk of introduction, spread and control (Mangen *et al.*, 2002; Boender *et al.*, 2008; Boklund *et al.*, 2009) and, hence, the consequences of strategies to manage livestock diseases. For instance, as explained in many studies (e.g. Mangen *et al.*, 2002; Mintiens *et al.*, 2003; Raulo and Lyytikäinen, 2005; Niemi *et al.*, 2008), contact-intensive and geographically concentrated farming systems are more susceptible to large-scale disease epidemics. Therefore, the rapid structural changes of livestock production, for example resulting in high geographical concentrations and increased sizes of production units, may increase the risk of highly contagious diseases. Subsequently, in the case of an outbreak of CSF, which can spread rapidly, increased transports of animals for live use due to more contact-intensive farms speed up the spread of the disease, resulting in major economic consequences. Present-day Dutch and German agriculture is entirely different from agriculture one or two decades ago and will continue to structurally change in the near future. Therefore, future-oriented control of livestock diseases has to take into account such developments.

Developments in these influencing factors are subject to driving forces that influence them both directly and indirectly. Driving forces can be divided into two categories: (i) autonomous (global) driving forces and (ii) institutional conditions.

The first category, *autonomous (global) driving forces*, can be defined as social, economic and technological trends that have no direct link with agriculture and are usually of a global nature. Examples include consumer preferences and population growth, macro-economic developments, and technological innovations (Nowicki *et al.*, 2007; Silvis *et al.*, 2009). These drivers operate mainly independently of policy making and influence the production structure of livestock indirectly via institutional conditions and via developments within markets and value chains.

The second category, *institutional conditions*, can be defined as EU and national agricultural, rural and environmental policies that are expected to have a major influence on the future of the Dutch and German production structure of livestock. Examples of these institutional conditions are subsidies for the dairy industry, and production restrictions, such as animal production rights, milk quotas and limited disposal of manure surpluses (Nowicki *et al.*, 2007; Silvis *et al.*, 2009).

Illustrations of the influence of driving forces on the production structure of livestock are, for example, an increased supply of broiler meat to the world market by third countries like Brazil and Thailand due to trade liberalisation, resulting in lower prices for Dutch and German produced broiler meat (Smit *et al.*, 2009). Additionally, environmental legislation resulted in a structural change in the pig production system in NL. Farmers decided to switch from the production of fattening pigs to the production of piglets (Silvis *et al.*, 2009).

Policy makers have to consider changes in influencing factors due to these driving forces because they are likely to influence total cross-border trade and trade contacts and, thus, the possibilities for cost-effectively improving routine veterinary measures and for cross-border harmonisation of, and collaboration in current disease control strategies.

Illustration of the framework

An integrated approach, as suggested in this chapter, offers different possibilities for use. First, a thorough quantitative analysis of possibilities for improving the cost-effectiveness of routine veterinary measures and for cross-border harmonisation of, and collaboration in current disease control strategies, as suggested in sections 'Routine veterinary measures' and 'Veterinary disease control measures', is necessary to provide insight into the economic advantages of increased cross-border collaboration. Based on quantification, scenarios with possibilities for further cross-border collaboration in contagious livestock disease management can be built at various ambition levels for cooperation. The higher the ambition level, the more factors must be considered.

A simple scenario with a low level of ambition involves one region, fits into the existing international and national legislation, includes a single group of stakeholders, has a short-term time span and does not increase the veterinary risks of disease introduction and spread. Implementation of such a scenario is relatively straightforward because there is no need for additional flanking measures to ease the process. On the other hand, it is not expected that such scenarios will tremendously decrease the economic impact of contagious livestock disease management.

More ambitious scenarios require complicated agreements on different levels, for example, on regional, national and EU levels and agreements with important non-EU countries. Presumably, changes in legal settings are needed. Different groups of stakeholders are involved with, most likely, different interests and different views on how to accept and adopt scenarios. Agreement between different interest groups is therefore essential to succeed in implementing such scenarios. Furthermore, rigorous changes in current disease management may incorporate the additional veterinary risks of disease introduction and spread. An example of such a complicated scenario is the case in which the joint region of NL–NRW–LS is treated as one epidemiological region without any borders. Thus, in the case of an epidemic, there would be no movement or trade restrictions between GER and NL, except for the protection and surveillance zones around the affected premises. In this scenario, routine veterinary measures are minimised because there are no internal borders, control strategies are harmonised by sharing vaccines and human and veterinary services' resources, for example, and economic instruments are implemented in addition to current control measures (e.g. the storage of products to buffer and/or mitigate market disruption). The whole set of measures is flanked by additional measures, for example compensation for stakeholders who are disproportionally affected due to the changed routine and control strategy.

Such a scenario is expected to lower the economic impact of livestock disease control substantially. The main challenge, however, is to reduce the costs of routine veterinary and disease control measures without compromising the control and impact of livestock diseases. In other words, treating NL–NRW–LS as a joint region should not increase veterinary risks. Nevertheless, it is more realistic to say that the risks of virus introduction and spread change when the region is treated as a single one. Here, virus introduction is defined as *the introduction of a highly contagious livestock disease virus into the commercial domestic livestock population of a particular region which is not epidemiologically linked with a previous outbreak in the same region* (CEC, 2006), whereas virus spread is defined as *the dissemination of the virus from one commercial farm to another within the affected region* (De Vos *et al.*, 2003). From these definitions, it becomes clear that virus routes previously regarded as introduction (through cross-border spread) should now be regarded as intra-region spread routes. Furthermore, with respect to virus introduction, Dutch trade partners now also constitute a direct threat to introducing a highly contagious livestock disease into NRW and LS and vice versa, that is, originally Dutch or German virus introduction routes now threaten the whole joint region.

However, an integrated approach, as described above, also includes supporting and/or flanking harmonisation measures, for example, improved communication, such as sharing information properly in times of an epidemic. Improved communication among veterinary policy makers and veterinary services of different countries, that is, by harmonising separate trade information-, and surveillance and monitoring systems, is essential. Such improvements reduce the period in which a population is in HRP and post-HRP, that is, it lowers the risk of virus spread (which is currently virus introduction and spread) within the joint region. Thus, the risks of virus introduction and spread may be altered when NL, NRW and LS are treated as one epidemiological region; consequently, it may change the overall impact of an outbreak of a highly contagious livestock disease.

When building these scenarios for future disease control decision making, three aspects are important to consider. First, the economic consequences are important to consider, that is, the total costs and its distribution over stakeholders and regions. The absolute and relative impact for stakeholders is likely to shift in these scenarios. Second, legal settings are important to consider, that is, existing legislation may need to change to be in agreement with the requirements of international and national legislation. Thirdly, it is important to examine the practical aspects, for instance the potential of implementation and its possible problems, perspectives in the short- and long-term, and the need for flanking instruments, like compensation measures and certification. Future research should pay attention to these three aspects because they are important for policy makers. These aspects determine the possibilities of implementation and acceptance of scenarios for future cross-border collaboration. Furthermore, they determine the possibilities for regions and stakeholders to negotiate about exchanging and accepting changes in measures so that they all benefit from intensifying cross-border collaboration. For example, minimising the effect of measures taken for cross-border trade in slaughter pigs will be beneficial to the Dutch pig-fattening sector. In turn, German decision makers may like to negotiate a change in measures that affect their farmers, not necessarily their pig production sector. To *ex ante* analyse and include the abovementioned aspects in scenarios for future decision making, both the described general framework and its illustration for use in the cross-border region of NL–NRW–LS offer good possibilities to provide insight into the economic advantages of increased cross-border collaboration in general. The framework shows the complexity of the problem due to the many interrelations, and it shows the importance of taking into account this complexity for disease control policy making and execution.

Discussion

The objective of this chapter was to present a conceptual framework of the potential gains and the main challenges for further cross-border collaboration in the control of highly contagious livestock diseases.

Results

Globalisation has, on the one hand, led to more and intensified trade in livestock and livestock commodities and, consequently, to regional specialisation of production resulting in large cross-border trade. On the other hand, countries' public administrations cannot keep pace with this strong trade globalisation as they now lack tailor-made institutional settings and constraint effective regional specialisation. These deficiencies in cross-border agency cooperation hamper effective retaining of the economic advantages of intensified cross-border trade at a low risk of contagious livestock diseases. In this context, possibilities for future policy making were discussed: cross-border cooperation to lower the impact of routine veterinary measures and veterinary disease control strategies. These two fields were considered jointly as a way to structurally increase cross-border collaboration and to reduce the economic consequences of routine veterinary and disease control measures. The general disease management framework described the way in which these two fields are related to and affect the epidemiological system and, consequently, how they impact the stakeholders. In addition, the importance of a good understanding of influencing factors, that is, the production structure of livestock, was stressed because these factors are important determinants of the frequency and impact of highly contagious livestock diseases. Finally, the use of the framework was illustrated.

Potential gains

Throughout the chapter, potential gains of cross-border collaboration in the field of highly contagious livestock disease control were identified for two main fields: cost-effectiveness improvement of routine veterinary measures and cross-border harmonisation of, and collaboration in veterinary disease control strategies. For both fields, actual differences between, and potential relaxation, harmonisation and collaboration opportunities for NL and GER were identified by applying the general disease management framework.

For routine veterinary measures, examining the validity of several measures can be worthwhile because of cost-saving possibilities, especially if veterinary statuses are similar. In the past decades, routine veterinary measures were essential due to large differences in veterinary status among countries and due to a different production structure of livestock compared with nowadays' structure, i.e., more but smaller farms. Cross-border transports were therefore more complicated and riskier: several batches from different farms were needed to fill trucks and, due to less technological possibilities in tracking and tracing of animals, transports were less transparent. EU-wide tracking and tracing systems, such as Traces that record cross-border trade of livestock, did not exist. Nowadays, however, differences in veterinary status of countries have been reduced and the livestock production structure has changed and as a result, examining the validity of several routine veterinary measures is advisable. In addition, veterinary policy makers' negotiations to relax routine veterinary measures may require a large effort and several years as most measures are based on international legislation. Therefore, as the production structure of livestock has proven to rapidly change in the past decades and is expected to change in the next decade (Hop *et al.*, 2014), it is worthwhile to take implications of these changes on cost-saving possibilities into account as well.

For veterinary disease control strategies, harmonisation and collaboration opportunities were discussed. Due to regional specialisation of production resulting in large cross-border trade and, consequently, mutual dependencies between livestock producers and consumers across the border, cross-border regions increasingly constitute into single epidemiological regions in which disease introduction is a shared veterinary and, consequently, economic risk. Improving the joint prevention and control of contagious livestock diseases is therefore increasingly important and of mutual interest. Throughout the chapter, potential gains were discussed for cross-border regions that are treated as single epidemiological regions without any borders, such as the larger capacity for, for example, channelling animals and animal products, that is, an enlarged 'domestic' market. In the case of NL, NRW and LS, this would result in a domestic market with approximately 42 million consumers. In case of an outbreak, a shared storage of products would, for example, smoothen out market disruptions. Another 'one-area advantage' is the better utilisation of a joint region's competitive advantage, for example, in our case study region a more efficient production of piglets and fattening pigs due to a minimum number of routine veterinary measures because there are no internal borders.

Main challenges

Besides potential gains, several challenges to actually realise the advantages of increased cross-border collaboration and harmonisation were discussed. Most importantly, effective cross-border communication and cooperation between countries' veterinary authorities and ministries are lacking, even though they are essential to ensure efficient animal disease control. The main challenge is therefore to improve the quality and intensity of cross-border communication and to harmonise organisational responsibilities and tasks. To keep pace with the strong trade globalisation, tailor-made institutional settings are necessary to effectively retain the economic advantages of intensified cross-border trade at a low risk of contagious livestock diseases.

Successful collaboration and harmonisation depend on the use of flanking instruments to increase the willingness to cooperate among the different stakeholders, such as harmonised compensation for affected stakeholders. This process, however, is complex, involving not only veterinary aspects but also economic consequences, legal aspects and implementation possibilities.

In conclusion, the described general framework was designed for various highly contagious livestock diseases and was described and illustrated for one specific cross-border region. The basic outline can easily be adapted to other cross-border regions because these regions encounter similar cross-border-related opportunities and difficulties. It is likely, however, that applying the general framework will lead to different gains and challenges due to differences in their cross-border routine veterinary and disease control measures as well as their livestock production structures.

Acknowledgements

The authors gratefully acknowledge the Dutch Ministry of Agriculture (EL&I), the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), the Dutch Product Boards for Livestock, Meat and Eggs (PVE) and the Dutch Animal Health Service (GD) for feedback on the lists of routine veterinary and disease control measures. This study is part of the project SafeGuard, which is financed within the INTERREG IV A programme Deutschland-Nederland by the European Regional Development Fund.

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3

Future structural developments in Dutch and German livestock production and implications for contagious livestock disease control

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Technological Forecasting and Social Change (2014) 82: 95-114
DOI: 10.1016/j.techfore.2013.05.011

Abstract

The structure of livestock production is subject to driving forces that alter veterinary and economic risks of contagious livestock diseases. Insight into changes in this structure is thus important for veterinary contingency planning.

The objective of this chapter was to explore changes in future production structure features within the cross-border region of the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (LS) projected towards 2020 using the Policy Delphi method. Additionally, the findings of this chapter were elaborated in terms of possible implications for contagious livestock disease introduction, spread and control.

Experts expected a sharp reduction in the number of farms, a sharp increase in farm size and regional concentration of livestock production, especially in NL. Increases in cross-border trade were expected, particularly in the pig sector, resulting in intensified mutual cross-border production dependency in most sectors. The cross-border region of NL-NRW-LS becomes, therefore, increasingly a single epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk. This situation results in increased need for collaboration among NL-NRW-LS to improve the joint prevention and control of contagious livestock diseases. It is concluded that veterinary policy makers should proactively anticipate these future changes in the production structure of livestock.

Introduction

The European Union (EU) aims to ensure a uniform and high level of animal health throughout the EU without compromising the functioning of the single market. The EU has, therefore, implemented a strategy of non-vaccination for most contagious livestock diseases, resulting in a highly susceptible livestock population (Directorate General for Health & Consumers, 2012). The single market, as such, has resulted in increased intra community cross-border trade in livestock (i.e., economic advantages) but also in increased veterinary and economic consequences due to outbreaks of contagious livestock diseases throughout the EU, as experienced in previous outbreaks of classical swine fever (CSF) (Meuwissen *et al.*, 1999) and foot-and-mouth disease (Thompson *et al.*, 2002).

The risks of the introduction and spread of such diseases are mainly determined by (in)direct animal contacts (Elbers *et al.*, 1999). These contacts are driven by features of the production structure of livestock, such as the number of farms, farm size, the concentration of farms in certain areas, specialisation of production, and reliance on cross-border production markets (see, e.g., Bigras-Poulin *et al.*, 2007; Boender *et al.*, 2008; Ribbens *et al.*, 2009; Lindström *et al.*, 2010). In other words, production structure features are important determinants of the frequency of occurrence and magnitude of contagious livestock diseases and, consequently, their economic impact. In addition to the production structure features, consumption market features, such as acceptance of products from affected livestock sectors and market disruptions, determine the economic impact directly (Longworth *et al.*, 2009).

During the last decades, major changes in the production structure of livestock have occurred within the EU. As a result, the mutual dependency on cross-border livestock trade among certain countries has increased. A particular example is the cross-border region of the Netherlands (NL) and the German states of North Rhine Westphalia (NordRhein-Westfalen, NRW) and Lower Saxony (Niedersachsen, LS). For example, Dutch environmental legislation caused a structural change in pig production in which farmers switched from the production of fattening pigs to that of piglets (Silvis *et al.*, 2009). As a result of a shortage of fattening places, a quarter of the Dutch piglet production is exported to Germany (GER) and consequently, Dutch piglet producers and German fattening pig farmers highly depend on each other with respect to pig production. In addition to pig production, other Dutch and German livestock sectors show similarly increased mutual cross-border dependency, and a further increase is expected in the near future (EC, 2010; Hop *et al.*, in press).

The foregoing example demonstrates that it is essential for veterinary policy makers to have a good insight into the future developments of those features of the livestock production structure that influence disease introduction, spread and control, such as the number of farms and farm size. In particular, veterinary contingency planning can benefit from and account for these insights into developments. Moreover, from an economic point of view, veterinary policy makers should consider future developments in consumer preferences and markets as well.

Existing studies that analysed the future structure of livestock production primarily explored the driving forces that affect the future supply and demand of (EU) agricultural commodities at the macroeconomic level (see, e.g., Silvis *et al.*, 2009; EC, 2010; OECD/FAO, 2011). That focus means that these studies ignored the consequences of changes in the production structure on the risks of disease introduction, spread and control. The same applies to country-specific and regional effects and effects on cross-border trade for countries that highly rely on such trade.

In the light of the foregoing, the objective of this chapter was to explore changes in future production structure features within the cross-border region of NL, NRW and LS projected towards 2020 using the Policy Delphi method. Additionally, the findings of this chapter were elaborated in terms of possible implications for contagious livestock disease introduction, spread and control.

Material and methods

Methodological justification

A good insight into the future developments of those features of the livestock production structure that influence disease introduction, spread and control is essential for future veterinary policy making. Several developments are possible because the livestock production structure is subject to a large number of driving forces. To explore how the future structure of livestock production will develop, several ways of gathering and analysing data have been integrated, i.e., data and method triangulation was adopted (Denzin, 1970). Data was gathered from several sources, that is, through a literature search, through a Policy Delphi study, by organising workshops and by carrying out interviews, and the data was analysed both quantitatively and qualitatively.

In this chapter, changes in the livestock production structure were explored for the period 2011–2020. This medium-term was chosen because a ten year time scale is common in studies that analyse the future structure of livestock production (e.g., Nowicki *et al.*, 2007; Silvis *et al.*, 2009; EC, 2010), which makes the results of this chapter comparable. Additionally, a longer time scale would include even more uncertainty with respect to the impact and value of the driving forces, making the assessment for the experts even harder. A shorter time scale would insufficiently show the effect of driving forces on the livestock production structure.

In the first place, insight was needed into those driving forces that directly and indirectly influence livestock production features. Studies that examined future production and consumption of agricultural commodities, such as Nowicki *et al.* (2007) and Silvis *et al.* (2009), primarily focused on a limited number of forces that affect supply and demand. To the best of our knowledge, in literature no detailed elaboration of driving forces exists that also includes the relationships between the driving forces, and between the driving forces and the livestock production structure. A schematic overview of driving forces that includes relationships was considered an essential basis of and a first step toward being able to explore possible scenarios of future production structure features. To construct such an overview, a literature search was conducted to identify the main driving forces and experts were consulted during an expert workshop. The main goal of this step was to reach an agreement regarding how the driving forces were categorised and organised within the framework.

In the second place, main driving forces needed to be identified and, additionally, insight was needed into the possible "values", i.e., positions, of these main driving forces. The future values of these driving forces are subject to uncertainty. Due to this uncertainty, exploring the future production structure of livestock based on one single most-likely-image of the future values of driving forces was considered to give an unrealistic outlook. To incorporate uncertainty in this respect, scenario construction is a widely used tool and a well-tested technique within futures studies (Van der Heijden *et al.*, 2002). This method has been identified as one of the most appropriate approaches to support strategic decision making in uncertain situations (Courtney *et al.*, 1997; Schoemaker, 2002; Von der Gracht and Darkow, 2010). A widely used technique for forming scenarios relevant to decision makers is the Policy Delphi technique (Turoff, 2002; Klenk and Hickey, 2011). This technique is able to incorporate different expert views on future production structure features and is particularly appropriate in situations in which consensus among the experts is not necessary. For more detailed information on the Delphi technique, we refer to (Rowe and Wright, 1999; 2011) (on the Delphi technique in general) and (Turoff, 2002; Rikkonen and Tapio, 2009; Klenk and Hickey, 2011) (on Policy Delphi). In this chapter, a disaggregative variant of the Policy Delphi method (Tapio, 2002) was used. This variant was chosen because this study included experts with various backgrounds, including global and regional economies, the organisation of regional livestock markets and chains, veterinary knowledge, and legislation and institutional conditions. It was expected that these experts would indicate different driving forces to be most important and the disaggregative Policy Delphi method enables the construction of various scenarios by grouping similar expert views using cluster analysis. During the first Policy Delphi round (including a feedback round and analysis of the results), scenarios were developed that contain the main driving forces but with different future values, that means, various scenarios that describe potential developments with respect to the driving forces that influence the future production structure of livestock. These scenarios should support strategic decision makers in developing medium-term strategies and guide decision makers in testing the robustness and relevance of current strategies and in defining proactive strategies contingent on potential future developments in the livestock production structure of NL-NRW-LS.

In the last place, the quantitative implications of the different scenarios for future production and consumption, as well as for the future production structure of livestock were explored. This was the ultimate aim of this research. The first part, implications for future production and consumption, was explored during a second Policy Delphi round. The second part, the impact of scenarios on the future production structure of livestock, was assessed in a workshop and in e-mail interviews. Initially, it was aimed to conduct three Delphi rounds. However, during the second Delphi round, Dutch experts indicated that for assessing the impact of scenarios on the future production structure of livestock (originally Delphi round 3), a different set-up would be helpful. They first wanted to discuss the possible impacts of scenarios with one another and then individually assess the impact of the scenarios on the livestock production structure. For this reason, a final expert workshop was organised in NL and e-mail interviews were conducted in NRW-LS.

Study design

The design of the study is presented in Figure 3.1, i.e., the process of developing Delphi-based scenarios and the assessment of their impact on the production, consumption and structure of livestock production.

Step 1: Exploratory study

The aim of step 1 was to create a framework that schematically presents all possible driving forces that influence the livestock production and consumption structure, including the relationships between the driving forces and among the driving forces and the livestock production and consumption structures.

First, a literature search was conducted to identify the main possible driving forces that are likely to impact the future structure of livestock production. This search focused on peer-reviewed English articles and Dutch, German and English (non)-published literature. The databases Scopus and Web of Science, and the search engine Google Scholar were searched, using key words such as '(agricultural) global driving forces', and 'developments in (agricultural) policy and institutional conditions'. This search resulted in a first version of a framework with driving forces.

Subsequently, an expert workshop was organised in which seven experts were asked to reflect on the first version of the framework. Experts were identified using Cook and Frigstad's (1997) standard for finding widely recognised and identifiable expert opinion. First, the experts were expected to be knowledgeable in at least one of four fields: (i) global agricultural developments and autonomous driving forces, (ii) agricultural policy and institutional conditions, (iii) organisation of and developments within the market, value chain and livestock sectors, and (iv) contagious livestock diseases. Experts who had worked in their main field of expertise for at least 10 years were preferred. Next, as recommended by Linstone (1975), the experts needed to be able to view their field of knowledge in a wider perspective. Having a helicopter view and the ability to place their expertise into a wider perspective was therefore a second criterion for the experts.

The workshop was structured around the following three subsequent sessions: (i) introduction and presentation of the framework (20 min.), (ii) identification and discussion of all possible driving forces for all four expertise fields (90 min.), and (iii) identification and discussion of all possible relationships between the driving forces and among the driving forces and the livestock production and consumption structures (20 min.).

The experts' reflections were included in a following version of the framework. Next, the adapted version was sent for feedback to the same experts via e-mail, and, after receiving feedback from three experts, their feedback was incorporated into the framework.

Based on the literature search and expert workshop, we defined the following categories of driving forces (terms are used in subsequent steps):

- *Autonomous driving forces* are defined as social, economic, and technological trends that have no direct link with agriculture and are typically of a global nature, such as macroeconomic developments, consumer preferences and technological innovations (Nowicki *et al.*, 2007; Silvis *et al.*, 2009). These drivers influence the production structure of livestock indirectly via (i) (agricultural) policies and institutional conditions and (ii) the organisation of and developments within the market, value chain and livestock sectors.
- *(Agricultural) policies and institutional conditions* are defined as EU and national agricultural, rural, and environmental policies that are expected to have a major influence on the future of the Dutch and German production structures of livestock. Examples of these institutional conditions are subsidies for the dairy industry and production restrictions, such as animal production rights, milk quotas, and limited disposal of manure surpluses (Nowicki *et al.*, 2007; Silvis *et al.*, 2009). These drivers influence the production structure of livestock indirectly via the organisation of and developments within the market, value chain and livestock sectors.

Step 2: Design of the Delphi study

The aim of step 2 was to select the experts for the Delphi study, and set-up and test the questionnaires of both Delphi survey rounds. Actions described in this step that relate to Delphi round 2 were taken before the start of step 5 (content of the Delphi survey, round 2), for example, setting-up and testing the questionnaires of Delphi round 2 were done after finishing the analyses of the first Delphi round.

Similar to selecting the experts for the expert workshop described in step 1, experts were identified using Cook and Frigstad's (1997) standard, were expected to be knowledgeable in at least one of the previously described four fields, had worked in their main field of expertise for at least 10 years, and, as recommended by Linstone (1975), they were able to view their field of knowledge in a wider perspective. The list of potential experts was discussed with two widely known experts in the field of worldwide agricultural developments and policy. The list was complemented until there were at least two experts per field in the panel, which was regarded as sufficient. Finally, 40 Dutch and 37 German experts from government, research and industry were selected for the Delphi study, including the consulted experts of the expert workshop described in step 1.

A letter containing a short description of the study was sent to the experts by e-mail to invite them to participate in a two-round Delphi study of approximately 45 min. per round. A reminder e-mail was sent to the experts two weeks later. The experts were guaranteed that their responses would be treated as anonymous and confidential. Of the approached experts, 23 Dutch and 15 German experts agreed to participate (representing response rates of 57.5% and 40.5%, respectively).

Both rounds of the Delphi study were developed using a web-based survey tool (Qualtrics Survey Software, version 2011), and both rounds were pre-tested for appropriateness and accessibility by researchers affiliated with Wageningen University. The recommendations from the pre-testers were incorporated into both rounds of questions to be sent to the experts.

The first Delphi round was developed by native Dutch and German language speakers to increase the response rate. In this round, the experts were asked for their language preferences, and as none of the experts indicated any problems with the English language, the second Delphi round was conducted in English. To further increase the survey accessibility, the experts were offered the opportunity to ask for a Word version of the survey, which could be completed off-line and returned by e-mail or post.

The survey invitations for both Delphi rounds were generated electronically, and the experts were given a period of three weeks to complete their survey. Electronically generated reminders were sent to participants who had not responded a week prior to the response deadline, on the deadline itself, and a week after the deadline. Two weeks after the deadline, the database was closed, and further entries were excluded from the analyses.

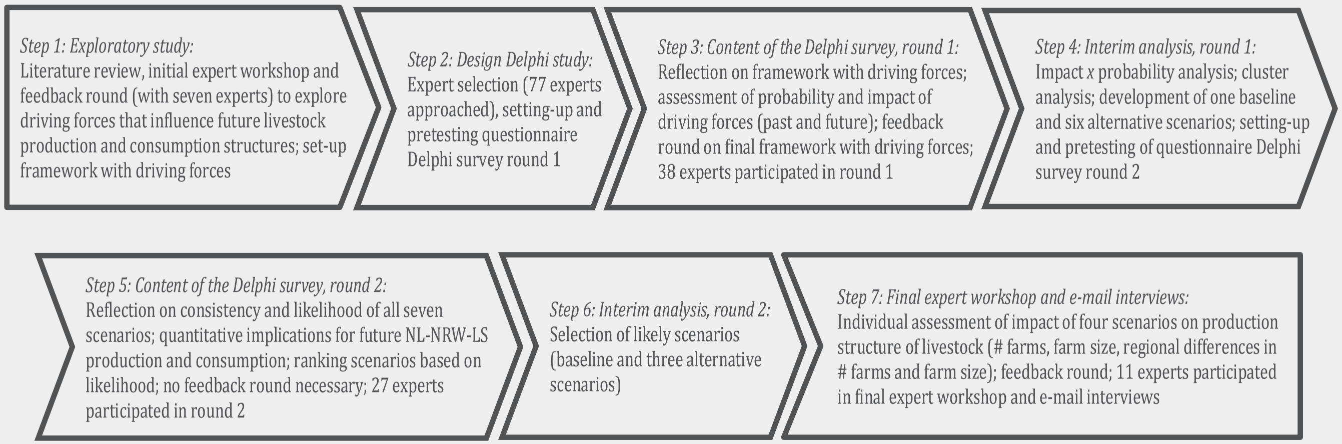


Figure 3.1 The process of developing Delphi-based scenarios and the assessment of their impact on the production, consumption and the structure of livestock production.

Step 3: Content of the Delphi survey, round 1

The aim of step 3 was to create a final framework that schematically presented the main driving forces based on an assessment of importance of driving forces.

In the first round of the Delphi survey, the experts were asked to review the framework with driving forces for completeness and for correct relationships between the driving forces and among the driving forces and the production and consumption parameters (open questions). Next, they were asked to assess the probability that the driving forces had influenced (during the years 2000–2010) and will influence (during the years 2011–2020) the demand, trade and supply of livestock commodities (closed questions using a Likert scale ranging from 1 to 5). The experts were also asked to indicate the two driving forces with the highest impact on the demand, trade and supply of livestock commodities, respectively. The driving forces with the highest impact were requested for the sub-blocks 'demand-influencing driving forces', 'trade-influencing driving forces' and 'supply-influencing driving forces' (two per sub-block), for individual livestock industries (the pig, poultry and dairy industries), and for both the past and future ten years. Based on the response to this survey, minor textual changes had to be made to the framework, after which it was sent to the experts for final feedback. After this feedback round, the framework was approved, and, although it was not the aim, consensus among all of the experts was reached.

Step 4: Interim analysis, round 1

The aim of step 4 was to analyse the importance of the driving forces, finalise the framework with driving forces and develop several scenarios with assumptions based on the values of these forces.

The two dimensions "probability that a driving force influences the demand, trade and supply of livestock commodities" and "impact of a driving force on the demand, trade and supply of livestock commodities" were analysed for the periods 2000–2010 and 2011–2020. First, the differences in the responses between the Dutch and German experts were assessed, using an independent sample T-test (SPSS, version 19). Next, the final framework with driving forces was developed, including driving forces with either a high probability, i.e., with an average score of ≥4 (out of 5), or a moderate to high impact, i.e., chosen in ≥25% of the cases per sub-block, or both, in at least one of the periods (past and future).

Differences in responses were observed among the experts with respect to the probability and impact of the driving forces. To identify driving forces on which groups of experts did not agree, Cluster Analysis (CA) was conducted using SPSS. Because no single procedure is available to decide on the most appropriate number of clusters, two variants of CA were used to ensure the stability of clusters: hierarchical and partitioning CA (Hair *et al.*, 2006; Bidogeza *et al.*, 2009). Ward's hierarchical procedure was used to minimise the variance within the clusters and to find the optimal solution for the number of clusters (Kobrich *et al.*, 2003). This number was used as the starting value in the partitioning CA, i.e., the K-means method using pairwise exclusion. The partitioning CA included a one-way analysis of variance test (i.e., Levene's test) whereby differences in variance among the clusters could be identified (Field, 2005). Therefore, the driving forces that caused the largest differences among clusters could be identified.

In the final step, a baseline scenario for the year 2020 was formulated. This scenario contained assumptions on the "value", i.e., the position, of the driving forces from the final framework (driving forces with a high score on either or both probability and impact). The assumptions were based on the European outlook for agricultural markets because it assumes "a status quo policy environment, stable macroeconomic conditions and relatively favourable world market perspectives" (EC, 2010). Six alternative scenarios were formulated based on the outcome of the CA i.e., those driving forces that caused large differences (F-value ≥ 10; p-value ≤ 0.01) among groups of experts were assumed to have a higher or lower value compared with the baseline scenario.

3

Step 5: Content of the Delphi survey, round 2

The aim of step 5 was to reflect on the scenarios based on their consistency and likelihood, and to quantitatively assess the implications for future NL-NRW-LS production and consumption.

In the second round of the Delphi survey, the experts were requested to reflect on the seven developed scenarios. The experts were asked whether they considered the scenarios to be consistent ("yes", "no", "if no, please explain"). A scenario was considered to be consistent if it lacked contradictions in the described assumptions; for example, whether the effect of increasing technological innovation on crop yield growth is indeed positive. For each scenario, the experts were asked to estimate the future production and consumption for NL and GER. NL and GER production and consumption data for 2009 were provided, as were projections for the EU for 2020 based on the European outlook for agricultural markets (EC, 2010). Production and consumption parameters were only available for GER as a whole, rather than for NRW and LS separately. As a final question, the experts were asked to rank the scenarios based on likelihood (anchored at 1 = "most likely" to 7 = "least likely"). The likelihood was defined as the probability that a scenario will come true during 2011-2020. Based on the comments given in this round, there was no need to change the content of the scenarios, and as a result, no additional feedback round was conducted.

Step 6: Interim analysis, round 2

The aim of step 6 was to select likely scenarios based on Delphi round 2.

In step 5, the experts considered all of the scenarios to be consistent. For that reason, the selection of scenarios was only based on the individual likelihood of the scenario. Because there was a clear distinction between the likely (average likelihood between 1.9 and 3.1) and unlikely (average likelihood between 4.8 and 5.3) scenarios, those scenarios that scored on average between 1.9 and 3.1 were selected for the final step (i.e., the assessment of the impact of the final scenarios on the production structure of the NL and NRW-LS livestock sectors). The scenarios that scored on average between 1.9 and 3.1 in only one of the regions were also selected for the final step. We chose a relatively high threshold value to assure that only unlikely scenarios were rejected.

Step 7: Final expert workshop and e-mail interviews

The aim of step 7 was to assess the impact of the final scenarios on the production structure of livestock.

A final expert workshop was organised to discuss and individually assess the impact of the four most likely scenarios on the structure of the Dutch livestock industry, i.e., the farm size, the number of farms, and the expected regional differences in the farm size and number of farms. No final expert workshop was organised to assess the impact on the NRW-LS livestock industry because only three German experts were available. The low response rate was mainly due to time constraints and the distance to the location of the workshop. Instead, e-mail interviews were conducted in which the same questions were asked as during the Dutch expert workshop.

The workshop was structured around the following three subsequent sessions: (i) introduction and presentation of the four most likely scenarios (30 min.), (ii) discussion of possible effects of these scenarios on the structure of livestock production (60 min.), and (iii) individual assessment of the impact of the four scenarios on the farm size, the number of farms, and the expected regional differences in farm size and number of farms (45 min.).

After the workshop, results were summarised and both NL and NRW-LS experts were asked by e-mail to provide feedback on the expected average farm sizes, number of farms, and regional differences, but no additional comments were given.

Lastly, it was tested whether the distribution of the experts' estimations of NL and GER production and consumption (step 5) and number of farms and farm size (step 7) across the assessed scenarios differed significantly. Using SPSS, it was first tested whether the variables were normally distributed using the Shapiro-Wilk test for small sample sizes. Based on the outcome, the nonparametric independent-samples Kruskal–Wallis one-way analysis of variance by ranks (an extension of the Mann–Whitney U test for ≥ three groups) was used to test whether the distribution of the experts' estimations across scenarios differed significantly (scenario-effect). The same test was used to test whether there was an expert-effect, i.e., whether certain experts consistently estimated the number of farms and farm size either lower or higher than the average.

Results

Participants

In the initial expert workshop, seven experts participated. In the first Delphi survey round, 38 experts provided useful data (a 49% response rate), and 27 of these experts participated in the second round (a 71% response rate). In the final expert workshop and e-mail interviews, 11 experts participated.

Table 3.1 provides an overview of the number of NL and NRW-LS experts by main and additional fields of expertise for both Delphi survey rounds. For both NL and NRW-LS, at least two experts per main expertise field were present. The vast majority (95% of the Dutch and 80% of the German experts) had ≥ ten years work experience in their expertise field.

Driving forces framework and scenarios

The detailed results of the procedure for identifying the important driving forces, the description of the scenario assumptions and the assessment of the scenarios are presented in the Appendix.

In Appendix Table A3.1, the results of the expert assessment of the probability and the impact of the major driving forces for the years 2000–2010 (past) and 2011–2020 (future) are given. Probabilities are presented as medians (1st quartile; 3rd quartile) and impact is presented as the percentage of times chosen as one of two driving forces with the highest impact on demand, trade and supply. In Figure 3.2, the important driving forces from Appendix Table A3.1 are presented schematically.

The figure shows the relationships between the driving forces and the relationships among the driving forces and the production, consumption, structure and movement parameters. Figure 3.2 is divided into two parts: driving forces (upper part) and parameters (lower part). The driving forces are divided into the blocks *autonomous (global) driving forces* (block 1), *institutional conditions* (block 2) and *value chain* (block 3). Blocks 1 and 2 are divided into sub-blocks: *demand-driving forces*, *market / trade-driving forces* or *institutional conditions* and *supply / input / production-driving forces* or *institutional conditions*. The arrows between the blocks indicate the influence of one block on another.

In Figure 3.2, the most important driving forces identified with respect to the autonomous (global) drivers (block 1) were the macroeconomic situation (in particular, economic growth), global production and consumption, EU population growth and factors related to consumer preferences and concerns. Next,

Table 3.1 The numbers of NL and NRW-LS experts by main and additional fields of expertise (Delphi survey, rounds 1 and 2).

	Total number of responses	Number of responses by main (M) and additional (A) fields of expertise							
		Global agricultural developments and autonomous driving forces		Agricultural policy and institutional conditions		Organisation of and developments within the market, value chain and livestock sectors		Contagious livestock diseases	
		M[1]	A[2]	M	A	M	A	M	A
Delphi survey, round 1									
Total number of experts	38	8	n.a.	8	n.a.	10	n.a.	12	n.a.
of which NL	23	5	10	5	11	6	11	7	9
of which GER	15	3	6	3	7	4	5	5	8
Delphi survey, round 2									
Total number of experts	27	6	n.a.	6	n.a.	7	n.a.	8	n.a.
of which NL	17	4	8	4	8	4	7	5	5
of which GER	10	2	4	2	5	3	4	3	4

[1] Main field of expertise.
[2] Additional fields of expertise. Only two additional fields of expertise were allowed.
[3] N.a. means 'not applicable'.

technological innovations, the availability of feed (for the poultry and pig sectors) and agricultural land (for the Dutch and German dairy sector and for the German poultry and pig sectors) were also identified as important. The identified major limiting institutional conditions (block 2) were subsidies for the dairy industry and production restrictions, such as animal production rights, milk quotas, limited disposal of manure surpluses, and the EU ban on traditional and enriched cages for laying hens, which is scheduled for 2012.

The framework of Figure 3.2 is the result of consensus among the experts that was reached after Delphi survey round 1. During Delphi survey round 2 and the final expert workshop and e-mail interviews, all of the experts used this framework as a common, systematic basis for exploring the future structure of livestock production without overlooking important driving forces.

For the baseline and alternative scenarios, assumptions on the "value", i.e., the position, of driving forces with a high score on either or both probability and impact are given in Appendix Table A3.2.

The baseline scenario assumptions are based on the European outlook for agricultural markets (EC, 2010). The baseline scenario is an overview of medium-term prospects based on assumptions concerning the future macroeconomic, policy and market environment. The baseline anticipates no disruptions related to animal health, normal weather conditions and stable demand and yield trends. However, as observed in the past and particularly over recent years, agricultural markets remain subject to a number of important uncertainties that form the basis of the projections (EC, 2010). A number of these uncertainties were addressed in alternative assumptions (alternative scenarios). Driving forces with these alternative assumptions were chosen based on the outcome of the CA, i.e., the driving forces that caused large differences among groups of experts were assumed to have a higher or lower value compared with the baseline scenario. The driving forces that caused large differences were the economic growth rate, crude oil prices, the Euro exchange rate, factors that influence consumer preferences, global production and consumption, technological innovation, and the availability of land, feed and fuel. Two groups of scenarios were distinguished in which a change in one driving force was dominating and changing the other driving forces that caused large differences among experts in the CA.

The first group of alternative scenarios (Appendix Table A3.2) assumed differences in macroeconomic environment (demand scenarios) and, consequently, in the global availability and trade-off among food, feed and fuel, and in EU consumer preferences, confidence and concerns. Hence, the force dominating in these scenarios was a change in the rate of economic growth, affecting consumer preferences and the availability of food, feed and fuel.

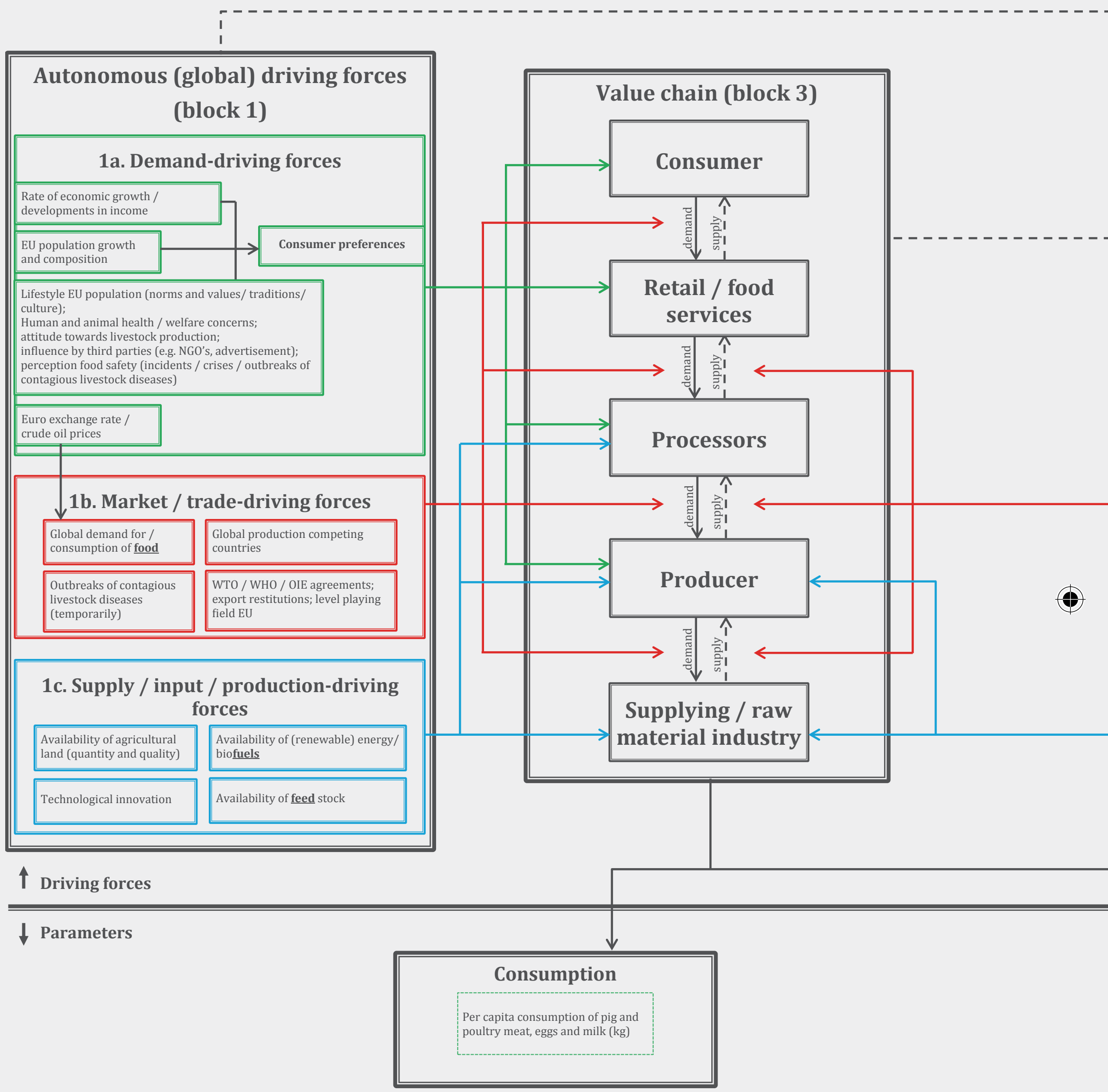
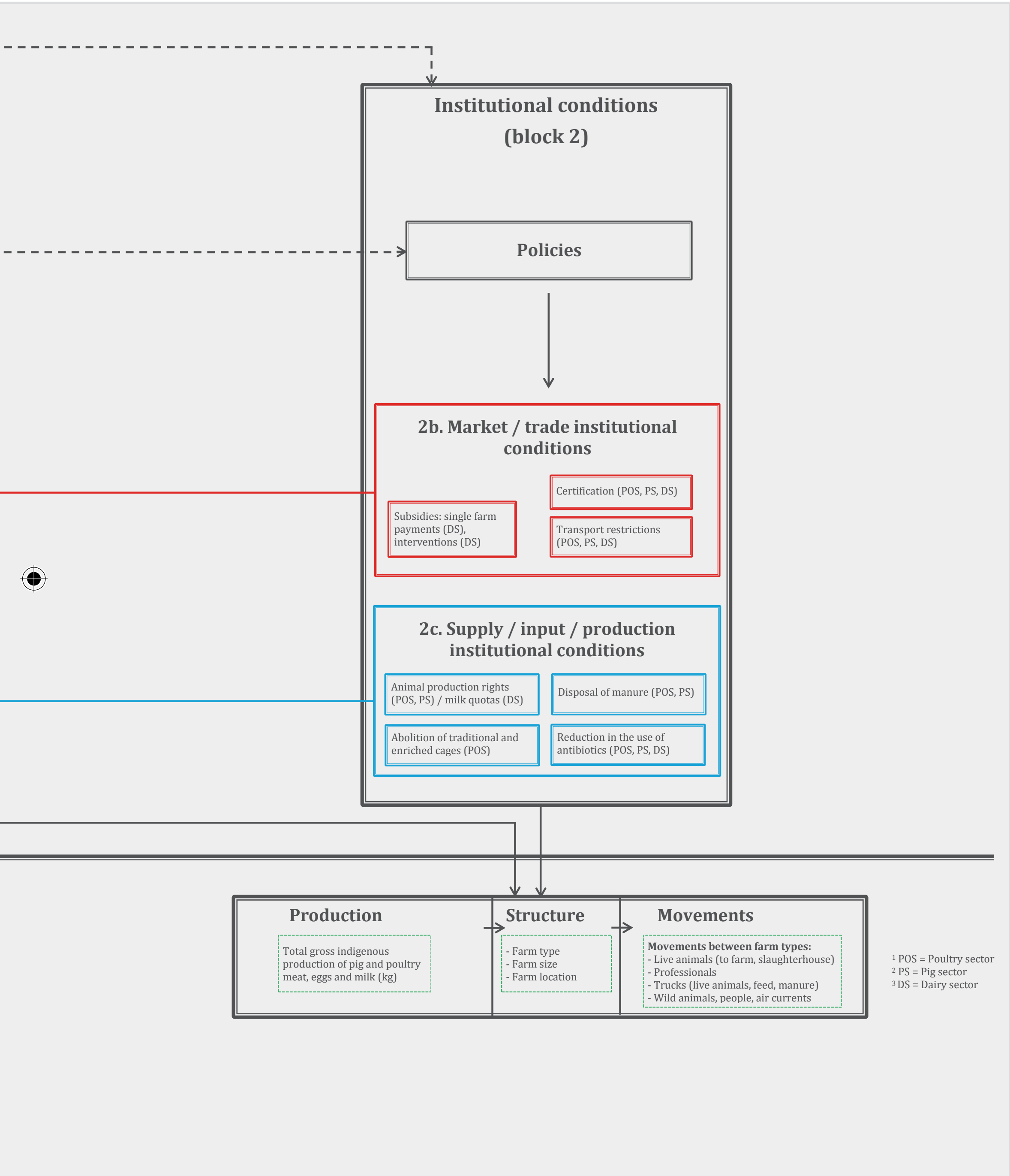


Figure 3.2 The framework with autonomous (global) driving forces, institutional conditions, and the value chain (*driving forces*), and consumption, production, structure and movement *parameters*.


Institutional conditions (block 2)
Policies
2b. Market / trade institutional conditions
Certification (POS, PS, DS)
Subsidies: single farm payments (DS), interventions (DS)
Transport restrictions (POS, PS, DS)
2c. Supply / input / production institutional conditions
Animal production rights (POS, PS) / milk quotas (DS)
Disposal of manure (POS, PS)
Abolition of traditional and enriched cages (POS)
Reduction in the use of antibiotics (POS, PS, DS)
Production
Total gross indigenous production of pig and poultry meat, eggs and milk (kg)
Structure
- Farm type
- Farm size
- Farm location
Movements
Movements between farm types:
- Live animals (to farm, slaughterhouse)
- Professionals
- Trucks (live animals, feed, manure)
- Wild animals, people, air currents
¹ POS = Poultry sector
² PS = Pig sector
³ DS = Dairy sector
3

The second group of alternative scenarios (Appendix Table A3.2) assumed differences in technological innovation and, as a result, in crop yield growth (supply scenarios). As a consequence, the availability of land, feed and fuel also differ.
For both groups of scenarios, a "higher / faster compared with baseline" and a "(s) lower" compared with baseline" scenario was considered. For two scenarios, an active stimulating policy variant was considered. The active variant assumed the EU and national policy to respond to the altering conditions (e.g., further stimulation to produce organically by providing subsidies and public information campaigns, or stimulating investments in innovation and subsidising research).
The consistency and likelihood rates of the seven scenarios proposed to the NL and NRW-LS experts are given in Appendix Table A3.3. For all of the scenarios, at least 80% of the experts rated them as being consistent. Based on likelihood, four scenarios qualified for the assessment of the impact of scenarios on the structure of NL and NRW-LS livestock sectors: the baseline scenario, both demand scenarios (fast and slow economic growth), and one supply scenario (higher crop yield growth). The NRW-LS and NL experts had different opinions on the likelihood of two scenarios. The fast economic growth scenario was considered to be likely by the NRW-LS experts, whereas the NL experts considered this scenario to be unlikely. The higher crop yield growth scenario was considered to be likely by the NL experts, whereas the NRW-LS experts considered this scenario to be unlikely.

Production and consumption in NL-NRW-LS in 2020

In Table 3.2, expert projections for NL and GER production and consumption of pig and poultry meat, eggs and milk are presented as average estimates, with the lowest and highest estimates in parentheses. Additionally, the differences between 2009 and 2020 are given as a percentage change (%). Based on the Kruskal–Wallis test, the experts' estimations are only given for the baseline scenario. The distribution of the experts' estimations across the scenarios did not differ significantly, i.e., there was no scenario-effect (Kruskal–Wallis test; $p \geq 0.05$).
Compared with 2009, the experts expected an increase of 4.2% on average for production and an increase of 3.0% on average for consumption for the baseline scenario. More specifically, a small decrease (−0.7%) in pork meat consumption in NL, an above average increase (+14.1%) in poultry meat production in GER compared with almost no increase (+1.1%) in NL, and hardly any increase in egg production in both GER (+0.4%) and NL (+0.8%) were expected.
The expected increases in NL and GER production and consumption are, on average, lower compared with the estimations for the EU production (+6.6%) and consumption (+4.7%) presented in the European outlook for agricultural markets for the same period (EC, 2010).

Table 3.2 The expert projections for NL and GER production and consumption of pig and poultry meat, eggs and milk.

	Past	Baseline scenario[1]	
	Absolute number	Absolute number	Percentage change (%)
	2009[2]	2020[3]	2020[4]
Pig meat			
Gross indigenous production ('000 t cwe)			
GER	4,718	5,091 (4,742–5,662)	+7.9
NL	1,766	1,807 (1,766–1,865)	+2.3
Per capita consumption (kg)			
GER	53.2	53.8 (50.5–56.0)	+1.1
NL	41.7	41.4 (39.6–42.0)	-0.7
Poultry meat			
Gross indigenous production ('000 t cwe)			
GER	1,397	1,594 (1,422–1,956)	+14.1
NL	701	709 (701–720)	+1.1
Per capita consumption (kg)			
GER	18.8	20.0 (19.2–20.7)	+6.4
NL	23	24.4 (23.0–26.0)	+6.1
Eggs			
Gross indigenous production ('000 t cwe)			
GER	787	790 (771–803)	+0.4
NL	638	643 (638–650)	+0.8
Per capita consumption (kg)			
GER	13	13.2 (13.0–13.3)	+1.5
NL	11.4	11.8 (11.4–12.5)	+3.5
Milk[5]			
Milk yield (kg/dairy cow)			
GER	7,043	7,409 (7,079–7,677)	+5.2
NL	7,919	8,389 (7,919–9,640)	+5.9
Milk production (mio t)			
GER	29	30.0 (29.4–30.5)	+3.4
NL	11.8	12.2 (11.8–13.0)	+3.4

[1] Experts' estimations are only provided for the baseline scenario. The distribution of the experts' estimations across the scenarios did not differ significantly, i.e., there was no scenario-effect (Kruskal-Wallis test; $p \leq 0.05$).
[2] The numbers for GER and NL(2009) are based on CBS (2009) (NL) and Eurostat (2009) (GER).
[3] For all future (year 2020) estimates, the average estimate is given, with the lowest and highest estimates in parentheses.
[4] Overall, production and consumption are expected to increase by 4.2% and 3.0%, respectively.
[5] Consumption for 2009 (reference value) was not available and therefore, no estimates were requested for the future scenarios.

Structure of livestock production in NL-NRW-LS in 2020

In Table 3.3, the expert projections for the NL-NRW-LS number of farms and average farm size for the pig, poultry and dairy sectors are given as average estimates, with the lowest and highest estimates in parentheses. Additionally, the differences between 2009 (NL)/2010 (NRW-LS) and 2020 are given as a percentage change (%). The experts' estimations are only given for the baseline scenario because of the absence of a scenario-effect (Kruskal–Wallis test; $p \geq 0.05$). Next, certain experts consistently estimated the number of farms and farm size to be either lower or higher than the average, i.e., there was an expert-effect (Kruskal–Wallis test; $p \leq 0.05$).

With respect to the average number of farms, compared with 2009 (NL) and 2010 (NRW-LS), the experts expected an overall decrease of 24% (−32%, −24% and −14% for NL, NRW and LS, respectively). With respect to the average farm size, compared with 2009 (NL) and 2010 (NRW-LS), the experts expected an overall increase of 33% (+57%, +17% and +15% for NL, NRW and LS, respectively) (not in Table 3.3).

These differences among countries are even larger for the pig sector, e.g., the experts expected 80.7% NL, 7.5% NRW, and 4.0% LS more fattening pigs per farm. In addition to these expected changes, an above-average increase in the NL laying hen farm size (+63.8%) and NRW dairy farm size (+31.3%), a below-average decrease in the NRW number of broiler farms (−11.0%) and NRW laying hen farms (−3.4%), and an above-average decrease in the NRW number of closed pig farms1 (−64.3%) were expected.

Regional differences within NL-NRW-LS

In Figures 3.3 and 3.4, the expert projections for the distribution of pig, poultry and dairy farms and farm size within specific regions of NL, NRW and LS are given. Estimations were only requested for the baseline scenario (year 2020) to avoid asking the experts for too many estimations and because the distribution of the experts' estimations across the scenarios did not differ significantly (Tables 3.2 and 3.3). NL, NRW and LS are divided into four, five and four regions, respectively. These regions were chosen because a similar division is used by statistical agencies, e.g., CBS (2009), and therefore, data on the number of farms and farm size per region were almost always available for 2009 (NL) (CBS, 2009) or 2007 (NRW and LS) (IT-NRW, 2008 and LSKN, 2009, respectively).

Figure 3.3a, b and c presents graphs with the number of farms within specific regions of NL, LS and NRW as percentages of the total number of NL, LS and NRW farms, respectively. The graphs present percentages rather than total number of farms because the differences in numbers of, e.g., dairy and broiler farms are large. To

1 Closed pig farms are farms where the reproduction and fattening are integrated at the same farm.

Table 3.3 The expert projections for the NL-NRW-LS total number of farms and average farm size for the pig, poultry and dairy sectors.

	Past	Baseline scenario[1]	
	Absolute number	Absolute number	Percentage change (%)
	2009 (NL) / 2010 (NRW–LS)[2]	2020[3]	2020[4]
Pig sector			
Sow farms			
NL: # farms with sows present	3,072	1,980 (1,000–2,500)	-35.5
NL: # sows / farm	366	560 (450–800)	+53.0
NRW: # farms with sows present	3,808	2,603 (2,010–3,300)	-31.6
NRW: # sows / farm	132	165 (150–180)	+25.0
LS: # farms with sows present	4,070	3,067 (2,700–3,500)	-24.6
LS: # sows / farm	147	178 (170–185)	+21.1
Fattening farms			
NL: # farms with fattening pigs present	6,508	4,253 (2,000–5,000)	-34.6
NL: # fattening pigs / farm	902	1,630 (1,250–2,500)	+80.7
NRW: # farms with fattening pigs present	4,312	3,767 (3,500–4,000)	-12.6
NRW: # fattening pigs / farm	456	490 (450–550)	+7.5
LS: # farms with fattening pigs present	4,703	4,417 (4,350–4,500)	-6.1
LS: # fattening pigs / farm	522	543 (480–610)	+4.0
Closed farms			
NL: # closed farms	2,013	1,430 (750–2,500)	-29.0
NL: # sows / farm *(estimated)*	229	306 (250–400)	+33.6
NL: # fattening pigs / farm *(estimated)*	796	1,380 (800–3,200)	+73.4
NRW: # closed farms *(estimated)*	3,500	1,250 (1,000–1,550)	-64.3
LS: # closed farms	*unknown*	n.a.[5]	n.a.
Poultry sector			
Broiler farms			
NL: # farms with broilers present	638	493 (400–550)	-22.7
NL: # broilers / farm	67,845	102,000 (75,000–150,000)	+50.3
NRW: # farms with broilers present	517	460 (430–500)	-11.0
NRW: # broilers / farm	8,672	9,600 (8,300–11,500)	+10.7
LS: # farms with broilers present	1,040	877 (730–1,100)	-15.7
LS: # broilers / farm	35,101	41,333 (32,000–52,000)	+17.8
Laying hen farms			
NL: # farms with laying hens present	1,277	763 (500–980)	-40.3
NL: # laying hens / farm	27,061	44,333 (38,000–60,000)	+63.8
NRW: # farms with laying hens present	4,141	4,000 (3,600–4,400)	-3.4

Table 3.3 Continued.

	Past	Baseline scenario[1]	
	Absolute number	Absolute number	Percentage change (%)
	2009 (NL) / 2010 (NRW–LS)[2]	2020[3]	2020[4]
NRW: # laying hens / farm	1,083	1,183 (1,000–1,350)	+9.2
LS: # farms with laying hens present	4,873	4,333 (3,600–5,000)	-11.1
LS: # laying hens / farm	2,309	2,650 (2,450–2,900)	+14.8
Dairy sector			
NL: # farms with dairy cows present	20,268	14,384 (10,000–18,000)	-29.0
NL: # dairy cows / farm	73	104 (97–111)	+42.5
NRW: # farms with dairy cows present	8,137	6,400 (5,300–7,900)	-21.3
NRW: # dairy cows / farm	48	63 (50–85)	+31.3
LS: # farms with dairy cows present	13,161	11,333 (10,500–12,500)	-13.9
LS: # dairy cows / farm	59	68 (60–80)	+15.3

[1] Experts' estimations are only given for the baseline scenario. The distribution of the experts' estimations across the scenarios did not differ significantly, i.e., there was no scenario-effect (Kruskal-Wallis test; $p \leq 0.05$).
[2] The numbers for NL (2009) and NRW-LS (2010) are based on CBS (2009) (NL) and Statistisches Bundesamt Deutschland (2011) (NRW and LS).
[3] For all future (year 2020) estimates, the average estimate is given, with the lowest and highest estimates in parentheses.
[4] Overall, the farm size is expected to increase by 33%, and the number of farms is expected to decrease by 24%.
[5] N.a. means 'not available'. The number of closed farms in LS was unknown for 2010 and therefore, no estimations were requested for 2020.

convey an idea of the number of farms within the different regions, the total number of farms in 2009 (NL)/2007 (NRW and LS) and the expected number of farms in 2020 are presented in small tables on the right of Figure 3.3a, b and c.

With respect to the distribution of farms within the regions of NL, NRW and LS, hardly any changes were expected for NRW and LS (in percentage change). The largest change concerned an expected increase of 5.4% in the number of sow farms in the region Weser-ems (LS). For NL, however, larger changes in regional distribution of farms were expected. Most strikingly, compared with 2009 it was expected that almost 15% more sow farms will exist in the East region in 2020 and 17.5% less sow farms in the South region. Similar percentage changes were expected for fattening farms in the East and South regions. Next, major changes were expected in the

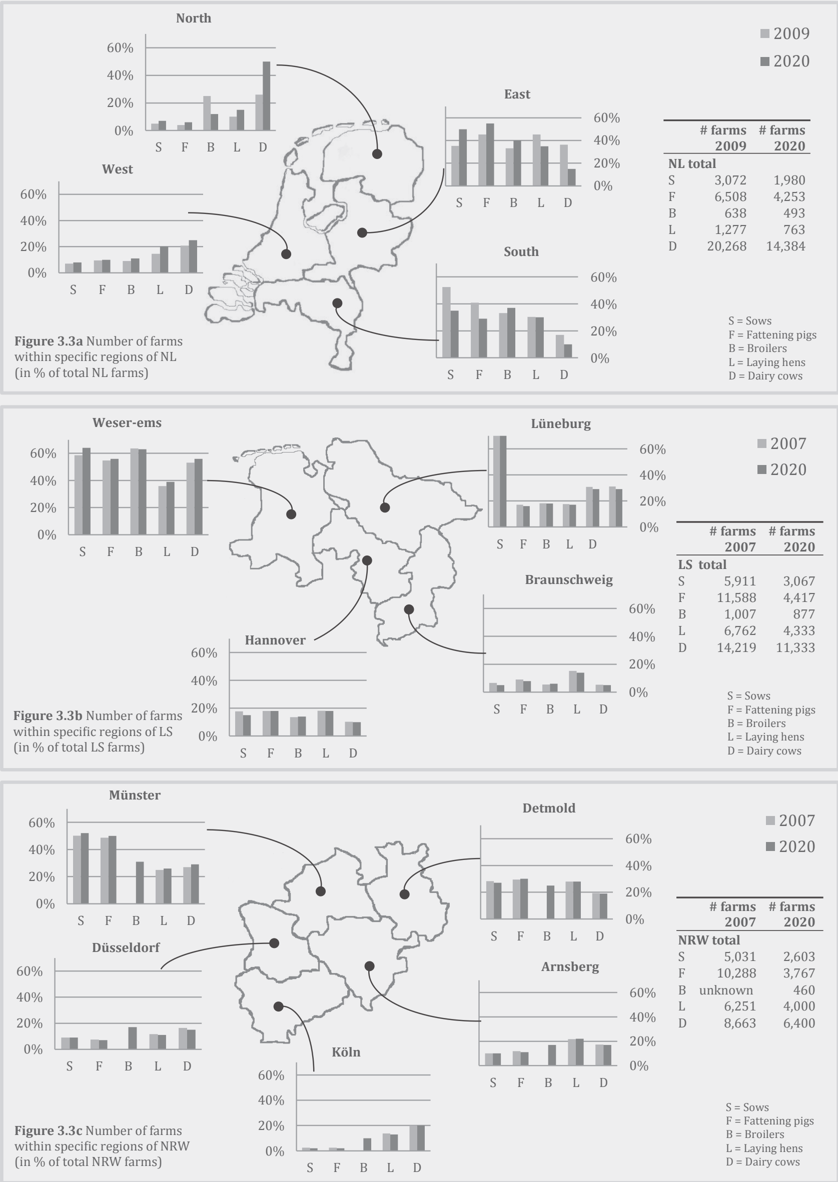
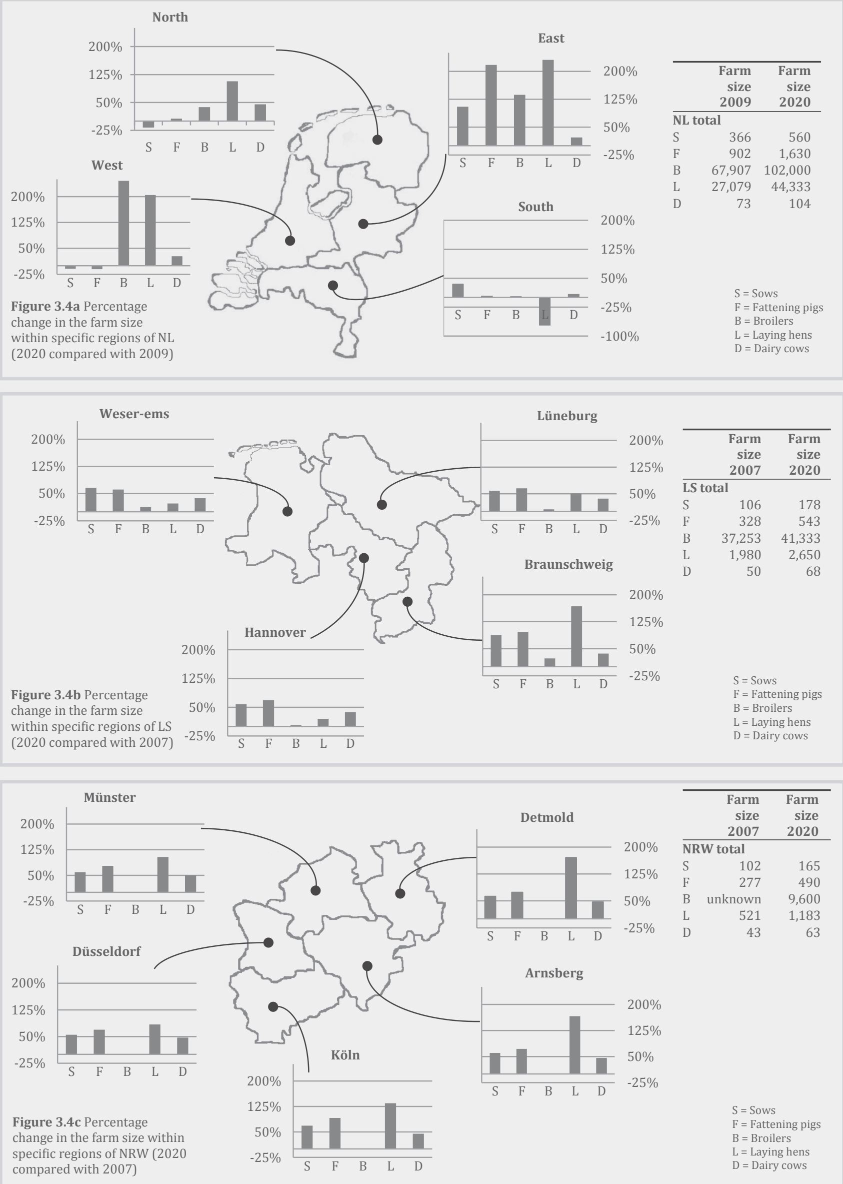


Figure 3.3a Number of farms within specific regions of NL (in % of total NL farms)

Figure 3.3b Number of farms within specific regions of LS (in % of total LS farms)

Figure 3.3c Number of farms within specific regions of NRW (in % of total NRW farms)

Figure 3.3 The expert projections of the numbers of farms within specific regions of NL, NRW and LS (in % of total number of farms) for the pig, poultry and dairy sectors (2020 compared with 2009 (NL) / 2007 (LS-NRW)).



	Farm size 2009	Farm size 2020
NL total		
S	366	560
F	902	1,630
B	67,907	102,000
L	27,079	44,333
D	73	104

Figure 3.4a Percentage change in the farm size within specific regions of NL (2020 compared with 2009)

	Farm size 2007	Farm size 2020
LS total		
S	106	178
F	328	543
B	37,253	41,333
L	1,980	2,650
D	50	68

Figure 3.4b Percentage change in the farm size within specific regions of LS (2020 compared with 2007)

	Farm size 2007	Farm size 2020
NRW total		
S	102	165
F	277	490
B	unknown	9,600
L	521	1,183
D	43	63

Figure 3.4c Percentage change in the farm size within specific regions of NRW (2020 compared with 2007)

Figure 3.4 The expert projections of the percentage change in farm size within specific regions of NL, NRW and LS for the pig, poultry and dairy sectors (2020 compared with 2009 (NL) / 2007 (LS-NRW)).

percentage of broiler farms in the North region (–12.8%), in the percentage of laying hen farms in the East region (almost–10%), and in the percentage of dairy farms in the North (almost +25%), East (–21.4%) and South (–7%) regions.

Figure 3.4a, b and c presents graphs with expected changes in farm size within specific regions of NL, NRW and LS, respectively. The year 2020 is compared with 2009 (NL) / 2007 (LS and NRW) and presented as the percentage change. The graphs present percentages rather than absolute farm sizes because the differences in numbers of, e.g., dairy cows and broilers are large. To convey an idea of the farm sizes within the different regions, the farm sizes in 2009 (NL) / 2007 (NRW and LS) and the expected farm sizes in 2020 are presented in small tables on the right of Figure 3.4a, b and c.

With respect to farm size, increases were expected for farm sizes within the regions of NRW and LS. For farm size within regions of NL, however, both increases and decreases were expected. For sow farm size, the North and West regions were expected to show decreases of 17.3% and 8.6% in farm size compared with 2009, respectively, whereas the average NL sow farm size was expected to increase by 53%. The fattening farm size in the West region was expected to decrease by 10.2%, with an average NL fattening farm size of +80.7%. The laying hen farm size in the South region was expected to decrease dramatically, by 72.5%, with an average NL laying hen farm size of +63.7%.

During the final workshop and e-mail interviews, the experts indicated that regional and even local policies are also important in determining the number of farms and farm size at a regional level and sometimes overrule developments as described in Figure 3.2. For example, the demand for agricultural land for regular housing, the bonds of local government with agriculture, and environmental policies certainly influence the future number of farms and farm size. It was not possible to include all of these regional and local policies in the framework with driving forces, but it is important to be aware of these specific driving forces as well.

Another important finding was the experts' expectation that farms are likely to cluster more in the future, i.e., farms concentrate in certain areas, most likely areas that are already densely populated. It is difficult to locate the areas that will develop into "islands of farms", but it is important to keep this trend in mind because concentration can impact the risks of both introducing and spreading contagious livestock diseases.

Discussion and future outlook

The objective of this chapter was to explore changes in future production structure features within the cross-border region of NL, NRW and LS projected towards 2020 using the Policy Delphi method. Below, the methodology is discussed, followed by a justification of the usefulness of the results to elaborate the possible implications for contagious livestock disease management. Additionally, the findings of this chapter are elaborated in terms of possible implications and future prospects for contagious livestock disease introduction, spread and control, as well as for veterinary contingency planning.

Methodology

The disaggregative variant of the Policy Delphi method was used to systematically construct and quantify various scenarios to explore changes in future production structure features and, consequently, to assess their impact on risks of contagious livestock diseases. Compared with other studies, this study had an extended scope in two ways. First, studies that analysed the future structure of livestock production did not address the impact of driving forces on country-specific and regional production structure features and, consequently, on risks of contagious livestock diseases (see, e.g., Nowicki *et al.*, 2007; EC, 2010; OECD/FAO, 2011). Second, most studies that constructed scenarios using the Delphi method did not quantify the impact on, e.g., the proposed scenarios (e.g., Gómez-Limón *et al.*, 2009). To enable both in our study, a wide variety of expertise had to be included in the expert panel, i.e., expertise on global and regional economies, organisation of regional livestock markets and chains, veterinary knowledge, and legislation and institutional conditions. Hence, an important criterion for expert selection was the ability to put their own expertise into a wider perspective. These criteria resulted in a critical selection of experts and, hence, impacted the potential size of the expert panel. Despite the critical selection, during the Delphi survey rounds, experts dropped out mostly because they questioned their ability to oversee all fields of expertise. The final estimations of the number of farms, farm size and regional differences in these two parameters were therefore performed by six NL and five NRW-LS experts, all having expertise in different fields and all with the ability to place their expertise in a wider perspective. Although studies that end with five or six experts are common rather than an exception (see, e.g., Rowe and Wright, 1999; Breukers *et al.*, 2006), the small size of the expert panel could explain the fact that no specific scenario was chosen as the most likely one and the large range in estimations. Despite the fact that no discrimination among the scenarios could be made, the most striking overall result was the consistency of the experts in estimating the future number of farms and farm size across all of the scenarios, i.e., the experts were consistent in both estimating the direction of the effects and the range of the estimations. Therefore, *given the objective of this chapter*, the followed Delphi approach turned out to be a suitable tool in providing useful results and, consequently, provided a good basis for elaborating the impact on the risks of contagious livestock diseases.

Results

For all of the scenarios, the experts' estimations (lowest, mean and highest estimations) were in the same range, which was partly attributable to an expert-effect, i.e., certain experts consistently estimated the number of farms and the farm size to be either lower or higher than the average. Due to the lack of a scenario-effect, we only presented the estimations for the baseline scenario rather than for all of the scenarios. We selected the baseline scenario because the experts rated this scenario as the most likely (Table A3.3).

On average, the experts expected a sharp reduction in the number of farms and a sharp increase in the farm size during 2011–2020, thereby confirming the earlier general findings (Nowicki *et al.*, 2007; Silvis *et al.*, 2009). The experts expected that small farms in particular will disappear in the coming years, resulting in fewer and, automatically, larger farms in a short time-period. At the same time, large farms were expected to increase their farm size considerably, resulting in even larger farms.

Experts particularly expected changes in the pig sector. The total number of produced piglets was expected to decrease by 0.4 million in NL and by 3.6 million in NRW-LS, based on *farm size × number of farms × 28.9 weaned piglets per sow per year* (Agrovision, 2012). The total number of fattening pig places was expected to increase by 1.1 million in NL and to decrease by 0.2 million in NRW-LS. The combined effect of the expected changes in the fattening pig places and the expected decrease in produced piglets resulted in an expected increase in the total available number of fattening pig places in both NL and NRW-LS. In the broiler sector, it was expected that the total number of NRW and LS produced broilers will decrease by 2.3 million (based on *number of farms × farm size × 7 rounds per year* (LEI, 2010)) and that the NL broiler sector will grow by 49 million broilers. In the laying hen sector, minor changes were expected, i.e., an increase of 430 thousand laying hens in NRW-LS (based on *number of farms × farm size × 0.9 rounds per year* (LEI, 2010)). In the dairy sector, an increase was expected in the total number of NRW-LS dairy cows, resulting in a slight increase in the number of veal calves produced.

Furthermore, the experts expected, especially in NL, a regional concentration of livestock production, i.e., farms will concentrate in certain areas, most likely those areas that are already densely populated. Sow and fattening pig farms in particular were expected to concentrate in the East region and to reduce in number in the South region. Additionally, the experts expected broiler farms to reduce in number in the North region and laying hen and dairy farms to reduce in number in the East region. Dairy farms were expected to concentrate even more in the North region.

Implications for contagious livestock disease control

The changes in the structure of livestock production as described above can have important implications for contagious livestock disease control, both within and between countries. Below, these implications are elaborated.

Within countries

Within NL, NRW and LS, two main developments were expected: (i) fewer but larger farms, i.e., a concentration of animals per farm, and (ii) a concentration of farms in certain areas, i.e., a concentration of livestock production, especially in NL.

As a favourable consequence of the first development, i.e., fewer but larger farms, the total number of animal contact possibilities will be reduced for the remaining farms, resulting in a decreased risk of disease introduction. In addition, larger than average farms could have a higher biosecurity level, again resulting in reduced risks of disease introduction and spread. Whether this development results in an increase or decrease of the total number of (in)direct animal contacts during 2011–2020 remains uncertain. It is, therefore, important to continue monitoring the features that influence these contacts, i.e., developments in the number of farms, farm size and number of (fixed) contact farms per farm. For instance, considerable changes in the livestock production structure, e.g., a drop in the number of farms to the level of the lowest experts' estimates, could influence introduction and spreading dynamics substantially. Developments in these livestock production features will determine whether current veterinary policies for the control of contagious diseases should be reconsidered.

The second development, i.e., the concentration of livestock production, especially in NL, has both favourable and unfavourable implications. If farms concentrate in certain areas, the distance between clusters of farms will most likely increase. Disease spread among clusters of farms may decrease as a result. However, a drawback of this development is that, once a disease is introduced into such a cluster, it will most likely affect a large number of farms and animals, resulting in an overall larger epidemiological and economic impact. Although it is difficult to determine these cluster areas, this parameter will be important to monitor in the future. Future veterinary policies need to anticipate these developments: if the experts' expectations come true, the potential impact of contagious livestock diseases for these areas is increasing, as is the need for preventing the introduction of diseases to these areas. That necessity means that the reconsideration of future veterinary policies needs to focus on preventing the spread of a virus to unaffected areas rather than preventing the spread of a virus within an area, e.g., by prolonging the transport standstill period. In addition, it is important to reconsider current compartmentalisation2 based on future developments in the clustering of farms in certain areas. Locating feed companies and slaughterhouses in certain compartments where livestock production is concentrated could be an option. In case of an outbreak, farms could still receive feed and reach slaughterhouses because they would be located in the same compartment. This arrangement could solve animal welfare problems due to transport bans, as observed in the outbreak of CSF in NL in 1997–1998 (Pluimers *et al.*, 1999).

As a result of both expected developments, i.e., the concentration of animals per farm and the concentration of farms in certain areas, the currently preferred veterinary policy in NL to control diseases, i.e., emergency vaccination, may no longer be adequate in controlling contagious livestock diseases in the future. Contagious livestock diseases need to be controlled in a short time-period to overcome rapid spread to unaffected areas. When animals are highly concentrated in certain areas, diseases spread more rapidly than the rate at which animals develop adaptive immunity to a disease by emergency vaccination. This consideration leaves the depopulation of affected areas, i.e., culling and destruction of the animals, as the only option to eradicate contagious livestock diseases. Although an effective measure to control diseases, depopulation has been subject to public criticism (Elbers *et al.*, 1999). In addition, depopulation based on the prioritisation of high-risk farms, i.e., the farms with a high number of contact farms in a certain radius around the affected farms, may also reduce virus spread. If the capacity to control contagious livestock diseases appears to become a problem, preventive measures to overcome these capacity problems will become increasingly important, e.g., biosecurity measures to prevent the introduction of contagious livestock diseases. Another option for overcoming capacity problems is capacity and resource sharing with adjacent regions, i.e., NL-NRW-LS. Examples are shared stocking of vaccines, conducting diagnostic tests and destructing of animals.

Between countries

Due to the expected increase in NL fattening pig places and decrease in produced NL piglets, it is likely that the total number of exported NL piglets, 6.7 million in 2010 (PVE, 2011), will decrease by a million in 2020. However, it is expected that this change will not decrease the export of NL piglets to NRW-LS. The potential surplus

2 A compartment is defined in the Terrestrial Animal Health Code of the OIE as "one or more establishments under a common biosecurity management system containing an animal subpopulation with a distinct health status with respect to a specific disease or specific diseases for which required surveillance, control and biosecurity measures have been applied for the purpose of international trade" (OIE, 2009). This legislation offers the opportunity to continue trading from free compartments during periods of disease outbreak in a country or zone.

of 3.5 million NRW-LS fattening pig places will most likely increase the export of NL piglets to NRW-LS and decrease the NL export to countries located further away. The expected increase in piglet export to NRW-LS appears reasonable, as the transport distance is short, as are the transport costs and discomfort of the animals due to the short journey. Additionally, NRW-LS and NL have similar health statuses for most diseases (Hop *et al.*, 2013). Therefore, no limitations are imposed on livestock trade, such as extra certification and trade exemptions. In 2010, approximately 3 million NL piglets were transported to NRW-LS with, on average, 488 piglets/transport (423 piglets/transport in 2008 and 441 piglets/transport in 2009). In 2020, the number of NL piglets transported to NRW-LS may increase by 0 to 3.5 million animals, and based on 500 piglets/transport, this scenario may change the total number of cross-border piglet transports by –150 to +12,800 transports.

In addition, due to the expected change of approximately +1 million NL fattening pigs, it is likely that the number of NL fattening pigs exported to NRW-LS's slaughter-houses will also increase. In 2010, approximately 4 million NL fattening pigs were transported to NRW-LS with, on average, 156 fattening pigs/transport (similar averages for 2009 and 2008 (LEI, 2010)). In 2020, the number of NL fattening pigs transported to NRW-LS may increase by 0 to 1 million animals, and based on 156 fattening pigs/transport, this scenario may change the total number of cross-border transports by 0 to +6,400 transports. Most likely, an increase of 6,400 transports will not be reached: transport size most likely increases if an additional 1 million fattening pigs need to be transported, either through larger livestock trucks or through a more efficient loading of trucks.

In addition to being substantial, the expected increases in export of NL piglets and fattening pigs to NRW-LS are quite likely. During 2008–2010, the number of NL piglets exported to NRW-LS increased from 1.9 million (2008) to 3 million (2010), and the number of NL slaughter pigs exported to NRW-LS increased from 3.1 million (2008) to 4 million (2010) (PVE, 2011). However, certain movements are more risky than others with respect to disease spread (i.e., transports for live use versus transport for slaughter) (Jalvingh *et al.*, 1999). As slaughter animals are dead-end hosts in terms of contagious livestock disease spread, most likely only the livestock trucks that transport these animals to slaughterhouses form a risk in spreading diseases (Jalvingh *et al.*, 1999). The expected increase in piglet transports, however, results not only in more livestock truck movements but also in more animal contacts between farms. These increasing numbers of animal contacts can result in increased spread dynamics of undetected contagious livestock diseases.

With respect to the broiler sector, 130 million of the 287 million produced NRW-LS broilers were slaughtered in NL in 2010 (PVE, 2011). Due to the expected decrease in NRW-LS produced broilers, a slight decrease in number of transports to NL was expected. In 2010, 39 million NL day-old broiler chicks were exported to NRW-LS

(PVE, 2011); due to the expected decrease in produced broilers in NRW-LS, it is likely that the transport of day-old broiler chicks will also decrease. In 2010, all NL broilers were slaughtered within NL (PVE, 2011). However, due to the expected increase in the number of broilers, cross-border slaughtering of broilers may be necessary due to limited domestic slaughterhouse capacities.

These expected increases in cross-border trade in most sectors result from the increasing mutual cross-border production dependency. This mutual dependency results in a cross-border region that increasingly constitutes a single epidemiological region in which disease introduction is a shared veterinary and, consequently, economic risk. Improving the joint prevention and control of contagious livestock diseases is therefore increasingly important and of mutual interest (Hop *et al.*, in press). As observed by Breuer *et al.* (2008), there is potential to improve collaboration beyond current levels based on EU legislation in veterinary disease control among countries, for example, as shown during the outbreak of CSF in NRW in 2006. A lack of cooperation between countries and insufficient information sharing wasted valuable time in controlling the epidemic (Breuer *et al.*, 2008). In addition to these harmonisation possibilities, economic instruments can be added to disease control strategies to lower the economic consequences, e.g., channelling animals and animal products to a lower quality and/or price segment of the market, storage of products to buffer and/or mitigate market disruptions, and mutual capacity building. Except for the latter instrument, these measures do not affect the veterinary control of diseases; however, they do change the total economic impact on the stakeholders. An advantage of the extended area of NL-NRW-LS is the larger capacity for, e.g., channelling animals and animal products. The primary requirement for successful implementation is the use of flanking instruments to increase the willingness to cooperate among the different stakeholders within NL-NRW-LS, e.g., harmonised compensation for affected stakeholders. However, this process is complex, involving not only veterinary aspects but also economic consequences, legal aspects and implementation possibilities.

Conclusions

This chapter used the Policy Delphi method to explore changes in future production structure features within the cross-border region of NL-NRW-LS. This method showed to be able to provide a basis for elaborating the possible implications of changes in the future production structure features for contagious livestock disease introduction, spread and control.

The experts expected a sharp reduction in the number of farms, a sharp increase in farm size, and a regional concentration of livestock production, especially in NL. The

experts consistently estimated both the range of the estimations and the direction of the changes across all of the scenarios.
The expected increases in cross-border trade in most sectors result from a mutual cross-border production dependency, particularly in the pig sector. This mutual dependency results in a cross-border region that increasingly constitutes a single epidemiological and economic livestock region in which disease introduction is a shared veterinary and, consequently, economic risk. This change results in both increased need and increased possibilities for collaboration among NL-NRW-LS to improve the joint prevention and control of contagious livestock diseases. Harmonisation is, however, a complex process, including veterinary, economic and legal aspects as well as implementation possibilities.
It is concluded that veterinary policy makers need to monitor changes in important driving forces and their effects on the production structure features and, consequently, to proactively anticipate these future changes in their disease policy making.

Acknowledgements

The authors gratefully acknowledge the experts who participated in the workshops and surveys, the pre-testers of the surveys, Roel Jongeneel for his feedback on lists of driving forces and scenario assumptions, Oliver Breuer for translating questionnaires into the German language and suggesting German experts, and Meike Wentholt for answering all questions related to the use of the Delphi method.
This study is part of project SafeGuard, which is financed within the INTERREG IV A program Deutschland-Nederland by the European Regional Development Fund.

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Appendix

Table A3.1 Expert assessment of the probability and impact of the major driving forces for NL and NRW-LS for the years 2000–2010 and 2011–2020 (the probabilities are presented as median (1st quartile; 3rd quartile)).

Major driving forces	Past (2000 – 2010)	
	NL	
	Probability[1]	Impact (%)[2]
Autonomous (global) driving forces (block 1)		
Demand-driving forces (sub-block 1a)		
Rate of economic growth / developments in income	4.5 (4;5)	28.9
Euro exchange rate / crude oil prices	4 (3;5)	3.9
EU population growth and composition	4.5 (3.5;5)	24.8
Factors that influence consumer preferences: lifestyle, health and welfare concerns, food safety concerns, discussions in society on very large farms, and the influence of third parties	4 (3;5)	29.9
Market / trade-driving forces (sub-block 1b)		
Global demand for / consumption of food	5 (3.5;5)	30.3
Global production competing countries	4.5 (4;5)	43.5
WTO/WHO/OIE agreements; export restitutions; level playing field EU	4 (4;5)	21.3
Outbreaks of contagious livestock diseases (temporarily)	n.a.[3]	n.a.
Supply / input / production-driving forces (sub-block 1c)		
Availability of agricultural land (quantity and quality)	3 (2;4)	28.5 (17.1/15.2/53.1)[4]
Availability of feed stock	4 (3;5)	27.7 (34.3/36.4/12.5)[4]
Availability of (renewable) energy / biofuels	3 (2;4)	3.0
Technological innovation	5 (4;5)	33.9
Institutional conditions (block 2)		
Market / trade institutional conditions (sub-block 2b)		
Subsidies: single farm payments / interventions[5]	5 (4;5)	37.2
Certification	3 (3;4)	36.6
Transport restrictions	3 (3;5)	26.2
Supply / input / production institutional conditions (sub-block 2c)		
Animal production rights[6] / milk quota[5]	5 (5;5)	40.5 (33.3/24.1/64.0)[4]

		Future (2011 – 2020)			
NRW-LS		NL		NRW-LS	
Probability	Impact (%)	Probability	Impact (%)	Probability	Impact (%)
4 (3;5)	22.6	4.5 (4;5)	23.8	4 (3;5)	13.9
3 (2;4)	3.3	4 (3.5;5)	9.2	4 (3;4)	7.8
4 (3;5)	17.7	4 (3;5)	14.1	4 (3;5)	12.2
4 (4;5)	52.1	4 (4;5)	41.8	4 (4;5)	53.7
4 (4;5)	39.2	5 (4.5;5)	25.1	5 (4;5)	33.1
4 (3;5)	49.9	5 (4;5)	40.0	4 (4;5)	40.0
4 (4;5)	5.5	5 (4;5)	19.5	4 (4;5)	9.9
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
4 (3;4.75)	38.0	4 (3;5)	23.4 (15.2/12.8/42.1)[4]	4.5 (3.25;5)	37.6
4 (3;5)	22.4 (27.3/26.3/13.6)[4]	5 (4;5)	30.6 (34.8/35.9/21.1)[4]	4.5 (4;5)	22.8
3 (2;4)	12.6	4 (3;5)	4.8	4 (3;4)	16.9
3.5 (3;4.75)	23.9	5 (4;5)	28.3	4 (3;5)	7.9
4 (3;5)	54.4	4 (3;5)	19.8	4 (2.5;5)	32.3
3 (2;3)	27.2	4 (3;4)	42.9	3 (3;4)	35.7
3 (2;3.75)	18.4	3 (3;5)	37.4	3 (2;4)	32.0
3 (2;5)	37.5 (11.1/25.0/76.5)[4]	4 (3;5)	26.7 (18.2/14.3/47.6)[4]	4 (3;5)	33.3

Table A3.1 Continued.

Major driving forces	Past (2000 – 2010)	
	NL	
	Probability[1]	Impact (%)[2]
Disposal of manure	5 (4;5)	25.2 (40.0/27.6/8.0)[4]
Abolition of traditional and enriched cages[7]	3 (2.75;4)	24.1
Reduction in the use of antibiotics	3 (2;3)	7.0

[1] Anchored at 1 = "not likely" to 5 = "very likely". Driving forces are presented if the probability is ≥ 4 for at least one country, or if chosen in ≥ 10% of the cases per sub-block (impact)2. The results are presented as the medians (1st quartile; 3rd quartile).
[2] Percentage of times chosen as one of two driving forces per sub-block with the highest impact on demand, trade and supply. Driving forces are presented if chosen in ≥ 10% of the cases for at least one country, or if the probability is ≥ 41. The number is the average for pig, poultry and dairy sectors, unless the difference among the sectors is ≥ 10%.
[3] N.a. means 'not available'. Driving force was added during the first Delphi survey round but not assessed with respect to impact and probability by all experts. During the feedback round, experts agreed that this driving force should be added to the list of major driving forces.
[4] Separate percentages are provided for the pig, poultry and dairy sectors, respectively, because the difference among the sectors is ≥ 10%.
[5] Only for the dairy sector.
[6] Only for the pig and poultry sectors.
[7] Only for the poultry sector.

	Past (2000 – 2010)		Future (2011 – 2020)			
	NRW-LS		NL		NRW-LS	
	Probability	Impact (%)	Probability	Impact (%)	Probability	Impact (%)
	3 (2;4)	22.8 (50.0/12.5/5.9)[4]	4 (3.5;5)	24.8 (36.4/28.6/9.5)[4]	3 (2;3)	14.7 (26.3/14.0/3.8)[4]
	4 (3;5)	37.5	3.5 (3;4)	11.4	4 (2;5)	14.0
	2 (2;3)	5.2	4 (3;4)	15.9	3 (2;4)	8.5

Table A3.2 Assumptions on the driving forces for the proposed scenarios.

Driving forces	Baseline scenario[1]
Demand-driving forces (block 1a)	
Macroeconomic conditions	
GDP growth	
• World	4% per year
• EU27	2% per year
Euro exchange rate	1.47 USD/EUR
Price crude oil	96 USD/barrel
Population growth	
World	1% per year
EU27	0.3% per year
EU12	-0.1% per year
EU consumer preferences and concerns	Growth in demand for value-added products and decline in demand for traditional / basic products
Market / trade-driving forces (block 1b)	
World market perspectives	Increasing demand for food in emerging markets
Global trade policy	Global trade policy follows the Doho Round Agreement on Agriculture (w.r.t. market access and subsidised exports)
Supply / input / production-driving forces (block 1c)	
Technological innovation	Small increase in the rate of technological progress[2]
Availability of agricultural land	Expected to become more and more a limiting factor for production
Availability of feed and fuel	Expected growth in demand for feed and fuel, higher prices

Demand scenarios		Supply scenarios	
Fast economic growth worldwide	**Slow economic growth worldwide**	**Higher crop yield growth worldwide**	**Lower crop yield growth worldwide**
6% per year	2% per year	*Same as in baseline*	*Same as in baseline*
3% per year	1% per year	*Same as in baseline*	*Same as in baseline*
1.60 USD/EUR	1.25 USD/EUR	*Same as in baseline*	*Same as in baseline*
120 USD/barrel	80 USD/barrel	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Growth in demand for value-added products much higher compared with baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Growth in demand worldwide even higher compared with baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	Higher increase in the rate of technological progress (compared with baseline)[3]	No technological progress[4]
Production factor even more limiting compared with baseline	*Same as in baseline*	Production factor even more limiting compared with baseline	*Same as in baseline*
Higher expected growth in demand compared with baseline	Lower expected growth in demand compared with baseline	Higher crop yields / lower crop prices due to increased technological progress -> lower feed and biofuel costs -> lower input costs for livestock sector -> increasing EU exports of pig and poultry meat	Lower crop yields / higher crop prices due to zero technological progress -> higher feed and biofuel costs -> higher input costs for livestock sector -> decreasing EU exports of pig and poultry meat

Table A3.2 Continued.

Driving forces	Baseline scenario[1]
Institutional conditions (block 2)	
Common Agricultural Policy (CAP)	Phasing out and abolition of milk quotas (2015); decoupling of the direct payments (Single Farm Payments) from production
National policy	Abolition of pig and poultry production rights (2015); reduction in the use of antibiotics

[1] Assumptions in baseline scenario are based on (EC, 2010).
[2] Indicates that, with an average yield growth of 1% (year 2010 = 100), the yield growth in 2020 is expected to be 110.46.
[3] Indicates that, with an average yield growth of 20% higher compared with baseline (baseline = 1% + extra 20% = 1.2% in this alternative scenario) (year 2010 = 100), the yield growth in 2020 is expected to be 112.67.
[4] Indicates 0% compared with 2010, so with an average yield growth of 1%, the yield growth in 2020 is expected to still be at 1%.

Table A3.3 The consistency and likelihood of seven scenarios proposed to NL and NRW-LS experts.

Scenarios	Consistency[1] (% positive answers)		Likelihood[2] (average)	
	NL	NRW-LS	NL	NRW-LS
Baseline scenario[3]	94	80	2.3	1.9
Demand scenarios				
Fast economic growth[3]	86	90	5.1	2.8
Slow economic growth[3]	100	80	3.1	3.0
Fast economic growth & active stimulating policy	93	100	4.9	4.8
Supply scenarios				
Higher crop yield growth[3]	92	80	2.9	5.3
Lower crop yield growth	83	80	5.2	4.9
Lower crop yield growth & active stimulating policy	92	90	5.3	5.1

[1] A scenario was considered to be consistent if it lacked contradictions in the described assumptions; for example, whether the effect of increasing technological innovation on crop yield growth is indeed positive.
[2] Likelihood anchored at 1 = "most likely" to 7 = "least likely". The likelihood was defined as the probability that a scenario will come true during 2011-2020.
[3] Scenario qualified for the final step (the assessment of the impact of the scenario on the structure of the NL and NRW-LS livestock sectors).

Demand scenarios		Supply scenarios	
Fast economic growth worldwide	**Slow economic growth worldwide**	**Higher crop yield growth worldwide**	**Lower crop yield growth worldwide**
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*
Same as in baseline	*Same as in baseline*	*Same as in baseline*	*Same as in baseline*

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Prospects for cost reductions from relaxing additional cross-border measures related to livestock trade

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Preventive Veterinary Medicine (2013) 109: 278-292
DOI: 10.1016/j.prevetmed.2012.10.008

Abstract

Compared with the domestic trade in livestock, intra community trade across the European Union is subject to costly, additional veterinary measures. Short-distance transportation just across a border requires more measures than long-distance domestic transportation, while the need for such additional cross-border measures can be questioned.

This chapter examined the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of the Netherlands (NL) and Germany (GER); that is, North Rhine Westphalia and Lower Saxony.

The chapter constructed a deterministic spread-sheet cost model to calculate the costs of both routine veterinary measures (standard measures that apply to both domestic and cross-border transport) and additional, veterinary cross-border measures (extra measures that only apply to cross-border transport) as applied in 2010. This model determined costs by stakeholder, region and livestock sector, and studied the prospects for cost reduction by calculating the costs after the relaxation of additional cross-border measures. The selection criteria for relaxing these measures were (i) a low expected added value on preventing contagious livestock diseases, (ii) no expected additional veterinary risks in case of relaxation of measures, and (iii) reasonable cost-saving possibilities.

The total cost of routine veterinary measures and additional cross-border measures for the cross-border region was €22.1 million, 58% (€12.7 million) of which came from additional cross-border measures. Two-thirds of this €12.7 million resulted from the trade in slaughter animals. The main cost items were veterinary checks on animals (twice in the case of slaughter animals), export certification and control of export documentation. Four additional cross-border measures met the selection criteria for relaxation. The relaxation of these measures could save €8.2 million (€5.0 million for NL and €3.2 million for GER) annually. Farmers would experience the greatest savings (99%), and most savings resulted from relaxing additional cross-border measures related to poultry (48%), mainly slaughter broilers (GER), and pigs (48%), mainly slaughter pigs (NL).

In particular the trade in slaughter animals (dead-end hosts) is subject to measures, such as veterinary checks on both sides of the border, that might not contribute to preventing contagious livestock diseases. Therefore, this chapter concluded that there are several possibilities for reducing the costs of additional cross-border measures in both countries.

Introduction

The establishment of the European Union (EU) single market in 1992 has caused European trade in livestock and livestock commodities among member states to increase (EU, 2010, PVE, 2011 and Bayerische Landesanstalt für Landwirtschaft, 2011). Compared with the domestic trade in livestock, intra community trade across the EU is subject to costly, additional cross-border measures, such as clinical examinations and health declarations for live and slaughter animals (McGrann and Wiseman, 2001). Short-distance cross-border transportation requires more measures than long-distance domestic transportation, while the need for these additional, veterinary cross-border measures with respect to preventing contagious diseases is often questioned by the livestock sector (Product Boards for Livestock, Meat and Eggs (PVE), personal communication).

In the past few decades, additional cross-border measures (extra measures that only apply to cross-border transport) have been implemented in addition to routine veterinary measures (standard measures that apply to both domestic and cross-border transport) to prevent, monitor and control contagious livestock diseases. These additional cross-border measures were essential to allow trade within the EU single market because of large differences in veterinary status among EU countries (McGrann and Wiseman, 2001). Furthermore, at the time these additional cross-border measures were introduced, the production structure of livestock differed from the current structure, meaning that smaller farms transported small batches of animals across borders. This meant that cross-border transportation was more complicated and riskier than it is currently: several batches of animals from different farms were needed to fill trucks and the tracking and tracing of animals were less well-developed than they are currently. This has resulted in less transparent transportation (Jan Klaver, personal communication). EU-wide tracking and tracing systems such as Traces[1], which record the cross-border trade of livestock, did not exist (Blancou, 2001).

More recently, there are fewer differences in the veterinary status of EU countries (Brückner, 2011) and the livestock production structure has changed into a region-specific one that often extends beyond borders, resulting in significant cross-border trade and mutual dependencies between producers and consumers across these borders (Hop *et al.*, in press). Livestock transports proceed – either via gathering places or not – to just one destination farm, and the loading of additional animals along the road is no longer allowed (McGrann and Wiseman, 2001). Tracking and tracing systems are used to check for this.

1 Traces is an intra-trade system for the cross-border trade of animals. It allows the relevant authorities of different member states to inform each other of the cross-border movements of animals submitted to veterinary certification.

As a consequence of the abovementioned changes, it is worthwhile examining the rationale of several additional cross-border measures because large savings may be achieved. This is especially worthwhile for neighbouring countries with similar veterinary status that rely heavily on cross-border trade, such as the regions of Germany (GER) and the Netherlands (NL), and GER and Luxembourg. Taking the latter case as an example, Luxembourg has no poultry slaughterhouses, resulting in a large number of cross-border transports in which slaughter animals are clinically checked on both sides of the border within 15 min.

Veterinary policy makers need to examine the rationale and potential cost-saving possibilities of changing the existing additional cross-border measures, without compromising the economic advantages of cross-border trade and without increasing veterinary risk (Brückner, 2011).

In this chapter, the cross-border region of NL and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS) is used as an example to show the prospects for cost reductions from relaxing additional cross-border measures. This region is a large and highly integrated livestock production area. For instance, 81% of the NL's total exported fattening pigs went to German slaughterhouses in 2010, 95% of which went to NRW and LS (PVE, 2011). Additionally, 52% of the NL's exported piglets went to GER in 2010, 84% of which were exported to NRW and LS (PVE, 2011). Over the years, this has resulted in mutual dependencies between producers and consumers across borders. Because the overall veterinary status of the three regions is similar (OIE, 2012), the NL–NRW–LS region is a useful example for investigating the impact of relaxing certain additional cross-border measures.

To the best of our knowledge, this is the first peer-reviewed study that examines opportunities for reducing the impact of existing additional cross-border measures at a detailed level and calculates the cost savings of these reductions. Various studies have addressed the impact of routine veterinary measures and additional cross-border measures on intra community trade across the EU (Ammendrup and Füssel, 2001 and McGrann and Wiseman, 2001), within the US (Thornsbury *et al.*, 1999) or on developing countries' exports (Henson and Loader, 2001 and Neeliah and Goburdhun, 2010). However, these studies only mention routine veterinary measures and additional cross-border measures at a highly aggregated level. They neither quantify the related costs at a detailed level nor investigate the implications for the different groups of stakeholders.

In the light of the foregoing, the objective of this chapter was to examine the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL-NRW–LS.

Materials and methods

Inventory of routine veterinary measures

An overview of both routine veterinary measures and additional, veterinary cross-border measures was needed in order to examine the prospects for cost reductions. However, such an overview was not available and details of the measures themselves, such as which animal type they were applied to, were especially lacking. To that end, an inventory of measures was made for the three main animal categories in the region of NL–NRW–LS: commercial pigs, cattle and poultry (PVE, 2011). Products from animal origin, like milk and eggs, were not considered because EU legislation is identical for transport within and among EU countries. Live animal products, such as hatching eggs, were taken into account; the cross-border transport of these products requires several additional measures. Measures related to hobby animals were not considered for two reasons: (i) the batch size and frequency of cross-border transport of hobby animals between NL and GER are low (Olink *et al.*, 2003), and (ii) there is almost no direct contact between hobby animals and commercial animals (Sijtsema *et al.*, 2005). For these reasons, the probability of introducing and spreading contagious livestock diseases via the cross-border transport of hobby animals is considered to be low.

The list of routine veterinary measures and additional cross-border measures is based on the protocols of the Netherlands Food and Consumer Product Safety Authority (NVWA), such as 'General Instructions for Export of Live Cattle from NL to Other Member States' (NVWA, 2012). These protocols are based on EU and national legislation and outline all the actions performed by NVWA veterinary officers. The list of measures was complemented with the help of experts from PVE, the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) and NVWA, i.e., veterinary policy makers that decide on these measures and the people that execute as well as report and process the results of these measures.

Current costs of routine veterinary measures and additional cross-border measures

To calculate the costs of current routine veterinary measures, additional cross-border measures and these measures' possible cost savings, a deterministic spread-sheet cost model (Microsoft Excel 2010) was constructed for the year 2010. Costs were determined as follows:

$$C = \sum_{r=1}^{R} \sum_{m=1}^{M} (T_{mr} \times F_{mr}) \quad (1)$$

where C represents the total costs of all routine veterinary measures and additional cross-border measures, and Tmr and Fmr represent the tariff and the frequency of executing measure *m* in region *r*, respectively. Besides the overall total costs (*C*), costs were also calculated per animal type and stakeholder.

The total number of transports and number of transported animals (per animal category and type) between NL and NRW–LS for 2010 were based on data from Traces (NVWA, 2011) and are presented in Appendix Table A4.1. The number of different types of poultry farms in NL, NRW and LS was needed for cost calculations of annual farm visits and is presented in Appendix Table A4.2 (CBS, 2011 and BMELV, 2010). The costs for animal health tests are based on expert information from the Dutch Animal Health Service (GD Deventer). Costs for the actions and visits of NVWA and BVL (German Federal Office of Consumer Protection and Food Safety) veterinary officers are based on the NVWA and BVL's 2010 tariffs. NVWA and BVL veterinarians are paid a call-out charge and a charge for every 15 min. spent on a farm. The clinical examination of slaughter animals is charged by time in NL (15-min. blocks) and by animal in NRW-LS. In the latter case, these per animal charges, as well as the minimum and maximum charges per transported batch of animals, are legislated for NRW (MIK NRW, 2011). The same charges were used for calculating the costs of clinical examinations of slaughter animals within LS because these were expected to be similar (Groeneveld, personal communication). An average charge per transport was used, based on the number of transports in 2010 (Appendix Table A4.1). In that year no slaughter turkeys were transported from NRW-LS to NL because there is no slaughterhouse in NL, and no slaughter pigs were transported from LS to NL, so the charged costs are zero in these cases. Farmers' labour costs (opportunity costs) are based on the Dutch handbook 'Quantitative Information: Livestock Sector' (KWIN, 2011). Costs for the activities of (office) employees of PVE, slaughterhouses and SKV (Foundation for Quality Guarantee of the Veal Sector) are calculated based on information from the company 'Intermediair' (Intermediair, 2011). All costs and tariffs are presented in Appendix Tables A4.3 and A4.4.

Possibilities for and calculation of cost reduction

Based on the list of routine veterinary measures and additional cross-border measures and the outcomes of the spread-sheet cost model, the possibilities for relaxing current additional cross-border measures were listed and discussed with PVE experts. The selection criteria for relaxing additional cross-border measures were (i) a low expected added value on preventing contagious livestock diseases, (ii) no expected additional veterinary risks in case of relaxation and (iii) reasonable cost-saving possibilities. Criteria one and two were assessed based on the opinions of experts from PVE and the Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I). The 'no additional veterinary risks' criterion was considered especially important because the costs of an outbreak are considerably higher than possible savings due to relaxing additional cross-border measures. The experts considered this issue carefully, and the only measures included were those whose relaxation would not result in additional risks of contagious livestock diseases. In general, it was assumed that relaxing measures related to slaughter animals would cause no additional veterinary risks because these animals reach their final destination once they enter the slaughterhouse: they are dead-end hosts. This study also assumed that livestock trucks strictly follow the cleansing and disinfection requirements. Relaxing measures related to animals transported for live use may result in additional veterinary risks because these animals may come into contact with other animals.

In addition to assessing veterinary risks, this chapter investigated the legal implementation possibilities for relaxing additional cross-border measures based on the opinions of experts from PVE and EL&I. For both assessing veterinary risks and implementation possibilities there was consensus among the experts involved.

The proposed measures for reducing costs were incorporated in the spread-sheet cost model described in the previous section and those outcomes compared with the current costs of additional cross-border measures.

To assess the long-term cost savings from relaxing additional cross-border measures, the spread-sheet cost model included expected changes in the future structure of livestock production for the year 2020. In Hop *et al.* (2014), changes were expected in the number of transports of and total number of transported piglets and fattening pigs and the number of broiler and laying hen farms. Average expected changes were computed based on this. Tariffs of the activities of, for example, veterinary services were not adjusted to the 2020 situation, meaning that inflation was not taken into account because the aim was to evaluate the persistence of cost savings rather than to forecast the exact costs of routine veterinary measures and additional cross-border measures in 2020.

Results

Inventory of routine veterinary measures and additional cross-border measures

Appendix Tables A4.5–A4.8 show the routine veterinary measures for domestic and cross-border transport, and additional, veterinary cross-border measures for the transport of livestock between NL and NRW–LS and vice versa. Table A4.5 shows measures that apply to cattle, pigs and poultry, whereas additional, species-specific measures are shown in Tables A4.6 (cattle), A4.7 (pigs) and A4.8 (poultry). A distinction was made between transports of animals for live use and animals for slaughter.

Table A4.5 shows that there are almost no differences between measures implemented for transport from NL to NRW–LS and vice versa. The only difference is that Dutch transporters need to have a permit for short-distance transports. Table A4.6

(pig-specific measures) shows that there are more differences between NL and NRW–LS. For example, if the transporting company or gathering place is certified according to the Quality system Livestock Logistics (QLL) regulations, it is allowed to clinically examine animals in barns instead of during loading in NL. In addition, for the cross-border transport of Dutch slaughter pigs a farmer's declaration regarding the animals' time at the farm of origin is not required. Animals for live use transported from NRW–LS to NL do not require the transport document 'regulation on pig deliveries' (in Dutch 'Verordening Varkensleveringen' (VVL)), which includes a certificate of Aujeszky's disease and swine vesicular disease (SVD) monitoring. Table A4.7 (cattle-specific measures) shows that testing for infectious bovine rhinotracheitis (IBR) and giving an overview of pregnant cattle based on insemination data or veterinarian declarations are obligatory for cattle transported from NL to NRW–LS but not vice versa. In addition, Dutch authorities check whether NRW–LS veal calf transports provide advance notice of the transport and destination farm to SKV to prevent additional loading of veal calves during transport. Table A4.8 (poultry-specific measures) shows that NL differs by requiring a physical check of day-old chicks and hatching eggs (in 2% of randomly selected export requests) and demands that changes in the number of animals on farms due to transport are registered in the PVE poultry database. Besides measures for the transport of poultry and hatching eggs, those for breeding animals for hatching eggs and day-old chicks are shown. Even though the breeding animals are not themselves transported, Table A4.8 shows these measures because they are obligatory for breeding farms that transport hatching eggs and day-old chicks across borders.

Current costs of routine veterinary measures and additional cross-border measures

The total costs of both routine veterinary measures and additional cross-border measures are shown in Table 4.1 and the total costs of the additional cross-border measures are shown separately in Table 4.2.

Table 4.1 shows that the total costs of routine veterinary measures and additional cross-border measures amounted to €22.1 million in 2010, of which €12.5 million were for NL and €9.6 million for NRW–LS. Using data on about 64,000 livestock transports (Appendix Table A4.1), the average cost per transport due to routine veterinary measures and additional cross-border measures was calculated as €350 (€385, €211 and €424 per transport of cattle, pigs and poultry, respectively).

Table 4.2 shows that the total costs of additional cross-border measures amounted to €12.7 million in 2010. Thus, additional cross-border measures accounted for 58% (€12.7 million/€22.1 million) of the total costs. That means that, based on the number of transported animals (Appendix Table A4.1), the additional cross-border measures result in extra costs of, for example, €5.02, €4.61 and €1.13 per

Table 4.1 Total costs (× €1,000) of routine veterinary measures and additional cross-border measures for transport of livestock and livestock commodities per animal category and region for 2010.

Animal category	Goal	Animal type	Costs NL[1]	Costs LS[1]	Costs NRW[1]	Subtotal costs LS + NRW	Total costs NL-LS-NRW
Cattle	Slaughter	Cattle	88	170	222	392	**480**
	Rearing	Veal calves	59	1,058	861	1,919	**1,978**
Pigs	Slaughter	Fattening pigs	6,815	0	19	19	**6,834**
	Rearing	Piglets	1,299	2	14	16	**1,315**
	Breeding	Breeding pigs	87	1	13	15	**102**
Poultry	Slaughter	Broilers	343	3,033	1,295	4,328	**4,671**
		Turkeys	820	1,170	717	1,886	**2,707**
	Rearing	Broilers (day-old chicks)	1,976	400	58	458	**2,433**
		Turkeys	0	114	35	149	**149**
		Laying hens	712	303	67	370	**1,082**
	Breeding	Great parents animals	299	0	0	0	**299**
		Hatching eggs	13	21	8	29	**42**
Total			**12,512**	**6,272**	**3,309**	**9,581**	**22,093**

[1] NL = the Netherlands, LS = Lower Saxony and NRW = North Rhine Westphalia.

cross-border transported slaughter cow, veal calf and slaughter pig, respectively. In the latter case, with profit margins of – €2.70 per slaughter pig in 2010 (De Bont *et al.*, 2011), it is extremely worthwhile investigating ways to relax additional cross-border measures to increase profit margins.

Of the total costs of the additional cross-border measures, those related to pigs, poultry and cattle accounted for 45%, 38% and 17%, respectively. For NL, 69% of the total costs of the additional cross-border measures can be attributed to measures related to slaughter animals, especially slaughter pigs. Piglets contribute most to costs related to the cross-border transport of animals for live use (€1.1 million). For NRW–LS, 61% of the total costs of the additional cross-border measures can be attributed to measures related to slaughter animals, especially slaughter broilers. Veal calves made the largest contribution to costs related to the cross-border transport of animals for live use (€1.7 million).

The additional cross-border measure that caused most of the costs was the clinical examination at the farm of origin, including the veterinarian's call-out charge, examination of the animals, completion of the export certificate and, in the case of cattle, checking the animal passports. Almost all costs were charged to the farmer (€12,127 out of €12,716 = 95%).

Possibilities for and calculation of cost reduction

Four possibilities for relaxing current additional cross-border measures were identified and categorised into measures related to transports of 'animals for slaughter', 'animals for live use' and 'animals for live use and slaughter'.

Animals for slaughter

Animals for both live use and slaughter are clinically checked by an NVWA or BVL veterinarian at the farm of origin or at the gathering place (Table A4.5). Slaughter animals, however, are also clinically checked on arrival at the slaughterhouse. PVE experts indicated that this double clinical examination is unnecessary because these animals' final destination is a dead-end. Therefore, cost savings were computed for removing the additional cross-border measure 'clinical examination of slaughter animals at the farm of origin'. Experts chose to remove the clinical examination at the farm of origin instead of at the slaughterhouse as this is the same as the regulation for domestic trade. The clinical examination of slaughter animals that are transported via a gathering place was maintained to avoid illegal, additional loading of animals from other farms of origin, i.e., continued control is necessary to avoid increasing the risks of contagious livestock diseases.

Table 4.2 Total costs (× €1,000) of additional cross-border measures for transport of livestock and livestock commodities per animal category and region for 2010.

Animal category	Goal	Animal type	Costs NL[1]	Costs LS[1]	Costs NRW[1]	Subtotal costs LS + NRW	Total costs NL-LS-NRW
Cattle	Slaughter	Cattle	69	144	183	328	**396**
	Rearing	Veal calves	54	956	778	1,735	**1,789**
Pigs	Slaughter	Fattening pigs	4,551	0	9	9	**4,560**
	Rearing	Piglets	1,075	2	10	12	**1,087**
	Breeding	Breeding pigs	72	1	11	12	**84**
Poultry	Slaughter	Broilers	0	2,058	841	2,899	**2,899**
		Turkeys	532	0	0	0	**532**
	Rearing	Broilers (day-old chicks)	525	91	21	113	**638**
		Turkeys	0	26	9	35	**35**
		Laying hens	474	75	20	94	**569**
	Breeding	Great parents animals	86	0	0	0	**86**
		Hatching eggs	13	21	8	29	**42**
Total			**7,451**	**3,374**	**1,891**	**5,265**	**12,716**

[1] NL = the Netherlands, LS = Lower Saxony and NRW = North Rhine Westphalia.

Animals for live use

Breeding animals for day-old chicks and hatching eggs are clinically examined by a veterinarian every 30 days (Table A4.8), which takes approximately one hour. PVE experts stated that the accuracy with which this measure is executed and its added value are often questioned. Removing this additional cross-border measure did not add any additional risks of contagious livestock diseases.

Animals for live use and slaughter

During every clinical examination at the farm of origin, an NVWA or BVL veterinarian must conduct a check on all documents needed for cross-border transport of livestock before they can complete the export certificate (Tables A4.5–A4.8). Our experts indicated that the documentary control and completion of certificates could effectively be conducted by office employees of the NVWA or BVL, who charge less than veterinarians. This is free from additional risk of contagious livestock diseases because the only change is at the location where these actions are performed. Relaxing this measure would mean that NVWA or BVL veterinarians no longer need to be present at the transport of slaughter pigs and slaughter poultry. In the case of slaughter cattle, a veterinarian needs to check the animal passports before or during loading the animals.

Another potential cost-saving measure involves removing the annual check on the export status of poultry breeding farms and hatcheries performed by the NVWA or BVL (Table A4.8). Based on this annual visit, the NVWA or BVL decides whether a farm is allowed to export animals. The accuracy with which this additional cross-border measure is executed is often questioned, as is the value it adds, and removing this measure carries no additional risks of contagious livestock diseases. However, relaxing this measure also means that the export status of poultry breeding farms and hatcheries would not be annually checked for exports to other EU and third countries. This may reduce veterinary policy makers' willingness to remove this measure, especially because it is arranged at EU level, as shown in Table 4.3.

Implementation possibilities

Table 4.3 also shows that, other than changing the location of documentary control and completion of the export certificate, the measures that are proposed for relaxation are derived from EU legislation. Relaxation therefore needs to be arranged at the EU level rather than bilaterally between NL and GER. Even though documentary control and completion of the export certificate are also based on EU legislation, changing the location does not change the control itself, and therefore this is the only relaxation possibility that can be arranged at the national level. However, because all four additional cross-border measures met the selection criteria which were described in the section 'Material and methods', all were included as candidates for

Table 4.3 Relaxation possibilities and their assessed effect on risks of contagious livestock diseases and level of implementation.

Relaxation possibilities	Effect on risks of contagious livestock diseases	Level of implementation
No clinical examination of slaughter animals at farm	No	EU
No clinical examination of breeding animals every 30 days (poultry)	No	EU
Documentary control and completion of export certificate by office employee of NVWA/BVL instead of by certifying veterinarian	No	National
No annual check on the export status of poultry breeding farms and hatcheries	No	EU

relaxation to show their potential cost savings. After relaxing these four additional cross-border measures (Table 4.3), possible cost savings were calculated per animal category, stakeholder and region. The results are shown in Table 4.4.

Potential cost savings

Relaxation of these four additional cross-border measures could save €8.2 million of the original €12.7 million (Table 4.2). NL could save €5.0 million and NRW–LS could save €3.2 million. The largest savings (99%) would be obtained by farmers, and most relate to relaxing additional cross-border measures for the transport of poultry (48%), mainly slaughter broilers (NRW–LS), and pigs (48%), mainly slaughter pigs (NL). In some cases negative cost savings, i.e., additional costs caused by the relaxation of the four additional cross-border measures, were calculated for the BVL and NVWA. These come from the relaxation of documentary control and the completion of export certificates, meaning that office employees of the BVL and NVWA would conduct these checks instead of veterinarians. Costs related to these measures would now be paid by the BVL and NVWA, whereas the original veterinarian costs were charged to the farmer.

After relaxing the four measures, the total costs of routine veterinary measures and additional cross-border measures amounted to €13.9 million, which is €215 per average transport, of which additional cross-border measures contributed €4.5 million. In 2010, 58% of the total costs arose from additional cross-border measures. Relaxing these four additional cross-border measures could reduce this share to 32%, resulting in a cost reduction of, on average, €135 per transport. In terms of cost

Table 4.4 Cost savings (× €1,000) per animal category, stakeholder and region after relaxing additional cross-border measures.

Animal category	Goal	Animal type	Stakeholder	Cost savings NL	Cost savings LS	Cost savings NRW	Subtotal cost savings LS+NRW	Total cost savings NL-LS-NRW
Cattle	Slaughter	Cattle	Farmer	17	42	55	97	114
			NVWA	-1	0	0	0	-1
			BVL	0	-1	-1	-2	-2
	Rearing	Veal calves	Farmer	5	125	102	227	232
			NVWA	-0	0	0	0	-0
			BVL	0	-6	-5	-11	-11
			SKV	0	0	0	0	0
Pigs	Slaughter	Fattening pigs	Farmer	3,781	0	7	7	3,788
			NVWA	-57	0	0	0	-57
			BVL	0	0	-0	-0	-0
	Rearing	Piglets	Farmer	213	1	4	5	218
			NVWA	-13	0	0	0	-13
			BVL	0	-0	-0	-0	-0
	Breeding	Breeding pigs	Farmer	14	0	3	3	17
			NVWA	-1	0	0	0	-1
			BVL	0	-0	-0	-0	-0
Poultry	Slaughter	Broilers	Farmer	0	1,882	769	2,652	2,652
			NVWA	0	0	0	0	0
			BVL	0	-30	-12	-42	-42

		Turkeys	Farmer	464	0	0	0	464
			NVWA	-6	0	0	0	-6
			PVE	0	0	0	0	0
	Rearing	Broilers (day-old chicks)	Farmer	354	73	12	84	438
			NVWA	64	0	0	0	64
			BVL	0	14	1	15	15
			PVE	0	0	0	0	0
		Turkeys	Farmer	0	21	7	27	27
			NVWA	0	0	0	0	0
			BVL	0	4	1	5	5
		Laying hens	Farmer	127	56	13	68	195
			NVWA	5	0	0	0	5
			BVL	0	10	2	12	12
			PVE	0	0	0	0	0
	Breeding	Great parents animals	Farmer	53	0	0	0	53
			NVWA	9	0	0	0	9
			PVE	0	0	0	0	0
		Hatching eggs	Farmer	0	0	0	0	0
			NVWA	13	0	0	0	13
			BVL	0	17	8	25	25
Total				**5,042**	**2,208**	**965**	**3,173**	**8,214**

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savings per individual transported animal, slaughter pigs and slaughter cattle in particular would benefit from relaxing additional cross-border measures: €0.92 and €1.41 per animal, respectively.
Expected changes in the future structure of livestock production (year 2020) only slightly alter the cost savings. Compared to the 2010 situation, an additional 8% (€0.6 million) could be saved. These extra savings are due to the relaxation of additional cross-border measures related to slaughter pig transports and result from an expected increase in the average number of these transports from NL to NRW–LS.

Discussion

This chapter hypothesised that examining the rationale of additional cross-border measures can generate large cost savings, especially for neighbouring countries with similar veterinary status that rely heavily on cross-border trade. The objective was to examine the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL–NRW–LS. To the best of our knowledge, this is the first peer-reviewed study to examine opportunities for reducing the impact of the existing additional cross-border measures at a detailed level and to calculate the cost savings of these reductions.
Both NL and GER have several possibilities for reducing the costs of additional cross-border measures, albeit for different animal species.
Besides cost savings, non-value benefits can also be expected. Combining the additional cross-border measures 'no clinical examination of slaughter animals' and 'changing the location of documentary control' implies that NVWA or BVL veterinarians no longer need to be present in the case of transports of slaughter pigs and slaughter poultry, resulting in a reduction in the costs of veterinary call-out fees. As a result, there will be more flexibility in employing certifying veterinarians, allowing them to be used more efficiently. However, the workload for office employees of veterinary services may increase and result in less efficient organisations, to which farmers may need to apply earlier than they currently do to export livestock.
All data used in the spread-sheet cost model is based on official (statistical) sources other than the list of routine veterinary measures, which is partly based on expert opinion. Therefore, the outcomes are considered to be reliable for the year 2010. Data on different years can slightly change the results, for example with respect to piglet and slaughter pig transports. Between 2008 and 2010 there was a noticeable increase in the number of these transports from NL to NRW–LS, as well as in the number of transports of cattle and veal calves from NRW–LS to NL (NVWA, 2011). Increases in the number of these transports were also mentioned by Silvis *et al.*

(2009) and Hop *et al.* (2014). As a result, there is likely to be an increase in the total costs related to this growing number of transports and, consequently, an increasing number of transported animals. Costs related to slaughter pigs, piglets and veal calves are especially likely to increase because large numbers of these animals are transported across borders. Additionally, the number of transports of and total transported hatching eggs fluctuated between 2008 and 2010, which means that costs related to routine veterinary measures for the transport of hatching eggs may not be representative for coming years. However, these costs are relatively low and are mainly determined by the annual check on export statuses of hatcheries, so only minor changes in these costs are expected.

No major changes are expected in the number, frequency, complexity and cost of routine veterinary measures and additional cross-border measures. Most measures are based on EU legislation and are not likely to change in the coming years.

Important considerations

Primary considerations regarding the relaxation of additional cross-border measures include the veterinary and regulatory implications.

With respect to veterinary implications, the four additional cross-border measures proposed for relaxation were assumed to have no impact on veterinary risks, based on the input of experts. This is important because the economic advantages of relaxing additional cross-border measures that increase veterinary risks most likely do not outweigh the costs of more frequent or larger outbreaks of contagious livestock diseases, for example by increasing the chance of an outbreak from once every 10 to once every five years.

Regarding implementation, all measures are based on EU legislation and therefore, relaxation cannot be arranged at national or bilateral levels, except for changing the location of documentary control and export certificate completion. With respect to export certification, EU regulations do not require veterinarians to sign export paperwork, meaning that office employees are allowed to sign export certificates. If so desired, relaxing this measure can be arranged within a short time-period. Changing the location of documentary control is relatively easy to arrange, but removing the clinical examination of slaughter animals at the farm of origin offers a wider scope for savings. Sectors that are not considered in this chapter, for example goat and sheep farming, can also benefit from removing this measure because they are also obliged to clinically examine slaughter animals twice.

As all measures are based on EU legislation, policy makers' negotiations for relaxing additional cross-border measures may take several years. As described above, expected changes in the future structure of livestock production only slightly alter the prospects for cost savings due to this relaxation. Therefore, it is likely that it is still worthwhile to negotiate relaxing the proposed additional cross-border measures.

Practical implications

To facilitate safe trade in livestock and livestock commodities, international animal health standards are set by the World Organisation for Animal Health under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) of the World Trade Organisation (WTO), and documented in the OIE's Terrestrial Animal Health Code (Wilson and Beers, 2001 and Thomson *et al.*, 2004). The routine veterinary measures and additional cross-border measures are derived from these requirements and transformed into EU directives and national legislation. However, the implemented measures may differ between countries such that some implement more stringent rules than others (Madec *et al.*, 2001). These variations are explained by differences in health status that aim to protect individual countries' export positions, for example by giving extra guarantees to importing countries with respect to the health status of their animals and animal products. In the case of NL and GER, there are minor differences in implemented measures and both countries have several possibilities for reducing the costs of additional cross-border measures. They first need to bilaterally agree on which measures to relax, thereby taking into account the effect this will have on different livestock sectors. It is pointless to negotiate about possibilities for relaxing measures that would only benefit one country. In addition, other cross-border trade partners encounter similar problems regarding additional cross-border measures for the transport of livestock, for example the major dependency of German fattening pig farmers on receiving Danish piglets, and the dependency of Luxembourg on German poultry slaughter-houses. Listing problems with and possibilities for relaxing the additional cross-border measures from an EU-wide perspective may create a basis of support from a large number of countries to change current EU legislation, meaning that a combined effort is needed.

Conclusion

This chapter has shown that an examination of the rationale for current additional cross-border measures identified a number of opportunities for cost reduction. Slaughter animals (dead-end hosts) in particular undergo additional cross-border measures, such as veterinary checks on both sides of the border that might not contribute to preventing contagious livestock diseases. This chapter therefore concludes that various possibilities exist for reducing the costs of additional cross-border measures which will be beneficial for both countries concerned.

Even though it has described one specific cross-border region, the approach followed here can be adapted to other regions that encounter similar problems. The potential cost savings and relaxation possibilities in other regions depend on country-specific regulations, the total cross-border transports and the number of transported animals. The support of a large number of EU countries will be needed to arrange changes in current EU legislation. It is advisable and worthwhile to examine problems with and possibilities for relaxing additional cross-border measures from an EU-wide perspective.

Acknowledgements

The authors gratefully acknowledge the experts from PVE (Dutch Product Boards for Livestock, Meat and Eggs), BMELV (German Federal Ministry of Food, Agriculture and Consumer Protection), NVWA (Netherlands Food and Consumer Product Safety Authority), EL&I (Dutch Ministry of Economic Affairs, Agriculture and Innovation), GD Deventer (Dutch animal health service) and Lohmann Tierzucht for feedback on and complementing the list of routine veterinary measures and additional cross-border measures, and for providing information on poultry breeding farm statistics, Traces' livestock transport data and the costs of animal health tests and NVWA/BVL tariffs.
This study is part of the project SafeGuard, which is financed within the INTERREG IV A programme Deutschland-Nederland by the European Regional Development Fund.

4

Appendix

Table A4.1 Number of transports and transported animals between the Netherlands (NL) and Lower Saxony (LS) – North Rhine Westphalia (NRW) in 2010.

Animal category	Goal	Animal type
Number of transports		
Cattle	Slaughter	Cattle total
		of which exported from farm (25%)
		of which exported via gathering place (75%)
	Rearing	Veal calves total
		of which exported from farm (85%)
		of which exported via gathering place (15%)
Pigs	Slaughter	Fattening pigs total
		of which exported from farm (85%)
		of which exported via gathering place (15%)
	Rearing	Piglets total
		of which exported from farm (80%)
		of which exported via gathering place (20%)
	Breeding	Breeding pigs
Poultry	Slaughter	Broilers
		Turkeys
	Rearing	Broilers (day-old chicks)
		Turkeys
		Laying hens
	Breeding	Great parent animals
Total		
Animal products		Hatching eggs
		Cattle semen
		Pig semen, ova and embryos
Total		
Number of transported animals		
Cattle	Slaughter	Cattle
	Rearing	Veal calves
Pigs	Slaughter	Fattening pigs
	Rearing	Piglets
	Breeding	Breeding pigs
Poultry	Slaughter	Broilers
		Turkeys
	Rearing	Broilers (day-old chicks)

Export from NL to NRW-LS	Export from LS to NL	Export from NRW to NL	Total
320	417	636	1,373
80	104	159	343
240	313	477	1,030
129	2,684	2,196	5,009
110	2,281	1,867	4,258
19	403	329	751
25,908	0	72	25,980
22,022	0	61	22,083
3,886	0	11	3,897
5,943	14	87	6,044
4,754	11	70	4,835
1,189	3	17	1,209
400	10	74	484
0	13,610	5,563	19,173
2,808	0	0	2,808
687	47	74	808
0	15	15	30
2,200	84	47	2,331
148	0	0	148
38,543	**16,881**	**8,764**	**64,188**
167	1,300	60	1,527
400	100	100	600
40	0	0	40
607	**1,400**	**160**	**2,167**
10,453	32,281	36,227	78,961
7,652	211,198	169,114	387,964
4,033,032	0	2,997	4,036,029
2,900,000	720	5,930	2,906,650
200,000	500	5,000	205,500
0	95,348,069	34,805,027	130,153,096
22,606,110	0	0	22,606,110
39,266,240	355,024	1,146,563	40,767,827

Table A4.1 Continued.

Animal category	Goal	Animal type
		Turkeys
		Laying hens
	Breeding	Great parent animals
Total		
Animal products		Hatching eggs
		Cattle semen
		Pig semen, ova and embryos
Total		

Source: Traces (NVWA, 2011).

Table A4.2 Number of poultry farms in the Netherlands (NL), Lower Saxony (LS) and North Rhine Westphalia (NRW) in 2010.

Farm type		NL	LS	NRW
Breeding	Great parent farms	41	–[1]	–[1]
	Breeding farms broilers	281	60	7
	Breeding farms laying hens	41	44	9
	Breeding farms turkeys	0	17	5
	Hatcheries	20	27	12
Slaughter/eggs	Broilers	681	980	510
	Laying hens	1,120	4,873	4,141
	Turkeys	52	377	231

[1] Data on LS and NRW great parent farms was not available and was not applicable because great parents were not exported from LS and NRW in 2010.
Sources: CBS (2011) and BMELV (2010).

	Export from NL to NRW-LS	Export from LS to NL	Export from NRW to NL	Total
	0	113,306	232,412	345,718
	51,889,224	1,175,870	332,346	53,397,440
	2,810,777	0	0	2,810,777
	123,723,488	**97,236,968**	**36,735,616**	**257,696,072**
	20,742,951	71,977,255	2,047,550	94,767,756
	300,000	100,000	100,000	500,000
	1,000	0	0	1,000
	21,043,951	**72,077,255**	**2,147,550**	**95,268,756**

Table A4.3 Tariffs (€) for routine veterinary measures and additional cross-border measures.

Measures	Costs (€)	Unit	Number of tests	Costs made by	Costs paid by
Tests animal diseases					
Infectious Bovine Rhinotracheitis (IBR)	16.00	Every transport	Each animal	Lab	Farmer
Salmonella SE and ST	22.80	Every transport	1 per barn	Lab	Farmer
LPAI broilers	11.40	Per farm	30 per year	Lab	Farmer
LPAI non-broilers	12.50	Per farm	30 per year	Lab	Farmer
Salmonella Gallinarum-Pullorum	9.98	Every transport	1% of barn (min. 30, max. 60)	Lab	Farmer
Salmonella hader, -infantis and -virchow	9.78	Every transport	1% of barn (min. 30, max. 60)	Lab	Farmer
Mycoplasma Gallisepticum (MG)	9.78	Per farm	10 samples/barn/ 12 weeks	Lab	Farmer
Clinical examination					
Call-out charge NVWA veterinarian	57.81	Every transport		NVWA veterinarian	Farmer
Tariff NVWA veterinarian	35.85	Per 15 minutes		NVWA veterinarian	Farmer
Call-out charge BVL veterinarian	20.00	Every transport		BVL veterinarian	Farmer
Tariff BVL veterinarian	46.60	Per 15 minutes		BVL veterinarian	Farmer
Check export status poultry breeding farms	233.91	Per farm (1 hour)		NVWA veterinarian	Farmer
Check export status hatcheries	640.35	Per farm (4 hours)		NVWA veterinarian	Farmer

Miscellaneous measures carried out by					
Farmer	26.00	Per hour		Farmer	Farmer
Office employee PVE	22.30	Per hour		PVE	
Office employee NVWA	22.00	Per hour		NVWA	
Office employee BVL	22.76	Per hour		BVL	
Transporter	22.00	Per hour		Transport company	Farmer
NVWA veterinarian at slaughterhouse	25.00	Per hour		NVWA veterinarian at slaughter-house	NVWA / slaughterhouse
Employee at slaughterhouse	22.30	Per hour		Employee slaughter-house	Slaughterhouse

Sources: GD Deventer, NVWA, BVL, KWIN (2011) and Intermediair (2011).

Table A4.4 Tariffs (€) for clinical examination in Lower Saxony (LS) and North Rhine Westphalia (NRW).

Animal type	Average costs per export[1] (€)	
	LS	NRW
Cattle (slaughter)	91	89
Veal calves	154	147
Fattening pigs	0	47
Piglets	34	36
Breeding pigs	28	138
Broilers (slaughter)	70	63
Turkeys (slaughter)	0	0
Broilers (day-old chicks)	76	155
Turkeys	76	155
Laying hens	140	71

[1] All costs are made by BVL veterinarians and paid by farmers.
Source: MIK NRW (2011).
Sources: CBS (2011) and BMELV (2010).

Table A4.5 Routine veterinary measures and additional cross-border measures implemented in the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (L) for transport of animals for live use (L) and for animals for slaughter (S) (general measures for cattle, pigs and poultry).

Measures	Export from NL to NRW-LS		Export from NRW-LS to NL	
	L	S	L	S
Routine veterinary measures (for domestic and cross-border trade)				
Farmer / trader				
Check cleansing and disinfection of truck (note of farmer in logbook)	x	x	x	x
Report births, deaths and changes in location of animals to identification and registration system	x	x	x	x
Fill out Food Chain Information (VKI) report before animals go to slaughterhouse		x		x
Call in transporter with correct permits[1]	x	x	x	x
Check documents transporter[2]	x	x	x	x
Transporter				
Execute cleansing and disinfection, plus sign logbook of truck	x	x	x	x
Transport <8 h and >65 km: permit for short journey	x	x		
Transport >65 km: driver has certificate of competence	x	x	x	x
Transport >8 h: certificate truck,[3] permit for long journey, journal	x	x	x	x
Compliance with animal welfare regulations during transport	x	x	x	x
Comply with regulation on load of transport	x	x	x	x
Return copy of journal (if applicable)	x	x	x	x
NVWA/BVL office employee				
Documentary control				
• 10% check on certificates of trucks[4]	x	x	x	x
Create and manage dossier	x	x	x	x

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Table A4.5 Continued.

Measures	Export from NL to NRW-LS		Export from NRW-LS to NL	
	L	S	L	S
Veterinarian at slaughterhouse				
Clinical examination (check clinical syndromes of diseases/other abnormalities/welfare) of animals during or after unloading truck at slaughterhouse		x		x
Check documents and identification origin of animals		x		x
Employee slaughterhouse				
Check VKI report		x		x
Additional, veterinary cross-border measures				
Farmer/trader				
Request execution of certification and clinical examination from NVWA/BVL[5]	x	x	x	x
Transporter				
Fill out part 1 of export certificate[6]	x	x	x	x
Provide evidence of travel time by printing out the route and reporting the destination farm[7]	x	x	x	x
Operator gathering place[8]				
Approved protocol of business	x	x	x	x
Call in transporter with correct permits	x	x	x	x
Check documents transporter (hand in control form to certifying veterinarian)[2]	x	x	x	x
NVWA/BVL office employee				
Send documents to certifying veterinarian	x	x	x	x
Enter export to TRACES	x	x	x	x
Documentary control: Check print-out route (proof of travel time) and destination farm, check QLL certification, etc.[7]	x	x	x	x

Certifying veterinarian				
Documentary control				
• Check animal category/type/status	x	x	x	x
• Check animal health status farms of origin (notifiable diseases)	x	x	x	x
• Check journal (if applicable)	x	x	x	x
• Check declaration of transporter with respect to load of transport	x	x	x	x
• Check print-out route (proof of travel time) and destination farm [7]	x	x	x	x
Check truck + documentation + execution cleansing and disinfection				
• Check identification of transport vehicle	x	x	x	x
• Check cleansing and disinfection in logbook of truck	x	x	x	x
• Check certificate of truck[4]	x	x	x	x
• Check permit for short journey (if applicable)	x	x		
• Check permit for long journey (if applicable)	x	x	x	x
• Check driver's certificate of competence	x	x	x	x
Check compliance with animal welfare regulations				
• Clinical examination: check animals for the presence of clinical syndromes of diseases/ other abnormalities	x	x	x	x
• Certification: fill out and give out export certificate (part 2)	x	x	x	x

1 If exported from farm.
2 If transporter (if exported from farm) or gathering place (if exported via gathering place; not applicable to poultry) is QLL-certified.
3 Applicable if transport >8 h (RDW certificate) or if transporter wants to profit from the advantages of QLL certification; that is, clinical examination in the barn without presence of truck (Dekra certificate).
4 Only if transporter is not QLL-certified.
5 Executed by farmer/trader (if exported from farm) or operator gathering place (if exported via gathering place; not applicable to poultry).
6 The organiser of the transport is responsible for filling out part 1 of the export certificate (in most cases the transporter, but sometimes the farmer, trader or operator of the gathering place).
7 A print-out of the route is only needed if transporter is not QLL-certified. NL uses Routenet, whereas GER uses TRACES for determining the travel time. Note that the systems use a different average speed for determining the travel time.
8 If exported via gathering place (not applicable to poultry).
Sources: NVWA (2012) and complemented with help of experts from PVE, BMELV and NVWA.

Table A4.6 Routine veterinary measures and additional cross-border measures implemented in the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (L) for transport of pigs (animals for live use (L) and animals for slaughter (S)).

Measures	Export from NL to NRW-LS		Export from NRW-LS to NL	
	L	S	L	S
Routine veterinary measures (for domestic and cross-border trade)				
Farmer / trader				
Add metal slaughter tags		x		x
Additional, veterinary cross-border measures				
Farmer/trader/exporter				
Clinical examination in the barn instead of during loading of animals[1]	x	x		
Delivering documents regarding origin/status of pigs				
• Transport document regulation on pig deliveries (VVL) containing certificate of Aujeszky's disease and SVD monitoring	x			
• 'Own declaration' of farmer regarding time of stay of animals at farm of origin	x		x	x
Certifying veterinarian				
Documentary control				
• Check VVL-transport document	x			
• Check 'own declaration' of farmer	x		x	x
Clinical examination				
• Check presence of metal slaughter tags		x		x
• Check presence of ear tags, plus random sampling to match ear tags with farm identification number	x	x	x	x
Certification				
• Fill out inspection report	x	x	x	x

[1] If the transporter (if exported from farm) or the gathering place (if exported via gathering place) is QLL-certified; not applicable if (part of) the exported animals are piglets or sows for slaughter.

Sources: NVWA (2012) and complemented with help of experts from PVE, BMELV and NVWA.

Table A4.7 Routine veterinary measures and additional cross-border measures implemented in the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (L) for transport of cattle (animals for live use (L) and animals for slaughter (S)).

Measures	Export from NL to NRW-LS		Export from NRW-LS to NL	
	L	S	L	S
Routine veterinary measures (for domestic and cross-border trade)				
Farmer / trader				
Clinical examination of animals	x	x	x	x
Additional, veterinary cross-border measures				
Farmer				
Present during Infectious Bovine Rhinotracheitis (IBR) tests and takes care of documents	x			
Veterinarian / lab				
Takes samples for IBR / carries out IBR serological tests	x			
Farmer / trader				
Delivers documents regarding origin, status of cattle and status of farm of origin				
• Passports	x	x	x	x
• Results of IBR serological tests IBR	x			
• Overview of pregnant cattle based on insemination data/ veterinarian declarations	x	x		
SKV office employee				
For veal calves: pre-announcement of transport and destination farm to prevent additional loading during transportation			x	
Certifying veterinarian				
Documentary control				
• 10% check of whether overviews of pregnant cattle match with passports	x			
• Check presence of results of IBR serological tests	x			
• Check passports (origin, status of cattle and status of farm of origin)	x	x	x	x

Clinical examination				
• Check presence of ear tags, plus random sampling to match ear tags with passports	x	x	x	x
Certification				
• Fill out inspection report	x	x	x	x

Sources: NVWA (2012) and complemented with help of experts from PVE, BMELV and NVWA.

Table A4.8 Routine veterinary measures and additional cross-border measures implemented in the Netherlands (NL), North Rhine Westphalia (NRW) and Lower Saxony (L) for transport of poultry (animals for live use (L) and animals for slaughter (S)).

Measures	Export from NL to NRW-LS		Export from NRW-LS to NL	
	L	S	L	S
Routine veterinary measures (for domestic and cross-border trade)				
Farmer + trader / veterinarian / lab				
Present during tests for / takes samples for / conducts tests for				
• Low pathogenic avian influenza (LPAI)	x		x	
• Salmonella Gallinarum (SG) and Pullorum (SP)[1]	x		x	
• Salmonella hader, -infantis and –virchow (S-HIV)[1]	x		x	
• Mycoplasma Gallisepticum (MG)[1]	x		x	
• Salmonella Typhimurium (ST) and Enteritidis (SE)	x	x	x	x
Additional, veterinary cross-border measures				
Farmer / trader / exporter				
Provides proof of vaccination for Newcastle Disease (NCD)	x	x	x	x
Present during clinical examination of breeding animals (every 30 days)[1]	x		x	
NVWA / BVL office employee				
Annual check on export status of poultry breeding farms and hatcheries, plus check presence of results of animal health tests (LPAI, SG and SP, S-HIV, MG, and ST and SE)[2]	x		x	
Random sampling (2%) physical check day-old chicks/hatching eggs	x			
Veterinarian				
Clinical examination of breeding animals (every 30 days)[1]	x		x	

Certifying veterinarian				
Reports percentage of dead animals	x	x	x	x
PVE office employee				
Reports changes in number of animals on farm due to transports (poultry-database)	x	x		

1 Applicable to breeding animals for hatching eggs and day-old chicks.
2 Applicable to hatcheries and breeding and rearing farms; not applicable to fattening and laying hen farms.
Sources: NVWA (2012) and complemented with help of experts from PVE, BMELV and NVWA.

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5

Simulation of cross-border impacts resulting from classical swine fever epidemics within the Netherlands and Germany

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Transboundary and Emerging Diseases (in press)
DOI: 10.1111/tbed.12236

Abstract

The cross-border region of the Netherlands (NL) and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS) is a large and highly integrated livestock production area. This region is increasingly a single epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk. The objective of this chapter was to examine classical swine fever (CSF) control strategies' veterinary and direct economic impacts for NL, NRW and LS given the current production structure, and to analyse CSF's cross-border causes and impacts within the NL-NRW-LS region.

The course of the epidemic was simulated by the use of InterSpread Plus, whereas economic analysis was restricted to calculating disease control costs and costs directly resulting from the control measures applied. Three veterinary control strategies were considered: a strategy based on the minimum EU requirements, and a vaccination and non-vaccination strategy based on NL and GER's contingency plans.

Regardless of the veterinary control strategy, simulated outbreak sizes and durations for 2010 were much smaller than those simulated previously, using data from over 10 years ago. For example, worst-case outbreaks (50th percentile) in NL resulted in 30–40 infected farms and lasted for two to four and a half months; associated direct costs and direct consequential costs ranged from €24.7–28.6 million and €11.7–26.7 million, respectively. Both vaccination and non-vaccination strategies were efficient in controlling outbreaks, especially large outbreaks, whereas the EU minimum strategy was especially deficient in controlling worst-case outbreaks. Both vaccination and non-vaccination strategies resulted in low direct costs and direct consequential costs.

The probability of cross-border disease spread was relatively low (4–16%) and cross- border spread resulted in small, short outbreaks in neighbouring countries. Few opportunities for further cross-border harmonisation and collaboration were identified, including the implementation of cross-border regions (free and contaminated regions regardless of the border) in case of outbreaks within close proximity of the border, and more and quicker sharing of information across the border.

It was expected, however, that collaboration to mitigate the market effects of an epidemic will create more opportunities to lower the impact of CSF outbreaks in a cross-border context.

Introduction

The establishment of the European Union (EU) single market in 1992 has stimulated European trade in livestock and livestock commodities among member states (EU, 2010; PVE, 2011; Bayerische Landesanstalt für Landwirtschaft, 2011). This growth in intra community trade has led to regional specialisation and intensified production (Arens *et al.*, 2010) and, consequently, has increased mutual dependencies between livestock producers and consumers across borders. Retaining the economic advantages of intensified cross-border trade while maintaining a low risk of highly contagious livestock diseases is important as was shown in the outbreaks of classical swine fever (CSF) in Germany (GER), Belgium and the Netherlands (NL) in 1997–98 (Stegeman *et al.*, 2002). Not only were these countries affected by the epidemic, but also their neighbouring countries' sectors: that is, the control of a disease like CSF is a cross-border challenge. Effective cross-border cooperation and communication between countries' public administration, e.g., veterinary authorities and ministries, is thus important to ensure efficient animal disease control (Arens *et al.*, 2010; Hop *et al.*, in press). Breuer *et al.* (2008) identified opportunities to harmonise disease control, such as shared vaccination and movement restriction areas, but the veterinary need and economic prospects for such a cross-border collaboration have never been investigated quantitatively.

The cross-border region of NL and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS) is a particular example of a large and highly integrated livestock production area. For instance, in 2010, 81% of the NL's total slaughter pig exports went to German slaughterhouses, 95% of which went to NRW and LS (PVE, 2011). Additionally, 52% of the NL's exported piglets went to GER, 84% of which went to NRW and LS (PVE, 2011). A further increase in cross-border production dependency is expected in the near future (Hop *et al.*, 2014). The cross-border region of NL-NRW-LS is increasingly a single epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk.

To investigate the opportunities for further cross-border collaboration within NL and GER control strategies, this chapter examined veterinary consequences of and direct costs for controlling CSF outbreaks for the cross-border region of NL-NRW-LS given the current veterinary contingency plans. To the best of our knowledge, this is the first study to examine both veterinary and economic consequences of CSF for NL and GER simultaneously. So far, veterinary consequences of CSF only have been examined for the two countries separately (see for GER, e.g., Karsten *et al.*, 2007 and for NL, e.g., Backer *et al.*, 2008), and studies that examined both veterinary and economic consequences are only known for NL (Mangen *et al.*, 2004; and the combined studies of Bergevoet *et al.*, 2007 and Backer *et al.*, 2008).

In the light of the foregoing, the objective of this chapter was to examine CSF control strategies' veterinary and direct economic impacts for NL, NRW and LS given the current production structure, and to analyse CSF's cross-border causes and impacts within the NL-NRW-LS region.

Material and methods

The course of the epidemic was simulated by the use of InterSpread Plus (ISP), whereas economic analysis was restricted to calculating disease control costs and costs directly resulting from the control measures applied.

Epidemiological model

The simulation model

The software ISP (version 2.001.10; Stern, 2003 and Stevenson *et al.*, 2013) was used to simulate the epidemiological consequences of different CSF control strategies in NL, NRW and LS, and enabled the parameterisation of a stochastic, dynamic and spatially explicit model for subsequent economic analysis.

During the last decade, ISP has been used to simulate the veterinary impact of various epizootic diseases, for instance, foot-and-mouth disease in the Republic of Korea (Yoon *et al.*, 2006), CSF in Belgium (Ribbens, 2009) and Denmark (Boklund *et al.*, 2009) and avian influenza in NL (Longworth *et al.*, in press, a-b). The suitability of ISP has been extensively discussed by Longworth *et al.* (in press, a), including its ability to model potential spatial jumps (between-farm contacts that can spread disease over long distances) in epidemics. These jumps are important for determining the economic consequences, particularly in a cross-border context. ISP parameter settings for CSF are well-described in the literature (see, e.g., Mangen *et al.*, 2002; Boklund *et al.*, 2009; and Ribbens, 2009) and were updated (if applicable) according to the latest contingency plans (Anonymous, 2011; Anonymous, 2013) based on expert opinion. A detailed description of ISP is provided by Stevenson *et al.* (2013).

Starting at an infected index farm (i.e., the first infected farm in an epidemic), ISP simulates the daily spread of disease between farms via movement contacts, local spread and airborne spread (if applicable). The stochastic spread mechanisms act spatially through the farm locations. The transmission probabilities of the different spread mechanisms are influenced by controls, including depopulation, vaccination, movement restrictions and surveillance. Details of these components are provided in subsequent sections and the original detailed parameter input file is available from the first author upon request.

The time unit considered was a single day, and the model was run for 500 days. For each simulated CSF control strategy, 1,000 iterations were run. The software SPSS (version 19) was used to analyse the ISP output following the approach of Longworth *et al.* (in press, a-b).

Population at risk

A key requirement to model between-farm spread is an explicit description of the population at risk through a farm file. This file includes a unique farm identifier, farm class, the number of animals of each type modelled (i.e., the number of animals per susceptible species) and a set of Cartesian coordinates defining the location of each farm in Euclidean space.

The population at risk was defined as the commercial pig population in NL, NRW and LS. For the purpose of modelling CSF spread and control, spatial information on slaughterhouses, destruction facilities, gathering places and recreational farms was included.

The farm file was derived from the following data sources:

1. NL: Data contained in the Dutch Farm Registration System (BRBS) and in the Dutch Identification and Registration (I&R) system, both maintained by the national Animal Health Service (GD), were used. These included unique farm identifiers, farm classes, the number of animals per farm type, and farm locations for the year 2010. Farms without transports (3,098 farms) and those without Cartesian coordinates (516 farms) were excluded from the file. Farms registered more than once in the database, but with the same unique identifier and location were treated as one farm.
2. NRW: Data for the year 2005 were used. These included unique farm identifiers, farm classes, the number of animals per farm type, and farm locations. These data were corrected for an increase in farm size and for farms that terminated their activities based on data from a statistical database aggregated on district level for the year 2007.
3. LS: No detailed data on pig farms were available for LS. Therefore, Bosman *et al.* (forthcoming) conducted a questionnaire among all veterinary offices in each LS district[1], in which the number of farms with sows, slaughter pigs and combined sows and slaughter pigs was tabulated per farm size class for the year 2010. The random points algorithm in Quantum GIS was used to create an equivalent number of locations per Kreis as the number of farms from the questionnaires, thereby excluding areas without agricultural use.

All farms that exported or imported animals from NL to NRW and LS and vice versa for live use, slaughter or both were labelled based on data from the I&R system, BRBS and Traces, the European tracking and tracing system that records cross-border livestock trade. For NL, the actual farm locations were used, whereas for NRW and

1 The districts of Germany are known as Kreise and are at an intermediate administration level between the states and municipal governments. NRW and LS consist of 54 and 48 districts, respectively.

LS, farm locations were chosen at postal code level: for each NL farm importing from or exporting to a specific postal code area in NRW or LS, a random location in that area was labelled as an importing or exporting farm.
The final farm file contained 41,484 records, with each record consisting of a unique farm identifier, farm class, export or import label (if applicable), numbers of animals per animal type and the Cartesian coordinates. Summary information on the total number of farms and the number of exporting and importing farms in each region and farm class is provided in Table 5.1. NL farm classes are based on the national-used system, whereas GER only distinguishes between farrowing, fattening and recreational farms.

Index farms
To simulate a disease epidemic, it is necessary to model its introduction into a primary case farm; that is, an index farm, from which it spreads to other farms. Reflecting representative and realistic outbreaks, only farms in densely populated livestock areas (DPLA) were considered suitable as index farms. Compared with medium- or low-density areas, DPLAs were assumed to have a higher likelihood of CSF introduction due to the higher absolute number of animal movements into and out of these areas.
Main pig-producing areas are the East and South regions (NL), the West and Southwest regions (LS), and the Northwest and North regions (NRW). Per main pig-producing region, one index farm was selected randomly from a sample of all farms for which the number within a 10 km radius exceeded the 50th percentile of pig farm densities in NL, NRW and LS (Table 5.2). The 50th percentile was used as threshold value to exclude farms from sparsely populated livestock areas from our sample as in reality, it is less likely that outbreaks start in such areas. Figure 5.1 shows the location of the index farms, whereas Table 5.3 shows the characteristics of each with respect to the number of farms within radii of 1, 3 and 10 km of the index farm. For NL, two additional index farms were selected: one on the NL-LS border where the closest LS farm was within one kilometre, and another which had also been used in previous simulation studies and represents the outbreak location of the Dutch epidemic of 1997–98. The first additional index farm (NL4 in Table 5.3) was chosen to examine cross-border CSF spread possibilities, whereas the subsequent one (NL1 in Table 5.3) was chosen as it was surrounded by almost the highest number of farms within radii of 1 and 10 km within NL, representing a worst-case scenario outbreak. All index farms were piglet-producing farms; that is, farm class B (NL), or farrowing farms (NRW-LS).

Table 5.1 Summary information on the total number of farms and the number of exporting and importing farms broken down by region and farm class.

Region	Farm class	Description of farm class	Total number of farms	No. of farms exporting animals for live use	No. of farms importing animals for live use
NL	A	Breeding farm, high hygiene	232	82	1
	B	Piglet-producing farm or mixed farm, standard hygiene	2,499	316	13
	C	Gilt-raising farm, high hygiene	87	7	1
	D	Fattening farm or mixed farm	5,501	28	7
	E	Weaner farm, high hygiene	4	-	-
	F	Weaner farm, standard hygiene	54	10	-
	RECR	Recreational farm	3,104	-	-
NRW	FAR	Farrowing farm	732	14	-
	FAT	Fattening farm	7,046	-	723
	MIX	Combined farrowing and fattening farm	4,204	1	405
	RECR	Recreational farm	899	-	58
LS	FAR	Farrowing farm	1,321	7	16
	FAT	Fattening farm	11,213	-	340
	MIX	Combined farrowing and fattening farm	3,794	8	50
	RECR	Recreational farm	794	-	17

Table 5.2 Pig farm densities (number of farms including recreational farms within radii of 1 and 10 km) for the regions NL, NRW and LS.

Region	Radius (km)	Farm density (number of farms)[1]		
			Percentiles	
		Mean	50th	90th
NL	1	5	3	10
	10	209	183	438
NRW	1	5	4	9
	10	220	229	352
LS	1	4	3	7
	10	225	193	479

[1] Pig farm densities are calculated for those regions that include at least one pig farm in a 1-km radius.

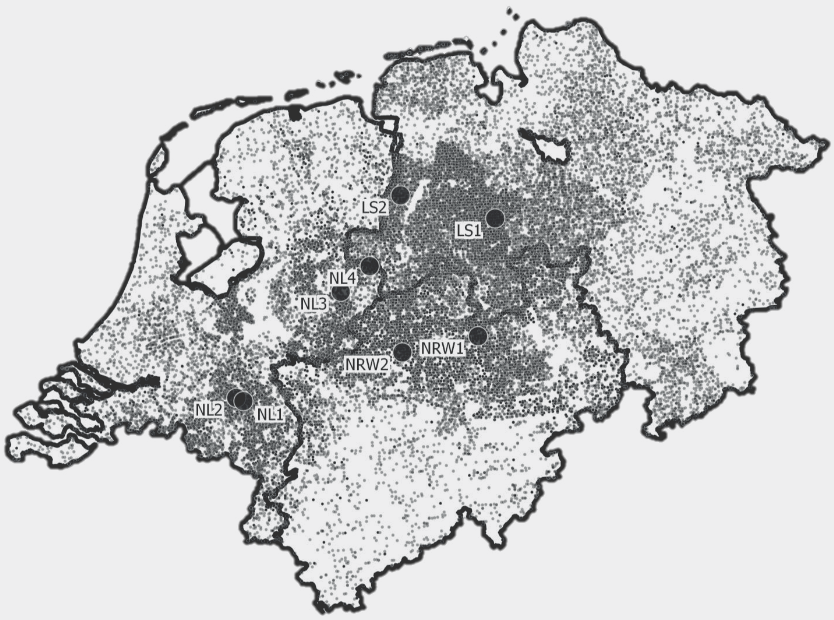

Figure 5.1 Location of pig farms and index farms in NL, NRW and LS used in the simulations.

Table 5.3 Summary information on the number of farms within radii of 1, 3 and 10 km of the index farm.

Index farm	Number of farms within radii of 1, 3 and 10 km of the index farm		
	1 km	**3 km**	**10 km**
NL1	21	73	469
NL2	10	55	486
NL3	2	19	267
NL4	4	21	116
NRW1	13	52	335
NRW2	3	28	384
LS1	7	59	564
LS2	3	21	237

Infectivity of CSF

A farm was assumed to be infectious until it has been depopulated, cleansed and disinfected; infectiousness was assumed to be constant over time (from infection until depopulation). It was further assumed that slaughterhouses and destruction facilities cannot become infected as they were considered 'dead ends'. Livestock trucks (coming from slaughterhouses, destruction facilities and farms) could become contaminated and infect other farms (see next section).

Parameters describing the spread of CSF

Within ISP, the main disease spread mechanisms are airborne spread, local spread and movements. There is no scientific evidence for long-distance, airborne CSF virus spread (DeWulf *et al.*, 2000; Boklund *et al.*, 2008; Ribbens *et al.*, 2012) and for that reason, the ISP airborne (long-distance, wind-driven) spread module was not used. Airborne spread over short distances (<2 km) was captured by the local spread mechanism.

Local spread

Local or neighbourhood spread is generally referred to as limited airborne spread via dust, or mechanical spread via rodents, birds and other wildlife carrying contaminated dust (Sharkey *et al.*, 2008; Boklund *et al.*, 2008). Appendix Table A5.1 shows the daily spread probability to farms located within radii of 0.5, 1 and 2 km of an infected farm (based on Mangen *et al.*, 2002). A latent period of four days was assumed at farm level, during which no local spread occurs. Thereafter, farms were

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considered to be infectious within five to 10 days. This was represented by the increasing values of the local spread parameters for days five through 10. After day 10, the local spread parameters remained constant over time until the farm was depopulated.

Movements

Within ISP, CSF could be transmitted via the movement of live pigs, livestock trucks and professionals. All movements included information on the frequency per farm type per day, including destination and distance distributions as well as the probability of transmission, the number of direct contacts, and the number of secondary contacts generated. These parameters rely on Dutch I&R data on livestock movements in 2010; GER movement parameters were deduced from these data. The frequency of domestic and cross-border off-farm transports are presented in Table 5.4 and were parameterised as a Poisson distribution with lambda (λ) equal to the average number of off-movements per farm per day. This means that, for example, every 12–13 days animals for live use were transported from a B farm to another farm. The frequency of professional off-farm movements was set as a Poisson distribution with $\lambda = 0.2$ (not shown in Table 5.4; based on Mangen *et al.*, 2002). Destination distributions, as well as the frequency of cross-border off-farm transports from farms that transport animals both for live use and slaughter or from farms that transport via gathering places are not shown in Table 5.4, but are available from the first author upon request.

The distance distributions for transport of domestic animals for live use and for vehicle contact are presented in Appendix Table A5.2; those for movements of professionals are presented in Appendix Table A5.3. Daily probabilities of transmission via the movement of pigs for live use, slaughter pigs, vehicle contact and professionals, including the number of direct and indirect contacts[2], are presented in Appendix Table A5.4. These probabilities and the number of direct and indirect contacts were based on Mangen *et al.* (2002).

Parameters describing the control of CSF

Based on the countries' contingency plans (Anonymous, 2011; Anonymous, 2013), three different control strategies were modelled in ISP: the EU minimum strategy and the NL and NRW-LS default strategies with and without vaccination. Additionally, combinations of the baseline control strategies were modelled to examine whether, for example, vaccination in NL affects the course of an outbreak in NRW and LS (under a non-vaccination strategy) after cross-border spread of the disease via jumps or local spread, and vice versa.

2 Direct contacts refer to those through animals for live use and professionals, whereas indirect contacts refer to those through vehicles.

Table 5.4 Frequency of domestic and cross-border off-farm transports of animals for live use and slaughter per day.

Source farm class	Frequency of domestic off-farm transports per day[1]		Frequency of cross-border off-farm transports per day[1]	
	Animals for live use	Slaughter animals	Animals for live use	Slaughter animals
A	0.152	0.108	0.061	0.034
B	0.080	0.086	0.044	0.038
C	0.091	0.033	0.038	0.002
D	-	0.048	0.037	0.026
E	0.136	0.064	-	-
F	0.053	0.039	0.053	0.039
FAR	0.085	-	0.03	-
FAT	-	0.048	-	0.05
MIX	0.06	0.048	0.03	0.05

[1] Frequency of domestic off-farm transports was the same for all farms within a certain farm class, whereas frequency of cross-border off-farm transports was only assigned to exporting farms within a certain farm class.

EU minimum strategy

A minimum set of control measures are common to all simulated control strategies and follow those outlined in EU Directive 2001/89/EC (CEC, 2001). These measures consist of the depopulation of detected farms, installation of and screening within a 0-3 km protection zone and a 3-10 km surveillance zone around each detected farm, movement restrictions on live pigs and manure, professionals and vehicles in these zones, and tracing and depopulation of contacts.

During the high-risk period (time from infection to detection; HRP), it was assumed that farmers inspect their herds daily. The detection probability was based on Klinkenberg *et al.* (2005), Engel *et al.* (2005) and on CSF modelled by Boklund *et al.* (2009). The time from infection until detection was parameterised based on a BetaPert distribution with a most likely value of 47 days and a range of 19–83 days. Additionally, during disease-free situations (including during the HRP) farms with high hygiene standards, that is, A, C and E farms, are tested monthly for the CSF virus (PVE, 2007), which can reduce the HRP. Monthly sampling, however, was modelled until the first detection of an infected farm because movement restrictions are in place. Detection probabilities for monthly sampling are presented in Appendix Table A5.5 and were based on Ribbens (2009).

Following the first detection (start of post-HRP), farmers were assumed to be more alert to clinical symptoms; therefore, the detection probabilities were higher (note that the time from infection until clinical signs was parameterised the same as during the HRP). The time from infection until clinical signs post-HRP was parameterised based on a BetaPert distribution with a most likely value of 18 and a range of 14–24. The onset of clinical signs was based on data of experimental infections (Laevens *et al.*, 1998; Laevens *et al.*, 1999; DeWulf *et al.*, 2001); the same distribution was used by Ribbens *et al.* (2012).

The depopulation capacity was assumed to be limited and depopulation was modelled to begin on day 1 following first detection.

The protection and surveillance zones were assumed to last for a period of 37 and 28 days following the last outbreak (that is, the last detection), respectively. This is longer than the period defined in EU Directive 2001/89/EC to account for time needed for depopulation, cleansing and disinfection, and screening. Within the zones, movements of live pigs (with a compliance probability of 1) and manure, professionals and vehicles (with a compliance probability of 0.98) were prohibited. It was assumed that the latter movements were restricted with a probability of 0.98, as some illegal movements will continue.

All farms within protection and surveillance zones were subject to screening. Within the protection zone, during the first week following the first outbreak all farms were clinically examined with a visit delay of BetaPert (2 3 5) days (due to limited resources) and a detection delay of two days (due to blood sampling in case of an outbreak), which is within the seven days as defined in EU Directive 2001/89/EC. The end screening included clinical examination and blood sampling and, after a detection delay of two days, the protection zone was lifted in case the test results were negative. In case of positive test results, the protection and surveillance zones lasted for another period of 37 and 28 days, respectively, during which the same procedure was followed as described for the first 37 and 28 days. Within the surveillance zone, all farms were clinically examined before lifting the zone. Additionally, according to the Diagnostic Manual (2002/106/EC), blood sampling was assumed to be required for farms without animals within two to eight months; that is, for sow farms. Detection probabilities are presented in Appendix Table A5.5.

For detected farms, 95% of the contacts were assumed to be traced. Farms with movements that occurred off (forward tracing) and onto (back tracing) the farm were traced and sampled with a detection delay of two days. Delays in visiting farms that had been in contact with a detected farm, as well as the probability that a movement had been forgotten (i.e., not reported, or forgotten by a farmer), are presented in Appendix Table A5.6 and were based on Mangen *et al.* (2002).

In the remainder of the chapter, this EU minimum strategy is referred to as *EU_min*.

Depopulation strategy

This strategy consisted of all control measures as stipulated in the EU minimum strategy plus a 72-h movement standstill, pre-emptive depopulation within a 1-km radius of detected farms, and the implementation of regionalisation with movement restrictions. All these additional measures are based on Anonymous (2011) and Anonymous (2013).

The 72-h standstill was modelled as a restriction on all movements throughout the entire NL, NRW and LS region after the first detection. The compliance probability was assumed to be 0.98 (all type of movements). Regarding pre-emptive depopulation, the same assumptions were made as for the depopulation of detected farms. Regionalisation was implemented for a period of seven days after first detection with a compliance probability of 0.98. NL, NRW and LS were divided into five, five and four regions, respectively, in which movements among regions were prohibited. Regions were defined as described in the contingency plans (Anonymous, 2011; Anonymous, 2013), which in GER are based on the so-called Regierungsbezirke. After seven days, regions without protection or surveillance zones (that is, without movement restriction zones; MRZ) were considered 'free regions'; movements among these regions were allowed within the same country. The Cartesian coordinates of the regions are available from the first author upon request.

In the remainder of the chapter, this depopulation strategy is referred to as *No_vacc*.

Vaccination strategy

This strategy consisted of all control measures as stipulated in the EU minimum strategy plus a 72-h movement standstill, pre-emptive depopulation within a 1-km radius of detected farms during the movement standstill, implementation of regionalisation with movement restrictions, and vaccination within a 2-km radius of detected farms from day four following first detection. All these additional measures are based on Anonymous (2011) and Anonymous (2013).

The vaccination capacity was assumed to be limited, and vaccination was modelled to begin on day four following first detection, accounting for the time veterinary authorities need to decide on and prepare for vaccination.

For NL, a vaccination-to-live (protective vaccination) strategy was simulated using an E2 sub-unit vaccine (marker vaccine), whereas for NRW and LS, a vaccination-to-kill (suppressive vaccination) strategy was simulated using a live Chinese strain vaccine (C-strain), representing the currently preferred vaccination strategies (Anonymous, 2011; Anonymous, 2013). At the end of the epidemic, all vaccinated animals in GER were assumed to be slaughtered and the carcasses rendered. In line with the Dutch contingency plan, NL sows were not vaccinated to avoid the risk of carrier sow syndrome (Backer *et al.*, 2008). The time in which marker and C-strain vaccinations resulted in herd immunity was similar to the immunity function used by Boklund *et al.* (2008) and Ribbens *et al.* (2012), the latter of which was based on Van Oirschot (2003), DeWulf *et al.* (2004) and DeWulf *et al.* (2005). The immunity function for NL farms with sows was adapted to account for non-vaccination of sows, based on the average percentage of sows within a farm class. For example, farm class D includes on average 0–10% sows, resulting in approximately 95% immunity on day 14 after vaccination (instead of 100% immunity). The time-dependent proportions of herd immunity that were assumed to be reached after vaccination with marker or C-strain vaccines are presented in Table 5.5. For marker vaccines, time to immunity was assumed to be eight to 14 days, whereas for C-strain vaccines this was two to seven days (Boklund *et al.*, 2009). Before the administration of vaccines, the model included clinical examination of the animals.

Table 5.5 Time-dependent proportion of herd immunity after vaccination with marker or C-strain vaccines.

Vaccination with	**Days after vaccination**								
	0–1	**2–3**	**4**	**5–6**	**7**	**8–9**	**10–11**	**12–13**	**≥14**
C-strain vaccine	0	0.25	0.5	0.75	1	1	1	1	1
Marker vaccine (farm classes C, E and F)[1]	0	0	0	0	0	0.25	0.5	0.75	1
Marker vaccine (farm class D)[2]	0	0	0	0	0	0.2375	0.475	0.7125	0.95
Marker vaccine (farm classes A and B)[3]	0	0	0	0	0	0.2125	0.425	0.6375	0.85

[1] Farm classes C, E, F farms do not include sows, resulting in 100% immunity on day 14 after vaccination.
[2] Farm class D includes on average 0–10% sows, resulting in 95% immunity on day 14 after vaccination.
[3] Farm classes A and B include on average 10–20% sows, resulting in 85% immunity on day 14 after vaccination.

According to the Dutch contingency plan, (partly) vaccinated farms with piglets that become part of a new vaccination circle during the outbreak need to vaccinate new-born piglets as well as piglets that were no more than two-weeks-old during the previous vaccination round. However, ISP does not include the simulation of piglets being born and hence, this was not included in the model. Vaccination of new-born and young piglets was assumed to require additional vaccination capacity; however, as described in the results, capacity was no limitation for controlling outbreaks and therefore, this was not included in the model.
In the remainder of the chapter, this vaccination strategy is referred to as *Vacc*.

Sensitivity analyses

To analyse epidemiological output sensitivity to changes in the control strategies, the HRP and the frequency of piglet movements, the three veterinary control strategies were run with different input parameters. All other parameter values were kept constant, i.e., the model was run eight times, each time changing only a single parameter. Changed parameters, including a description of the values used in the sensitivity analyses, are presented in Table 5.6. As described in the results, index farm NL1 resulted in the largest outbreaks and therefore, was assumed to be most sensitive to changes in input parameters. For that reason, NL1 was chosen for sensitivity analyses.

In short, vaccination and depopulation capacities were set to 1,000 farms per day; that is, unlimited capacities to analyse whether current capacities are limiting the control of CSF. The effect of no regionalisation was modelled as it was unclear whether this alters the course of the outbreak. The HRP was increased and decreased by five days to simulate increased and diminished farmer CSF alertness. For NL, the effect of vaccinating sows was included to examine whether reaching full herd immunity influences the course of the outbreak. The average number of off-farm movements per B farm was altered from once every fortnight to once every week and once per month to examine how influential movements are in spreading CSF.

Table 5.6 Changes in the input parameters as modelled in the sensitivity analyses.

Strategy	Abbreviation of changed parameter	Description of parameter value
EU_min, No_vacc and Vacc	Cap_depop	Depopulation capacity: 1,000 farms/day (unlimited capacity)
	No_region	No regionalisation and no additional movement restrictions due to regions
	HRP+5	HRP[1] was increased by five days to 52 days
	HRP-5	HRP was decreased by five days to 42 days
	Mov+	The average number of off-movements per B farm per day was doubled to 0.16
	Mov-	The average number of off-movements per B farm per day was halved to 0.04
Vacc (additional)	Cap_vacc	Vaccination capacity: 1,000 farms/day (unlimited capacity)
	Vacc_sows	Vaccination of sows was included, resulting in 100% immunity on day 14 after vaccination in NL

[1] HRP = high-risk period.

Economic model

The total economic impact included direct costs (DC), direct and indirect consequential costs (DCC and ICC, respectively), and aftermath costs (AC; costs that occur after eradication of the disease and lifting of all restriction measures.). As the focus of this chapter is on comparing veterinary and direct economic impacts of several control strategies, only DC and DCC were included. For the ICC (that is, the market effects) of CSF outbreaks, reference is made to Hop *et al.* (submitted).
The DC and DCC were restricted to those for farmers and for the governments that organise CSF control. The impact on related industries, such as feed companies, slaughterhouses and veterinary services, was not quantified.

Direct costs

DC refer to costs associated with the control of the disease (Longworth *et al.*, in press, b), including those related to organising the disease, clinical examination and serological screening, depopulation, vaccines and administration of vaccination, and feed destruction. DC cost parameters are presented in Table 5.7.
Organisational costs include running the crisis centre, monitoring compliance with movement restrictions, tracing, hiring personnel; i.e., costs made by authorities responsible for CSF control. For the CSF outbreak in NL in 1997–98, organisational costs were estimated at €35 million (Meuwissen *et al.*, 2009), which was approximately €75,000 per day. For the avian influenza outbreak in NL in 2003, these costs were estimated at €30 million (Meuwissen *et al.*, 2009), which was approximately €250,000 per day. In this chapter, the amount of €150,000 per day was used. This is higher than the amount spent per day during the CSF outbreak in 1997–98. However, that outbreak lasted for 15 months and especially in the first months, organisational costs were high due to setting up the crisis centre (Meuwissen *et al.*, 2009). For GER, the same amount of €150,000 per day was used.
Clinical examination costs include preparation and materials needed for a farm visit, a call-out charge and one hour of labour by a vet and two helpers. Serological screening costs include the same cost categories as for clinical examination and, additionally, include one extra helper, blood sampling material and extra labour (€3.75/animal * sample of 55 animals at a sampling speed of 50 sows (incl. piglets)/hour, or 70 slaughter pigs/hour). All tariffs used for actions by Dutch and German veterinarians, helpers, people from Food Safety Authorities (NVWA in NL and BVL in GER), and call-out charges were based on Hop *et al.* (2013).
Depopulation of sows (incl. piglets) and slaughter pigs includes organisational costs (diagnosis, valuation, slaughtering and cleansing and disinfecting) and costs related to the values of an average sow (incl. piglets; €362.25) or slaughter pig (€67.15). The latter values were based on the Dutch handbook 'Quantitative Information: Livestock Sector' (KWIN, 2011).

Table 5.7 Per-unit cost parameters used in the calculation of direct costs.

Direct cost category	Abbreviation of cost category	Unit	NL value	NRW-LS value
Organisation	cOrg	€ / day (duration)	150,000	150,000
Clinical examination and serological screening	cScreen	€ / farm in MRZ[1]	396.91	408.45
Depopulation of sows	cDepop	€ / depopulated sow	391.02	440.03
Depopulation of slaughter pigs	cDepop	€ / depopulated slaughter pig	76.48	83.95
Vaccination of sows	cVacc	€ / vaccinated sow	n.a.[2]	1.36
Vaccination of gilts or slaughter pigs	cVacc	€ / vaccinated gilt or slaughter pig	1.93	1.36
Vaccination of piglets	cVacc	€ / vaccinated piglet	1.96	1.39
Destruction of sow feed	cFeed	€ / depopulated sow	20.00	20.00
Destruction of slaughter pig feed	cFeed	€ / depopulated slaughter pig	3.20	3.20

1 MRZ = movement restriction zone.
2 n.a. = not applicable

Vaccination costs include vaccines and administration of vaccination. Vaccine costs were valued as €1/marker vaccine and €0.25/C-strain vaccine. Administration includes costs for a vet and four helpers at a vaccination speed of 250 animals/hour. Costs for Dutch sows were set to zero as they were not vaccinated. Costs for clinical examination prior to vaccination were included in the cost category 'clinical examination and serological screening'.
Costs related to the destruction of potentially contaminated sow feed (incl. feed for piglets) or slaughter pig feed were based on the value of the average amount of feed in stock, which, for sow feed, was based on 14 days and for slaughter pig feed on 7 days (KWIN, 2011).
Differences in the cost parameters' values between NL and NRW-LS resulted from different tariffs used for, for example, clinical inspection of animals (that is, labour costs) and different vaccine costs.

Direct consequential costs
DCC refer to costs that directly result from disease control (Longworth *et al.*, in press, b), including welfare problems, empty stables (idle production factors), and movement restrictions. DCC cost parameters are presented in Table 5.8.
According to the Dutch contingency plan (Anonymous, 2013), farmers are supposed to have enough free space available to house their animals during the first six weeks once they are located inside an MRZ. In line with this, farms inside MRZs were modelled to have welfare problems related to housing from week seven onwards. The Dutch contingency plan envisages that these problems will be addressed by controlled slaughter of slaughter pigs or by exemptions in movement restrictions to allow for the movement of vaccinated piglets within MRZs (from week seven onwards; only to empty or vaccinated fattening farms). These assumptions were used for both NL and GER. Controlled slaughter of slaughter pigs and movements of vaccinated piglets require organisational costs related to valuation, clinical examination, serological screening and transport. Due to vaccination, the value of piglets was assumed to decrease when sold to fattening farms[3]. Also, vaccination was assumed to cause profit losses once the slaughter pigs reach the slaughter age due to reduced slaughter values and costs related to stocking and channelling[4] of vaccinated animal meat (Bergevoet *et al.*, 2007).
The daily costs of completely empty stables due to depopulation were based on fixed costs including profit margins per sow or slaughter pig place (KWIN, 2011). It was assumed that farmers' labour was not used elsewhere during the period of empty stables.

3 Transport of vaccinated piglets is only allowed to empty or vaccinated fattening farms.

4 Meat from vaccinated animals can be sold under certain conditions, that is, if processed and stored separately from non-vaccinated meat.

Table 5.8 Per-unit cost parameters used in the calculation of direct consequential costs.

Direct consequential cost category	Abbreviation of cost category	Unit	NL value	NRW-LS value
Controlled slaughter of slaughter pigs due to welfare problems	cWelf	€ / slaughter pig in MRZ for > 6 weeks	10.11	10.16
Exemptions in movement restrictions to allow for movement of vaccinated piglets due to welfare problems	cWelf	€ / piglet in MRZ for > 6 weeks	9.58	9.62
Empty stables sows incl. piglets (idle production factors)	cIdle	€ / depopulated sow / day	0.99	0.99
Empty stables slaughter pigs (idle production factors)	cIdle	€ / depopulated slaughter pig / day	0.18	0.18
Movement restrictions piglets	cMovRes	€ / piglet in MRZ	0.78	0.78
Movement restrictions slaughter pigs	cMovRes	€ / slaughter pig in MRZ	1.65	1.65

[1] MRZ = movement restriction zone.

Farms that face movement restrictions were modelled to have losses due to supply and delivery problems. In the first six weeks of an outbreak, these farms were not allowed to deliver slaughter pigs or to deliver and receive piglets. Costs included those for feed for maintenance and for mortality.
Differences in the cost parameters' values between NL and NRW-LS resulted from different tariffs used for organising the valuation and clinical inspection of animals that are subject to welfare problems (that is, labour costs).

Results

Epidemiological results

Simulated control strategies
The epidemiological results for the three control strategies for simulated outbreaks indexed in NL, NRW and LS are presented in Table 5.9. The 50th and 95th percentile are shown for the number of farms infected, depopulated, vaccinated and located at least once inside a protection or surveillance zone, as well as the duration of the outbreak (excluding the HRP). For comparison reasons, the results are shown only for the country where the index farm is located, meaning that, for example, results for NL1 excludes the epidemiological results for cross-border outbreaks in GER. The veterinary impact of cross-border spread is presented in the section 'Cross-border impact of CSF'.
The *EU-min* strategy resulted in the highest number of infected farms. For both the 50th and 95th percentiles, there was little difference between the strategies *No_vacc* and *Vacc* in terms of number of infected farms. For the 95th percentiles of simulated outbreaks indexed in the most densely populated areas (NL1 and NL2), strategy *Vacc* tended to outperform strategy *No_vacc*.
Strategy *No_vacc* resulted in the highest number of depopulated farms because it included pre-emptive depopulation of farms within a 1-km radius of detected farms. Depopulating the 81 farms under the *No_vacc* strategy for index NL1 resulted in the culling of 202,909 animals (animal numbers are not shown in Table 5.9, but are available upon request from the first author).
With respect to the number of farms located inside a protection or surveillance zone, there was little difference among the strategies for most index farms, although *EU_min* resulted in the highest number of farms within an MRZ. Similarly, this strategy was the least efficient in terms of length of the epidemics for all index farms. Clearly, *No_vacc* outperformed the other two strategies with respect to duration, except for the 95th percentiles where *No_vacc* and *Vacc* performed similarly. For NL2, both strategies resulted in an outbreak length of five months (95th percentile), whereas *EU_min* resulted in an outbreak of almost seven and a half months.

Regarding the differences across index farms, outbreaks starting at NL1, NL2, NRW1 and LS1 were the largest in terms of the duration and the number of farms located within an MRZ. All four farms were located in areas with high farm densities (Table 5.3).

Sensitivity analyses

Index farm NL1 resulted in the largest outbreaks and therefore, was assumed to be most sensitive to changes in input parameters. For that reason, NL1 was chosen for sensitivity analyses; results are presented in Table 5.10 as absolute changes from the baseline strategies.

For all baseline strategies, a change in parameters *Cap_depop* and *No_region* had almost no impact on the number of farms infected, depopulated, located inside a protection or surveillance zone or on the length of the epidemic. For strategy *Vacc*, a change in *Cap_vacc* and *Vacc_sows* did not impact the course of the epidemic. Changing the length of the HRP by +5 and -5 days had minor to moderate impact on all three strategies (i.e., the epidemiological results change on average by +/- 10%). Changing the average number of off-farm movements per B farm had a large impact on all three strategies, especially on *EU_min* and especially on the number of farms located inside a protection or surveillance zone which altered by 14–37%. For all strategies, the length of the epidemic was least influenced by changes in input parameters.

Overall, although the absolute numbers changed due to changes in input parameters, the ranking of most efficient strategy per indicator did not change.

Cross-border impact of CSF

To investigate CSF's cross-border impact, the percentage and cause of cross-border spread per control strategy and the effect of a different control strategy in one country on the course of the epidemic in the other country were examined.

Table 5.11 presents the percentage of outbreaks (out of 1,000 iterations) resulting in cross-border spread between NL, NRW and LS broken down by infection type.

With respect to spread between NL and GER, simulated outbreaks indexed in NL (excl. NL4) resulted in the highest percentages (4–16%) of cross-border spread, whereas outbreaks starting in NRW and LS only spread to NL in 0–2% of the outbreaks. Clearly, outbreaks that started at NL4 caused more outbreaks in LS; that is, in about 50% of the cases. Also shown in Table 5.11, spread between NRW and LS was frequent, showing the difference in CSF spread between two regions within a country versus between two regions in two different countries.

In general, cross-border spread from NL index farms was mainly caused by export of animals for live use, professional contact and vehicle contact. Only when the index farm was close to the border (NL4), local spread and professional contact were main causes. Spread from NRW to LS and vice versa was mainly caused by transport of animals for live use and vehicle contact (that is, returning vehicles).

Table 5.9 Epidemiological results for three control strategies for simulated outbreaks indexed in NL, NRW and LS (results are shown for the index country only).

Index farm	Strategy	No. of farms infected		No. of farms depopulated		No. of farms vaccinated		No. of farms in MRZ		Duration in days (excl. HRP)	
		50th	95th	50th	95th	50th	95th	50th	95th	50th	95th
NL1	EU_min	40	96	48	113	0	0	1,727	3,391	138	248
	No_vacc	31	72	81	191	0	0	1,698	3,344	90	175
	Vacc	30	68	47	91	163	391	1,660	3,172	107	166
NL2	EU_min	22	75	26	87	0	0	1,298	2,942	123	221
	No_vacc	15	54	46	144	0	0	1,220	2,840	78	149
	Vacc	16	49	25	70	105	301	1,196	2,571	94	147
NL3	EU_min	6	41	7	48	0	0	599	1,764	80	186
	No_vacc	5	24	15	77	0	0	580	1,707	64	108
	Vacc	5	25	9	35	34	167	585	1,645	74	126
NL4	EU_min	6	42	8	47	0	0	369	1,483	78	192
	No_vacc	6	25	14	68	0	0	358	1,465	64	127
	Vacc	6	26	9	35	30	151	360	1,379	72	131
NRW1	EU_min	24	50	27	57	0	0	827	2,127	109	166
	No_vacc	19	45	35	84	0	0	804	2,035	73	140
	Vacc	19	43	23	51	57	160	797	1,908	86	147
NRW2	EU_min	7	41	8	46	0	0	745	1,983	81	150
	No_vacc	6	31	15	68	0	0	733	1,943	61	118
	Vacc	6	30	9	39	34	130	735	1,873	71	123
LS1	EU_min	10	35	11	38	0	0	1,071	2,284	90	177
	No_vacc	7	26	21	64	0	0	1,027	2,232	63	117
	Vacc	7	23	13	33	54	170	1,033	2,218	74	125
LS2	EU_min	5	22	6	26	0	0	554	1,726	71	149
	No_vacc	4	19	11	44	0	0	537	1,715	61	108
	Vacc	4	18	7	25	25	110	544	1,717	66	118

Table 5.10 Results for the sensitivity analyses for index farm NL1 as an absolute change from the baseline strategies (results are shown for the index country only).

Strategy	Changed parameter[1]	No. of farms infected[2]		No. of farms depopulated[2]		No. of farms vaccinated[2]		No. of farms in MRZ[2]		Duration in days (excl. HRP)[2]	
		50th	95th	50th	95th	50th	95th	50th	95th	50th	95th
EU_min		**40**	**96**	**48**	**113**	**0**	**0**	**1,727**	**3,391**	**138**	**248**
	Cap_depop	0	0	0	-1	0	0	0	-6	0	+4
	No_region	+1	-1	+1	0	0	0	+19	+64	0	+2
	HRP+5	+4	+7	+8	+9	0	0	+118	+324	+16	+21
	HRP-5	-7	0	-7	0	0	0	-216	-213	-7	0
	Mov+	+15	+57	+22	+69	0	0	+500	+924	+10	+15
	Mov-	-13	-34	-16	-40	0	0	-484	-712	-7	-25
No_vacc		**31**	**72**	**81**	**191**	**0**	**0**	**1,698**	**3,344**	**90**	**175**
	Cap_depop	0	-3	0	-6	0	0	0	-116	0	+3
	No_region	0	-1	+1	0	0	0	+6	+16	0	+1
	HRP+5	+3	+8	+9	+26	0	0	+142	+206	+8	+32
	HRP-5	-7	-3	-12	-16	0	0	-209	-103	-8	-2
	Mov+	+14	+43	+19	+53	0	0	+415	+759	+9	+13
	Mov-	-6	-15	-12	-33	0	0	-313	-566	-6	-18
Vacc		**30**	**68**	**47**	**91**	**163**	**391**	**1,660**	**3,172**	**107**	**166**
	Cap_vacc	0	-1	0	-1	0	-4	0	0	0	0
	Vacc_sows	-1	-1	0	-1	+1	-3	0	0	-1	0
	Cap_depop	0	0	0	-1	0	0	0	-4	0	+3
	No_region	0	-1	+1	-1	+2	-1	+12	+29	0	+1
	HRP+5	+3	+6	+5	+16	+13	+35	+168	+235	+6	+18
	HRP-5	-3	-6	-3	-10	-19	-42	-116	-93	-7	-2
	Mov+	+10	+28	+16	+41	+67	+184	+621	+1095	+11	+39
	Mov-	-4	-10	-5	-18	-33	-69	-299	-454	-8	0

1 Abbreviations of changed parameters are explained in Table 6.
2 Numbers in bold are the epidemiological results for the baseline scenarios from Table 9, whereas the results for the changed parameters are presented as the absolute change from these baseline strategies.

In Table 5.12, the 50th percentile is shown for the number of farms infected, located at least once inside an MRZ, as well as the duration of the outbreak in days (excluding the HRP) caused by cross-border spread. For all index farms, outbreaks caused by cross-border spread were small in the majority of the cases, that is, only 0–3 farms were infected and between 35–411 farms were located inside an MRZ at the 50th percentile. In case of cross-border spread, affected neighbouring regions were cut off the market for approximately two to four and a half months. However, the percentage of cross-border spread from GER to NL was small (see Table 5.11); therefore, the epidemiological impact of spread between these regions should be interpreted with caution as it is based on only 1–17 cases.

Additionally, Table 5.12 shows the number of farms located inside an MRZ due to an outbreak in the neighbouring country (50th percentiles), whereas there are no infected farms in their own country. The percentage of iterations in which MRZs were extended into the neighbouring country is shown in brackets. For example, in 28% of all iterations, an outbreak starting at index farm NL1 (strategy *EU_min*) resulted in 24 farms located inside an MRZ in NRW (50th percentile). In 4–28% of all iterations, farms in NRW-LS were restricted in movements due to an outbreak in NL and vice versa. Exceptions are outbreaks starting at index farms NL4, NRW1 and LS2 where 42–54% of all iterations resulted in movement restrictions in LS, LS, and NRW, respectively. The location of the index farm, that is, the distance to the border, is the main reason for imposing MRZs across borders.

For both Tables 5.11 and 5.12, differences among control strategies per index farm were minor and across index farms, the ranking of preferred strategies was similar. Lastly, the effect of a different control strategy in one country on the course of the epidemic in the other country was examined by making combinations of the baseline control strategies. For example, it was examined whether vaccination in NL affected the course of an outbreak in NRW and LS (under a non-vaccination strategy) after cross-border spread of the disease, and vice versa. Compared with the baseline strategy outcomes, there were no differences in the number of farms infected, depopulated, and located inside a protection or surveillance zone or in the length of the epidemic.

Economic results

Simulated control strategies

Associated DC and DCC (in million €) for the three control strategies for simulated outbreaks indexed in NL, NRW and LS are presented in Tables 5.13a and 5.13b. Similar to the epidemiological results, DC and DCC are only shown for the country where the index farm is located. The direct economic impact of cross-border spread is presented in the next section.

At the 50th percentile, strategy *No_vacc* resulted in the lowest DC, closely followed by strategies *Vacc* and *EU_min*. Exceptions were the German index farms, where depopulation of vaccinated animals in strategy *Vacc* resulted in the highest DC, and the index farm that caused the largest outbreaks (NL1), where *Vacc* resulted in the lowest median DC. Similarly, for the largest NL simulated epidemics (that is, at the 95th percentile), *Vacc* resulted in the lowest DC, followed by *No_vacc* and *EU_min*, whereas strategy *Vacc* resulted in the highest DC for GER index farms. Organisational costs contributed most to DC, and costs related to depopulation came second and increased considerably with the size of the outbreak or in case a vaccination-to-kill strategy was applied.

At both the 50th and 95th percentiles, strategy *No_vacc* had the lowest DCC, followed by *Vacc* and *EU_min*. Especially for index farms that caused large outbreaks, there was a clear difference in DCC among the three control strategies. Costs related to welfare measures increased with the size of the outbreak, particularly for index farms NL1 and NL2.

Considering the total of DC and DCC, both at the 50th and 95th percentiles the preferred strategy for all index farms was *No_vacc*, whereas *EU_min* was the least preferred. Exceptions were the total DC and DCC for the German index farms, where *Vacc* was the least preferred strategy at the 95th percentile. The high costs for strategy *Vacc* were, besides the organisational costs, mainly a result of the culling of vaccinated animals.

Cross-border impact of CSF

To further investigate CSF's cross-border impact, the related costs of cross-border spread per control strategy were examined. Table 5.14 presents DC, DCC and total DC and DCC (50th percentiles) caused by cross-border spread between NL, NRW and LS (results are shown for iterations with cross-border spread only).

Total DC and DCC range from €8.2 million to €20.5 million with minor differences among control strategies per index farm. Total DC and DCC are for 91–99% determined by organisational costs, which are part of DC. Organisational costs are driven by the length of the epidemic; therefore, duration is mainly determining DC and DCC of cross-border disease spread.

DC and DCC associated with movement restrictions due to an outbreak in the neighbouring country (whereas there are no infected farms in their own country) are not shown in Table 5.14, but are minor; that is, similar to the DCC presented in Table 5.14.

Table 5.11 Percentage of outbreaks resulting in cross-border spread between NL, NRW and LS broken down by infection type.

Index farm	Strategy	Total percentage of cross-border spread between regions (% of 1,000 iterations in which this happens)			Cross-border spread between regions broken down by infection type (%)											
					Local spread			Vehicle contact			Professional contact			Export of animals for live use[1]		
		NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS
NL1	EU_min	14.5	4.5	-[2]	0	0.2	-	0.6	0.1	-	2.4	0.1	-	11.5	4.1	-
	No_vacc	15.4	4.8	-	0	0.2	-	0.8	0.1	-	2.7	0.6	-	11.9	3.9	-
	Vacc	15.7	4.5	-	0.1	0.3	-	0.6	0.1	-	3.2	0.1	-	11.8	4.0	-
NL2	EU_min	9.7	3.9	-	0.1	0	-	0.6	0.6	-	1.5	0.1	-	7.5	3.2	-
	No_vacc	10.3	4.5	-	0.1	0	-	0.7	0.6	-	1.5	0.4	-	8.0	3.5	-
	Vacc	9.7	4.2	-	0.1	0	-	0.7	0.6	-	1.4	0.5	-	7.5	3.1	-
NL3	EU_min	8.1	5.0	-	0.3	0.4	-	2.1	1.4	-	4.1	2.4	-	1.6	0.8	-
	No_vacc	8.2	4.6	-	0.4	0.2	-	2.1	1.4	-	4.2	2.2	-	1.5	0.8	-
	Vacc	8.2	4.8	-	0.3	0.4	-	2.1	1.4	-	4.3	2.3	-	1.5	0.7	-
NL4	EU_min	5.4	49.0	-	0.2	37.2	-	0.2	0.2	-	3.7	11.1	-	1.3	0.5	-
	No_vacc	5.6	46.3	-	0.2	34.4	-	0.2	0.2	-	3.7	11.3	-	1.5	0.4	-
	Vacc	5.7	46.4	-	0.2	34.4	-	0.3	0.2	-	3.7	11.4	-	1.5	0.4	-
NRW1	EU_min	0.3	-	52.8	0.1	-	0.1	0	-	13.1	0.2	-	6.4	0	-	33.2
	No_vacc	0.3	-	54.8	0	-	0	0	-	13.7	0.3	-	5.9	0	-	34.2
	Vacc	0.2	-	53.1	0	-	0.1	0	-	13.2	0.2	-	6.1	0	-	33.7
NRW2	EU_min	1.4	-	23.3	0.2	-	0.1	0	-	5.7	1.1	-	1.5	0.1	-	16.0
	No_vacc	1.6	-	23.5	0.1	-	0.1	0	-	5.9	1.4	-	1.6	0.1	-	15.9
	Vacc	1.7	-	22.9	0.3	-	0.2	0	-	5.8	1.3	-	1.3	0.1	-	15.6

LS1	EU_min	-	0.1	20.7	-	0.1	0.2	-	0	6.4	-	0	1.4	-	0	12.7
	No_vacc	-	0.1	21.4	-	0.1	0.2	-	0	6.8	-	0	1.8	-	0	12.6
	Vacc	-	0.1	20.9	-	0.1	0.2	-	0	6.7	-	0	1.5	-	0	12.5
LS2	EU_min	-	1.5	14.0	-	0	0	-	0	3.9	-	1.5	0.8	-	0	9.3
	No_vacc	-	1.4	13.5	-	0	0	-	0	3.9	-	1.4	0.3	-	0	9.3
	Vacc	-	1.4	13.3	-	0	0	-	0	3.8	-	1.4	0.4	-	0	9.1

[1] Spread between NRW and LS is a result of transport instead of export of animals for live use.
[2] Not applicable because this region does not involve the region of the index farm.

Table 5.12 Number of farms infected, located in an MRZ and duration in days caused by cross-border spread (50th percentiles), and number of farms located inside an MRZ due to an outbreak in the neighbouring country (50th percentiles), including the percentage of iterations in which this happens (in brackets).

Index farm	Strategy	Cross-border spread									No. of farms in MRZ due to outbreak in neighbouring country (% of 1,000 iterations in which this happens)[2]		
		No. of farms infected (50th percentile)[1]			No. of farms in MRZ (50th percentile)[1]			Duration in days (excl. HRP) (50th percentile)[1]					
		NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS
NL1	EU_min	2	1	-	318	255	-	94	91	-	24 (28)	61 (6)	-
	No_vacc	2	1	-	298	216	-	72	74	-	23 (27)	53 (6)	-
	Vacc	2	1	-	288	208	-	85	89	-	21 (27)	59 (6)	-
NL2	EU_min	2	1	-	332	214	-	92	89	-	28 (19)	45 (4)	-
	No_vacc	2	1	-	316	196	-	74	71	-	28 (19)	44 (4)	-
	Vacc	2	1	-	305	185	-	88	84	-	29 (17)	39 (4)	-

Table 5.12 Continued.

Index farm	Strategy	Cross-border spread: No. of farms infected (50th percentile)[1]			No. of farms in MRZ (50th percentile)[1]			Duration in days (excl. HRP) (50th percentile)[1]			No. of farms in MRZ due to outbreak in neighbouring country (% of 1,000 iterations in which this happens)[2]		
		NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS
NL3	EU_min	1	1	-	369	197	-	104	88	-	31 (26)	54 (18)	-
	No_vacc	1	1	-	356	181	-	84	76	-	28 (26)	49 (18)	-
	Vacc	1	1	-	339	163	-	96	81	-	21 (25)	51 (17)	-
NL4	EU_min	2	2	-	365	148	-	91	62	-	47 (18)	73 (54)	-
	No_vacc	2	2	-	352	139	-	77	54	-	47 (18)	70 (53)	-
	Vacc	2	2	-	343	133	-	86	60	-	47 (17)	71 (54)	-
NRW1	EU_min	0	-	3	138	-	411	121	-	91	21 (7)	-	46 (47)
	No_vacc	0	-	3	138	-	397	121	-	81	13 (7)	-	46 (46)
	Vacc	0	-	3	127	-	381	129	-	87	19 (6)	-	46 (47)
NRW2	EU_min	0	-	2	221	-	257	95	-	77	24 (19)	-	40 (11)
	No_vacc	0	-	2	214	-	243	76	-	62	24 (18)	-	40 (11)
	Vacc	0	-	2	198	-	236	83	-	71	23 (17)	-	40 (11)
LS1	EU_min	-	0	2	-	35	275	-	68	78	-	18 (5)	24 (12)
	No_vacc	-	0	2	-	35	269	-	68	63	-	11 (5)	21 (11)
	Vacc	-	0	2	-	35	258	-	68	75	-	15 (4)	23 (12)
LS2	EU_min	-	0	1	-	138	329	-	91	82	-	16 (43)	52 (7)
	No_vacc	-	0	1	-	134	316	-	82	65	-	16 (42)	46 (6)
	Vacc	-	0	1	-	127	300	-	88	75	-	16 (42)	50 (6)

[1] Epidemiological results are presented for iterations with cross-border spread only; that is, for NL1 under strategy EU_min cross-border spread only resulted in two infected NRW farms at the 50th percentile.

[2] The number of farms located inside an MRZ are presented resulting from an outbreak in the neighbouring country, whereas there are no infected farms in their own country; that is, in 28% of all iterations an outbreak starting at index farm NL1 (strategy EU_min) resulted in 24 farms located inside an MRZ in NRW at the 50th percentile.

Table 5.13a Direct costs (million €) for three control strategies for simulated outbreaks indexed in NL, NRW and LS (results are shown for the index country only).

Index farm	Strategy	Direct cost (DC) categories[1]											
		cOrg		cScreen		cDepop		cVacc		cFeed		Total DC	
		50th	95th	50th	95th	50th	95th	50th	95th	50th	95th	50th	95th
NL1	EU_min	20.7	37.2	0.6	1.2	7.0	13.4	-[2]	-	0.3	0.6	**28.6**	**52.4**
	No_vacc	13.5	26.3	0.7	1.3	11.1	22.9	-	-	0.5	1.1	**25.8**	**51.6**
	Vacc	16.1	24.9	0.7	1.3	7.2	12.3	0.4	1.1	0.3	0.6	**24.7**	**40.2**
NL2	EU_min	18.5	33.2	0.5	1.0	2.7	8.7	-	-	0.1	0.4	**21.8**	**43.3**
	No_vacc	11.7	22.4	0.5	1.1	4.8	15.6	-	-	0.2	0.7	**17.2**	**39.8**
	Vacc	14.1	22.1	0.5	1.0	2.7	7.5	0.3	0.8	0.1	0.4	**17.7**	**31.8**
NL3	EU_min	12.0	27.9	0.2	0.7	0.8	3.8	-	-	0.0	0.3	**13.0**	**32.7**
	No_vacc	9.6	16.2	0.2	0.7	1.3	5.9	-	-	0.1	0.3	**11.2**	**23.1**
	Vacc	11.1	18.9	0.2	0.7	0.8	3.1	0.1	0.3	0.0	0.1	**12.2**	**23.1**
NL4	EU_min	11.7	28.8	0.1	0.6	0.3	3.1	-	-	0.0	0.1	**12.1**	**32.6**
	No_vacc	9.6	19.1	0.1	0.6	0.6	4.6	-	-	0.0	0.2	**10.3**	**24.5**
	Vacc	10.8	19.7	0.1	0.6	0.4	2.4	0.1	0.3	0.0	0.1	**11.4**	**23.1**
NRW1	EU_min	16.4	24.9	0.3	0.7	1.4	2.9	-	-	0.1	0.1	**18.2**	**28.6**
	No_vacc	11.0	21	0.3	0.8	1.8	4.2	-	-	0.1	0.2	**13.2**	**26.2**
	Vacc	12.9	22.1	0.3	0.8	4.0	10.9	0.0	0.1	0.1	0.1	**17.3**	**34.0**
NRW2	EU_min	12.2	22.5	0.3	0.8	0.3	2.6	-	-	0.0	0.1	**12.8**	**26.0**
	No_vacc	9.2	17.7	0.3	0.8	0.7	3.5	-	-	0.0	0.1	**10.2**	**22.1**
	Vacc	10.7	18.5	0.3	0.8	2.2	9.4	0.0	0.1	0.0	0.1	**13.2**	**28.9**
LS1	EU_min	13.5	26.6	0.4	0.9	0.7	2.4	-	-	0.0	0.1	**14.6**	**30.0**
	No_vacc	9.5	17.6	0.4	0.9	1.3	4.0	-	-	0.1	0.2	**11.3**	**22.7**
	Vacc	11.1	18.8	0.4	0.9	4.0	12.8	0.1	0.2	0.0	0.1	**15.6**	**32.8**
LS2	EU_min	10.7	22.4	0.2	0.7	0.3	1.4	-	-	0.0	0.1	**11.2**	**24.6**
	No_vacc	9.2	16.2	0.2	0.7	0.6	2.4	-	-	0.0	0.1	**10.0**	**19.4**
	Vacc	9.9	17.7	0.2	0.7	1.7	7.8	0.0	0.1	0.0	0.1	**11.8**	**26.4**

[1] Abbreviations of DC categories are explained in Table 7.
[2] Not applicable.

Table 5.13b Direct consequential costs (million €) for three control strategies for simulated outbreaks indexed in NL, NRW and LS (results are shown for the index country only).

Index farm	Strategy	Direct consequential cost (DCC) categories[1]									
		cIdle		cMovRes		cWelf		Total DCC		Total DC and DCC	
		50th	95th	50th	95th	50th	95th	50th	95th	50th	95th
NL1	EU_min	0.9	2.1	2.4	4.5	23.3	49.5	**26.7**	**56.0**	**55.3**	**108.4**
	No_vacc	1.2	2.3	2.7	4.9	7.8	19.9	**11.7**	**27.1**	**37.5**	**78.7**
	Vacc	1.0	1.6	2.7	4.9	15.3	35.6	**18.9**	**42.1**	**43.6**	**82.3**
NL2	EU_min	0.3	1.1	1.9	3.9	15.2	38.8	**17.3**	**43.9**	**39.1**	**87.2**
	No_vacc	0.5	1.5	1.9	4.2	4.1	15.5	**6.5**	**21.2**	**23.7**	**61.0**
	Vacc	0.3	0.9	1.9	4.0	9.6	28.0	**11.8**	**32.9**	**29.5**	**64.7**
NL3	EU_min	0.1	0.4	0.6	1.8	1.4	10.9	**2.1**	**13.0**	**15.1**	**45.7**
	No_vacc	0.1	0.5	0.6	1.9	0.1	4.1	**0.8**	**6.5**	**12.0**	**29.6**
	Vacc	0.1	0.3	0.6	1.8	0.9	8.2	**1.6**	**10.3**	**13.8**	**33.4**
NL4	EU_min	0.0	0.4	0.3	1.5	0.7	10.7	**1.0**	**12.5**	**13.1**	**45.1**
	No_vacc	0.1	0.5	0.3	1.5	0.1	3.0	**0.5**	**4.9**	**10.8**	**29.4**
	Vacc	0.0	0.3	0.3	1.4	0.4	7.0	**0.7**	**8.7**	**12.1**	**31.8**
NRW1	EU_min	0.2	0.4	0.5	1.4	4.1	9.9	**4.8**	**11.6**	**23.0**	**40.2**
	No_vacc	0.2	0.4	0.6	1.6	1.1	4.0	**1.9**	**6.0**	**15.1**	**32.2**
	Vacc	0.1	0.3	0.6	1.5	2.2	7.1	**3.0**	**8.9**	**20.3**	**42.9**
NRW2	EU_min	0.0	0.3	0.7	1.6	2.0	10.0	**2.7**	**11.8**	**15.5**	**37.8**
	No_vacc	0.1	0.3	0.7	1.6	0.0	4.0	**0.8**	**5.9**	**11.0**	**28.0**
	Vacc	0.0	0.2	0.7	1.6	1.0	7.5	**1.7**	**9.2**	**14.9**	**38.1**
LS1	EU_min	0.1	0.2	1.1	2.4	5.4	16.4	**6.6**	**19.0**	**21.2**	**49.0**
	No_vacc	0.1	0.3	1.1	2.3	0.3	5.9	**1.5**	**8.6**	**12.8**	**31.3**
	Vacc	0.1	0.2	1.1	2.3	1.6	10.7	**2.8**	**13.1**	**18.4**	**45.9**
LS2	EU_min	0.0	0.1	0.4	1.6	0.5	7.3	**1.0**	**9.0**	**12.2**	**33.6**
	No_vacc	0.1	0.2	0.4	1.6	0.0	2.5	**0.5**	**4.2**	**10.5**	**23.6**
	Vacc	0.0	0.1	0.4	1.6	0.7	5.4	**0.6**	**7.1**	**12.4**	**33.5**

[1] Abbreviations of DCC categories are explained in Table 8.

Table 5.14 Direct and direct consequential costs (50th percentiles in million €) caused by cross-border spread between NL, NRW and LS (results are shown for iterations with cross-border spread only).

Index farm	Strategy	DC			DCC			Total DC and DCC[1]		
		NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS	NL-NRW	NL-LS	NRW-LS
NL1	EU_min	14.2	13.6	-	0.1	0.2	-	14.3	13.8	-
	No_vacc	11.2	11.4	-	0.2	0.1	-	11.4	11.5	-
	Vacc	13.0	13.5	-	0.3	0.2	-	13.3	13.7	-
NL2	EU_min	14.0	13.5	-	0.1	0.1	-	14.1	13.6	-
	No_vacc	11.5	10.9	-	0.3	0.1	-	11.8	11.0	-
	Vacc	13.5	12.8	-	0.2	0.1	-	13.7	12.9	-
NL3	EU_min	16.0	13.4	-	0.8	0.3	-	16.8	13.7	-
	No_vacc	13.2	11.7	-	0.3	0.2	-	13.5	11.9	-
	Vacc	14.8	12.3	-	0.6	0.3	-	15.4	12.6	-
NL4	EU_min	13.9	9.3	-	0.3	0.5	-	14.2	9.8	-
	No_vacc	12.0	8.1	-	0.3	0.1	-	12.3	8.2	-
	Vacc	13.2	9.1	-	0.3	0.1	-	13.5	9.2	-
NRW1	EU_min	18.5	-	14.0	0.1	-	1.0	18.6	-	15.0
	No_vacc	18.5	-	12.7	0.1	-	0.6	18.6	-	13.3
	Vacc	19.6	-	13.4	0.9	-	0.9	20.5	-	14.2
NRW2	EU_min	14.4	-	11.8	0.4	-	0.2	14.8	-	12.0
	No_vacc	11.9	-	9.7	0.3	-	0.2	12.2	-	9.9
	Vacc	12.6	-	10.9	0.5	-	0.2	13.1	-	11.1
LS1	EU_min	-	10.3	11.9	-	0.0	0.3	-	10.3	12.2
	No_vacc	-	10.3	9.8	-	0.0	0.2	-	10.3	10.0
	Vacc	-	10.3	11.5	-	0.0	0.2	-	10.3	11.7
LS2	EU_min	-	13.9	12.5	-	0.2	0.4	-	14.1	12.9
	No_vacc	-	12.9	10.2	-	0.1	0.2	-	13.0	10.4
	Vacc	-	13.7	11.5	-	0.2	0.2	-	13.9	11.7

[1] The total DC and DCC is for 91–99% determined by organisational costs.

Discussion

The objective of this chapter was to examine CSF control strategies' veterinary and direct economic impacts for NL, NRW and LS given the current production structure, and to analyse CSF's cross-border causes and impacts within the NL-NRW-LS region.

Country-specific results

Most strikingly, the simulated outbreak sizes and durations for 2010 are much smaller than those simulated previously, using data from over 10 years ago (see, e.g., Jalvingh *et al.*, 1999; Mangen *et al.*, 2002; Karsten *et al.*, 2007), regardless of the veterinary control strategy. This could be explained by major changes that have occurred in the pig production structure during the last decade. For example, in 10 years' time, the number of NL pig farms and NL pig farm density have decreased by 43% and 49%, respectively. Due to this decrease in NL farm density, the average number of off-farm movements within DPLAs during the HRP has decreased considerably: within DPLAs (~95th percentile), these movements have decreased from 748 to 543 transports from the 10 km zone, and from 20 to 10 transports from the 1 km zone (derived from Dutch I&R data). Regarding the transport distance, in 2001, about 50% of the transports with animals for live use stayed within 10 km of the farm of origin, whereas in 2010 this increased to 20–30 km. These changes in the pig production structure have resulted in a change in the strength of 'spread driving forces', that is, fewer spread possibilities within close proximity of the index farm resulting in a substantial decrease in the simulated number of infected farms. Another important difference with a decade ago concerns depopulation capacity: in the past, depopulation capacity was insufficient (Pluimers *et al.*, 1999; Mangen *et al.*, 2002), whereas with the current pig production structure, increasing the current depopulation capacity does not impact the course of the epidemic as was shown in the sensitivity analysis. Regarding the NRW and LS pig production structure, similar trends in terms of decreased numbers of farms and decreased pig farm densities were seen (Hop *et al.*, 2014).

With respect to the most efficient control strategy, *EU_min* was the least preferred strategy as it resulted in the highest number of farms infected and located inside an MRZ, and the longest duration. *EU_min* was observed to be especially deficient in controlling large outbreaks. Strategies *Vacc* and *No_vacc* were indifferent regarding the number of farms infected; for the duration of the epidemic and total DC and DCC, *No_vacc* outweighed strategy *Vacc*. Regardless of the index country, *No_vacc* and *Vacc* were both efficient strategies in controlling the epidemic and resulted in the lowest total DC and DCC, especially in worst-case outbreaks. Choosing a strategy leads to a trade-off between a higher number of culled animals (*No_vacc*) and vaccinated animals and products that may be difficult to market to fattening pig farmers and consumers (*Vacc*). However, both strategies *Vacc* and *No_vacc* included the culling of animals within a 1-km radius of detected farms, although strategy *Vacc* only included 1 km culling zones during the 72-h movement standstill. This had a major impact on the simulated course of the epidemic and, therefore, explains the small differences in outbreak size and duration between strategies *Vacc* and *No_vacc*. Although strategy *No_vacc* resulted in the highest number of culled animals (median of 202,909 culled animals for index farm NL1), strategy *Vacc* was still two-thirds of this (median of 139,831 culled animals for NL1). However, a risk exists that vaccination decreases the market value of animals and products due to channelling as well as a decrease in demand from consumers and, as a result, from fattening pig farmers. This could lead to large market effects, especially for net exporting countries. This risk is much smaller for non-exporting countries (Mangen *et al.*, 2002; Boklund *et al.*, 2009). For a detailed elaboration of the market effects, reference is made to Hop *et al.* (submitted). The outcomes regarding control strategy efficiency are comparable to those found by a fairly recent study (Backer *et al.*, 2008): the ranking of control strategies in relation to the number of farms infected and the duration of the epidemic, as well as the absolute numbers for these parameters are similar.

These outcomes were also supported by the sensitivity analyses. These analyses demonstrated that the ranking of the strategies is robust to changes in input parameter values. More importantly, it shows that there is only a limited scope for improving the current control. For example, parameter changes in *Vacc* and *No_vacc* (*Cap_vacc* and *Vacc_sows*, or *Cap_depop*, respectively) did not affect these baseline strategies. Creating more awareness for detecting CSF (i.e., decreasing the HRP) slightly impacted the simulated course of the epidemic, but major impact can be expected from changes in the pig production structure as was demonstrated by modelling changes in the number of livestock transports (*Mov+* and *Mov-*). Doubling the average number of off-farm movements per B farm, for example, resulted in a large increase in farms located within protection and surveillance zones. These new MRZs were a consequence of increased geographical disease jumps toward other regions. An increase in the future number of livestock transports is likely as farms become larger; however, large herds maintain a higher level of bio-security than small herds (Boklund, 2008) which may result in less CSF introduction and spread possibilities. Additionally, the number of farms decreased in the past and is expected to decrease in the future (Hop *et al.*, 2014), resulting in less local spread possibilities. It is expected that this effect outweighs the effect of an increase in future number of livestock transports. Therefore, as concluded by Hop *et al.* (2014), the number of farms, farm size and number of livestock transports are important parameters to monitor in the future.

Cross-border results

The percentage of outbreaks resulting in cross-border spread was relatively low with main causes being the export of animals for live use, professional contact and vehicle contact. Those iterations that caused cross-border spread resulted in small, short outbreaks.

On the one hand, the low percentages of cross-border outbreaks are surprising. During the last decade, the absolute number of cross-border transports from NL to NRW-LS has increased to over 32,000 in 2010, 6,500 of which were transports of animals for live use. However, only 4–16% (excluding NL4) of the iterations resulted in disease spread from NL to GER. This percentage was even lower (0.1–1.7%) for disease spread from GER to NL. These low percentages are in line with those of De Vos *et al.* (2005), in which the probability of virus introduction from GER to NL during an outbreak was estimated at 0.5%. These low percentages are also expected given the low number of farms moving animals for live use between regions. From NL to NRW-LS, only 443 out of 2,876 farms export animals for live use and from NRW-LS to NL, only 30 out of 10,051 farms (Table 5.1). In general, cross-border outbreaks were detected at an early stage and remained small due to a simulated increased farmers' alertness across the border to detect the disease. Only 1–2 out of 1,000 iterations resulted in larger cross-border outbreaks, that is, approximately 20–30 infected farms were infected. In reality, this may happen as a result of late detecting and reporting of the disease, or due to delayed or inaccurate reporting to Traces.

The percentage of cross-border spread through local spread was also low. A relatively small number of farms is located within 1 km of the border and only 35 NL and 31 NRW-LS farms are located within 1 km of an NRW-LS farm or NL farm, respectively. If one of these 35 NL or 31 NRW-LS farms becomes infected, the probability of the disease spreading across the border is moderate, as was seen for index farm NL4. However, the size of the outbreaks probably remains small, as shown for cross-border outbreaks caused by NL4. Generally, it was seen that, after inspecting the geographic locations of all NL-NRW-LS farms in the border regions, DPLAs on the Dutch side of the border are located next to NRW-LS low-density areas, and vice versa.

Cross-border spread outbreaks resulted in relatively low DC and DCC (€8.2 million to €20.5 million; mainly determined by organisational costs), whereas DC and DCC associated with outbreaks in the index country ranged from €10.5 million to €55.3 million. However, the potential impact of cross-border outbreaks may be much higher due to market disturbance; it is uncertain how trade partners will react to these relatively small cross-border outbreaks.

Opportunities for further cross-border collaboration

The probability of CSF introduction across the border was relatively low and was mainly caused through transportation of animals for live use. Future developments in the number of cross-border transports may alter the probability of disease introduction. Hop *et al.* (2014) expect a further increase in cross-border transports and, with continuing discussions on the maximum transport duration, the number of cross-border transports from NL to GER is likely to increase even further. Although these developments increase the number of transports, they do not necessarily imply an increased probability of cross-border virus introduction. On the one hand, if the disease is introduced to NL, the probability of introducing it into NRW-LS may increase. On the other hand, if NL piglets replace piglets previously originating from countries with lower bio-security levels, the overall probability of virus introduction into NRW-LS may decrease. It is important to note, though, that the described developments will increase the mutual dependence between NL and NRW-LS. An outbreak resulting in border closure between the two countries will result in increasing shortages of piglets in GER and large piglet surpluses in NL (Bosman *et al.*, 2012; Hop *et al.*, submitted).

Our results show that once CSF enters a neighbouring country, even in situations with frequent cross-border contacts outbreaks can remain small and last for only a short duration. However, a cross-border outbreak in a DPLA can affect a relatively large number of farms due to movement restrictions. These farms are cut off from the market for at least a few months; especially in the case of a protective vaccination strategy, this can cause severe market disruptions and high ICC.

Based on the results presented in this chapter, some of Breuer *et al.*'s proposals (2008) to improve cross-border collaboration were shown to be more-or-less redundant. More and quicker sharing of information may help reduce HRP length, although this has a minor to moderate impact on the simulated course of the epidemic as shown in the sensitivity analyses. Although being able to rely on accurate and easily accessible data by keeping Traces up-to-date is important, further investments in such a system, most likely, will only slightly impact the course of an epidemic. Shared resources for vaccination and depopulation will not impact the course of an epidemic because current capacities are sufficient. A shared use of resources, such as stocking of vaccines, may lower vaccination costs. However, vaccine costs are rather low and are negligible compared with total DC and DCC. Only in case of an outbreak within close proximity of the border, that is, when farms across the border are restricted in movements due to an outbreak in the neighbouring country (without any locally infected farms), farms in cross-border MRZs can be treated as being part of the country with the epidemic. This can be realised, for example, through the implementation of cross-border regions (free and contaminated regions regardless of the border). Although this may not reduce associated DC and DCC, which were minor as shown in the section 'Economic results', it can prevent other countries from temporarily closing their borders to animals and products from a country with farms within close proximity of an infected farm.

In this chapter, the focus was on the veterinary and direct economic impact of cross-border CSF control. It is expected that cross-border collaboration to mitigate the market effects of an epidemic will create more opportunities to reduce the impact of CSF outbreaks. Therefore, the outcomes of this chapter are used in chapter 6 which analyses the prospects for mitigating the ICC (that is, the market effects) of CSF outbreaks in a cross-border context, for example, by channelling surpluses of (vaccinated) piglets in the joint region of NL-NRW-LS (Hop *et al.*, submitted).

Conclusion

Regardless of the veterinary control strategy, the simulated outbreak sizes and durations for 2010 were much smaller than those simulated previously, using data from over 10 years ago. This favourable change is most likely a result of major changes in the pig production structure during the last decades.
Both strategies *No_vacc* and *Vacc* were efficient in controlling outbreaks, especially large ones, whereas *EU_min* was especially deficient in controlling worst-case outbreaks. Both *No_vacc* and *Vacc* resulted in low DC and DCC compared to the past (see, e.g., Meuwissen *et al.* (2009)).
The probability of cross-border disease spread was relatively low (4–16%) and cross-border spread resulted in small, short outbreaks. Few opportunities for further cross-border harmonisation and collaboration were identified, including the implementation of cross-border regions (free and contaminated regions regardless of the border) in case of outbreaks within close proximity of the border, and more and quicker sharing of information across the border.
It is expected, however, that collaboration to mitigate the market effects of an epidemic will create more opportunities to reduce the impact of CSF outbreaks in a cross-border context.

Acknowledgements

The authors gratefully acknowledge Koenraad Bosman for his support with ISP and SPSS modelling, Willie Loeffen, Marieke Augustijn, Albert Groeneveld, Annette vom Schloß, Yvonne Epker, and experts from the Netherlands Food and Consumer Product Safety Authority (NVWA) for providing data and information on the control of CSF in NL and GER, and partners of the SafeGuard project for critical reflection. This study is part of the project SafeGuard, which is financed within the INTERREG IV A programme Deutschland-Nederland by the European Regional Development Fund.

Appendix

Table A5.1 Daily probability of spread to farms located within radii of 0.5, 1 and 2 km of an infected farm.

Day	Probability of infection for farms located within radii of 0.5, 1 and 2 km		
	0–0.5 km	0.5–1 km	1–2 km
1–4	0	0	0
5	0.00122	0.0004	0.000003
6	0.00305	0.001	0.0000075
7	0.0061	0.002	0.000015
8	0.00915	0.003	0.0000225
9	0.01098	0.0036	0.000027
≥10	0.0122	0.004	0.00003

Table A5.2 Distance distributions for transport of domestic animals for live use and for vehicle contact.

Distance band (km)	Probability of transport
0–5	0.11
5–10	0.12
10–20	0.22
20–30	0.16
30–50	0.19
50–75	0.11
75–100	0.05
100–500	0.04

Table A5.3 Distance distributions for movements of professionals.

Distance band (km)	Probability of transport
0–3	0.36
3–10	0.40
10–30	0.14
30–60	0.10

Table A5.4 Daily probability of transmission via the movement of pigs for live use, slaughter pigs, vehicle contact and professionals, including number of direct and indirect contacts.

Movement type	Probability of transmission per day							Number of contacts	
	1–4	5	6	7	8	9	≥10	Direct	Indirect via vehicles
Pigs for live use	0.277	0.277	0.277	0.277	0.277	0.277	0.277	Constant (1)	Poisson (2)
Slaughter pigs	0	0	0	0	0	0	0	Constant (0)	Poisson (1)
Vehicle contact	0	0.0048	0.012	0.024	0.036	0.0432	0.048	Constant (0)	-
Professionals	0	0.003	0.0075	0.015	0.0225	0.027	0.03	Constant (1)	-

Table A5.5 Cumulative detection probabilities for each day for monthly sampling during HRP, first screening in the 3 km zone, end screening in the 3 and 10 km zones, and screening of vaccinated farms.

	Probability of detection per day[1]										
	1–7	8–9	10–11	12–13	14–15	16–17	18	19–20	21–22	23–24	25
Probability	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.99

[1] Number of days since the day of infection.

Table A5.6 Farm visit probabilities per day for farms that had been in contact with a detected farm and probabilities of movements forgotten for the movement types 'animals for live use', 'professionals' and 'vehicles'.

Movements	Farm visit probabilities per day						Probability of movements forgotten
	0	1	2	3	4	5	
Animals for live use	0	1	-	-	-	-	0.05
Professionals	0	0	1	-	-	-	0.05
Vehicles	0	0	0.25	0.25	0.25	0.25	0.3

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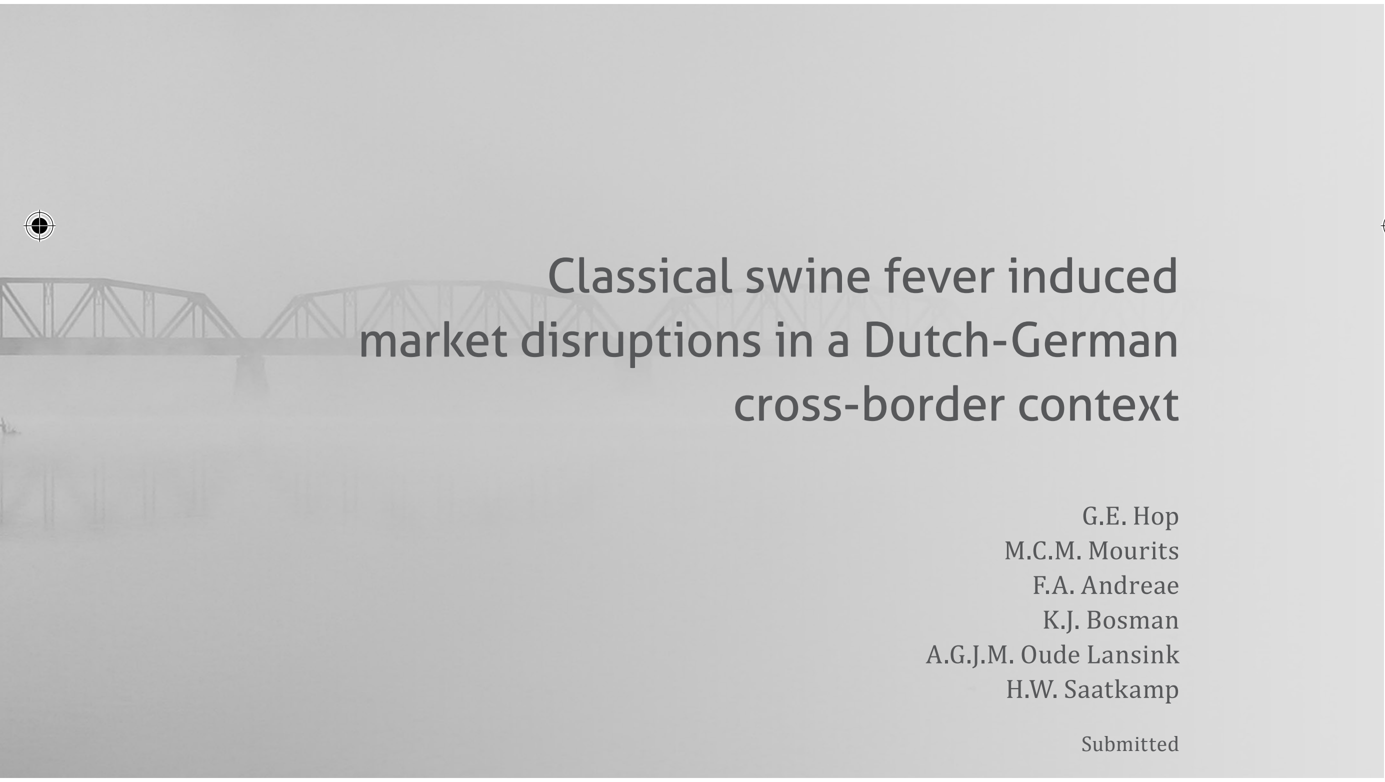

Classical swine fever induced market disruptions in a Dutch-German cross-border context

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Abstract

The economic impact of an outbreak of the regulated contagious livestock disease classical swine fever (CSF) can be extensive, especially as a result of market disruptions. Over the past decade, changes in the Dutch and German pig production structure and in their veterinary contingency plans have occurred that make previous studies on CSF induced market disturbances less representative for examining the impact of CSF on the current market situation. Nowadays, multiple, temporal shocks on multiple sub-markets at several moments in time are expected in case of an outbreak. This altered situation is caused by three main developments that have occurred in the past decade: regionalisation (dividing the country into a diseased region with and free regions without movement and trade restrictions), vaccination and regional specialisation of pig production.

This chapter aimed at (i) obtaining insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation, vaccination, and regional specialisation of pig production, and (ii) assessing the potential for mitigating these market disruptions in a cross-border context. Expert workshops and spread-sheet models were used to examine changes in trade volumes and corresponding prices.

This chapter showed that changes in NL-NRW-LS' veterinary contingency plans and regional specialisation result in a new market situation in case of a CSF outbreak. Consequently, a CSF outbreak nowadays would result in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak, that is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions. These trade bans and movement restrictions mainly result from regionalisation. Ways to mitigate the size and duration of market shocks include altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context.

The vaccination's market impact was expected to be subject to uncertainty due to trade partners' perception and, consequently, unpredictable trade responses. Elucidating the uncertainty around the acceptance of vaccinated animals, primarily by retailers, and possible compensation for primary producers was recommended. To alleviate any potential demand shocks in response to vaccination, collective producers' voluntary restriction of products from vaccinated pigs to either the domestic or processed markets was proposed as a potential policy tool.

It was concluded that – during a future CSF outbreak – veterinary policy makers are advised to follow a similar approach to obtain insights into CSF induced market disturbances and incorporate these insights into their tactical disease control. In case control measures have similar epidemiological impact, market effects should be incorporated in decision making, especially because these effects largely outweigh the costs that directly result from disease control.

Introduction

The economic impact of an outbreak of the regulated contagious livestock disease classical swine fever (CSF) can be extensive (see, e.g., Meuwissen *et al.*, 1999), especially as a result of market disruptions (Mangen and Burrell, 2003; Saatkamp and Bruijnen, 2009). Studies that (partly) analyse the economic effects of CSF outbreaks include, among others, Meuwissen *et al.* (1999), Mangen and Burrell (2001; 2003), Mangen *et al.* (2002; 2004), Niemi *et al.* (2006; 2008), Bergevoet *et al.* (2007), Saatkamp and Bruijnen (2009) and Boklund *et al.* (2009). In past CSF outbreaks, costs due to market disruptions majorly exceeded costs that directly resulted from controlling the disease, especially for areas with an important export market like the Netherlands (NL) (Meuwissen *et al.*, 1999; Mangen and Burrell, 2003). In this chapter, we explore the impact of market disruptions (indirect consequential costs; ICC) for primary producers due to a CSF outbreak in the cross-border region of NL and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS), a large and highly integrated pig production area (Hop *et al.*, in press, a). The CSF outbreaks in Germany (GER), Belgium and NL in 1997–98 underlined that the control of a disease like CSF is a cross-border challenge: not only these countries were affected by the epidemic, but also their neighbouring countries' sectors (Stegeman *et al.*, 2002).

Over the past decade, changes in the NL-NRW-LS' pig production structure and in their veterinary contingency plans have occurred that make previous studies on CSF induced market disturbances (e.g., Meuwissen *et al.*, 1999; Mangen and Burrell, 2003) less representative for examining the impact of CSF on the current market situation. In the CSF outbreak in 1997-98, large numbers of animals were culled pre-emptively and for welfare reasons, resulting in one shock (i.e., piglet and slaughter pig shortages) over the course of the entire outbreak. Nowadays, multiple, temporal shocks on multiple sub-markets at several moments in time are expected in case of an outbreak. This altered situation is caused by three main developments that have occurred in the past decade.

First, current veterinary contingency plans make use of the concept of *regionalisation*, that is, establishing trade regions within a country, mainly based on geographical criteria (OIE, 2007; Junker *et al.*, 2009). The rationale for regionalisation, i.e., dividing the country into a diseased region with and free regions without movement and trade restrictions, is based on principles of quick recovery of export from an affected country's free regions. Regionalisation is implemented in addition to the EU-required movement restriction zones (MRZ) around each detected farm (CEC, 2001). Depending on the size of the diseased regions and their export or import orientation, the implementation of regionalisation can lead to (large) piglet and slaughter pig surpluses or shortages in diseased and free regions. Over the course of an epidemic, gradually lifting export bans and movement restrictions can lead to multiple, temporary shocks on multiple sub-markets at several moments in time, causing market turbulence: relatively small changes in piglet and slaughter pig supply can already lead to large price effects (Mangen and Burrell, 2003).

Second, current veterinary contingency plans include the option to apply marker *vaccination* during an epidemic. In the past, vaccination caused the slaughter and rendering of vaccinated animals to guarantee absence of virus. At that time, it was not possible to serologically distinguish between animals that obtained immunity through vaccination or through an encounter with the actual virus. Through the application of marker vaccination, this distinction can now be made and can avoid the preventive culling of large numbers of (mainly healthy) animals (Backer *et al.*, 2008). However, a risk exists that marker vaccination decreases the demand for and prices of piglets, slaughter pigs and meat, both during and after a CSF outbreak. During the outbreak, moving vaccinated animals is prohibited; however, trade partners could perceive the existence of marker-vaccinated animals as risky. After the outbreak, vaccinated animals need to be channelled and sold within the affected country, whereas meat from vaccinated animals needs processing and can be exported. Both during and after an epidemic, these perceived risks caused by the sub-market of vaccinated animals could lead to price effects, especially for net exporting countries. This risk is much smaller for non-exporting countries (Mangen and Burrell, 2003; Boklund *et al.*, 2009).

Third, the *regional specialisation of pig production* enhances the effect of trade bans and movement restrictions caused by the current veterinary control strategies and trade partners' responses. The establishment of the European Union (EU) single market in 1992 has stimulated European trade in livestock and livestock commodities among member states (EU, 2010). Taking account of CSF induced market disturbances within the whole EU market is therefore desirable. The growth in intra community trade has led to regional specialisation and intensified production (Arens *et al.*, 2010; Marquer, 2010), particularly in the cross-border region of NL-NRW-LS. During the last decades, NL has specialised towards piglet production and NRW-LS towards fattening pig production. Due to their high level of integration, these regions highly depend on each other regarding pig production, making producers more vulnerable to market distortions due to trade restrictions.

The three developments described cause a completely new market situation in which their combined effects increase the magnitude of market disruptions in case of an outbreak. For example, both *regionalisation* and *vaccination* lead to the creation of several temporary sub-markets with each having its own trade restrictions. Due to the increased *regional specialisation of pig production*, in a short time-period large surpluses and shortages of piglets and slaughter pigs lead to large temporary, multiple and opposite market shocks within a country's diseased and free regions and within other EU countries due to large cross-border production dependencies. To smoothen out these market disruptions, further cross-border collaboration within a highly integrated livestock production area such as NL-NRW-LS offers opportunities to lower the market shocks during CSF outbreaks. Options include, for example, harmonisation of current – although based on EU minimum requirements, still country-specific – disease control (e.g., lowering the impact of regionalisation) or by treating (part of) the NL-NRW-LS region as a single production region without any borders to create an enlarged "domestic" market (Hop *et al.*, in press, a). In the latter case, channelling animal trade flows within such an enlarged production region would level out the market disruptions caused by large piglet surpluses and shortages.

In the light of the foregoing, the objectives of this chapter were (i) to obtain insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation, vaccination, and regional specialisation of pig production, and (ii) to assess the potential for mitigating these market disruptions in a cross-border context.

Material and methods

Approach

Hop *et al.* (in press, b) analysed the epidemiological and direct economic consequences of CSF in NL, NRW and LS. In this chapter, Hop *et al.*'s (in press, b) epidemiological outcomes were used in three subsequent expert workshops in which experts estimated the magnitude of CSF induced market disruptions in terms of changes in trade volumes and prices. The epidemiological outputs include the number of farms infected, depopulated, vaccinated and located at least once inside a protection or surveillance zone, as well as the duration of the outbreak. These outputs were generated by the stochastic, dynamic and spatially explicit simulation model Interspread Plus (ISP), which was parameterised for CSF epidemics in the cross-border region of NL-NRW-LS. The outputs were used as input for a conversion model programmed in SPSS, which analysed the output and calculated direct costs (DC) and direct consequential costs (DCC). These direct economic consequences are mainly determined by the number of farms located inside a protection or surveillance zone (MRZ). The market disturbances described in this chapter are mainly determined by movement restrictions imposed on farms. This chapter focuses on the impact of movement restrictions due to regionalisation rather than on the impact of movement restrictions due to the much smaller MRZs. The number of animals restricted in movement within a diseased region entirely outnumbers those restricted in movements within MRZs. Additionally, the duration of the epidemic and, thus, of trade restrictions is important as well for determining the impact of market disturbances.

Epidemiological scenarios

NL and NRW-LS' CSF control strategies are described in their contingency plans (Anonymous, 2011; Anonymous, 2013) and follow the minimum set of control measures as outlined in EU Directive 2001/89/EC (CEC, 2001) and include additional, country-specific measures. These measures are described in full detail in Hop *et al.* (in press, b). Summarising, EU minimum measures include the depopulation of detected farms, installation of and screening within the MRZs around each detected farm, movement restrictions on live pigs and manure, professionals and vehicles in these zones, and tracing and depopulation of contacts. In addition to the control measures as stipulated in the EU minimum strategy, the national control strategies based on *depopulation* include a 72-h movement standstill, pre-emptive depopulation within a 1-km radius of detected farms, and the implementation of regionalisation with movement restrictions. The national control strategies based on *vaccination* consist of all control measures as stipulated in the EU minimum strategy plus a 72-h movement standstill, pre-emptive depopulation within a 1-km radius of detected farms during the movement standstill, implementation of regionalisation with movement restrictions, and vaccination within a 2-km radius of detected farms from day four following first detection. To avoid preventive culling of large numbers of (mainly healthy) animals, NL prefers a vaccination-to-live (protective vaccination) strategy using an E2 sub-unit vaccine (marker vaccine), whereas LS prefers a vaccination-to-kill (suppressive vaccination) strategy using a live Chinese strain vaccine (C-strain) (Anonymous, 2011; Anonymous, 2013).

Regionalisation is expected to induce shocks in supply and/or demand due to trade restrictions. The scenarios discussed during the workshops included a baseline scenario with regionalisation according to the current contingency plans, and scenarios in which the duration and strictness of movement restrictions varied. These variants were included for two reasons: (i) the length of trade bans is uncertain as this relates to the trade partners' responses as well as the course of the outbreak, and (ii) veterinary policy makers can alter the duration and strictness of movement restrictions as a way to mitigate the volume and price changes that result from multiple market shocks due to CSF. The latter reason also considers mitigating the effect of trade bans within a cross-border context, i.e., by channelling trade flows across borders.

Outbreaks are likely to start in densely populated livestock areas (DPLA) due to the higher absolute number of animal movements within these areas (Hop *et al.*, in press, b). Consequently, these areas have the highest need and offer the largest prospects for mitigating CSF's market effects. Therefore, epidemiological scenarios were based on (i) simulated outbreaks within the South region of NL and (ii) simulated outbreaks on the border of NL-LS (NL: East region – LS: Weserems region). The South region is a large piglet surplus area, whereas the East-Weserems region is a piglet surplus (NL) and shortage (LS) area. As both NRW and LS are piglet shortage areas, it was chosen to focus on one of these two areas (i.e., LS) to avoid asking the experts for too many estimations regarding volume and price changes.

Market shocks and corresponding changes in trade volumes and prices: procedure

During a CSF outbreak, the three developments (i.e., regionalisation, vaccination and regional specialisation of pig production) will induce a new, complex market situation, implying multiple shocks on different sub-markets at several moments in time. To obtain insight into this complex and dynamic market situation, a panel of four experts was consulted during three subsequent workshops in which market shocks and corresponding changes in trade volumes and prices were explored.

The experts were knowledgeable in the EU-wide pig market in general as well as in region-specific trade volumes and prices of piglets, slaughter pigs and pork. The experts originated from private companies and public organisations. The three expert workshops were organised within a timeframe of two months. This short time span kept the experts focussed, i.e., no repetitive explanations regarding the problem were needed. It allowed the researchers to evaluate the workshop's outcomes and to model CSF induced volume changes.

Preceding the first workshop, experts were provided a description of the procedure, including the epidemiological scenarios and underlying assumptions, as well as a schematic overview of NL-NRW-LS' important import and export markets, those markets' imports, exports and domestic productions, i.e., their demand for piglets and slaughter pigs, and corresponding prices. All data provided were based on the official statistical databases Traces, Circabc and Eurostat and all data were for the year 2010.

The *first workshop* aimed at creating a common understanding of the proposed approach, including an introduction to and discussion of the epidemiological scenarios and the assumptions regarding the market situation. Based on this workshop, more variations on the concept of regionalisation were included in the epidemiological scenarios. Additionally, missing or incomplete data on pig prices and the number of slaughterings were included.

The *second workshop* aimed at creating a common understanding of CSF's market effects, including reaching consensus on the underlying assumptions and estimating trade volume changes. The experts reached consensus on the following underlying assumptions regarding CSF market shocks:

- A CSF outbreak was assumed *not to impact the demand* for meat, slaughter pigs or piglets, based on studies by Mangen and Burrell (2001; 2003).

- The use of vaccination to control CSF was assumed *not to impact trade volumes* but lower prices could occur within the affected country during the outbreak. Although vaccinated animals are not allowed to be moved during the outbreak, trade partners could perceive the existence of the sub-market of vaccinated animals as risky. Therefore, other EU countries are expected to lower their prices for the affected countries' non-vaccinated animals during the outbreak. After the outbreak, which is outside the scope of this research, vaccinated animals stay within the affected country and were expected to be consumed domestically: the weekly domestic consumption is sufficient to cover this.
- The *supply* of piglets, slaughter pigs and pork *is inelastic in the short run*. Moreover, the total EU production outside the affected area was assumed to remain constant because the duration of CSF outbreaks is on average shorter (two to four and a half months; Hop *et al.*, in press, b) than a full production cycle (ten months).
- The *shocks* in trade volumes and corresponding prices within the affected area are assumed to *level out across the EU market*, affecting both direct and indirect trade partners. Hence, as it was assumed that CSF has no impact on the demand, and the supply of animals is inelastic in the short run, the EU market's surpluses and shortages due to trade bans are assumed to last until trade bans are lifted. After lifting these bans, surpluses and shortages may last for another two to four weeks, depending on the slaughter capacities and the rate at which empty slaughter pig places become available in previously-diseased regions.
- The season of year in which the outbreak occurs was expected to influence the economic impact because trade volume and price volatility differ across seasons. To *exclude the effect of seasonality*, the CSF epidemic was assumed to start in April, that is, a period in which piglet and slaughter pig volumes and prices are at an average level within the EU.
- During the outbreak, piglet and slaughter pig surpluses and shortages differ due to multiple shocks within a short time-period, i.e., due to the implementation of regions with trade restrictions (weeks 0-6) and lifting these regions (week 7 until the end of the outbreak), resulting in different volume and price equilibriums during these two periods. Therefore, for both periods trade volumes and prices were estimated by the experts. The impacts that directly or indirectly result from the disease but occur after controlling the outbreak (i.e., the aftermath costs) are not included in this chapter. Likewise, market effects for consumers, slaughter-houses, etc. are excluded from this chapter; only the effects for primary producers are explored.

Based on the second workshop and the assumptions regarding CSF market shocks, a spread-sheet model was constructed to calculate volume changes in the affected country's free and diseased regions' trade, as well as changes in the separate EU countries' trade. First, the change in trade volume for the whole EU market was calculated based on the affected country's trade-banned volume. Next, EU region-specific changes in trade volumes were calculated in line with the principle 'the shock in one region levels out across the EU market'. For example, a shortage of 72,000 piglets on the EU market was divided by the total EU demand for piglets to fill empty slaughter pig places (= slaughter pig demand = 4.5 million piglets), where slaughter pig demand equals the total piglet production minus piglet export plus piglet import. A shortage of 72,000 piglets on the EU market corresponds with –1.59% piglets (72,000 divided by 4.5 million), that is, 1.59% of the available slaughter pig places remains empty. Similarly, volume changes in slaughter pig trade were calculated based on slaughterhouses' demand for slaughter pigs within the EU market (i.e., slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import).

The *third workshop* aimed at creating a qualitative estimation of CSF's price effects due to changes in trade volumes. As it was considered not feasible to estimate exact price changes at this stage, the experts suggested to use the signs '+', 'o' and '–' to approximate price effects in a qualitative way because of the large uncertainty. Based on the discussion during the workshop, these signs were included afterwards and send to the experts for final approval.

Results

Current NL-NRW-LS market situation

Figure 6.1 presents NL-NRW-LS' most important import and export markets for piglets and slaughter pigs, including net trade flow volumes, during a disease-free situation. Countries in East- and South-Europe were aggregated to better show the most important trade flows for NL, NRW and LS. Countries not indicated in Figure 6.1 do not play an important role in live pigs' trade. Net trade flows are shown; arrows between countries indicate trade in both directions but only net trade values are presented. Some trade flows are valued at zero, indicating a marginal trade in piglets or slaughter pigs. However, it was expected that during a CSF outbreak these existing trade relationships can easily be extended. Both NL and Denmark are large exporters of high-quality piglets, mostly going to GER. Eastern Europe imports large numbers of lower-quality piglets. Additionally, NRW is a large importer of slaughter pigs.

Epidemiological scenarios for analysis of market disturbances

Figure 6.2 presents the epidemiological results for the two simulated outbreaks indexed in NL and NL-LS. Regions South (outbreak in NL) and East and Weserems (outbreak on the border of NL-LS) are highlighted in dark grey on the maps as they are the simulated diseased regions; the other regions are free of disease.

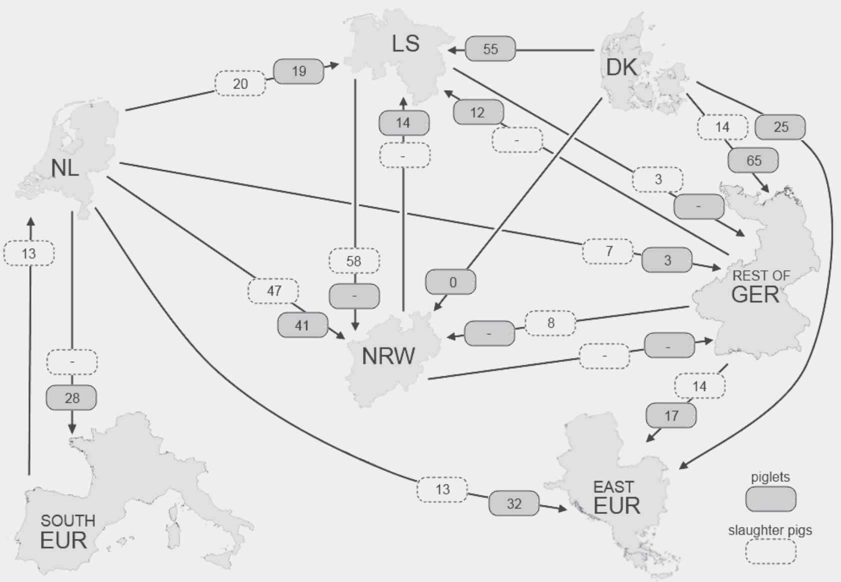
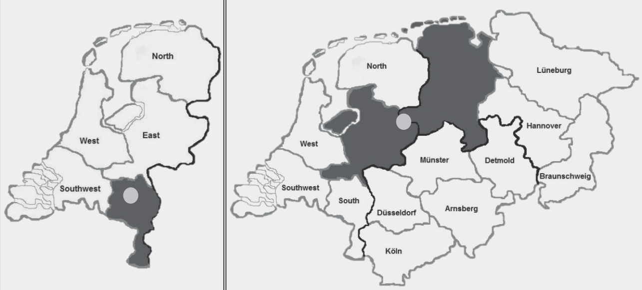


Figure 6.1 Net trade flows among NL-NRW-LS' most important EU import and export markets (number of animals x 1,000).

Additionally, the *weekly* production figures for NL and LS are presented. Out of the 484,000 piglets produced within NL, 256,000 are produced within region South and 148,000 within region East. Similarly, out of the 278,000 piglets produced within LS, 205,000 are produced within region Weserems. For slaughter pigs, out of the 339,000 slaughter pigs produced within NL, 158,000 and 110,000 are produced within regions South and East, respectively. Weserems produces 267,000 slaughter pigs out of the total 339,000 slaughter pigs produced within LS. Regions South and East are net exporters of piglets (76,000 and 29,000, respectively) and slaughter pigs (23,000 and 46,000, respectively), whereas Weserems is a net importer of piglets (88,000) and net exporter of slaughter pigs (27,000). Within regions South and East, only 1 fattening place is available for every 1.6 and 1.3 piglets, resulting in a weekly surplus production of 98,000 and 38,000 piglets, respectively. Outbreaks in region South result in the largest numbers of animals culled, vaccinated and located in MRZs, and last for approximately 13 weeks. Outbreaks in East-Weserems last for approximately 10 weeks and result in smaller numbers of animals culled, vaccinated and located in MRZs (see Figure 6.2). However, not only animals located within MRZs are restricted in movements; a relatively large number of animals within diseased regions are also subject to movement restrictions, resulting in large trade disturbances. Restrictions for farms located in diseased and free regions are given in Table 6.1 for different scenarios.

	Scenarios 1–2[1]		Scenarios 3-4[1]			
Production figures *Weekly numbers (x 1,000):*	NL total	South[2]	NL total	East[2]	LS total	Weserems[2]
• Piglet production	• 484	• 256	• 484	• 148	• 278	• 205
• Net import of piglets[3]	• -123	• -76	• -123	• -29	• 100	• 88
• Slaughter pig production	• 339	• 158	• 339	• 110	• 389	• 294
• Net import of slaughter pigs[3]	• -74	• -23	• -74	• -46	• -41	• -27
• No. of slaughterings	• 272	• 143	• 272	• 128	• 339	• 267
• Piglet surplus	• 144	• 98	• 144	• 38	• -111	• -88



Epidemiological figures	NL	NL	LS
• Length outbreaks (weeks)	• 13	• 10	• 9
Weekly numbers (x 1,000): • No. culled piglets / slaughter pigs	• 6 / 3	• 0 / 0	• 0 / 0
• Piglet / slaughter pig production in MRZ[4]	• 41 / 28	• 5 / 4	• 1 / 1
• No. vaccinated piglets / slaughter pigs	• 7 / 8	• 1 / 1	• 0 / 0

[1] A description of the scenarios is provided in Table 1.
[2] Regions South (NL, scenarios 1-2), East (NL, scenarios 3-4) and Weserems (LS, scenarios 3-4) are diseased regions (highlighted in dark grey on the maps).
[3] Negative net import = export.
[4] MRZ means movement restriction zone (light grey dot on the maps).

Figure 6.2 Epidemiological results for the two simulated outbreaks indexed in NL and NL-LS, including weekly piglet and slaughter pig production figures per region (number of animals x 1,000).

Scenarios 1 and 2 refer to an outbreak in region South (NL). Scenario 1 is the baseline scenario and is based on the current veterinary contingency plans (Anonymous, 2013). In this scenario, export from free regions was assumed to be allowed only after two weeks following the initial outbreak and domestic transport from previously-diseased regions after 6 weeks. Additionally, all animal movements within the diseased region were prohibited during the first six weeks following the initial

Table 6.1 Movement restrictions for diseased and free regions within NL and LS due to a CSF outbreak.

Scenarios[1]	Weeks following first detection	Movement restrictions: Diseased region within country[2]
1: NL_baseline	0-2:	· No movements allowed within region South
	3-6:	· No movements allowed within region South
	>6:	· Domestic transport allowed to/from region South
2: NL_transpdisreg	0-2:	· No domestic transport allowed to/from region South; movements within region South allowed
	3-6:	· Same as weeks 0-2
	>6:	· Domestic transport allowed to/from region South
3: NL+LS_baseline		NL: see NL_baseline_novacc
		LS
	0-2:	· No domestic transport allowed to/from region Weserems; movements within region Weserems allowed
	3-6:	· Same as weeks 0-2
	>6:	· Export allowed to/from region Weserems
4:NL+LS_channelling		NL
	0-2:	· No movements allowed within region East
	>3:	· Channelling allowed with region Weserems; movements allowed within region East
		LS
	0-2:	· No domestic transport allowed to/from region Weserems; movements within region Weserems allowed
	>3:	· Channelling allowed with region East; movements allowed within region Weserems

1 All scenarios include a non-vaccination and a vaccination variant. Veterinary strategies with vaccination do include additional transport restrictions for farms with vaccinated animals (farms within a 2-km radius of detected farms).

2 Piglets and slaughter pigs from a previously diseased region stay within their own country, as it was assumed that other EU countries do not want to buy piglets and slaughter pigs from a diseased region.

outbreak. Scenario 2 is similar to the baseline scenario, except that diseased regions were assumed to *transport animals within the diseased regions* instead of prohibition of all animal movements within the diseased region. This scenario represents the current NRW-LS legislation. Scenarios 3 and 4 refer to an outbreak on the border of regions East (NL) and Weserems (LS). To avoid asking the experts for too many estimations regarding volume and price changes, only a baseline and a channelling scenario were included. Scenario 3 included the same assumptions for NL as presented for scenario 1. For LS, the current veterinary contingency plans (Anonymous, 2011) differ from NL's plans: movements within the diseased region

Free regions within country
· No export allowed to/from free regions within NL · Export allowed to/from free regions within NL · Export allowed to/from free regions within NL · No export allowed to/from free regions within NL · Export allowed to/from free regions within NL · Export allowed to/from free regions within NL
NL: see NL_baseline_novacc LS · No export allowed from free regions within LS; import piglets/sl.pigs allowed (except first 3 days) · Export allowed to/from free regions within LS · Export allowed to/from free regions within LS
NL · No export allowed to/from free regions within NL · Export allowed to/from free regions within NL LS · No export allowed from free regions within LS; import piglets/sl.pigs allowed (except first 3 days) · Export allowed to/from free regions within LS

are allowed during the first six weeks following the initial outbreak and export to/from this region was assumed to be allowed after week six. Additionally, free regions within LS are allowed to import piglets and slaughter pigs after three days following the initial outbreak; export was assumed to be allowed after two weeks. To explore ways to mitigate market effects, scenario 4 included the channelling of animal trade flows across the diseased regions East and Weserems. From week three, movements within the whole East-Weserems region were assumed to be allowed to overcome the East region's piglet and slaughter pig surpluses and the Weserems region's piglet shortage.

Market disturbances: emergence of supply shocks

CSF induced market disturbances directly follow from the epidemiological scenarios. The expert workshops 1 and 2 resulted in a qualitative overview of the market disturbances for the direct and (in applicable) indirect trade partners over the course of the epidemic. This overview is presented in Tables 6.2a and 6.2b. Table 6.2a shows the overall disturbances for an outbreak in NL, i.e., a net exporting market for piglets and slaughter pigs, while Table 6.2b shows the disturbances for a net importing piglet region (LS).

Tables 6.2a and 6.2b both show the normal situation (before an outbreak) and the market shocks' impact due to lifting movement restrictions at three different moments in time: weeks 1-2, weeks 3-6 and weeks 7 until the end of the outbreak. During these different periods, new volume and price equilibriums arise as a result of surpluses and shortages of piglets and slaughter pigs at the EU market. As shown in the tables, market effects mainly result from the restricted movements within diseased and free regions. During the first two weeks following the initial outbreak, indirect trade partners were assumed not to be affected, whereas for the remainder of the epidemic, also they were assumed to be affected by the market disturbances.

Market disturbances: trade volume changes

In Figures 6.3a (scenarios 1-2; outbreak within NL) and 6.3b (scenarios 3-4; outbreak on the border of NL-LS), the calculated shocks in trade volumes for affected countries and the EU market are shown. The scenarios' trade bans and related movement restrictions are briefly mentioned on top of the graphs to indicate what causes the differences across the scenarios. The upper row graphs represent cumulative surpluses or shortages of piglets and slaughter pigs for the affected country. The lower row graphs show those effects for the aggregate EU market; the effects within the affected country are excluded from the EU graphs. As experts assumed no additional shocks in trade volumes after applying vaccination, the graphs therefore represent both the non-vaccination and vaccination variants.

Due to the prohibition of all animal movements within the diseased region South (NL), scenario 1 in Figure 6.3a shows large piglet and slaughter pig surpluses (cumulative surpluses of 1.54 and 0.95 million animals, respectively) during weeks 0-6 following the initial outbreak. These numbers are based on the duration of the outbreak (epidemiological scenarios) and the production figures of the diseased region. Relaxing the prohibition of animal movements results in piglet surpluses only (0.59 million animals for scenario 2). After lifting the movement restrictions within the diseased region, piglet and slaughter pig surpluses slowly diminish as it requires time and slaughter capacity to empty slaughter pig places on which piglets can be placed (scenario 1). As a result of the oversupply of piglets onto the NL market, NL's free regions are assumed to export their piglets and slaughter pigs because NL's prices were expected to drop to an absolute minimum from week 7 until the end of the outbreak. In the first weeks of period 'weeks 7-end', prices within the EU were assumed to remain high due to their shortages; in the last weeks of this period, EU prices were assumed to drop because NL's free regions remain exporting their piglets due to expected very low prices within their own country. From week 7 until the end of the outbreak, NL was assumed to weekly export 42,000 piglets more than asked for by the other EU countries (scenario 1). Regarding slaughter pigs, NL's slaughter capacity was expected to expand during this period, resulting in an adequate supply from NL onto the EU market. However, by increasing slaughter capacity, NL's slaughterhouses produce more meat than in a disease-free situation. It was expected that the EU's demand for meat will increase during this period. This effect, however, is not further stressed in this chapter, as it is outside the scope of this research.

In general, the surpluses within the diseased region (e.g., in scenario 1) do not always correspond with similar, opposite effects on the EU market because, in the outbreak-free situation, diseased region-animals partly stay within its own region or country.

In Figure 6.3b, the cumulative piglet and slaughter pig surpluses and shortages are presented for an outbreak on the border of NL-LS. Both NL and LS implement regionalisation, resulting in a large diseased region with in-between the NL-LS border. In scenario 3, the diseased region of NL builds up surpluses of 0.89 million piglets and 0.66 million slaughter pigs, NL's free regions have piglet surpluses of 0.21 million animals, whereas region Weserems (LS) has a shortage of 0.53 million piglets even though this region allows transportation of animals within the diseased region. The combined effects of a CSF outbreak on the NL-LS border result in an EU piglet surplus of 0.21 million and a slaughter pig shortage of 0.30 million animals (these numbers exclude the NL and LS surpluses and shortages). LS' free regions have no piglet shortages even though they are net importers of piglets. This is because their contingency plan allows the import of piglets after three days following the initial outbreak. In scenario 4, the effect of a border within the large diseased region of NL-LS was mitigated by allowing transport within the whole diseased region after two weeks following the initial outbreak. Figure 6.3b shows the positive effect of inter-regional trade between a piglet surplus and a piglet shortage area: within six weeks the cumulative surpluses and shortages within diseased and free regions, as well as within the EU are brought back to zero. This shows the potential of and mutual interest in a joint cross-border region without internal borders. This potential, however, highly depends on the production characteristics of a certain region.

Whereas Figures 6.3a-b show the shortages and surpluses of piglets and slaughter pigs for the aggregate EU market, Tables 6.3 and 6.4 present the calculated weekly trade volume changes for specific EU regions, as well as for the outbreak-affected

Table 6.2a Market disturbances for different trade partners within the EU due to a CSF outbreak within region South (NL).

Trade partners	Before outbreak (normal situation)	Outbreak: weeks 0-2[1,2]
NL: net exporting market for piglets and slaughter pigs	All European markets (regions and countries) are related, but not all markets have direct trade relationships (they are in equilibrium)	Due to trade ban and movement restrictions: · large piglet and slaughter pig surpluses
LS: net importing market for piglets / net exporting market for slaughter pigs		Due to NL trade ban: · piglet shortages · decrease in slaughter pig export (no slaughter pig import from NL)
NRW: net importing market for piglets and slaughter pigs		Due to NL trade ban: · piglet and slaughter pig shortages
Other direct trade partners		Due to NL trade ban: · net importing markets: piglet and slaughter pig shortages · net exporting markets: increase in piglet and slaughter pig export
Indirect trade partners		No shock
Third countries		Borders closed for live animals (during whole outbreak)

1 Important assumptions: CSF does not impact demand for piglets and slaughter pigs; the supply of animals is inelastic in the short run.
2 Within the first six weeks following an outbreak, a new trade volume and price equilibrium will be realised; the same holds for the period of weeks 7 until the end of the outbreak.

countries (different effects for the free and diseased regions). The default weekly net imports and aggregate prices of piglets and slaughter pigs within the EU market are presented as well.

Tables 6.3 and 6.4 show that non-affected EU regions with a large demand for piglets or slaughter pigs import or export higher absolute numbers of animals during the shock. This results in, for example, South Europe changing from being a net importer

Outbreak: weeks 3-6[1,2]	Outbreak: weeks 7-end[1,2]
Due to movement restrictions within diseased region: · large piglet and slaughter pig surpluses	Due to lifting movement restrictions within diseased region: · large piglet and slaughter pig surpluses within own country as animals from previously diseased region stay within own country. Piglet and slaughter pig surpluses slowly diminish as it requires time and slaughter capacity to empty slaughter pig places on which piglets can be placed · increased export of piglets and slaughter pigs from free regions to decrease the shortages on the EU market and to lower own surpluses · In case of vaccination: vaccinated animals stay within own country and are consumed within own country; vaccination has no effect on demand but prices for vaccinated animals/products are lower (compared with non-vaccination)
Due to movement restrictions (trade ban) within diseased region NL: · piglet and slaughter pig shortages and increase in corresponding prices · trade volume and price effects level out across the EU market · large variations among individual farms exist (i.e., individual farm ≠ average for the aggregate sector)	Due to lifting movement restrictions within diseased region NL: · increase in import of piglets / slaughter pigs to decrease the shortages on the EU market · Due to the large surpluses within NL, NL's free regions export more piglets than asked for by other EU countries, thereby lowering the EU prices. However, exporting is still beneficial to NL as prices within NL drop to an absolute minimum due to large surpluses. · In case of vaccination within NL: no effect on EU demand or prices (no export of vaccinated animals or products)

(28,000 piglets) to being a net exporter (4,000 piglets) during weeks 0-6 following the initial outbreak within NL (Table 6.3a). It is uncertain and difficult to determine where these piglets will be exported to. Most likely, countries will increase or decrease their exports or imports to direct trade partners and consequently, these partners will do similarly to their trade partners, i.e., the shock will level out across the EU but exact changes in trade flows are hard to determine. Experts expected

Table 6.2b Market disturbances for different trade partners within the EU due to a CSF outbreak within region Weserems (LS).

Trade partners	Before outbreak (normal situation)	Outbreak: weeks 0-2[1,2]
LS: net importing market for piglets / net exporting market for slaughter pigs	All European markets (regions and countries) are related, but not all markets have direct trade relationships (they are in equilibrium)	Due to trade ban for diseased region: · large piglet shortages · slight increase in number of slaughterings to overcome slaughter pig surpluses
NL: net exporting market for piglets and slaughter pigs		Due to trade ban for diseased region LS: · piglet surpluses · slight increase in number of slaughterings to overcome slaughter pig surpluses and export of slaughter pigs to other EU countries instead of LS
NRW: net importing market for piglets and slaughter pigs		Due to trade ban for diseased region LS: · small piglet surpluses · small slaughter pig shortages
Other direct trade partners		Due to trade ban for diseased region LS: · net importing piglet markets: slight decrease in import (piglet shortages) · net exporting piglet markets: increase in export (piglet shortages) · small slaughter pig shortages
Indirect trade partners		No shock
Third countries		Borders closed for live animals (during whole outbreak)

[1] Important assumptions: CSF does not impact demand for piglets and slaughter pigs; the supply of animals is inelastic in the short run.
[2] Within the first six weeks following an outbreak, a new trade volume and price equilibrium will be realised; the same holds for the period of weeks 7 until the end of the outbreak.

existing trade relationships to be extended rather than establishing relationships with new trade partners.

Market disturbances: price changes

Experts considered it not feasible to estimate exact CSF induced price changes – based on the volume figures – because large uncertainty exists regarding the exact trade responses within the affected country as well as on the EU market. In general, price effects were expected to dilute on the EU market because a supply shock only

Outbreak: weeks 3-6[1,2]	Outbreak: weeks 7-end[1,2]
Due to trade ban for diseased region: · large piglet shortages · slight increase in number of slaughterings to overcome slaughter pig surpluses	Due to lifting trade ban for diseased region: · Increased import of piglets
Due to trade ban for diseased region LS: · piglet surpluses · slight increase in number of slaughterings to overcome slaughter pig surpluses and export of slaughter pigs to other EU countries instead of LS	↑
Due to trade ban for diseased region LS: · small piglet surpluses · small slaughter pig shortages	Due to lifting trade ban for diseased region LS: · Increased export of piglets
Due to trade ban for diseased region LS: · net importing piglet markets: slight increase in import (piglet surpluses) · net exporting piglet markets: increase in export (piglet surpluses) · small slaughter pig shortages · trade volume and price effects level out across the EU market	↓

affects a small part of the total EU demand for piglets and slaughter pigs. The outbreak-affected country, however, was assumed to experience large price effects. In Tables 6.3 and 6.4, the larger those prices deviate from the default situation, the more plusses or minuses are given to a certain region. These plusses and minuses are based on the calculated changes in trade volumes. Additionally, the expected risk attitude is incorporated in these price changes.

For example, in Table 6.3a (weeks 0-6, non-vaccination scenario) the price for piglets from free regions within NL is marked as a single '+', even though the demand for

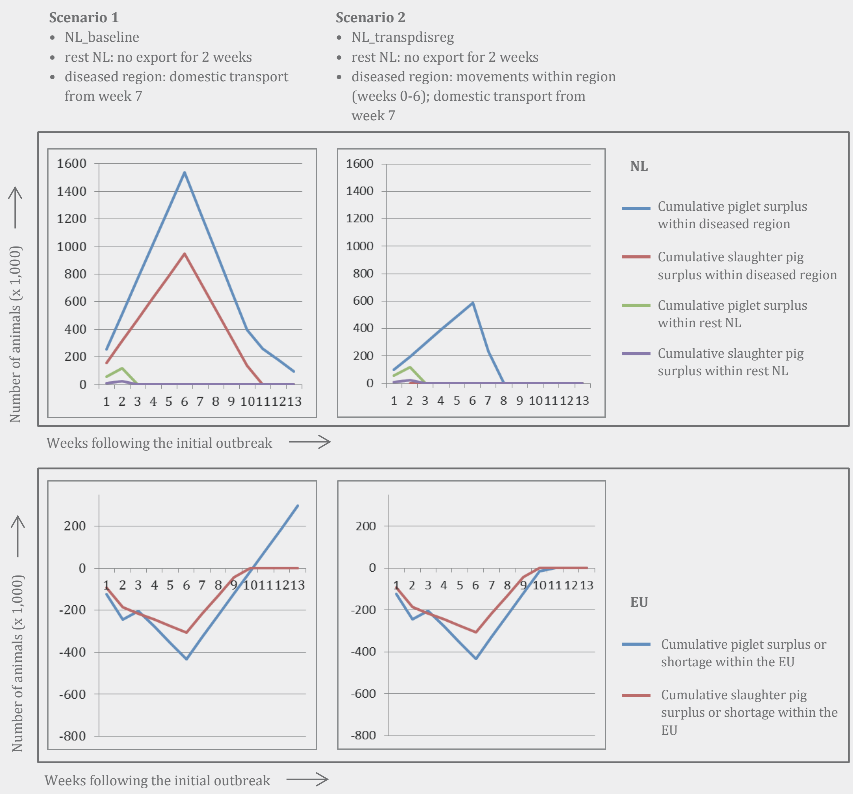


Figure 6.3a Cumulative piglet and slaughter pig surpluses or shortages during a CSF outbreak within NL for various regions and scenarios (number of animals x 1,000).

piglets from other EU countries is high, i.e., other EU countries weekly demand 72,000 piglets (not shown in Table 6.3a) more than can be delivered by NL. However, it was expected that trade partners are cautious to import large numbers of piglets from NL's free regions due to the CSF outbreak, causing a relatively small piglet price increase.

In Table 6.4, the calculated weekly import of piglets and slaughter pig as well as expected price changes are given for a CSF outbreak on the border of NL-LS. The following example illustrates the complexity of such a situation in detail for piglet imports and prices in scenario 3. During weeks 0-6, NL lowers its export from 123,000 (i.e., 94,000 + 29,000; see also the production figures presented in Figure 6.2) to 70,000 piglets. Nevertheless, piglet prices are still lower (sign '-') than during the

Scenario 3

- NL+LS_baseline
- rest NL: no export for 2 weeks
- diseased region NL: domestic transport from week 7
- rest LS: no export for 2 weeks; import allowed (except first 3 days)
- diseased region LS: movements allowed within region (weeks 0-6); export allowed from week 7

Scenario 4

- NL+LS_channelling
- rest NL: no export for 2 weeks
- diseased region NL: channelling allowed with diseased region LS after 2 weeks
- rest LS: no export for 2 weeks; import allowed (except first 3 days)
- diseased region LS: channelling allowed with diseased region NL after 2 weeks

Figure 6.3b Cumulative piglet and slaughter pig surpluses or shortages during a CSF outbreak on the border of NL-LS for various regions and scenarios (number of animals x 1,000).

default situation. The diseased region of LS normally imports 88,000 piglets from other EU countries, however, due to the outbreak it is no longer allowed to export to this region. Therefore, even though NL lowered their piglet export already, they still export more piglets than actually needed within the EU; also other EU countries export more than necessary. This oversupply is graphically presented in Figure 6.3b (scenario 3) where the cumulative EU piglet surplus increases to 212,000 piglets

Table 6.3 Weekly net import of piglets (A) and slaughter pigs (B) within the EU market in a default situation and imports and expected price changes during a CSF outbreak within NL for weeks 0-6 and weeks 7-end following the initial outbreak.

A.

Region	Weekly slaughter pig demand[1]	Weekly net import of piglets[2]										
		Default situation		CSF outbreak								
				Weeks 0-6			Weeks 7-end					
				Scenarios 1-2			Scenario 1			Scenario 2		
	Number[3]	Number[3]	Price[4]	Number[3]	Price[5]		Number[3]	Price[5]		Number[3]	Price[5]	
					NV	V		NV	V		NV	V
NL	361											
• Rest country		-47	46.5	-51	+	-	-227	--	---	-185	+/o	-
• South		-76	46.5	0	x	x	0	---	----	0	-/o	--
NRW	265	27	46.6	22	+	+	34	-	-	31	+	+
LS	378	100	46.8	93	+	+	109	-	-	106	+	+
Rest of Germany	415	39	46.2	32	+	+	49	-	-	45	+	+
Denmark	380	-145	46.7	-152	+	+	-136	-	-	-139	+	+
South Europe	1,838	28	45.5	-4	+	+	74	-	-	55	+	+
East Europe	903	74	45.5	58	+	+	96	-	-	87	+	+

B.

Region	Weekly slaughterings demand[6]	Weekly net import of slaughter pigs[2]										
		Default situation		CSF outbreak								
				Weeks 0-6			Weeks 7-end					
				Scenarios 1-2			Scenario 1			Scenario 2		
	Number[3]	Number[3]	Price[7]	Number[3]	Price[5]		Number[3]	Price[5]		Number[3]	Price[5]	
					NV	V		NV	V		NV	V
NL	265											
• Rest country		-51	1.350	-23	+	-	-118	o	-	-118	o	-
• South		-23	1.350	0	x	x	0	-	--	0	-	--
NRW	384	113	1.353	108	+	+	117	o	o	117	o	o
LS	348	-41	1.353	-45	+	+	-37	o	o	-37	o	o
Rest of Germany	361	2	1.340	-2	+	+	6	o	o	6	o	o
Denmark	366	-14	1.353	-18	+	+	-10	o	o	-10	o	o
South Europe	1,825	-13	1.310	-35	+	+	6	o	o	6	o	o
East Europe	930	27	1.310	16	+	+	37	o	o	37	o	o

1 Slaughter pig demand = piglet production – piglet export + piglet import.
2 A negative number for net import means export.
3 Number of animals (x 1,000).
4 The average price (€, excluding VAT) for piglets of 25 kg going to or coming from the regions as mentioned in the table.
5 Price for non-vaccinated (NV) and vaccinated (V) animals. Prices are presented as higher (+), lower (-) or indifferent (o) compared with the default situation or prices are not determined (x).
6 Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import.
7 The average price (€,excluding VAT) per kg (slaughter weight) going to or coming from the regions as mentioned in the table.

Table 6.4 Weekly net import of piglets (A) and slaughter pigs (B) within the EU market in a default situation and imports and expected price changes during a CSF outbreak on the border of NL-LS for weeks 0-6 and weeks 7-end following the initial outbreak.

A.

Region	Weekly slaughter pig demand[1]	Weekly net import of piglets[2]									
		Default situation		CSF outbreak							
				Weeks 0-6				Weeks 7-end			
				Scenario 3		Scenario 4		Scenario 3		Scenario 4	
	Number[3]	Number[3]	Price[4]	Number[3]	Price[5]	Number[3]	Price[5]	Number[3]	Price[5]	Number[3]	Price[5]
NL	361										
• Rest country		-94	46.5	-70	-	-94	o	-153	o	-94	o
• East		-29	46.5	0	x	-29	x/o	0	o	-29	o
NRW	265	27	46.6	29	-	27	o	29	o	27	o
LS	378					100	o			100	o
• Rest country		12	46.8	12	o			175	o		
• Weserems		88	46.8	0	+++			0	o		
Rest of Germany	415	39	46.2	43	-	39	o	42	o	39	o
Denmark	380	-145	46.7	-141	-	-145	o	-142	o	-145	o
South Europe	1,838	28	45.5	45	-	28	o	42	o	28	o
East Europe	903	74	45.5	82	-	74	o	81	o	74	o

B.

Region	Weekly slaughterings demand[6]	Weekly net import of slaughter pigs[2]									
		Default situation		CSF outbreak							
				Weeks 0-6				Weeks 7-end			
				Scenario 3		Scenario 4		Scenario 3		Scenario 4	
	Number[3]	Number[3]	Price[4]	Number[3]	Price[5]	Number[3]	Price[5]	Number[3]	Price[5]	Number[3]	Price[5]
NL	265										
• Rest country		-28	1.350	-23	+	-28	o	-117	o	-28	o
• East		-46	1.350	0	x	-46	x/o	0	o	-46	o
NRW	384	113	1.353	108	+	113	o	117	o	113	o
LS	348	-41	1.353			-41	o			-41	o
• Rest country				-45	+			-37	o		
• Weserems				0	-			0	o		
Rest of Germany	361	2	1.340	-2	+	2	o	6	o	2	o
Denmark	366	-14	1.353	-18	+	-14	o	-10	o	-14	o
South Europe	1,825	-13	1.310	-35	+	-13	o	6	o	-13	o
East Europe	930	27	1.310	16	+	27	o	37	o	27	o

1 Slaughter pig demand = piglet production – piglet export + piglet import.
2 A negative number for net import means export.
3 Number of animals (x 1,000).
4 The average price (€,excluding VAT) for piglets of 25 kg going to or coming from the regions as mentioned in the table.
5 No difference between non-vaccinated and vaccinated slaughter pigs. Prices are presented as higher (+), lower (-) or indifferent (o) compared with the default situation or prices are not determined (x).
6 Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import.
7 The average price (€,excluding VAT) per kg (slaughter weight) going to or coming from the regions as mentioned in the table.

(weeks 0-6), corresponding with a weekly piglet surplus of 35,000. Within the diseased region East (NL), due to the transport ban there is no piglet or slaughter pig market or corresponding prices in weeks 0-6 (sign 'x'). For the diseased region Weserems (LS) during that same period, even with the allowance of within-diseased region movements, a cumulative shortage of 528,000 piglets (graph scenario 3 in Figure 6.3b) occurs. Therefore, piglet prices within this diseased region increase tremendously (sign '+++') due to a high demand for piglets: i.e., the region's piglet-slaughter pig production is very unbalanced.
The assumption that the use of vaccination to control CSF does not impact trade volumes but lowers the prices within the affected country during the outbreak was illustrated in Tables 6.3a and 6.3b. It was expected that, during the outbreak, trade partners perceive the existence of the sub-market of vaccinated animals as risky and for that reason, trade partners are expected to pay less for the affected country's non-vaccinated animals. Tables 6.3a and 6.3b show this for NL's free regions where changing from a depopulation to a vaccination strategy results in an expected price change from, for example, "+" to "-" in weeks 0-6 (for piglets and slaughter pigs). In LS (scenarios 3 and 4), applying C-strain vaccination results in the culling and destructing of vaccinated animals. This means that no sub-market of vaccinated animals exists and therefore, no price effects due to vaccination in LS were expected.

Discussion

This chapter aimed at (i) obtaining insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation, vaccination, and regional specialisation of pig production, and (ii) assessing the potential for mitigating these market disruptions in a cross-border context.

Results

This chapter showed that changes in NL-NRW-LS' veterinary contingency plans and regional specialisation result in a new market situation in case of a CSF outbreak. As a result, multiple, temporary shocks on multiple sub-markets at several moments in time occur during a CSF outbreak. Such market turbulence differs from CSF outbreaks analysed in the past. As described in Mangen and Burrell (2003), one large shock (i.e., piglet shortages) occurred during the epidemic, resulting in welfare losses for both producers and consumers in case of a trade ban. This chapter shows that a CSF outbreak nowadays results in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak. That is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions. Past studies (Mangen and Burrell, 2001; 2003) show that unaffected regions benefited from higher prices due to piglets shortages; these unilateral effects are not likely to happen in future outbreaks due to multiple, temporary market shocks (sub-markets). This chapter also shows that the magnitude of these shocks is highly region-specific, i.e., it depends on the export or import orientation, the (im)balance in the production of piglets and slaughter pigs, and the farm density. Additionally, the occurrence of pig shortages and surpluses depends on the implemented disease control measures and the response of trade partners as well: the size and direction of volume changes and price effects differ across sub-markets. The rationale for *regionalisation* is based on principles of quick recovery of export from the affected country's free regions, i.e., it provides trade partners warranties to guarantee safe trade. These ideas were incorporated in the epidemiological scenarios examined in this chapter. The CSF outbreak in 1997-98 caused the slaughtering of approximately 10 million pigs for welfare reasons (Pluimers *et al.*, 1999). Afterwards, it was decided to introduce the concept of regionalisation into current contingency plans to better control future outbreaks. This chapter, however, shows that regionalisation leads to the following trade-off. On the one hand, it leads to a quicker lifting of trade bans for free regions within an affected country due to providing trade partners warranties to guarantee safe trade. However, the trade partners' willingness to accept these trade warranties is uncertain and depends on the outbreak situation. On the other hand, as Modisane (2009) already pointed out, disease control measures often cause unintended side effects: regionalisation leads to large surpluses of overweighed, over-aged and, possibly, unmarketable pigs in export-oriented diseased regions and, consequently, overcrowded farms. The impact of the existence of pools of overweighed, over-aged and unmarketable animals is also underlined by Bosman *et al.* (2013), although for smaller movement restriction areas (MRZ) and resulting from a different contagious disease (Aujeszky's Disease). This could imply that welfare slaughter will again be inevitable in future CSF outbreaks, although for different reasons. Veterinary policy makers are therefore advised to reconsider the current outline of regionalisation, especially regarding the size and duration of the diseased region in relation to the production figures of the proposed region. This recommendation is underlined by the outcomes of the different epidemiological scenarios as discussed with the expert panel. The different scenario outcomes illustrate that altering the duration and strictness of movement restrictions within diseased regions, and channelling trade flows within a cross-border context reduce the extent of animal surpluses and shortages and, consequently, reduce the magnitude of price effects. The effectiveness of channelling has also been shown by Bosman *et al.* (2013). Mitigating CSF market effects is therefore considered worthwhile.

Regarding the *vaccination*'s market impact during a CSF outbreak, the trade partners' perception mainly determines the additional impact and in that respect, large uncertainty exists. As said, during an epidemic the movement of vaccinated animals is prohibited. However, the existence of the sub-market of vaccinated animals could be perceived as risky by trade partners (Boklund *et al.*, 2009). Hop *et al.* (in press, b) showed that control strategies based on either depopulation or vaccination result in similar simulated outbreak sizes and durations, as well as similar associated direct costs and direct consequential costs. Thus, choosing between a depopulation or vaccination strategy requires a trade-off between either a larger number of culled animals or a larger magnitude of market effects, respectively. Although a depopulation strategy results in the largest number of culled animals, a vaccination strategy only reduces this by one-third (Hop *et al.*, in press, b). Regarding the vaccination's market effects, uncertainty exists regarding the trade responses by primary producers, retail and consumers within the affected country, EU countries and 3rd (non-EU) countries. If farmers expect that vaccination may result in larger losses, they may try to prevent veterinarians from vaccinating their animals which could worsen the epidemic (van Asseldonk *et al.*, 2005). Retailers depend on consumer responses but may influence these by offering meat from vaccinated animals at a lower price. Elucidating the uncertainty around the acceptance of vaccinated animals, primarily by retailers, and possible compensation for primary producers is therefore recommended. Besides, to alleviate any potential demand shocks in response to vaccination, collective producers' voluntary restriction of products from vaccinated pigs to either the domestic or processed markets was proposed as a potential policy tool (Longworth *et al.*, forthcoming).

Experts expected that piglet producers most likely bear the highest losses due to market disturbances. Within the pig value chain, slaughterhouses determine prices for slaughter pigs based on consumer demand and their slaughter capacity. If fattening farmers expect slaughter pig prices to be low within 120 days from now (that is, at the end of the slaughter pig production cycle), they either do not buy piglets or wait for 1-2 weeks, or they buy now at lower prices. In both cases, piglet producers lose due to the slaughterhouses' and fattening farmers' market power, as the latter two parties can choose what and when to buy at what price. Piglet producers have no choice but to sell at any price; after all, piglet producers simply cannot stop the production. Additionally, experts expected that piglet surpluses cause larger price effects than the same shortages. Fattening farmers and slaughterhouses can wait until prices are lower, whereas for surpluses, farrowing farmers need to get rid of their ready-to-deliver animals at any price because these animals reach a certain weight or age and a prolonged stay at the farm could result in unmarketable piglets, and the available number of pig places is limited as well. To some extent, the opportunity exists to slaughter weaned piglets. However, the slaughter and processing capacity, as well as the demand for such products is assumed to be limited.

Approach

Changes in trade volumes and corresponding prices were explored by means of expert workshops and spread-sheet models. This chapter provided semi-quantitative insights into CSF induced market disturbances rather than the exact size of the effects. In that respect, consensus among the experts was reached on several assumptions and expectations that influence the market effects, as well as on the approximate size and direction of volume and price changes. The experts' most crucial assumption implies that shocks level out across the EU market, affecting both direct and indirect trade partners. As most studies analyse CSF induced market shocks at country level, it was not possible to verify this assumption. Similarly, the assumptions of inelastic short-run supply and unchanged demand determine the size and direction of volume and price changes as well. The assumption of inelastic short-run supply within the affected country as well as the EU is supported by biological constraints and addressed by many studies (see, e.g., Berentsen *et al.*, 1992a; 1992b; Mangen *et al.*, 2004; Niemi *et al.*, 2006; 2008; Boklund *et al.*, 2009). However, during an outbreak the opportunity exists to slaughter weaned piglets, or to slaughter finishing pigs at a lower slaughter weight to create empty slaughter pig places, which could change the total supply. This chapter did not take account of these options, although this might happen to some extent. The assumption of unchanged demand is based on studies by Mangen and Burrell (2001; 2003) but is controversial. There is little empirical evidence with respect to the consumers' perceptions for vaccinated products (see, e.g., Scudamore, 2007). As pointed out by Schoenbaum and Disney (2003) and Boklund *et al.* (2009), potential demand shocks in response to vaccination are unpredictable. If the experts' assumption of unchanged demand fails in a real CSF outbreak, the described volume and price changes may alter, resulting in even more complexity.

This chapter used a semi-quantitative approach to obtain insights into CSF induced market disturbances. The insights presented in this chapter could provide a basis for modelling CSF shocks in, for example, a partial equilibrium model, and could be used for calculating exact impacts of CSF outbreaks on producer and consumer surpluses. However, the added value of modelling exact changes over obtaining market insights as presented in this chapter can be questioned. Both in semi-quantitative and quantitative approaches, uncertainty regarding trade partners' responses could dominate the actual trade changes which is difficult to incorporate in both approaches. Modelling exact market effects could even create a false sense of security in the modelled results. Our approach clearly indicate the large impact of multiple, temporary market shocks due to an outbreak of CSF, e.g., large volume and price changes due to animal surpluses and shortages at different stages of the outbreak, differences among veterinary control scenarios, and the effects for various (in)direct trade partners. The added value of knowing the exact trade volumes and prices is therefore assumed to be low.

The semi-quantitative approach employed in this chapter provided valuable insights for veterinary policy makers that can be used for managing future outbreaks. During the first days of an outbreak, after having obtained the insights into the expected course of the outbreak, our approach could create awareness of the proposed disease control's market impacts. Decision makers could incorporate these insights into their tactical disease control. In case control measures have similar epidemiological impact, market effects should be incorporated in decision making, especially because these effects largely outweigh the costs that directly result from disease control (Saatkamp *et al.*, 2000; Boklund *et al.*, 2009).

The approach used in this chapter can be applied for analysing the impacts of other contagious livestock diseases in which supply shocks occur to the market. Results are conditional on the Dutch and German pig production sectors' characteristics and their control strategies, but they provide a point of reference for countries with similar conditions.

Conclusion

This chapter showed that changes in NL-NRW-LS' veterinary contingency plans and regional specialisation result in a new market situation in case of a CSF outbreak. Consequently, a CSF outbreak nowadays would result in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak. That is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions. These trade bans and movement restrictions mainly result from regionalisation. Ways to mitigate the size and duration of market shocks include altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context.

The vaccination's market impact was expected to be subject to uncertainty due to trade partners' perception and, consequently, unpredictable trade responses. Elucidating the uncertainty around the acceptance of vaccinated animals, primarily by retailers, and possible compensation for primary producers was recommended. To alleviate any potential demand shocks in response to vaccination, collective producers' voluntary restriction of products from vaccinated pigs to either the domestic or processed markets was proposed as a potential policy tool.

It was concluded that – during a future CSF outbreak – veterinary policy makers are advised to follow a similar approach to obtain insights into CSF induced market disturbances and incorporate these insights into their tactical disease control. In case control measures have similar epidemiological impact, market effects should be incorporated in decision making, especially because these effects largely outweigh the costs that directly result from disease control.

Acknowledgements

The authors gratefully acknowledge the experts for their participation in the workshops, and the data and feedback provided by e-mail.
This study is part of project SafeGuard, which is financed within the INTERREG IV A programme Deutschland-Nederland by the European Regional Development Fund.

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7

General discussion

G.E. Hop

Introduction

The cross-border region of the Netherlands (NL) and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS) is a large and highly integrated livestock production area. This region increasingly develops towards a single epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk. Policy makers recognise this problem and are aware of the need to structurally improve cross-border collaboration in contagious livestock disease management (MUNLV, 2007; Breuer *et al.*, 2008). This dissertation, therefore, aimed at examining the potential gains and main challenges for a more intensive cross-border collaboration. The dissertation's underlying assertion was that further cross-border collaboration can mitigate the veterinary and, especially, the economic impacts of existing (in peacetime) and emerging (during crisis situations) borders between NL and NRW–LS, without compromising the economic advantages of cross-border trade and without increasing veterinary risk.

As described in Chapter 1, the overall objective was split into five sub objectives, which were studied in chapters 2-6. Chapter 2 presented a conceptual framework of the potential gains and main challenges for further cross-border collaboration in the control of highly contagious livestock diseases within the cross-border region of NL–NRW–LS. In this chapter, possibilities for future policy making in contagious livestock disease management were discussed: peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade (elaborated in chapter 4), and crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences (elaborated in chapters 5 and 6 for classical swine fever (CSF)). In addition, chapter 2 addressed the need for a good understanding of future developments in those features of the livestock production structure that influence the risks of disease introduction, notification and eradication. Changes in these risks can affect the consequences of strategies and the routine veterinary and disease control measures needed to regulate contagious livestock diseases. Adjusting current legislation according to the changes in risks requires a large effort and several years, i.e., changing current legislation is laborious. The livestock production structure has proven to rapidly change in the past decades and is expected to change in the next decade (EC, 2010). Therefore, it is worthwhile to take into account the implications of these changes on the potential of mitigating the veterinary and economic impacts of existing (peacetime) and emerging (crisis situations) borders between NL and NRW–LS. Therefore, chapter 3 explored changes in future production structure features within the cross-border region of NL, NRW and LS projected towards 2020. Additionally, the findings of this chapter were elaborated in terms of possible implications for contagious livestock disease introduction, spread and control. Chapter 4 hypothesised that relaxing additional cross-border measures may be well-justified from a veterinary perspective, i.e., without increasing veterinary risks, and can generate cost savings, especially for neighbouring countries with similar veterinary status that are characterised by large cross-border trade. The objective of this chapter was to examine the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL–NRW–LS. Chapter 5 examined CSF control strategies' veterinary and direct economic impacts for the NL-NRW-LS region given the current production structure, and analysed CSF's cross-border spread causes and impacts within the NL-NRW-LS region. Chapter 6 obtained insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation (dividing the country into a diseased region with and free regions without movement and trade restrictions), vaccination, and regional specialisation of pig production, and assessed the potential for mitigating these market disruptions in a cross-border context.

This concluding chapter synthesises the results of the different chapters, elaborates the implications for future research, discusses the (im)possibilities and further action needed to implement the proposed cross-border collaboration opportunities from chapters 2-6 into national and EU legislation, reflects on the applied research approach and methods, and ends with a summary of this dissertation's main conclusions.

Synthesis

This dissertation's underlying assertion was that further cross-border collaboration can mitigate the veterinary and, especially, the economic impacts of existing (in peacetime) and emerging (during crisis situations) borders between NL and NRW–LS. The evidence found in this dissertation that supports this assertion is summarised as follows. Chapter 2 identified several possibilities for further peacetime and crisis cross-border collaboration, as well as for harmonisation of current contagious livestock disease control strategies. Chapter 4 supported the dissertation's underlying assertion for the peacetime situation. Chapter 5, however, partly supported this assertion because, in terms of mitigating the *veterinary impact* of CSF (chapter 5), only limited possibilities for further harmonisation and collaboration were found, mainly due to changes in the production structure of livestock. Both chapters 5 and 6 showed that there is still a substantial scope for mitigating the *economic impact* through further cross-border collaboration. This synthesis' next sections elaborate the evidence for this message from the various chapters.

Peacetime: mitigating the economic impact of existing borders

The findings of chapter 4 on the peacetime harmonisation of additional, veterinary cross-border measures showed that several measures related to trade in slaughter animals (dead-end hosts), such as veterinary checks on both sides of the border, do not contribute to preventing contagious livestock diseases. This chapter showed the need for an across-sectors, across-countries discussion on the necessity of additional cross-border measures, as it is pointless to negotiate about possibilities for relaxing veterinary measures that would only benefit one country. For example, minimising the effect of measures taken for cross-border trade in slaughter pigs is beneficial to the Dutch fattening pig sector. In turn, minimising slaughter broilers-related measures is beneficial to the German poultry sector. Across-sectors, across-countries negotiations are thus needed (chapter 4).

Due to the further harmonisation of EU countries' high veterinary status (Brückner, 2011), veterinary policy makers need to shift their attention. A shift is needed from additional, veterinary cross-border measures that may not contribute to further preventing within-EU spread of contagious livestock diseases, towards measures that prevent the veterinary risks posed by the ongoing enlargement of the EU (Anonymous, 2013) to ensure the current EU countries' high biosecurity levels. Nigsch *et al.* (2013) underline this and discuss that, since the introduction of African swine fever into Georgia in 2007 from Africa, African swine fever has spread to several regions close to the EU's external border with cases reported in Russia, Armenia and Azerbaijan, increasingly posing veterinary risks (OIE, 2012).

Chapter 4 also underlined the usefulness of accounting for the expected changes in the future livestock production structure (chapter 3) and provided insights for future decision making. Incorporating expected developments in the total number of cross-border transports and the total number of animals transported across the border (derived from chapter 3) hardly changed the expected cost saving possibilities (chapter 4), which is positive, as it is laborious to change current legislation on routine veterinary measures. If certain sectors decrease cross-border transports over the coming years, hard-won relaxation of measures could result in much lower cost savings than originally expected. Contrarily, increasing numbers of cross-border transports could potentially result in larger cost savings but also in faster spread of contagious livestock diseases, assuming that countries' veterinary status remain at current levels. Therefore, decision makers need to be sure that relaxing certain routine veterinary measures does not increase veterinary risks. After all, the costs of an outbreak are considerably higher than possible savings due to relaxing additional cross-border measures (chapters 4 and 5).

Crisis situations: mitigating the veterinary impact and the effect of changes in the livestock production structure

Although chapter 4 supported the dissertation's underlying assertion, chapter 5 only partly supported this assertion because, in terms of mitigating the *veterinary impact* of CSF (chapter 5), only limited possibilities for further harmonisation and collaboration were found. This is surprising because it was expected that current CSF outbreaks require, for example, additional depopulation and vaccination resources to adequately control the epidemic. Chapters 2 and 3 were written with the previous studies on the Dutch CSF outbreak in 1997-98 in mind, during which the depopulation capacity was insufficient and during which approximately 10 million pigs were culled for welfare reasons (Pluimers *et al.*, 1999; Mangen *et al.*, 2002). Even though chapter 3 showed large changes in the livestock production structure, it still concluded that concentration of farms in certain areas may leave an eradication strategy based on depopulation rather than vaccination as the only option. In chapter 3's discussion-section, it was expected that contagious livestock diseases spread faster than the speed at which animals develop adaptive immunity by applying vaccination. Chapter 5 showed that, in case of CSF, this is most likely incorrect: control strategies based on depopulation or vaccination resulted in similar courses of the outbreak. This is caused by the changes in the livestock production structure and resulted in surprisingly small simulated outbreaks. Changes in the livestock production structure caused a steady decrease in the pig farm density (see Box 7.1)

Box 7.1 Changes in the livestock production structure.

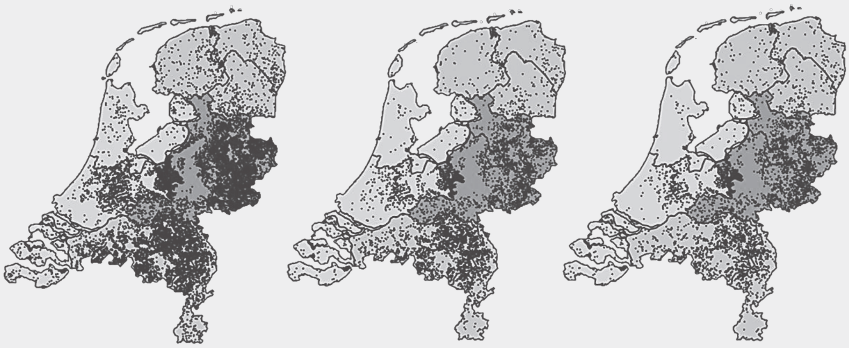
Changes in the livestock production structure (chapter 3) caused a steady decrease in the pig farm density, especially within NL (chapter 5). In 10 years' time, the number of NL pig farms and NL pig farm density have decreased by 43% and 49%, respectively (chapter 5). Due to this decrease in NL farm density, the absolute number of livestock transports has decreased from 137,466 in 2001 to 80,750 in 2010. However, the average number of transports per farm per year has only decreased from 9.64 to 9.35 (derived from Dutch I&R data). More importantly, the average number of off-farm movements within densely populated livestock areas (DPLA) during the outbreak's high risk period (HRP) has decreased considerably: within DPLAs (~95th percentile), these movements have decreased from 748 to 543 transports from the 10 km zone (derived from Dutch I&R data). These changes in the pig production structure have resulted in a change in the strength of 'spread driving forces', that is, fewer spread possibilities within close proximity of the index farm resulting in a substantial decrease in the simulated number of infected farms. Regarding the NRW and LS pig production structure, similar trends in terms of decreased numbers of farms and decreased pig farm densities were seen (chapter 3) but comparisons with past farm densities cannot be made due to lack of detailed data.

and a further reduction in the number of farms was expected for the year 2020 (chapter 3). Additionally, further increases in farm sizes were expected in chapter 3. Regarding the decreasing number of farms, Dutch pig farm densities for the years 1997 (CSF outbreak), 2010 (chapter 5) and the expected density for the year 2020 (chapter 3) are presented in Figure 7.1. This overview visualises the large decrease in number of farms, especially for the period 1997-2010. The decrease in farm density from 2010 towards 2020 is expected to be considerably smaller. The impact of farm density on the size and duration of CSF outbreaks was shown in chapter 5, in which the 1997-98 outbreak and the simulated 2010-outbreaks were discussed. The impact of a further decrease in farm density on the size and duration of CSF outbreaks was simulated for the year 2020 and was seen to be smaller, even though simulated outbreak sizes and durations decreased (results not presented). Also sensitivity analyses (results not presented) showed that an increase in farm density results in relatively larger epidemiological impacts compared with the same decrease in farm density. Interspread Plus (ISP) model validation results (results not presented) with the 2001-farm structure underline these findings: considerably larger outbreaks were found.

These findings, as well as those presented in chapter 5, show that the livestock production structure is an important determinant of the course of an outbreak. Veterinary policy makers should monitor and incorporate structural changes in their future contingency planning, rather than further fine-tuning veterinary measures that are anchored on past experiences. Contrary to the past, there seems to be no further need for more or improved veterinary measures to *control* CSF. The concepts of vaccination and regionalisation (chapter 6) need reconsidering for *economic* reasons. Of course, this conclusion is limited to CSF: for other contagious livestock diseases that involve high farm densities, like foot-and-mouth disease (FMD), improvements in current veterinary disease control, for example in depopulation and vaccination resources, might be needed. Therefore, obtaining insights into contagious livestock disease management in peacetime by veterinary policy makers is considered important, especially because time is limited in case of an outbreak.

Crisis situations: mitigating the economic impact

Contrary to the veterinary impact, there is substantial scope for mitigating the *economic impact* through further cross-border collaboration (chapters 5 and 6). Chapter 5 showed that, although there are limited possibilities for further harmonisation of, and collaboration in current CSF control strategies to *mitigate direct costs*, the shared organisation in case of a CSF outbreak in both NL and Germany (GER) could generate the largest cost savings. After all, direct costs are mainly determined by organisation costs (chapter 5). Chapter 6 showed that CSF



A. 1997 **B.** 2010 **C.** 2020 (expected)

Figure 7.1 Overview of Dutch pig farm densities for the years 1997 and 2010, and expected pig farm density for the year 2020.

induced *market distortions can be mitigated* through the channelling of trade flows within a cross-border context. This reduces the animal surpluses and shortages and, consequently, reduces the price effects. The effectiveness of channelling was confirmed by the study of Bosman *et al.* (2013).

Chapter 6 underlined the statement of Modisane (2009): disease control measures often cause unintended effects. The chapter showed that a disease control strategy based on *depopulation or vaccination*, as well as *implementing regionalisation* lead to trade-offs: A disease control strategy based on either *depopulation or vaccination* leads to the trade-off between higher numbers of culled animals or risking larger market effects, respectively. *Regionalisation* leads to the trade-off between a potentially quick recovery of export from the affected country's free regions or large animal surpluses and shortages due to movement restrictions. Large surpluses of overweight, overage and, perhaps, unmarketable animals in diseased regions will inevitably result in the precautionary slaughtering of healthy animals for welfare reasons. Reconsidering the duration and strictness of movement restrictions within diseased regions as well as their size was, therefore, recommended, particularly due to the ongoing specialisation and integration of the Dutch and German pig production (chapter 3).

However, chapter 5 showed that 'vaccination vs. depopulation' and 'regionalisation vs. no regionalisation' hardly affected the course of an outbreak, even in the event of a worst-case outbreak within a DPLA (i.e., index farm NL1 as described in chapter 5) and even for the corresponding 95th percentile. Thoroughly reconsidering the need for vaccination and regionalisation in current veterinary contingency plans *given the current livestock production structure* is therefore recommended. As shown in chapter 6, reconsidering the concepts of regionalisation and vaccination could smoothen out supply shocks during a CSF epidemic, resulting in lower economic impacts. Additionally, elucidating the uncertainty around the acceptance of vaccinated animals, primarily by retailers, and possible compensation for primary producers whose animals were vaccinated during the epidemic was recommended. To alleviate any potential demand shocks in response to vaccination, collective producers' voluntary restriction of products from vaccinated pigs to either the domestic or processed markets was proposed as a potential policy tool.

Implications for future research

Although this dissertation has partly disregarded the impact of farm size, future research on contagious livestock disease management should incorporate the effect of increasing farm sizes (chapter 3). For instance, large herds maintain a higher level of bio-security than small herds (Boklund, 2008; Ribbens *et al.*, 2008), which may result in less contagious livestock disease introduction and spread possibilities. However, large herds are also likely to have a higher *frequency* of contacts (movements and professional contacts), whereas the *total number* of contact farms is restricted. The combined effect on contagious livestock disease introduction, spread and corresponding economic consequences is therefore uncertain and needs to be studied in future research. Additionally, large farms nowadays are heavily financed (LEI, 2013) and highly specialised, making them more vulnerable to disruptions in production, e.g., because of contagious livestock disease outbreaks and market distortions resulting from trade restrictions. Future research should account for that as well. Such research can benefit veterinary policy makers through creating awareness regarding the impact of specific control measures, for example, long-lasting movement restrictions could disrupt large farms' production in such a way that these farms could eventually go bankrupt.

Particularly due to the ongoing specialisation and integration of the Dutch and German pig production (chapter 3), reconsidering the duration and strictness of movement restrictions within diseased regions as well as these regions' size was recommended. Regarding the duration of movement restrictions within diseased regions, this should depend on the expected disease risk posed by farms within specific radii of detected farms. Within diseased regions, farms closely located to regions' borders (i.e., the farthest away from the detected farm(s)) pose the lowest veterinary risk. Additionally, most farms are located in the outer part of diseased regions, that is, the inner part of a diseased region contains a very small number of farms compared with the outer part of the region. In that respect, gradually lifting movement restrictions from the outer to the inner part of the diseased region can generate the largest cost savings at the lowest veterinary risk (Saatkamp *et al.*, 1997; Bosman *et al.*, 2013). This gradual lifting of restrictions is already partly addressed by current contingency plans. However, future research could support veterinary policy makers by determining optimal durations of movement restrictions within, and sizes of, diseased regions based on expected disease risk and regional production structure figures (i.e., the total regional piglet and slaughter pig production and the balance between these two). Future research can enrich the ISP model (chapter 5) by including ranges of movement restrictions' durations within, and sizes of, diseased regions, and can use these outcomes to more precisely determine the corresponding market effects (chapter 6).

Within this dissertation, the prime focus was on cross-border collaboration prospects for primary producers (except for chapter 3). This could be extended by including prospects for up- and downstream value chain stakeholders, such as the meat processing industry, and allied industries, such as veterinarians and the feed industry. As stressed by Pritchett *et al.* (2005), contagious livestock diseases are not only a threat to the primary producers but affect the entire value chain as well as the broader economy. Future research could benefit from including all the value chain's stakeholders: this could unravel currently unidentified prospects for further cross-border collaboration, giving policy makers additional incentives to concentrate on the mitigation of the veterinary and economic impacts of existing borders.

Regarding CSF, chapters 5 and 6 showed that the epidemiological impact is relatively small compared with previous outbreaks (Mangen *et al.*, 2002), whereas economic consequences are major. These chapters also showed that there is especially room for mitigating the economic impact of CSF rather than mitigating the veterinary impact. This development asks for a further transition towards a multidisciplinary integration in which economics plays a central role to support decision making in animal health (Gibbens, 2013; Antón *et al.*, 2013). This is in line with Howe *et al.* (2013)'s statement: *"Animal disease is an economic problem with veterinary implications, not a veterinary problem with economic implications"*. Including further insights into the economic consequences enhances *"…making rational choices/ decisions in the allocation of scarce resources for the achievement of competing goals"* (Rushton, 2009).

The 1997-98 CSF outbreak evoked large public resistance against the culling of millions of healthy animals. Future research can benefit from including current consumer preferences with respect to the discussion 'vaccination vs. depopulation'. Analysing the effect of a CSF outbreak nowadays (i.e., small simulated outbreaks and corresponding small number of animals that needs to be culled) on consumer preferences could create public awareness. Awareness can potentially reduce consumers' resistance regarding a disease control strategy based on depopulation, especially because vaccination's intended effects are surrounded by uncertainty (chapter 5).

Lastly, this dissertation only partly discussed the importance of improving cross-border information exchange. Further research can benefit from obtaining insight into the potential quantitative gains of improving information exchange, such as cross-border communication and data exchange.

From research to implementation

Background

This dissertation studied a variety of cross-border collaboration options to mitigate the veterinary and economic impacts of existing (in peacetime) and emerging (during crisis situations) borders. As discussed in chapter 2, future contagious livestock disease management should consider three important aspects: (i) the economic consequences and the distribution of costs and potential cost shifts over stakeholders and regions, (ii) the legal settings, i.e., the national, EU and international legislation, and (iii) the practical aspects, i.e., the potential of implementation and its possible problems. So far, the latter two aspects were (partly) omitted from research. This section, therefore, discusses the (im)possibilities of implementing the proposed cross-border collaboration opportunities from chapters 2-6 into national and EU legislation. However, the policy-making process includes several steps in between the conduction of research and the actual implementation phase.

Policy making is a negotiated and complex process (Mitton *et al.*, 2007; Nutley *et al.*, 2007; Greenhalgh and Russell, 2009). Rajić and Young (2013) argued that multiple and competing forces need to be considered, such as research knowledge and stakeholder views and experiences. The policy-making process was visualised by Rajić *et al.* (2013); an extended version is presented in Figure 7.2.

The World Health Organisation (WHO, 2004) and Graham *et al.* (2006) discussed that, in general, research knowledge is underutilised in policy making. To enhance the influence of research knowledge in policy making, Figure 7.2 illustrates that a favourable political climate and ongoing researcher and policy-maker interactions are important factors. Research knowledge can compete with or complement internal (e.g., values and habits) and external (e.g., lobbyists, stakeholders) influences in the policy-making process (Figure 7.2). Following an outbreak of a contagious livestock disease, for example, a window for policy change often occurs due to public pressure and political will (Rajić and Young, 2013) which not necessarily reflects the evidence-based research view. It is therefore important to continuously provide research knowledge, even – or, perhaps, especially – in peacetime when an obvious policy windows is lacking, because it can affect policy makers' understanding and viewpoints (Lavis *et al.*, 2005; Mitton *et al.*, 2007); additionally, it can affect the internal and external influences by creating awareness (Figure 7.2). Good examples that demonstrate the need for creating more awareness were mentioned in chapter 6, including the trade-offs with respect to regionalisation and with respect to vaccination.

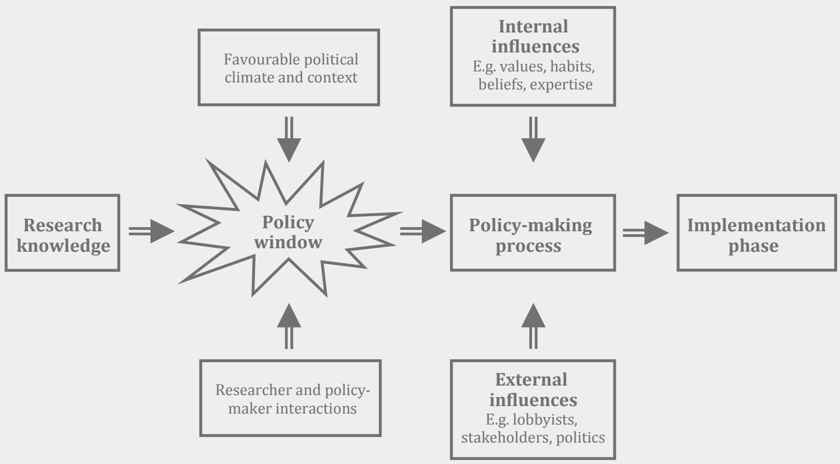


Figure 7.2 Overview of the policy-making process (adapted from Rajić *et al.*, 2013).

An interactive workshop to enhance valorisation of research outcomes

To discuss the (im)possibilities of implementing the proposed cross-border collaboration opportunities from chapters 2-6 into national and EU legislation, an interactive workshop was organised (December 2013) in which sector representatives and veterinary policy makers from NL, GER and the European Commission (EC) discussed the proposed gains and challenges. In total, six sector representatives, five veterinary policy makers (national and EC) and three researchers joined the workshop. To structure the discussion, the sector, national policy and EC's viewpoints were individually requested on three distinct issues: additional, veterinary cross-border measures, CSF control strategies, and CSF market disturbances. Per issue, sector representatives were asked first whether the proposed gains and challenges matched their demands and were asked for additional options. Next, national and EC policy makers were asked for (im)possibilities regarding implementation, their willingness to facilitate, the implementation level at which this should be arranged, as well as the broader EU context (for example, exemptions for the region NL-NRW-LS might result in unfair competition).

Table 7.3 presents an overview of the potential gains and challenges in peacetime and crisis situations derived from chapters 2-6 at different implementation levels. That means, these gains and challenges are ordered at the level at which changes are potentially required, i.e., at single country, bilateral or EU level. The table shows that most gains and challenges need to be arranged at EU level.

Workshop findings

During the workshop, it was concluded that existing (in peacetime) and emerging (during crisis situations) borders continue to exist. Borders exist based on cultural, historical and linguistic grounds and, despite the establishment of the EU single market, contagious livestock disease management remains a 'single country'-affair. Hence, a complete cross-border harmonisation of contagious livestock disease management will not occur in the nearby future.

Nevertheless, it was recognised that contagious livestock disease management relates to and depends on other countries' livestock trade relationships and dependencies, as well as their prevention, monitoring (peacetime) and control (crisis situation) strategies. To that end, crossing-off borders with respect to information exchange was considered a first priority. The importance of cross-border information exchange was discussed by Breuer (2011) and, therefore, not discussed in full detail within this dissertation.

The workshop participants stressed the importance of information exchange at all stakeholder levels: ideally, all stakeholders (veterinary policy makers, primary producers, traders, etcetera) at both sides of the border should receive similar, accurate information regarding, for example, trade and biosecurity status, both in peacetime and crisis situations. The quality (accurateness) and quantity of information as well as the speed at which it is exchanged can be improved, for example through the further digitalisation of data and through the linking of existing or new databases.

In this dissertation and during the workshop, the gains through improving information exchange were discussed at peacetime and crisis levels. Peacetime improvement of information exchange results in direct gains whereas in crisis situations, this could result in indirect gains and intangible gains. As shown in chapter 5, shortening the HRP through, for instance, exchanging additional information slightly decreased the simulated CSF outbreak sizes and durations, resulting in indirect gains. The impact of improving the information exchange on other contagious livestock diseases might be more extensive, especially on high-virulent diseases with a short HRP like highly pathogenic avian influenza (HPAI). Additionally, the impact of *trust in information* during an epidemic was

Table 7.3 Overview of the potential gains and challenges in peacetime and crisis situations derived from chapters 2-6 at different implementation levels.

	Implementation level		
	Single country	**Bilateral (without need for EC permission)**	**Within EU (with need for EC permission)**
Peacetime: additional, veterinary cross-border measures ***(chapter 4)***	• Documentary control by office employees instead of through certifying veterinarians	• More and quicker information/data sharing	• No clinical examination of slaughter animals at the farm • No clinical examination of poultry parent stocks • No annual check of “export status” of poultry farms
Crisis situation: CSF control strategies (veterinary and direct economic impacts) ***(chapter 5)***		• ~~Shared depopulation and vaccination resources~~ • More and quicker information/data sharing • Shared organisation of cross-border outbreaks (organisational costs)	• Establishment of cross-border regions with similar control strategies during outbreaks close to the border (no border in between)
Crisis situation: CSF market disturbances (volume and price changes) ***(chapter 6)***	• Regionalisation: alter duration and strictness of movement restrictions; alter the size of the diseased region • Vaccination: increase marketability of products from vaccinated animals (within own country)	• More and quicker information/data sharing	• Channelling of animal surpluses to shortage areas (regardless of the border) • Vaccination: increase marketability of products from non-vaccinated animals (label shows country of origin from January 2014 onwards)

stressed, for example, with respect to data on animal movements and the corresponding confidence that a certain outbreak is, e.g., restricted to one area. Trust in data leads to confidence in the implemented control strategy and can prevent overreaction. Similarly, improving information exchange may increase a trade partner's confidence and trust (intangible gains), which could result in the earlier lifting of trade bans (chapter 6).

Regarding *peacetime* specifically, a high biosecurity status was considered crucial in preventing contagious livestock diseases. For that reason, the workshop participants proposed to change peacetime export regulations from individual transport-based veterinary measures (chapter 4) towards veterinary measures based on a farm's biosecurity status. Such a system already exists for poultry breeding farms and hatcheries who export hatching eggs and day-old chicks, but not for the export of other animals. The set-up of an export system based on a farm's biosecurity status costs money due to the structural collection and exchange of data regarding a farm's status, but it also leads to a decrease in the number of additional, veterinary cross-border measures and their corresponding costs, especially with respect to those measures related to short-distance transportation. It was suggested to exclude lower-biosecurity farms from export, or add additional veterinary measures. However, these measures will not result in large, additional costs because only a relatively small number of farms export (chapters 3 and 5).

The EC's main principle is that the information collected in peacetime should be of sufficient quality to control crisis situations. Within current EU legislation, a farm status based export system is not allowed. As the EC requires uniform legislation across all EU member states, the cross-border region NL-NRW-LS was suggested to combine forces and jointly request attention regarding this issue.

Regarding *crisis situations* specifically, the national veterinary policy makers were clear: contagious livestock disease control currently is and will continue to be a national contingency plan-based matter, even in case of an epidemic close to the border. Country-specific differences in the legal basis, e.g., who is in charge, and in technical issues, e.g., diagnostic and screening procedures, result in both countries continuing to apply their own control strategies. Again, the importance of quick and transparent information sharing was stressed, both at country level and between the two countries. After all, both countries aim for the same result: to eradicate contagious livestock diseases as quickly as possible. Such a quick control is of mutual interest and therefore, being prepared and informed was considered important as it avoids time-consuming discussions and explanations, and it creates trust and confidence in one another's plans.

The sector representatives agreed with the national veterinary policy makers, except regarding the separate contingency plans in case of an outbreak near the border. The sector representatives were in favour of treating cross-border regions as one infected area for reasons of quick and efficient controlling of the epidemic, including applying the same control strategy. Additionally, quickly informing the public on the reasons of applying a certain control strategy was considered important, especially due to the impact of social media. The significance of communicating the underlying reasoning of policy to ensure public compliance was also underlined by Ge (2008). Lastly, sector representatives emphasised the importance of a region-specific control, i.e., a control strategy that incorporates regional production figures. The EC emphasised the countries' freedom to have their own veterinary contingency plans, as long as they are consistent with the EU legislation. In that respect, countries are free to work closely together and harmonise their contingency plans. National policy makers prefer working closely together; however, they prefer to continue with country-specific (non-harmonised) contingency plans.

Besides these general conclusions, the issue of vaccination was thoroughly discussed. In CSF control, both NL and GER prefer a vaccination-to-live strategy using a marker vaccine. For GER, this is contrary to what has been modelled in chapter 5 (vaccination-to-kill using a live vaccine); this reversal in policy is only recent and for that reason, not incorporated in this dissertation. Additionally, according to the EC representative a more flexible attitude towards vaccination-to-live will be incorporated in future legislation, including the possibility to immediately start vaccinating after detecting a contagious livestock disease. In current legislation, an EU permission for vaccination is needed, which delays the start of administrating the vaccines and results in the culling of animals during at least the first three days following the initial outbreak (chapter 5). The effect of an immediate start of vaccination on disease eradication, without depopulating farms within a 1-km radius of detected farms, is likely to be negative: the time in which marker vaccination results in herd immunity is between 8-14 days, whereas depopulating farms has an immediate effect.

Sector representatives proposed to take vaccinated animals out of the market, process them and collectively pay the bill rather than letting individual farmers pay. This way, countries regain their non-vaccination status quicker compared with allowing vaccinated animals on the market; this contributes to a quicker recovery of export to third countries. Transparency regarding the location of vaccinated and non-vaccinated farms was assumed to cause less and shorter trade bans within the EU.

EU and national policy makers stressed that outbreak induced market effects are a sector problem, also when caused by applying vaccination. However, both sector representatives and policy makers wondered whether a reduction in the outbreak's direct costs due to vaccination (direct costs are partly compensated by the national government and the EU) could be transferred to compensating the vaccination's expected higher market effects. From an EC point of view, this could be considered as unfair competition. Still, all workshop participants recognised the need for short-term action to elucidate the uncertainty around the acceptance of vaccinated animals. Otherwise, if farmers expect that vaccination may result in larger losses, they may try to prevent veterinarians from vaccinating their animals which could worsen the epidemic.

Given that existing (in peacetime) and emerging (during crisis situations) borders continue to exist, it was concluded that a common information-exchange platform, i.e., borderless information exchange, is the basis for further cross-border collaboration. As already stressed by Wyss (2013), strong communication is crucial to disease control, and communication must be fluid instead of unidirectional. In the next years, therefore, effort is needed to build interfaces among the different, country-specific information systems (Breuer, 2011). This, most likely, increases global early warning and gives trade guarantees both in peacetime and during crisis situations. Ultimately, a common information-exchange platform could take down barriers for and lead to further cross-border collaboration in contagious livestock disease management.

From the workshop, the following main conclusions are drawn:

- Country-specific differences in contingency planning limit further cross-border harmonisation of contagious livestock disease management, implying the continuation of existing (in peacetime) and emerging (during crisis situations) borders.
- A common information-exchange platform, i.e., borderless information exchange, is the basis for more intensive cross-border collaboration in contagious livestock disease management. The quality, quantity and speed of information exchange can be improved at all stakeholder levels both in peacetime and crisis situations.

Approach and methods

Cross-border collaboration is complex as it concerns a large number of related issues (multi-problem), involves several disciplines (multi-disciplinary) and underlying processes interact on various scale levels (e.g., spatial) and on different temporal (*ad hoc* and long-term) scales (multi-scale), and concerns many different stakeholders with different interests (multi-actor; multi-country). This complexity set specific demands to the approach and methods, including a good conceptual understanding of the problem. Therefore, this dissertation used an integrated, participatory and *ex ante* approach that elaborated on all of these aspects. Chapter 2 explained the need for an approach that integrates peacetime and crisis situations, as well as changes in the future structure of livestock production (chapters 3–6). Chapter 2 used a general disease management framework to describe the way in which chapters 3–6 relate to and affect the epidemiological system and, consequently, how they affect the stakeholders in terms of economic consequences. Chapters 4-6 elaborated on ways to mitigate these economic consequences within a cross-border context, both in peacetime and crisis situations.

An integrated approach

To explore prospects for further cross-border collaboration in contagious livestock disease management, it is imperative to use an integrated approach that combines the multi-problem, multi-disciplinary, multi-scale, multi-actor and multi-country issues, and integrates peacetime and crisis situations, as well as changes in the future structure of livestock production. Throughout the dissertation, a variety of methods was integrated within and across chapters. The within-chapters' integration includes, for example, the integration of a Policy Delphi with interviews and workshops (chapter 3) and the integrated epidemiological and economic modelling of CSF (chapter 5). The across-chapters' integration includes incorporating the results of chapter 3 (future changes in the livestock production structure) in chapters 4, 5 and 7, and using the epidemiological results from chapter 5 in chapter 6.
Such integration stresses the importance of a conceptual understanding of the problem, i.e., it shows the importance of thoroughly conceptualising the problem to maximise research utility. The development of a conceptual framework to visualise the main fields of consideration, including their relationships (chapter 2) was, therefore, considered useful throughout the whole dissertation. The conceptual framework was essential in facilitating a coherent approach to inquiry, and resulted in a strong focus on the pre-identified fields of consideration.
This was particularly experienced during the interactive workshop with the research end-users (elaborated in the previous section of this chapter) in which gains and challenges for both peacetime and crisis situations were discussed in an integrated way. For example, throughout this workshop the impact of decisions made in peacetime on crisis situations was stressed, e.g., with respect to the quantity, quality and speed of information exchange. Nevertheless, the integrated approach has one potential disadvantage: time-limited research, such as PhD research, could lead to the trade-off between either in-depth and, consequently, 'limited to a few fields'-research, or covering a broad number of fields without much depth. In this dissertation, a combination of drawing the overall picture and in-depth research on the pre-identified fields was preferred. Due to time-limitations, however, the combination of broad and in-depth research was not always achieved: chapters 5 and 6, for example, focussed on one specific contagious livestock disease rather than a range of diseases that affect the three main livestock sectors pig, poultry and dairy. Hence, although the integrated approach provided useful insights into prospects for further cross-border collaboration, it is just a first set of steps towards gaining further insights. In consultation with the end-users, several aspects for different livestock sectors were studied but, obviously, a number of aspects were not

examined, for example: prospects for cross-border collaboration in contagious livestock diseases other than CSF, and collaboration within other cross-border production regions. The approach, though, allows for *extrapolation* towards other integrated cross-border production regions, such as GER-Denmark and Portugal-Spain, but also the United States, Canada, and Mexico who already have a shared FMD vaccine bank (USDA, 2013), and towards other contagious livestock diseases, such as FMD and avian influenza. The conceptual framework, as presented in chapter 2, is generic and therefore of use to any integrated cross-border region and contagious livestock disease. Obviously, results presented in this dissertation are conditional on the Dutch and German production sectors' characteristics and their prevention and control strategies. However, they do provide a point of reference for regions and diseases with similar conditions and characteristics (Niemi *et al.*, 2008). For example, in case of an outbreak that affects livestock production sectors other than pig, these sectors experience similar control strategies and could mitigate these strategies' impacts similarly as proposed in chapters 5 and 6. Examples include the sharing of depopulation and vaccination resources, more and quicker sharing of information (chapter 5), altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context (chapter 6). Nevertheless, the possible cost savings due to further cross-border collaboration as well as the total disease costs could differ greatly for other diseases and cross-border regions. After all, the overall consequences depend on factors such as the livestock density of the outbreak region, livestock movement patterns, disease control options, the export or import status of a country and, consequently, the response of (in)direct trade partners, as well as virus-related factors such as the virus strain (Schoenbaum and Disney, 2003). These dependencies link the consequences closely with each individual government and country.

A participatory approach

Within this dissertation, the research was designed, performed and evaluated in close collaboration with (i) the *research end-users*, i.e., veterinary policy makers and livestock sector representatives, and (ii) *other experts*. End-users were asked for input especially during the conceptual framing of this research (chapter 2) and the discussion on policy-implementation possibilities (chapter 7). In addition, the research end-users and the other experts provided input for and feedback on chapters 3-6. It is known that research applying a participatory approach runs the risk of losing its objectivity (Adams *et al.*, 2011), i.e., the degree to which end-users weigh issues on the merits versus the way these issues relate to the end-users' specific self-interests (Fishkin, 2002; Fishkin *et al.*, 2002). To prevent losing research objectivity, the end-users were primarily asked for feedback, rather than letting them decide the research agenda (chapters 2 and 7). In chapters 3-6, the end-users and the other experts were asked to complete missing details and provide feedback on (details of) proposed scenarios. They had no saying in the chosen methodology. Experts were selected from various fields and originated from private companies and public organisations and in most cases, consensus was reached among the experts.

This participatory approach turned out to be especially useful due to the complexity of the subject, which was addressed in this chapter's section 'An integrated approach'. As argued by a large number of studies (see, e.g., Toth and Hizsnyik, 1998; Kasemir *et al.*, 1999; Van Asselt, 2000), a participatory approach improves the quality of research by the engagement of different actors with a wide range of perspectives, practical knowledge and experience, and this dissertation fully underlines this statement. Common methods applied within a participatory approach include expert and scenario workshops (or, focus groups), policy exercises, and participatory modelling (Van Asselt and Rijkens-Klomp, 2002). This dissertation included a large range of these methods and demonstrated the usefulness of this participatory approach by generating a shared insight and understanding among stakeholders on prospects for further cross-border collaboration.

An *ex ante* approach

The livestock production structure has proven to rapidly change in the past decades and is expected to change in the next decade (EC, 2010). For that reason, the dissertation explicitly included the implications of these changes on the potential of mitigating the veterinary and economic impacts of existing (peacetime) and emerging (crisis situations) borders between NL and NRW–LS. These insights from chapter 3 were incorporated in chapter 4 (peacetime) and partly in chapters 5 and 7 (crisis situations).

Chapter 3 stressed the veterinary policy makers' necessity of having a good insight into the future developments of those features of the livestock production structure that influence disease introduction, spread and control, such as the number of farms and farm size. This is in line with Boehlje (1999) who stressed the importance of incorporating a vision of the future in environments with great structural changes *"…instead of using an* ex post *analysis approach based on historical data sets"*. Veterinary contingency planning can benefit from and account for these insights into future developments.

Chapters 5 and 6 included past changes in the structure of livestock production and in veterinary contingency planning to *ex ante* analyse policy alternatives to mitigate the economic consequences of contagious livestock disease management. The importance of *ex ante* analyses in contagious livestock diseases management has been stressed by several studies (see, e.g., Mahul and Gohin, 1999; Dijkhuizen *et al.*, 1994; Ge, 2008). When analysing low-likelihood, high-impact events, such as outbreaks of contagious livestock diseases (chapters 5 and 6), the projected outcomes' confidence intervals are rather wide. Still, such outcomes are useful for comparative purposes as pointed out by Gibbens (2013) and Ribbens (2009): even with uncertainty, systematic analysis of control strategies, associated direct costs and market effects allows policy makers to understand the factors that must be considered when making decisions. Based on the disease control scenarios (control alternatives) starting at different locations, policy makers can identify approximately where an actual outbreak lies in the distribution of possible outcomes identified *ex ante*, given their detailed knowledge of delay to initial diagnosis and movement contacts (Hagerman *et al.*, 2012). Although unlikely that a scenario will match the actual epidemic exactly, *ex ante* decision support makes policy makers arriving at informed decisions (Gibbens, 2013; Hagerman *et al.*, 2012).

Policy makers' risk attitude plays an important role in the choice of optimal contagious livestock disease management (Dijkhuizen *et al.*, 1994; Mahul and Gohin, 1999; Elbakidze *et al.*, 2009). During the extreme case of Mexican flu (New Influenza A (H1N1)) in 2009 which threatened public health, the precautionary principle 'better safe than sorry' resulted in the overbuying of 34 million vaccine doses by the Dutch Ministry of Health, Welfare and Sport (Anonymous, 2011). Policy makers assumed the occurrence of the worst-possible scenario and this over-pessimistic view resulted in large overreacting and in billions of euros allocated to vaccines stockpiling (Basili *et al.*, 2013). Mitigating or preventing such overreactions by investigating policy alternatives asks for an *ex ante* approach, which creates awareness and preparedness, and reduces uncertainty and contagious livestock disease costs (Laddomada, 2013). This statement corresponds with Mahul and Gohin (1999) and Elbakidze *et al.* (2009)'s research results which show that uncertainty affects the decision maker's choice of contagious livestock disease management. Moreover, Ge (2008) points out that a risk-averse choice based on pessimistic expectations may turn out to be risk-taking in case an outbreak turns out to be optimistic.

Main conclusions

From this dissertation, the following main conclusions are drawn:

- Potential gains for further cross-border collaboration in contagious livestock disease management are (i) peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade, and (ii) crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences *(chapter 2)*.
- Main challenges for further cross-border collaboration are (i) improving the

quantity, quality and speed of cross-border communication between countries' veterinary authorities and ministries, and (ii) keeping pace with the increasing globalisation of trade flows through implementing tailor-made institutional settings and harmonising organisational responsibilities *(chapter 2)*.

- Towards 2020, three main developments in the NL-NRW-LS livestock production structure are expected: fewer but larger farms, regional concentration of livestock production, especially within NL, and increasing cross-border trade, especially in the pig sector. These developments further increase the cross-border production dependency and change the likelihood and impact of contagious livestock diseases *(chapter 3)*.
- Without increasing veterinary risks, both NL and GER have several possibilities for reducing the costs of additional, veterinary cross-border measures, albeit for different animal species. Most cost savings can be realised by relaxing measures related to slaughter broilers (GER) and slaughter pigs (NL) *(chapter 4)*.
- The sizes and durations of CSF simulated outbreaks for 2010 are much smaller than those simulated previously, using data from over 10 years ago. Both vaccination and non-vaccination strategies are efficient in controlling CSF outbreaks and result in low direct costs and direct consequential costs compared with previous (simulated) outbreaks *(chapter 5)*.
- The probability of CSF cross-border spread between NL and NRW-LS is relatively low and cross-border spread results in small, short outbreaks in the neighbouring country. To mitigate the veterinary impact, few opportunities for further cross-border control harmonisation and collaboration are identified, including more and quicker sharing of information across the border *(chapter 5)*.
- Regional specialisation of pig production and changes in NL-NRW-LS' veterinary contingency plans result in a new market situation in case of a CSF outbreak *(chapter 6)*.
- A CSF outbreak nowadays results in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak. That is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions *(chapter 6)*.
- CSF induced market shocks can be mitigated without increasing veterinary risks through altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context *(chapter 6)*.
- Country-specific differences in contingency planning limit further cross-border harmonisation of contagious livestock disease management, implying the continuation of existing (in peacetime) and emerging (during crisis situations) borders *(chapter 7)*.
- A common information-exchange platform, i.e., borderless information exchange,

is the basis for more intensive cross-border collaboration in contagious livestock disease management. The quality, quantity and speed of information exchange can be improved at all stakeholder levels both in peacetime and crisis situations *(chapter 7)*.

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Summary

Samenvatting

Zusammenfassung

Summary

Regional specialisation of production and increased regional production of livestock have led to an integration of European Union (EU) livestock production across borders, i.e., integrated production areas, and livestock value chains have globalised in recent decades. Nevertheless, contagious livestock disease management is still a 'single country'-affair, even though it relates to and depends on other countries' livestock trade relationships and dependencies, as well as their prevention, monitoring (peacetime) and control (crisis situation) strategies. A particular example of a large and highly integrated livestock production area is the cross-border region of the Netherlands (NL) and the two German states of North Rhine Westphalia (NRW) and Lower Saxony (LS). In this dissertation, the cross-border region of NL-NRW-LS was used as case study region. This region increasingly develops towards a single epidemiological area in which disease introduction is a shared veterinary and, consequently, economic risk. Policy makers recognise this problem and are aware of the need to structurally improve cross-border collaboration in contagious livestock disease management. The overall objective of the dissertation was to examine the potential gains and main challenges for further cross-border collaboration in contagious livestock disease management within this cross-border region. The dissertation's underlying assertion was that further cross-border collaboration can mitigate the veterinary and, especially, the economic impacts of existing (in peacetime) and emerging (during crisis situations) borders between NL and NRW–LS, without compromising the economic advantages of cross-border trade and without increasing veterinary risk.

Chapter 2 presented a conceptual framework of the potential gains and main challenges for further cross-border collaboration in the control of highly contagious livestock diseases within the cross-border region of NL–NRW–LS. This chapter used a general disease management framework to describe the way in which chapters 3–6 relate to and affect the epidemiological system and, consequently, how they affect the stakeholders in terms of economic consequences. In this chapter, potential gains for further cross-border collaboration in contagious livestock disease management were discussed: peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade (elaborated in chapter 4), and crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences (elaborated in chapters 5 and 6 for classical swine fever (CSF)). The importance of jointly considering mitigating the impact of peacetime and crisis borders was discussed. Improving the quality or quantity of peacetime information collection can affect the control strategy and information needed to eradicate livestock diseases in both short- and long-term. Chapter 2 also identified main challenges for further cross-border

collaboration: improving the quantity, quality and speed of cross-border communication between countries' veterinary authorities and ministries, and keeping pace with the strong trade globalisation through implementing tailor-made institutional settings and harmonising organisational responsibilities. In addition, this chapter addressed the need for a good understanding of future developments in those features of the livestock production structure that influence the risks of disease introduction, notification and eradication. Changes in these risks can affect the consequences of strategies and the routine veterinary and disease control measures needed to regulate contagious livestock diseases. Adjusting current legislation according to the changes in risks requires a large effort and several years, i.e., changing current legislation is laborious. The livestock production structure has proven to rapidly change in the past decades and is expected to change in the next decade. Therefore, it is worthwhile to take into account the implications of these changes on the potential of mitigating the veterinary and economic impacts of existing (peacetime) and emerging (crisis situations) borders between NL and NRW–LS. The findings of this chapter were based on a literature search and research end-users' and other experts' consultation.

Chapter 3 explored changes in future production structure features within the cross-border region of NL–NRW–LS projected towards 2020. Additionally, the findings of this chapter were elaborated in terms of possible implications for contagious livestock disease introduction, spread and control. Chapter 3 identified the main driving forces that are likely to impact the future structure of livestock production (pig, poultry and dairy sectors), quantitatively assessed their impact on the future structure of livestock production and explored possible implications for contagious livestock disease management. This chapter explored these expected structural developments through a literature search, through a Policy Delphi study, by organising workshops and by carrying out interviews. Experts expected a sharp reduction in the number of farms, a sharp increase in farm size and regional concentration of livestock production, especially in NL. An increase in cross-border trade was expected, particularly in the pig sector, resulting in intensified mutual cross-border production dependency in most sectors. This situation results in increased need for collaboration among NL-NRW-LS to improve the joint prevention and control of contagious livestock diseases. It was concluded that veterinary policy makers should proactively anticipate these future changes in the production structure of livestock. The outcomes of this chapter were used as input for chapters 4 (for peacetime), 5 and 7 (for crisis situations as discussed in chapters 5 and 6).

Chapter 4 hypothesised that relaxing additional cross-border measures may be well-justified from a veterinary perspective, i.e., without increasing veterinary risks, and can generate cost savings, especially for neighbouring countries with similar veterinary status that are characterised by large cross-border trade. The objective of this chapter was to examine the prospects for cost reductions from relaxing additional cross-border measures related to trade within the cross-border region of NL–NRW–LS. The chapter constructed a deterministic spread-sheet cost model to calculate the costs of both routine veterinary measures (standard measures that apply to both domestic and cross-border transport) and additional cross-border measures (extra measures that only apply to cross-border transport) as applied in 2010. This model determined costs by stakeholder, region and livestock sector, and studied the prospects for cost reduction by calculating the costs after the relaxation of additional cross-border measures. The selection criteria for relaxing these measures were (i) a low expected added value on preventing contagious livestock diseases, (ii) no expected additional veterinary risks in case of relaxation of measures, and (iii) reasonable cost-saving possibilities. The total cost of routine veterinary measures and additional cross-border measures for the cross-border region was €22.1 million, 58% (€12.7 million) of which came from additional cross-border measures. Two-thirds of this €12.7 million resulted from the trade in slaughter animals. The main cost items were veterinary checks on animals (twice in the case of slaughter animals), export certification and control of export documentation. Four additional cross-border measures met the selection criteria for relaxation. The relaxation of these measures could save €8.2 million (€5.0 million for NL and €3.2 million for GER) annually. Farmers would experience the greatest savings (99%), and most savings resulted from relaxing additional cross-border measures related to poultry (48%), mainly slaughter broilers (GER), and pigs (48%), mainly slaughter pigs (NL). In particular, the trade in slaughter animals (dead-end hosts) is subject to measures, such as veterinary checks on both sides of the border, that might not contribute to preventing contagious livestock diseases. Therefore, this chapter concluded that there are several possibilities for reducing the costs of additional cross-border measures in both countries.

Chapters 5 and 6 used the example of CSF to elaborate crisis time cross-border harmonisation of, and collaboration in current contagious livestock disease control strategies to mitigate these strategies' economic consequences. **Chapter 5** examined CSF control strategies' veterinary and direct economic impacts for the NL-NRW-LS region given the current production structure, and analysed CSF's cross-border spread causes and impacts within the NL-NRW-LS region. The stochastic, dynamic and spatially explicit simulation model Interspread Plus was parameterised for CSF epidemics in the cross-border region of NL-NRW-LS. The epidemiological outputs were used as input for a conversion model programmed in SPSS, which analysed the output and calculated direct costs and costs directly resulting from the control measures applied. Three veterinary control strategies were considered: a strategy based on the minimum EU requirements, and a vaccination and non-vaccination strategy based on NL and GER's contingency plans. Regardless of the veterinary

control strategy, simulated outbreak sizes and durations for 2010 were much smaller than those simulated previously, using data from over 10 years ago. For example, worst-case outbreaks (50th percentile) in NL resulted in 30–40 infected farms and lasted for two to four and a half months; associated direct costs and direct consequential costs ranged from €24.7–28.6 million and €43.6–55.3 million, respectively. Both vaccination and non-vaccination strategies were efficient in controlling outbreaks, especially large outbreaks, whereas the EU minimum strategy was especially deficient in controlling worst-case outbreaks. Both vaccination and non-vaccination strategies resulted in low direct costs and direct consequential costs. The probability of cross-border disease spread was relatively low (4–16%) and cross-border spread resulted in small, short outbreaks in neighbouring countries. Few opportunities for further cross-border harmonisation and collaboration were identified, including the implementation of cross-border regions (free and contaminated regions regardless of the border) in case of outbreaks within close proximity of the border, and more and quicker sharing of information across the border. It was expected, however, that collaboration to mitigate the market effects of an epidemic will create more opportunities to lower the impact of CSF outbreaks in a cross-border context. These market effects were examined in chapter 6.
Chapter 6 obtained insights into CSF induced market disruptions for primary producers within NL-NRW-LS through the combined effects of regionalisation (dividing the country into a diseased region with and free regions without movement and trade restrictions), vaccination, and regional specialisation of pig production, and assessed the potential for mitigating these market disruptions in a cross-border context. Expert workshops and spread-sheet models were used to semi-quantitatively estimate the magnitude of CSF induced market disruptions in terms of changes in trade volumes and prices. This chapter showed that changes in NL-NRW-LS' veterinary contingency plans and regional specialisation result in a new market situation in case of a CSF outbreak. Consequently, a CSF outbreak nowadays would result in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak. That is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions. These trade bans and movement restrictions mainly result from regionalisation. Ways to mitigate the size and duration of market shocks include altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context. The vaccination's market impact was expected to be subject to uncertainty due to trade partners' perception and, consequently, unpredictable trade responses. Elucidating the uncertainty around the acceptance of vaccinated animals, primarily by retailers, and possible compensation for primary producers was recommended.

To alleviate any potential demand shocks in response to vaccination, collective producers' voluntary restriction of products from vaccinated pigs to either the domestic or processed markets was proposed as a potential policy tool. It was concluded that – during a future CSF outbreak – veterinary policy makers are advised to follow a similar approach to obtain insights into CSF induced market disturbances and incorporate these insights into their tactical disease control. In case control measures have similar epidemiological impact, market effects should be incorporated in decision making, especially because these effects largely outweigh the costs that directly result from disease control.

Chapter 7 synthesised the results of the different chapters and discussed implications for future research. Overall, it was concluded that the livestock production structure plays an important role in the need for and needlessness of further cross-border collaboration in contagious livestock disease management. Additionally, the chapter discussed the (im)possibilities and further action needed to implement the proposed cross-border collaboration opportunities from chapters 2-6 into national and EU legislation. To that end, an interactive workshop was organised in which sector representatives and veterinary policy makers from NL, GER and the European Commission (EC) discussed the proposed gains and challenges. During the workshop, it was concluded that existing (in peacetime) and emerging (during crisis situations) borders continue to exist. Borders exist based on cultural, historical and linguistic grounds and, despite the establishment of the EU single market, contagious livestock disease management remains a 'single country'-affair. Hence, a complete cross-border harmonisation of contagious livestock disease management will not occur in the nearby future. Nevertheless, it was recognised that contagious livestock disease management relates to and depends on other countries' livestock trade relationships and dependencies, as well as their prevention, monitoring (peacetime) and control (crisis situation) strategies. To that end, crossing-off borders with respect to information exchange was considered a first priority. It was concluded that a common information-exchange platform, i.e., borderless information exchange, is the basis for more intensive cross-border collaboration in contagious livestock disease management. The quality, quantity and speed of information exchange can be improved at all stakeholder levels both in peacetime and crisis situations. The chapter also reflected on the applied research approach and methods. It was stressed that cross-border collaboration in contagious livestock disease management is complex and set specific demands to the approach and methods, including a good conceptual understanding of the problem. Chapter 7 underlined the usefulness of an integrated, participatory and *ex ante* approach.

From this dissertation, the following main conclusions are drawn:

- Potential gains for further cross-border collaboration in contagious livestock disease management are (i) peacetime collaboration to mitigate the economic impact of routine veterinary measures related to cross-border livestock trade, and (ii) crisis time harmonisation of, and collaboration in current contagious livestock disease control to mitigate economic consequences *(chapter 2)*.

- Main challenges for further cross-border collaboration are (i) improving the quantity, quality and speed of cross-border communication between countries' veterinary authorities and ministries, and (ii) keeping pace with the increasing globalisation of trade flows through implementing tailor-made institutional settings and harmonising organisational responsibilities *(chapter 2)*.
- Towards 2020, three main developments in the NL-NRW-LS livestock production structure are expected: fewer but larger farms, regional concentration of livestock production, especially within NL, and increasing cross-border trade, especially in the pig sector. These developments further increase the cross-border production dependency and change the likelihood and impact of contagious livestock diseases *(chapter 3)*.
- Without increasing veterinary risks, both NL and GER have several possibilities for reducing the costs of additional, veterinary cross-border measures, albeit for different animal species. Most cost savings can be realised by relaxing measures related to slaughter broilers (GER) and slaughter pigs (NL) *(chapter 4)*.
- The sizes and durations of CSF simulated outbreaks for 2010 are much smaller than those simulated previously, using data from over 10 years ago. Both vaccination and non-vaccination strategies are efficient in controlling CSF outbreaks and result in low direct costs and direct consequential costs compared with previous (simulated) outbreaks *(chapter 5)*.
- The probability of CSF cross-border spread between NL and NRW-LS is relatively low and cross-border spread results in small, short outbreaks in the neighbouring country. To mitigate the veterinary impact, few opportunities for further cross-border control harmonisation and collaboration are identified, including more and quicker sharing of information across the border *(chapter 5)*.
- Regional specialisation of pig production and changes in NL-NRW-LS' veterinary contingency plans result in a new market situation in case of a CSF outbreak *(chapter 6)*.
- A CSF outbreak nowadays results in both welfare gains and losses for spatially and temporarily separated groups of primary producers within and outside the affected country during the outbreak. That is, during an outbreak one group of primary producers gains for a certain period and loses during the next due to the occurrence of sub-markets caused by the lifting of trade bans and movement restrictions *(chapter 6)*.
- CSF induced market shocks can be mitigated without increasing veterinary risks through altering the duration and strictness of movement restrictions and channelling trade flows within a cross-border context *(chapter 6)*.

- Country-specific differences in contingency planning limit further cross-border harmonisation of contagious livestock disease management, implying the continuation of existing (in peacetime) and emerging (during crisis situations) borders *(chapter 7)*.
- A common information-exchange platform, i.e., borderless information exchange, is the basis for more intensive cross-border collaboration in contagious livestock disease management. The quality, quantity and speed of information exchange can be improved at all stakeholder levels both in peacetime and crisis situations *(chapter 7)*.

Samenvatting

Toenemende regionale specialisatie van de dierlijke productie in de Europese Unie (EU) heeft geleid tot een integratie van dierlijke productie over de landsgrenzen heen (geïntegreerde productieregio's). Tevens zijn dierlijke productieketens in de afgelopen decennia in toenemende mate geglobaliseerd. Ondanks deze integratie en globalisatie is het management van besmettelijke dierziektes nog steeds gereguleerd op nationaal niveau, terwijl dergelijk management direct gerelateerd is aan de handelsafhankelijkheid met andere landen alsook de toegepaste dierziekte managementstrategieën in deze landen. Een bijzonder voorbeeld van een zeer geïntegreerde dierlijke productieregio is de grensregio Nederland (NL) en de Duitse deelstaten Noordrijn-Westfalen (NRW) en Nedersaksen (NDS). In dit proefschrift is deze grensregio gebruikt als casestudie regio. Deze regio ontwikkelt zich in toenemende mate naar één epidemiologische regio waarin de introductie van besmettelijke dierziektes een gezamenlijk veterinair en, derhalve, economisch risico is geworden. Veterinaire beleidsmakers erkennen dit probleem en zijn zich bewust van de noodzaak om grensoverschrijdende samenwerking in het management van besmettelijke dierziektes structureel te verbeteren. Het doel van dit proefschrift was daarom om de potentiële voordelen en belangrijkste uitdagingen van toenemende grensoverschrijdende samenwerking in het management van besmettelijke dierziektes in de regio NL-NRW-NDS te onderzoeken. Een belangrijke veronderstelling daarbij was dat een toename in grensoverschrijdende samenwerking de veterinaire, maar vooral ook de economische impact van bestaande (in vredestijd: geen uitbraak van besmettelijke dierziektes) en nieuw te ontstane (in crisissituaties: tijdens een uitbraak van een besmettelijke dierziekte) grenzen tussen NL en NRW–NDS kan verminderen, zonder de economische voordelen van de handel in dieren en dierlijke producten te schaden en zonder de veterinaire risico's te verhogen.

Hoofdstuk 2 presenteert een conceptueel raamwerk van de potentiële voordelen en belangrijkste uitdagingen van toenemende grensoverschrijdende samenwerking in het management van besmettelijke dierziektes in de regio NL-NRW-NDS. Het hoofdstuk gebruikt een generiek dierziektemanagement raamwerk om te beschrijven hoe hoofdstuk 3-6 gerelateerd zijn aan het epidemiologische systeem en hoe ze dit systeem en de betrokken stakeholders beïnvloeden. Hoofdstuk 2 bediscussieert de potentiële voordelen van toenemende grensoverschrijdende samenwerking middels: (i) grensoverschrijdende samenwerking in vredestijd om de economische impact van additionele, veterinaire routinemaatregelen gerelateerd aan grensoverschrijdende handel in dieren en dierlijke producten te beperken (uitgewerkt in hoofdstuk 4), en (ii) grensoverschrijdende harmonisatie van, en samenwerking in de huidige besmettelijke dierziektebestrijding om de economische consequenties van besmettelijke dierziektes te beperken (uitgewerkt in hoofdstuk 5 en 6 voor klassieke varkenspest

(KVP)). Het hoofdstuk bediscussieert hoe belangrijk het is om het verminderen van de impact van grenzen in vredes- en crisistijd gezamenlijk in ogenschouw te nemen, daar deze grenzen aan elkaar gerelateerd zijn. Bijvoorbeeld, het verhogen van de kwaliteit en kwantiteit van informatie verzameld in vredestijd kan van invloed zijn op de manier waarop in crisistijd besmettelijke dierziektes kunnen worden bestreden. Naast potentiële voordelen identificeert hoofdstuk 2 ook uitdagingen voor het realiseren van toenemende grensoverschrijdende samenwerking: (i) allereerst is het belangrijk om de kwaliteit, kwantiteit en snelheid van grensoverschrijdende communicatie tussen de veterinaire autoriteiten en ministeries van NL en NRW-NDS te verbeteren; (ii) daarnaast zijn op maat gesneden institutionele kaders en harmonisatie van organisatorische verantwoordelijkheden nodig om gelijke tred te kunnen houden met de sterke globalisering van de handel in dieren en dierlijke producten. Tevens wijst hoofdstuk 2 op de noodzaak om een goed inzicht te hebben in díe toekomstige ontwikkelingen in de dierlijke productiestructuur die van invloed zijn op de risico's van introductie, notificatie en bestrijding van besmettelijke dierziektes. Veranderingen in deze risico's kunnen de consequenties van preventie-, monitorings- en bestrijdingsstrategieën beïnvloeden, alsook de benodigde veterinaire routine- en bestrijdingsmaatregelen om besmettelijke dierziektes te kunnen managen. Het aanpassen van de huidige regelgeving overeenkomstig deze risicoveranderingen kost veel tijd en inspanning. Daarnaast is de dierlijke productiestructuur in de afgelopen decennia drastisch veranderd en verwacht wordt dat deze trend doorzet in de toekomst. Het is daarom lonend om de implicaties van deze veranderingen mee te nemen op het potentieel van de te verminderen impact van bestaande (in vredestijd) en nieuw te ontstane (in crisissituaties) grenzen tussen NL en NRW–NDS. De bevindingen van hoofdstuk 2 zijn gebaseerd op literatuuronderzoek en op overleg met de eindgebruikers van dit onderzoek alsook met andere experts.

Hoofdstuk 3 onderzoekt veranderingen in de toekomstige dierlijke productiestructuur in de grensregio NL-NRW-NDS voor het jaar 2020. Hoofdstuk 3 identificeert de belangrijkste drijvende krachten ten aanzien van de toekomstige productiestructuurveranderingen (in zowel de varkens-, pluimvee- en rundveesector), kwantificeert hun impact en bediscussieert de mogelijke implicaties voor het management van besmettelijke dierziektes. De veranderingen in de toekomstige dierlijke productiestructuur zijn onderzocht middels een literatuuronderzoek, een Policy Delphi studie, workshops en interviews. De geraadpleegde experts verwachten een sterke daling in het aantal bedrijven, een sterke stijging in bedrijfsgrootte en een regionale concentratie van dierlijke productie, vooral in NL. Tevens wordt een toename in grensoverschrijdende handel verwacht, vooral in de varkenssector. Verwacht wordt dat deze toename resulteert in een verdere intensivering van de grensoverschrijdende productieafhankelijkheid in de meeste sectoren. Deze verwachtte veranderingen bevestigen de noodzaak om grensoverschrijdende samenwerking in het management van besmettelijke dierziektes structureel te verbeteren. Het hoofdstuk eindigt met de conclusie dat veterinaire beleidsmakers deze veranderingen in de dierlijke productiestructuur proactief mee moeten nemen in toekomstig beleid. De bevindingen van dit hoofdstuk zijn gebruikt als input voor hoofdstuk 4 (vredestijd), 5 en 7 (crisissituaties; uitgewerkt in hoofdstuk 5 en 6).

Hoofdstuk 4 veronderstelt dat het versoepelen van additionele, veterinaire routinemaatregelen gerelateerd aan grensoverschrijdende handel in dieren en dierlijke producten gerechtvaardigd is vanuit veterinair oogpunt, mits de randvoorwaarde 'geen additioneel veterinair risico' in acht wordt genomen. Deze versoepeling kan vooral kosten besparen voor buurlanden met een gelijke veterinaire status en met tevens een aanzienlijke wederzijdse productieafhankelijkheid (oftewel, veel grensoverschrijdende handel). Het hoofdstuk onderzoekt het potentieel om kosten te besparen binnen de regio NL-NRW-NDS. Een deterministisch spreadsheet kostenmodel is ontwikkeld om de kosten van veterinaire routinemaatregelen (standaardmaatregelen geldend voor binnenlandse en grensoverschrijdende handel) en additionele, veterinaire routinemaatregelen (extra maatregelen alleen geldend voor grensoverschrijdende handel) voor het jaar 2010 te berekenen. De kosten zijn berekend per stakeholder, regio en dierlijke sector, en tevens zijn de mogelijke kostenbesparingen na het versoepelen van een aantal additionele, veterinaire routinemaatregelen berekend. De selectiecriteria voor het versoepelen van deze maatregelen zijn: (i) weinig tot geen toegevoegde waarde in het voorkómen van besmettelijke dierziektes, (ii) geen additionele veterinaire risico's door het versoepelen van maatregelen, en (iii) redelijke mogelijkheden tot kostenbesparingen. De totale kosten van veterinaire routinemaatregelen en additionele, veterinaire routinemaatregelen tezamen zijn €22,1 miljoen, waarvan 58% (€12,7 miljoen) wordt veroorzaakt door de additionele, veterinaire routinemaatregelen. Twee-derde van deze €12,7 miljoen komt voort uit handel in slachtdieren. De belangrijkste kostenposten behelzen de klinische keuring van dieren (twee inspecties in geval van slachtdieren), exportcertificering, en de controle van exportdocumentatie. Vier additionele, veterinaire routinemaatregelen voldoen aan de selectiecriteria voor versoepeling. Het versoepelen van deze maatregelen kan jaarlijks €8,2 miljoen besparen (€5,0 miljoen voor NL en €3,2 miljoen voor NRW-NDS). Veehouders profiteren het meest van deze kostenbesparingen (99%). De grootste besparingen komen voort uit het versoepelen van additionele, veterinaire routinemaatregelen voor pluimvee (48%), vooral slachtvleeskuikens (NRW-NDS), en varkens (48%), vooral slachtvarkens (NL). Vooral de handel in slachtdieren kent additionele, veterinaire routinemaatregelen die waarschijnlijk niet bijdragen aan het voorkómen van besmettelijke dierziektes, bijvoorbeeld de klinische keuring van slachtdieren aan beide zijden van de grens. Daarom eindigt dit hoofdstuk met de conclusie dat er verscheidene mogelijkheden zijn voor beide landen om de kosten van additionele, veterinaire routinemaatregelen te verminderen.

Hoofdstuk 5 en 6 gebruiken het voorbeeld van KVP om mogelijkheden voor grensoverschrijdende harmonisatie van, en samenwerking in de huidige besmettelijke dierziektebestrijding te onderzoeken om zo de economische consequenties van besmettelijke dierziektes te beperken. **Hoofdstuk 5** onderzoekt de veterinaire en de directe economische impact van de huidige KVP bestrijdingsstrategieën in NL, NRW en NDS gegeven de huidige productiestructuur. Daarnaast analyseert dit hoofdstuk de oorzaken en impact van grensoverschrijdende KVP verspreiding in de NL-NRW-NDS regio. Het stochastische, dynamische en spatiale simulatiemodel Interspread Plus is geparameteriseerd voor KVP uitbraken in de regio NL-NRW-NDS. De epidemiologische output is omgezet middels een model geprogrammeerd in SPSS ter berekening van de directe bestrijdingskosten en de gevolgkosten die direct voortvloeien uit de toegepaste bestrijdingsstrategieën. De impact van drie veterinaire bestrijdingsstrategieën is onderzocht: een strategie gebaseerd op de EU minimumvereisten, en vaccinatie- en non-vaccinatiestrategieën gebaseerd op de NL en NRW-NDS bestrijdingsdraaiboeken. Ongeacht de gemodelleerde veterinaire bestrijdingsstrategie zijn de gesimuleerde uitbraakgroottes en –lengtes voor 2010 veel kleiner dan de gesimuleerde uitbraken op basis van productiestructuurdata van meer dan 10 jaar geleden. Worst-case uitbraken (50e percentiel) in NL op basis van de 2010-productiestructuur resulteren in 30-40 geïnfecteerde bedrijven, duren 2-4,5 maanden en resulteren in directe bestrijdingskosten van €24,7–28,6 miljoen en directe gevolgkosten van €43,6–55,3 miljoen. Vaccinatie- en non-vaccinatiestrategieën zijn beide efficiënt in het bestrijden van uitbraken, met name grote uitbraken, en resulteren beide in lage directe bestrijdings- en gevolgkosten. De strategie gebaseerd op de EU minimumvereisten schiet vooral te kort in het bestrijden van worst-case uitbraken. De waarschijnlijkheid dat KVP zich verspreid over landsgrenzen heen is betrekkelijk klein (4-16%) in de regio NL-NRW-NDS; grensoverschrijdende verspreiding resulteert in kleine, korte uitbraken in de buurlanden. In hoofdstuk 5 worden weinig mogelijkheden voor verdere grensoverschrijdende samenwerking in het management van besmettelijke dierziektes geïdentificeerd. Geïdentificeerde mogelijkheden zijn het implementeren van grensoverschrijdende regio's (vrije en besmette regio's ongeacht de locatie van de grens) in geval van een KVP uitbraak dicht bij de grens, en het verhogen van de kwantiteit en snelheid van informatie-uitwisseling over grenzen heen. Ondanks deze beperkte mogelijkheden is er de verwachting dat er meer opties zijn om, door grensoverschrijdende harmonisering en samenwerking, de markteffecten van KVP uitbraken te verminderen. Deze markteffecten zijn verder onderzocht in hoofdstuk 6.

Hoofdstuk 6 verwerft inzicht in de omvang van marktverstoringen ten gevolge van KVP voor veehouders in de regio NL-NRW-NDS. Deze marktverstoringen treden met name op door het gecombineerde effect van regionalisering (het land verdelen in een besmette regio met, en vrije regio's zonder transport- en handelsbeperkingen), vaccinatie, en regionale specialisatie van de varkensproductie. Daarnaast focust het hoofdstuk zich op mogelijkheden om deze marktverstoringen te verminderen in een grensoverschrijdende context. Expert workshops en spreadsheet modellen zijn gebruikt om de omvang van marktverstoringen in termen van veranderingen in handelsvolumes en –prijzen semi-kwantitatief in te schatten. Het hoofdstuk laat zien dat de veranderingen in de bestrijdingsdraaiboeken en in de productiestructuur een nieuwe marktsituatie veroorzaken in geval van een KVP uitbraak. Als gevolg hiervan resulteert een uitbraak in de huidige situatie in welvaartstoe- en afnames voor ruimtelijk- en tijdelijk-gescheiden groepen veehouders in en buiten het getroffen land. Dat betekent dat gedurende een uitbraak een groep veehouders voor een bepaalde periode profiteert en gedurende de volgende periode verliest door het ontstaan van sub-markten veroorzaakt door het opheffen van transport- en handelsbeperkingen. Deze transport- en handelsbeperkingen zijn vooral een gevolg van regionalisering. Manieren om deze marktverstoringen te verminderen, omvatten aanpassingen in de lengte en omvang van transport- en handelsbeperkingen, en het kanaliseren van handelsstromen in een grensoverschrijdende context. De impact van vaccinatie op de markt is onzeker, aangezien het onvoorspelbaar is hoe handelspartners zullen reageren op de aanwezigheid van (producten van) gevaccineerde dieren. Het verminderen van onzekerheid betreffende de acceptatie van gevaccineerde dieren, vooral door retailers, en mogelijke compensatie voor getroffen veehouders is aanbevolen. Collectieve, vrijwillige vermarkting van producten van gevaccineerde dieren op alleen de binnenlandse markt of op de markt voor be-/verwerkte producten is voorgesteld als beleidsinstrument om mogelijke vraagverstoringen als gevolg van vaccinatie te temperen. Afsluitend worden veterinaire beleidsmakers geadviseerd om, gedurende een toekomstige KVP uitbraak, een zelfde approach te volgen om inzichten te verkrijgen in marktverstoringen veroorzaakt door KVP. Indien bestrijdingsmaatregelen een vergelijkbare epidemiologische impact hebben, wordt geadviseerd om markteffecten te integreren in de besluitvorming rond dierziektebestrijding, vooral ook omdat deze effecten vele malen groter zijn dan de kosten die resulteren uit de directe dierziektebestrijding.

Hoofdstuk 7 eindigt met een synthese van de resultaten van de verschillende hoofdstukken en bediscussieert implicaties voor toekomstig onderzoek. In het algemeen wordt geconcludeerd dat de dierlijke productiestructuur een belangrijke rol speelt in de – al dan niet bestaande – noodzaak om grensoverschrijdende samenwerking in het management van besmettelijke dierziektes structureel te verbeteren. Daarnaast bediscussieert hoofdstuk 7 de (on)mogelijkheden om de voorgestelde grensoverschrijdende samenwerkingsmogelijkheden uit hoofdstuk 2-6 te implementeren in nationale en EU wetgeving. Om hier inzicht in te verkrijgen, is een interactieve workshop georganiseerd waarin sectorvertegenwoordigers en veterinaire beleidsmakers uit NL, NRW en NDS, alsook uit de Europese Commissie (EC), de potentiële voordelen en belangrijkste uitdagingen bediscussieerden. Tijdens de workshop werd geconcludeerd dat bestaande (in vredestijd) en nieuw te ontstane (in crisissituaties) grenzen tussen NL en NRW–NDS gehandhaafd blijven. Grenzen zijn gebaseerd op verschillen in cultuur, historie en taal, en ondanks de oprichting van de Europese interne markt blijft het management van besmettelijke dierziektes gereguleerd op nationaal niveau. Een volledige harmonisatie hiervan zal daarom niet plaatsvinden in de nabije toekomst. Desondanks werd in de workshop onderstreept dat het management van besmettelijke dierziektes gerelateerd is aan de handelsafhankelijkheid met andere landen alsook de toegepaste dierziekte managementstrategieën in deze landen, en daarom werd het vervagen van grenzen middels een verbeterde informatie-uitwisseling gezien als een eerste vereiste voor verdere samenwerking. Een gezamenlijk informatie-uitwisselingsplatform (grenzeloze informatie-uitwisseling) werd gezien als dé basis voor intensievere samenwerking, waarbij kwaliteit, kwantiteit en snelheid van informatie-uitwisseling in vredes- en crisistijd verbeterd dient te worden voor alle direct betrokkenen. Hoofdstuk 7 reflecteert ook op de toegepaste onderzoeksapproach en -methodieken. Het hoofdstuk benadrukt de complexiteit van het management van besmettelijke dierziektes, waardoor specifieke eisen aan de approach worden gesteld, inclusief een goed conceptueel inzicht in het probleem. Hierbij wordt het nut van een geïntegreerde, participatie- en *ex ante* approach onderstreept.

De belangrijkste conclusies van dit proefschrift zijn:

- Potentiële voordelen van toenemende grensoverschrijdende samenwerking zijn te verwezenlijken middels (i) grensoverschrijdende samenwerking in vredestijd om de economische impact van additionele, veterinaire routinemaatregelen gerelateerd aan grensoverschrijdende handel in dieren en dierlijke producten te beperken, en (ii) grensoverschrijdende harmonisatie van, en samenwerking in de huidige besmettelijke dierziektebestrijding om de economische consequenties van besmettelijke dierziektes te beperken *(hoofdstuk 2)*.
- Belangrijke uitdagingen voor het realiseren van toenemende grensoverschrijdende samenwerking zijn (i) het verbeteren van de kwaliteit, kwantiteit en snelheid van grensoverschrijdende communicatie tussen de veterinaire autoriteiten en ministeries van NL en NRW-NDS, en (ii) het implementeren van op maat gesneden institutionele kaders en het harmoniseren van organisatorische verantwoordelijkheden om gelijke tred te kunnen houden met de sterke globalisering van de handel in dieren en dierlijke producten *(hoofdstuk 2)*.
- Richting 2020 worden drie belangrijke veranderingen in de dierlijke productiestructuur van NL-NRW-NDS verwacht: (i) een sterke daling in het aantal bedrijven en een sterke stijging in bedrijfsgrootte, (ii) regionale concentratie van dierlijke

productie, vooral in NL, en (iii) een toename in grensoverschrijdende handel, vooral in de varkenssector. Deze veranderingen resulteren in een verdere intensivering van de grensoverschrijdende productieafhankelijkheid in de meeste sectoren, en veranderen de kans op en impact van besmettelijke dierziektes *(hoofdstuk 3)*.

- Er zijn verscheidene mogelijkheden voor NL en NRW-NDS om de kosten van additionele, veterinaire routinemaatregelen te verminderen zonder het veterinair risico te vergroten. De grootste besparingen zijn te realiseren door maatregelen voor slachtvleeskuikens (NRW-NDS) en slachtvarkens (NL) te versoepelen *(hoofdstuk 4)*.
- De gesimuleerde KVP uitbraakgroottes en –lengtes voor 2010 zijn veel kleiner dan de gesimuleerde uitbraken op basis van productiestructuurdata van meer dan 10 jaar geleden. Vaccinatie- en non-vaccinatiestrategieën zijn beide efficiënt in het bestrijden van uitbraken en resulteren beide in lage directe (gevolg)kosten vergeleken met gesimuleerde uitbraken uit het verleden *(hoofdstuk 5)*.
- De waarschijnlijkheid dat KVP zich verspreid over landsgrenzen heen is betrekkelijk klein in de regio NL-NRW-NDS; grensoverschrijdende verspreiding resulteert in kleine, korte uitbraken in de buurlanden. Naast het verhogen van de kwantiteit en snelheid van informatie-uitwisseling over grenzen heen zijn er weinig mogelijkheden voor verdere grensoverschrijdende samenwerking in het management van besmettelijke dierziektes *(hoofdstuk 5)*.
- Veranderingen in de NL-NRW-NDS productiestructuur en de bestrijdingsdraaiboeken veroorzaken een nieuwe marktsituatie in geval van een KVP uitbraak *(hoofdstuk 6)*.
- Een uitbraak in de huidige situatie resulteert in welvaartstoe- en afnames voor ruimtelijk- en tijdelijk-gescheiden groepen veehouders in en buiten het getroffen land. Dat betekent dat gedurende een uitbraak een groep veehouders voor een bepaalde periode profiteert en gedurende de volgende periode verliest door het ontstaan van sub-markten veroorzaakt door het opheffen van transport- en handelsbeperkingen *(hoofdstuk 6)*.
- Marktverstoringen door KVP kunnen, zonder de veterinaire risico's te verhogen, verminderd worden middels aanpassingen in de lengte en omvang van transport- en handelsbeperkingen, en middels het kanaliseren van handelsstromen in een grensoverschrijdende context *(hoofdstuk 6)*.
- Land-specifieke verschillen in de bestrijdingsdraaiboeken staan een verdere grensoverschrijdende samenwerking in het management van besmettelijke dierziektes in de weg, waardoor bestaande (in vredestijd) en nieuw te ontstane (in crisissituaties) grenzen tussen NL en NRW–NDS gehandhaafd blijven *(hoofdstuk 7)*.
- Een gezamenlijk informatie-uitwisselingsplatform (grenzeloze informatie-uitwisseling) is dé basis voor intensievere samenwerking in het management van besmettelijke dierziektes. De kwaliteit, kwantiteit en snelheid van informatie-

uitwisseling in vredes- en crisistijd kan verbeterd worden voor alle direct betrokkenen *(hoofdstuk 7)*.

Zusammenfassung

Nachdem die regionale Produktion von Nutztieren innerhalb der EU in den zurückliegenden Jahrzehnten immer spezialisierter und intensiver geworden ist, verstärkt sich infolgedessen auch die grenzüberschreitende Integration der Wertschöpfungsketten, die längst innerhalb eines globalen Marktes agieren. Gleichwohl wird das Management zur Beherrschung von hoch ansteckenden Tierseuchen nach wie vor als eine Angelegenheit einzelner Länder betrachtet. Und dies obwohl es offensichtlich ist, dass hier wesentliche Zusammenhänge bestehen: einerseits durch die Handelsbeziehungen zu anderen Ländern, andererseits durch die geltenden Beherrschungsstrategien im Bereich Prävention, Monitoring (Friedenszeiten) und Krisenmanagement. Ein besonders gutes Beispiel für eine umfangreiche und stark integrierte Erzeugerregion ist die Grenzregion zwischen den Niederlanden und den beiden angrenzenden deutschen Bundesländern Nordrhein-Westfalen (NRW) und Niedersachsen (NI). In dieser Dissertation wird diese Grenzregion als ein Fallbeispiel betrachtet. Diese Region entwickelt sich in zunehmendem Maße hin zu einer epidemiologischen Einheit, in der der Ausbruch einer Tierseuche ein gemeinsames veterinärmedizinisches und infolgedessen auch ein gemeinsames wirtschaftliches Risiko darstellt. Die politisch verantwortlichen Personen beiderseits der Grenze sind sich dieser Problematik vollkommen bewusst. Einer Weiterentwicklung der grenzüberschreitenden Zusammenarbeit im Bereich des Tierseuchenmanagements steht man grundsätzlich positiv gegenüber.

Die zentrale Fragestellung dieser Dissertation bestand in der Untersuchung der potentiellen Vorteile und der wesentlichen Herausforderungen bei einer Weiterentwicklung der grenzüberschreitenden Zusammenarbeit im Bereich des Tierseuchenmanagements innerhalb der genannten Grenzregion. Es wurde angenommen, dass durch ein Mehr an grenzüberschreitender Kooperation sowohl die veterinärmedizinischen als auch – und dies in besonderem Maße – die wirtschaftlichen Auswirkungen von bestehenden (in Friedenszeiten) und entstehenden (im Verlauf einer Krise) Grenzen zwischen den Niederlanden und den beiden deutschen Bundesländern verringert werden können, ohne wiederum auf diese Weise wirtschaftliche Vorteile durch grenzüberschreitenden Handel zu gefährden oder bestehende veterinärmedizinische Risiken zu erhöhen.

In **Kapitel 2** wurde ein Rahmenkonzept vorgestellt, dass die potentiellen Vorteile und die wesentlichen Herausforderungen bei einer Weiterentwicklung der grenzüberschreitenden Zusammenarbeit im Bereich des Tierseuchenmanagements innerhalb der genannten Grenzregion veranschaulicht. In diesem Kapitel wurde ein grundlegendes Tierseuchenmanagementkonzept präsentiert, anhand dessen nachvollzogen werden kann, in welcher Beziehung die folgenden Kapitel 3-6 zum epidemiologischen System stehen und wie diese in direkter Folge die wirtschaftlichen

Konsequenzen für die beteiligten Stakeholder beeinflussen. Im Verlauf des zweiten Kapitels wurde zunächst der mögliche Mehrwert von grenzüberschreitenden Kooperationen im Tierseuchenmanagement erörtert: einerseits im Bereich der Zusammenarbeit in Friedenszeiten mit dem Ziel die wirtschaftlichen Auswirkungen zu verringern, die im Zusammenhang mit veterinärmedizinischen Routinemaßnahmen entstehen (ausgearbeitet in Kapitel 4), andererseits auf dem Gebiet der Kooperation im Krisenfall, wo es ebenfalls um das Verringern von wirtschaftlichem Schadenspotenzial geht (ausgearbeitet in Kapitel 5 und 6 für Klassische Schweinepest (KSP)). Die Bedeutung gemeinsamer Bemühungen um eine Verringerung der Auswirkungen von Grenzen in Friedenszeiten und in Krisenzeiten wurde hier diskutiert. Ein weiterer Aspekt lag in der Betrachtung der Qualität oder Quantität von entscheidungsrelevanten Informationen, die bereits in Friedenszeiten gesammelt werden: dies kann sowohl die Beherrschungsmaßnahmen beeinflussen als auch den Informationsbedarf hinsichtlich der Bekämpfung von Tierseuchenausbrüchen (kurzfristig / langfristig). Zudem wurden im zweiten Kapitel die zentralen Herausforderungen identifiziert, denen man sich bei der Erweiterung der grenzüberschreitenden Zusammenarbeit zu stellen hat: Verbesserung der quantitativen und der qualitativen Kommunikation über die Grenze hinweg sowie der Geschwindigkeit von Kommunikation zwischen den Veterinärbehörden beider Länder. Ein wesentlicher Aspekt besteht in diesem Zusammenhang in der Anpassung an die fortgeschrittene Globalisierung des Handels mittels u.a. der Harmonisierung von Zuständigkeiten. Nicht zuletzt wurde in diesem Kapitel auch die mögliche zukünftige Entwicklung in den für die Beherrschung von Tierseuchen relevanten Bereichen berücksichtigt. Eine Verschiebung der Risikobewertung würde bedeuten, dass auch die Strategien der alltäglichen Veterinärarbeit bzw. im Krisenmanagement beeinflusst werden würden. Eine Anpassung der Gesetzgebung als Folge einer veränderten Risikobewertung erfordert erheblichen Aufwand und dauert mitunter einige Jahre. Die Struktur der Tierproduktion wiederum hat sich immer wieder kurzfristig geändert und wird dies den Erfahrungen nach auch weiterhin tun. Daher ist es wichtig die Auswirkungen dieser möglichen Veränderungen auf das Potenzial von veterinärmedizinischer und wirtschaftlicher Verringerung von Schäden durch bestehende (Friedenszeiten) sowie entstehende (Krisenzeiten) Grenzen frühzeitig zu berücksichtigen. Die Resultate aus diesem Kapitel basieren auf Literaturstudien sowie auf Expertengesprächen und Beratung mit Anwendern.
In **Kapitel 3** wurden mögliche Veränderungen in den Tierproduktionsstrukturen innerhalb der deutsch-niederländischen Grenzregion bis 2020 ermittelt. Die hier gewonnenen Erkenntnisse wurden zusätzlich untersucht vor dem Hintergrund der Auswirkungen auf den Eintrag, die Weiterverbreitung sowie die Bekämpfung von hoch ansteckenden Tierseuchen. In diesem Kapitel wurden ferner die wesentlichen Triebkräfte identifiziert, die aller Wahrscheinlichkeit nach die zukünftige Struktur

der Tierproduktion beeinflussen werden (Schwein, Geflügel sowie Milchvieh). Diese wurden quantitativ bewertet bevor mögliche Auswirkungen auf das Tierseuchenmanagement abgeleitet werden konnten. Die methodische Grundlage dieses Kapitels bestand in Literaturstudien, einer Delphi-Studie sowie der Durchführung von Experten-Workshops und Interviews. Die befragten Fachleute gaben folgende Erwartungen zu Protokoll: eine erhebliche Verringerung der Anzahl der Betriebe, eine deutliche Erhöhung der Betriebsgröße sowie eine verstärkte regionale Konzentration der Tierhaltungen (v.a. in den Niederlanden). Zudem wurde eine Steigerung des grenzüberschreitenden Handels erwartet, vor allem in der Schweineproduktion, was wiederum zu einer intensiveren grenzüberschreitenden Abhängigkeit zwischen den einzelnen Stufen der meisten Wertschöpfungsketten führen wird. Die Grenzregion zwischen NL-NRW-NI entwickelt sich auch deshalb in zunehmendem Maße hin zu einer epidemiologischen Einheit, innerhalb dessen Grenzen der Ausbruch einer Tierseuche ein gemeinsames veterinäres und wirtschaftliches Risiko darstellt. Vor diesem Hintergrund ist es besonders wichtig, die Zusammenarbeit zwischen den drei Ländern NL-NRW-NI im Bereich Prävention und Bekämpfung von hoch ansteckenden Tierseuchen zu intensivieren. Eine zentrale Schlussfolgerung beinhaltete, dass die hier vorgelegten Erkenntnisse zur zukünftigen Entwicklung des Sektors bei der politischen Arbeit proaktiv berücksichtigt werden müssen. Die Resultate aus diesem Kapitel wurden als Input verwendet für die Kapitel 4 (Friedenszeiten) und 7 (Krisenzeiten wie diskutiert in Kapitel 5 und 6).

In **Kapitel 4** wurde die Hypothese aufgestellt, dass das Auflockern von grenzüberschreitenden Maßnahmen gut begründet werden muss vor dem Hintergrund möglicher veterinärmedizinischer Risiken. Andererseits können Kosten eingespart werden, vor allem in einer Situation, in der benachbarte Länder den gleichen Tierseuchen-Status haben und zugleich über einen regen grenzüberschreitenden Handel verfügen. Die Zielsetzung dieses Kapitels bestand in der Untersuchung des Mehrwerts bei Kosteneinsparungen durch das Auflockern von zusätzlichen grenzüberschreitenden Maßnahmen im Verhältnis zum Handel innerhalb der Grenzregion NL-NRW-NI. Das Kapitel beinhaltet ein deterministisches Spread-sheet Modell zur Kalkulation von Kosten die auf Seiten der Routine-Veterinärmaßnahmen (Standardmaßnahmen die sowohl auf den nationalen als auch auf den grenzüberschreitenden Transport angewendet werden) entstehen sowie zusätzliche Maßnahmen (Maßnahmen die lediglich auf den grenzüberschreitenden Transport angewendet werden). In diesem Modell werden die Kosten ausgewiesen nach Stakeholder, Region und Sektor. Untersucht wurden die Aussichten für eine Vergünstigung durch das Berechnen der Kosten nach der Auflockerung der zusätzlichen Maßnahmen. Die Auswahlkriterien für die Auflockerung der Maßnahmen bestanden in (i) einem geringen zu erwartenden Mehrwert bei der Prävention von hoch ansteckenden

Tierseuchen, (ii) keine zusätzlichen veterinärmedizinischen Risiken durch die Auflockerung der Maßnahmen, und (iii) beträchtliche Verringerung der Kosten. Die Gesamtkosten von regulären Veterinärmaßnahmen sowie zusätzlichen Maßnahmen für die Grenzregion beliefen sich auf 22.1 Millionen €, darunter 58% (12.7 Millionen €) allein aus den zusätzlichen Maßnahmen. Ganze zwei Drittel dieser 12.7 Millionen € resultieren aus dem Handel mit Schlachttieren. Hauptsächlich wurden Kosten generiert mit Veterinäruntersuchungen (zweifach bei Schlachttieren), Exportzertifikaten sowie der Kontrolle der Exportdokumente. Vier zusätzliche grenzüberschreitende Maßnahmen entsprachen den gesetzten Auswahlkriterien. Durch das Aufheben dieser Maßnahmen könnten jährlich allein 8.2 Millionen € eingespart werden (5.0 Millionen € in den NL, 3.2 Millionen € in DE). Der Großteil dieser Kosten würde auf Seiten der Landwirte eingespart werden (99%), wobei der Hauptanteil wiederum durch die Lockerung von Maßnahmen im Geflügelbereich (48%), vor allem bei Schlachttieren, zustande käme sowie im Schweinesektor (48%), hier erneut vor allem bei Schlachtschweinen. Der Handel mit Schlachttieren verursacht den Großteil der zusätzlichen Maßnahmen, so etwa durch Veterinäruntersuchungen auf beiden Seiten der Grenze, die das Ausbreitungsrisiko von Tierseuchen allerdings nicht verringern. Daher wurde in diesem Kapitel die Schlussfolgerung gezogen, dass es verschiedene Möglichkeiten gibt, im Bereich der zusätzlichen Maßnahmen in beiden Ländern Kosten einzusparen.

In den folgenden **Kapiteln 5 und 6** wurde das Fallbeispiel KSP herangezogen um grenzüberschreitende Kooperationen im Krisenfall und deren wirtschaftliche Konsequenzen zu untersuchen. In **Kapitel 5** wurden die veterinärmedizinischen und die direkten wirtschaftlichen Folgen untersucht, die durch die KSP Bekämpfungsstrategien im Grenzgebiet NL-NRW-NI unter den aktuell vorhandenen Produktionsstrukturen verursacht werden. Zudem wurde analysiert, wie unter den genannten Bedingungen die Verbreitung eines KSP-Ausbruchs innerhalb der Grenzregion aussehen würde. Das stochastische, dynamische und räumliche (spatial) Simulationsmodell Interspread Plus wurde zu diesem Zweck parametrisiert für KSP Epidemien innerhalb der Grenzregion NL-NRW-NI. Die epidemiologischen Erkenntnisse wurden verwendet als Input für ein Konvertierungsmodell in SPSS, womit die direkten Kosten sowie die Kosten, die aus den eingesetzten Bekämpfungsmaßnahmen entstanden, berechnet werden konnten. Insgesamt drei veterinärmedizinische Bekämpfungsstrategien fanden Berücksichtigung: eine Strategie auf der Grundlage der minimalen EU-Anforderungen, eine Impfstrategie sowie eine Nicht-Impfstrategie basierend auf dem niederländischen und dem deutschen Bekämpfungshandbüchern. Unabhängig von der jeweiligen Bekämpfungsstrategie entwickelten sich die Ausbruchssimulationen in Dauer und Umfang deutlich weniger stark als noch mit der Datengrundlage von vor zehn Jahren. So führten zum Beispiel die Worst case Ausbrüche (50th Perzentile) in den Niederlanden zu lediglich 30-40

infizierten Betrieben und dauerten zwischen zwei und viereinhalb Monaten. Die zu berücksichtigenden direkten Kosten sowie die direkten Folgekosten beliefen sich auf 24,7 bis 28,6 Millionen € sowie 43,6 bis 55,3 Millionen €. Sowohl die Impfstrategie als auch die Nicht-Impfstrategie zeigten sich als effizient in der Eindämmung des Ausbruchs, vor allem bei großflächigen Ausbrüchen, bei denen die Minimalstrategie sehr schlecht abschnitt. Die Strategien mit und ohne Impfung erwiesen sich zudem als besonders kostengünstig. Die Wahrscheinlichkeit einer grenzüberschreitenden Verbreitung war relativ gering (4-16%), wobei die Ausbrüche sich im Falle einer grenzüberschreitenden Übertragung sehr schnell beenden ließen. Einige wenige Alternativen für weitere grenzüberschreitende Kooperationen konnten identifiziert werden: u.a. die Implementierung von grenzüberschreitenden Regionen (freie sowie gesperrte Regionen unabhängig von den Landesgrenzen) im Falle eines Ausbruchs in der unmittelbaren Nähe der Landesgrenze, sowie mehr und schnellere Datenaustauschoptionen über die Grenze hinweg. Trotzdem war zu erwarten dass Kooperationen, die eine Abschwächung der Markteffekte zufolge haben, mehr Chancen bergen, die Auswirkungen von KSP-Ausbrüchen im grenzüberschreitenden Kontext zu mindern. Diese Markteffekte wurden in Kapitel 6 analysiert.
Mit **Kapitel 6** wurden Einblicke ermöglicht in Störungen des Marktes, die aus der Sicht von Erzeugerbetrieben durch KSP-Ausbrüche ausgelöst werden können. Von besonderer Bedeutung waren dabei die Kombination der Effekte, die durch Regionalisierung (Aufteilung eines Landes in freie Zonen, in denen Transport gestattet ist und Sperrgebiete mit Transport- und Handelsrestriktionen), Impfung sowie regionale Spezialisierung von Schweineproduktion entstehen. Bewertet wurde das Potenzial für die Verringerung von Marktstörungen im grenzüberschreitenden Kontext. Eingesetzt wurden sowohl Expertenworkshops als auch Spread-sheet Modelle um in einer halb-quantitativen Weise den Umfang der durch KSP verursachten Marktstörungen anhand der beiden Faktoren Handel und Preisentwicklung zu ermitteln. In diesem Kapitel wurde aufgezeigt, dass Veränderungen innerhalb der Veterinärmedizinischen Krisenhandbücher der besagten Grenzregion zu einer neuen Marktsituation führen. Folglich würden heutzutage im Falle eines KSP-Ausbruchs sowohl wirtschaftliche Gewinne als auch Verluste für die zeitweise unter Restriktionen sich befindenden Gruppen der Tierhalter anfallen. Genauer gesagt bedeutet dies, dass im Verlauf eines Ausbruchs eine Gruppe von Erzeugerbetrieben für eine bestimmte Zeit Gewinne verzeichnet, bevor Sie in der folgenden Phase aufgrund der Wiederaufhebung von Sperrgebieten und den somit entstehenden Sub-Märkten wiederum Verluste verzeichnet. Diese Handelseinschränkungen und Transportrestriktionen sind eine wesentliche Folge der Regionalisierung. Mögliche Wege diese Marktstörungen zu vermindern liegen demnach in der Verkürzung bzw. Abschwächung von Transportrestriktionen sowie der Ermöglichung von Handelskanälen innerhalb der Grenzregion. Die Auswirkungen

der Impfung auf die Marktsituation wurden als ungewiss eingeschätzt aufgrund der Schwierigkeit, die Einschätzung der Handelspartner vorherzusehen. Daher wurde dringend angeraten, die Akzeptanz von Produkten geimpfter Tiere v.a. auf Seiten des Handels sowie mögliche Kompensationsmodelle für Erzeugerbetriebe zu überprüfen. Um mögliche Nachfrageprobleme infolge einer Impfung zu lindern wurde empfohlen, eine politische Maßnahme in Erwägung zu ziehen, mit der eine vorübergehende freiwillige Beschränkung der Heimatmärkte bzw. der weiterverarbeitenden Märkte auf geimpfte Produkte veranlasst werden kann. Es wurde ferner die Schlussfolgerung gezogen, dass es während eines KSP-Ausbruchs sehr wichtig ist das die politischen Entscheidungsträger die jeweiligen Marktstörungen bei der Wahl ihrer Maßnahmen berücksichtigen. Im Falle einer entsprechenden epidemiologischen Wirkung sollten Markteffekte in jedem Fall die Entscheidung maßgeblich beeinflussen, zumal diese in der Regel viel umfangreichere Kosten verursachen als die Kosten aus der direkten Seuchenbekämpfung.

In **Kapitel 7** wurden die Resultate der verschiedenen Kapitel zusammengeführt und im Hinblick auf weiteren Forschungsbedarf diskutiert. Grundsätzlich wurde festgehalten, dass die Produktionsstrukturen eine wesentliche Rolle spielen bei der weiteren Entwicklung der grenzüberschreitenden Zusammenarbeit in der Tierseuchenbekämpfung. Zudem wurden in diesem Kapitel die (Un-)Möglichkeiten diskutiert sowie die weiteren Schritte im Hinblick auf eine Implementierung der in den Kapiteln 2-6 vorgestellten grenzüberschreitenden Kooperationsansätze in nationales und europäisches Recht. Abschließend fand ein interaktiver Workshop statt in dessen Verlauf Vertreter der Privatwirtschaft sowie der Veterinärverwaltungen der Niederlande, Deutschlands und der Europäischen Kommission die möglichen Vorteile und Herausforderungen dieser Arbeit erörterten. In diesem Workshop wurde verdeutlicht, dass bestehende (in Friedenszeiten) und entstehende (in Krisenzeiten) Grenzen weiter Bestand haben werden. Diese basieren auf kulturellen, historischen und mitunter auch sprachlichen Grundlagen und machen somit die Tierseuchenbekämpfung trotz eines Europäischen Binnenmarkts auch weiterhin zu einer Angelegenheit einzelner Länder.

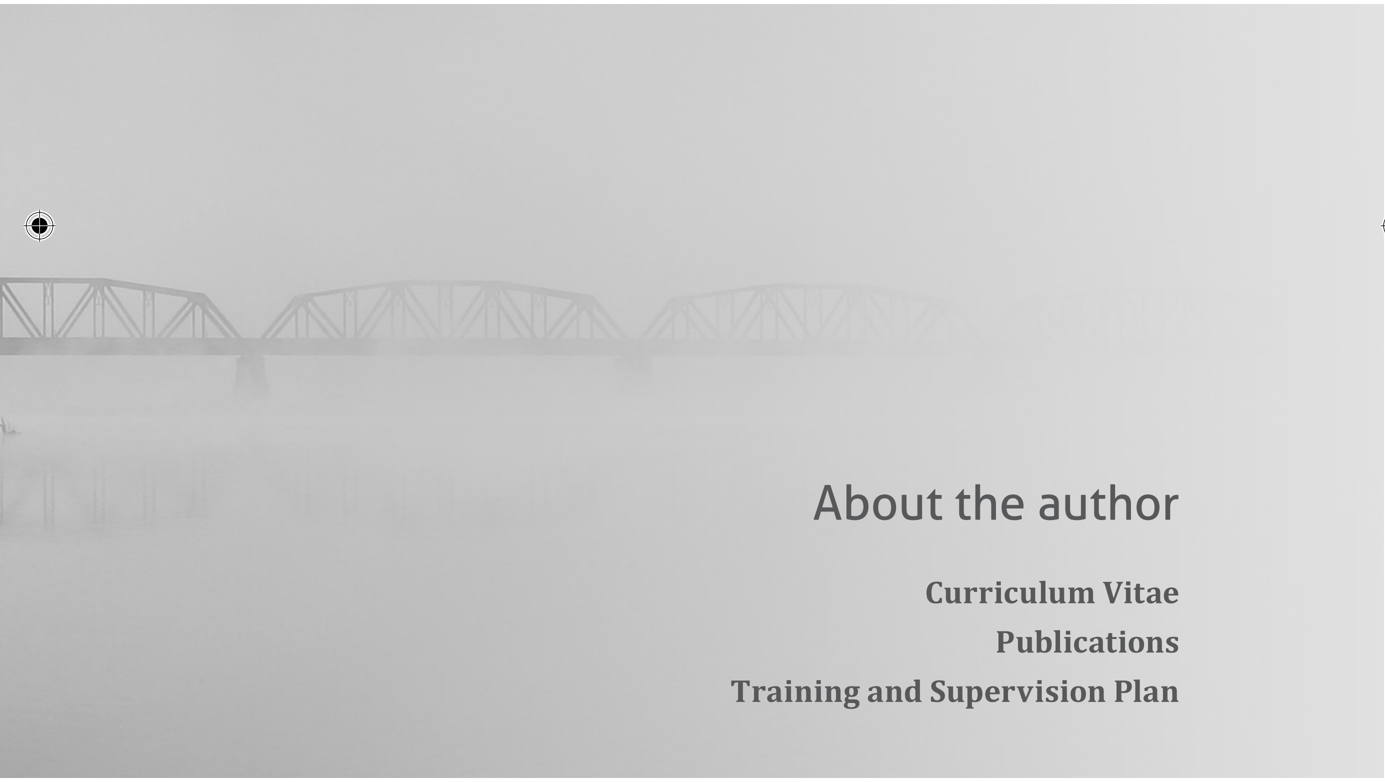
Dies bedeutet dass eine vollständige Harmonisierung der Tierseuchenbekämpfung in der nahen Zukunft keine Option sein wird. Trotzdem konnte festgestellt werden, dass es eindeutige Sinnzusammenhänge gibt zwischen der Tierseuchenbekämpfung und den Handelsbeziehungen mehrerer Staaten. Aus diesem Grund betrachtet man die grenzüberschreitende Verfügbarkeit von entscheidungsrelevanten Informationen als höchste Priorität. Eine gemeinsame Informationsplattform würde die Grundlage für eine Intensivierung der grenzüberschreitenden Zusammenarbeit weiter verbessern. Qualität, Quantität sowie Geschwindigkeit von Datenaustausch könnten damit sowohl in Friedens- als auch in Krisenzeiten auf allen Ebenen erhöht werden. In diesem Kapitel wurden zudem die für diese Dissertation gewählten Verfahren und Methoden einer Prüfung unterzogen. Es zeigte sich, dass die grenzüberschreitende Zusammenarbeit in der Tierseuchenbekämpfung eine durchaus komplexe und spezifische Angelegenheit ist, was wiederum besondere Anforderungen an wissenschaftliche Ansätze und Methoden stellt. In diesem Kapitel wurde abschließend betont, dass ein integrierter, mitbestimmender und ex ante-Ansatz empfehlenswert ist.

Aus der vorliegenden Dissertation wurden die folgenden Schlussfolgerungen gezogen:

- Mögliche Vorteile bei der Weiterentwicklung der grenzüberschreitenden Zusammenarbeit in der Tierseuchenbekämpfung sind (i) Kooperationen in Friedenszeiten, die eine Verringerung der wirtschaftlichen Belastungen durch veterinärmedizinische Routinemaßnahmen im Handel ermöglichen, und (ii) Harmonisierungen und Kooperationen in Krisenzeiten, durch die sich wirtschaftliche Konsequenzen einschränken lassen *(Kapitel 2)*.
- Die wesentlichen Herausforderungen für zukünftige grenzüberschreitende Kooperationen lauten (i) Verbesserung der Qualität, der Quantität sowie der Geschwindigkeit von grenzüberschreitender Kommunikation zwischen den Veterinärverwaltungen, und (ii) Schritt zu halten mit der enormen globalen Veränderung der Märkte mittels maßgeschneiderten Regulierungen sowie der Gleichschaltung von Zuständigkeiten *(Kapitel 2)*.
- Schaut man bis in das Jahr 2020, so sind innerhalb der NL-NRW-NI Grenzregion drei verschiedene Entwicklungen zu erwarten: weniger aber immer größere Betriebe, regionale Konzentration der Tierproduktion, vor allem in den Niederlanden, und eine Zunahme der Handelsbeziehungen, vor allem im Schweinebereich. Diese Entwicklungen erhöhen in zunehmendem Maße die grenzüberschreitende Abhängigkeit innerhalb der Wertschöpfungsketten und verändern die Wahrscheinlichkeit von Ausbrüchen sowie ihre Wirkungskraft *(Kapitel 3)*.
- Ohne das veterinärmedizinische Risiko zu erhöhen verfügen sowohl die Niederlande als auch Deutschland über eine Reihe von Möglichkeiten zur Kostenreduzierung bei zusätzlichen grenzüberschreitenden Maßnahmen, allerdings in unterschiedlichem Maße für verschiedene Tierarten. Der Großteil der Einsparungsmöglichkeiten wurde für Schlachtgeflügel (DE) und Schlachtschweine (NL) festgestellt *(Kapitel 4)*.
- Die Größe und die Dauer von simulierten KSP-Ausbrüchen für 2010 sind weitaus geringer als im Fall von Simulationen mit Daten die mehr als zehn Jahre zurückliegen. Sowohl die Strategie mit Impfung als auch die ohne erweisen sich als effizient in der Bekämpfung von KSP-Ausbrüchen und resultieren in niedrigen direkten Kosten sowie niedrigen direkten Folgekosten im Vergleich mit früheren (simulierten) Ausbrüchen *(Kapitel 5)*.
- Die Wahrscheinlichkeit von grenzüberschreitenden Übertragungen eines KSP-Ausbruchs zwischen den NL und NRW-NI ist relativ gering und führen, falls es doch vorkommt, nur zu kurzen Seuchengeschehen im Nachbarland. Wenige

Alternativen für weitere grenzüberschreitende Maßnahmen zur Harmonisierung und Kooperation sind identifiziert worden, worunter das schnellere Austauschen von mehr Informationen über die Grenze besondere Bedeutung erhält *(Kapitel 5)*.

- Regionale Spezialisierung der Schweineproduktion sowie Veränderungen in den Bekämpfungshandbüchern der Länder NL-NRW-NI führen im Falle eines KSP-Ausbruchs zu einer neuen Marktsituation *(Kapitel 6)*.
- Ein KSP-Ausbruch würde gegenwärtig sowohl zu Gewinnen als auch zu Verlusten auf Seiten von zeitweise sich unter Restriktionen liegenden Betrieben führen. Dies ist der Fall, da während eines KSP-Geschehens eine bestimmte Gruppe von Betrieben in einer Phase profitiert, während sie in der nächsten Phase nach der Aufhebung von Handels- und Transportrestriktionen mit Sub-Märkten konfrontiert wird, die wiederum für Verluste sorgen *(Kapitel 6)*.
- Die Möglichkeiten durch einen KSP-Ausbruch verursachte Marktstörungen zu verringern ohne das tiermedizinische Risiko zu erhöhen, beinhalten eine Änderung der Dauer sowie des Umfangs der Handels- und Transportrestriktionen innerhalb der Grenzregion *(Kapitel 6)*.
- Länderspezifische Unterschiede in der Handhabung des Krisenmanagements (Notfallplanung) limitieren eine Erweiterung der grenzüberschreitenden Zusammenarbeit in der Tierseuchenbekämpfung, was wiederum die Beständigkeit der bestehenden (Friedenszeiten) und entstehenden (Krisenzeiten) Grenzen untermauert *(Kapitel 7)*.
- Eine gemeinsame Informationsplattform zum grenzüberschreitenden Datenaustausch bietet die Grundlage für eine intensivere Zusammenarbeit in der Tierseuchenbekämpfung. Die Qualität, Quantität sowie die Geschwindigkeit der Kommunikation können auf diese Weise auf allen Stakeholderebenen sowohl vor als auch in der Krise erhöht werden *(Kapitel 7)*.



About the author

Curriculum Vitae

Publications

Training and Supervision Plan

Curriculum Vitae

Geralda (G.E.) Hop – van den Hazel was born on February 16, 1985, in Putten, the Netherlands. She attended Johannes Fontanus College in Barneveld, and after graduating from secondary school she studied Animal Sciences at Wageningen University (2003-2008) and obtained her BSc and MSC degrees. During her studies, she specialised in Quantitative Veterinary Epidemiology (QVE), Business Economics (BEC) and Management Studies (MST). For her specialisation QVE, she worked at the Department of Primary Industries (DPI) in Kyabram, Victoria, Australia, where she analysed – in close collaboration with local DPI veterinary officers – the role of weather conditions and old stock routes with respect to the occurrence and spread of anthrax in Northern Victoria, Australia. For her specialisation BEC, she assessed Dutch farmers' incentives to join a voluntary Johne's Disease programme, and for her specialisation MST, she examined the economic valuation of knowledge gain through inter-enterprise information systems in the pork chain. From 2008-2009, Geralda worked as functional application manager (business consultant) at CRV Holding BV in Arnhem. In 2009, she started her PhD research at the Business Economics Group of Wageningen University, where she examined the potential gains and main challenges for further cross-border collaboration in contagious livestock disease management within the cross-border region of the Netherlands, North Rhine Westphalia and Lower Saxony. Her project was part of the project SafeGuard (GIQS, Germany). Within this project she worked with a large group of Dutch and German veterinary policy makers and agri-sector representatives. Her work has been presented in international conferences and published in peer-reviewed journals. During her PhD research, she followed her education programme at the Wageningen School of Social Sciences (WASS) and was member of the WASS PhD Council and the Wageningen PhD Council (2011-2012). In 2012, Geralda was awarded the WASS Junior Researcher Grant and in 2013, she received the Cross Border Public Private Partnership (CBP^3) Junior Award.

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Contributions to conferences and seminars

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2013). Contagious livestock disease control in a Dutch-German cross-border context. In: New Developments in Animal Sciences: Relevance for Practical Implementation, Studiemiddag Nederlandse Zoötechnische Vereniging (NZV), Wageningen, the Netherlands, 17 October 2013.

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2012). Towards one economic livestock production Euregio of the Netherlands – North Rhine Westphalia – Lower Saxony. In: Proceedings of the International SafeGuard Conference, Wageningen, the Netherlands, 13 December 2012.

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2012). Scenario development for mitigating the economic consequences of classical swine fever (CSF) outbreaks in the cross-border region of the Netherlands, North Rhine Westphalia and Lower Saxony. In: International workshop on Farm Animal Health Economics, Foulum, Denmark, 4–5 October 2012.

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2012). Possible consequences of changes in livestock production structure on cross-border contagious livestock disease control. In: Proceedings of the 13th International Symposium on Veterinary Epidemiology and Economics (ISVEE), Maastricht, the Netherlands, 20–24 August 2012.

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2012). Improving cost-effectiveness of cross-border routine veterinary measures. In: Proceedings of the 13th International Symposium on Veterinary Epidemiology and Economics (ISVEE), Maastricht, the Netherlands, 20–24 August 2012.

Saatkamp, H.W., Mourits, M.C.M., Hop, G.E., Bosman, K.J., Breuer, O. (2012). Livestock disease control in frontier regions: problems and prospects, challenges and limitations for cross-border collaboration. In: Proceedings of the 13th International Symposium on Veterinary Epidemiology and Economics (ISVEE), Maastricht, the Netherlands, 20–24 August 2012.

Hop, G.E., Mourits, M.C.M., Oude Lansink, A.G.J.M., Saatkamp, H.W. (2011). Towards an integrated approach to intensify cross-border collaboration in the field of highly contagious livestock diseases: a general framework for decision support. In: Proceedings of the International SafeGuard Conference on Food Safety and Animal Health, Münster, Germany, 12 October 2011.

Hop, G.E., Saatkamp, H.W. (2010). A PathWayDiagram for introduction and prevention of avian influenza in the Netherlands. In: International workshop on Farm Animal Health Economics, Atlantic National College of Veterinary Medicine, Food Science and Engineering (ONIRIS), Nantes, France, 14–15 January 2010.

Other publications

Hop, G.E., Saatkamp, H.W. (2014). Aanpak uitbraak afstemmen op regio. Nieuwe Oogst yr 10, no. 8, p. 22, 22 February 2014.

Training and Supervision Plan

Wageningen School of Social Sciences

Description	Institute[1]	Year	ECTS[2]
General courses			
Introduction course	WASS	2011	1.5
Writing PhD research proposal	WASS	2009	6.0
Scientific Writing	WGS	2010	1.8
Techniques for Writing and Presenting a Scientific Paper	WGS	2011	1.2
English speaking and listening IV	Language Services, WUR	2009-2010	2.0
Discipline-specific courses			
Econometrics	AEP, WUR	2010	6.0
Advanced econometrics	AEP, WUR	2010	6.0
Organisation of the agribusiness	BEC, WUR	2010	6.0
Economic models	AEP, WUR	2011	3.0
Microeconomics	ECH, WUR	2009	6.0
Business Economics PhD Meetings	BEC, WUR	2009-2013	4.0
Contributions to conferences and seminars			
"A PathWayDiagram for introduction and prevention of avian influenza in the Netherlands"	IWFAHE, Nantes, France	2010	1.0
"Towards an integrated approach to intensify cross-border collaboration in the field of highly contagious livestock diseases: a general framework for decision support"	International SafeGuard Conference, Münster, Germany	2011	1.0
"Possible consequences of changes in livestock production structure on cross-border contagious livestock disease control"	ISVEE, Maastricht, the Netherlands	2012	1.0
"Improving cost-effectiveness of cross-border routine veterinary measures"	ISVEE, Maastricht, the Netherlands	2012	1.0
"Scenario development for mitigating the economic consequences of classical swine fever (CSF) outbreaks in the cross-border region of the Netherlands, North Rhine Westphalia and Lower Saxony"	IWFAHE, Foulum, Denmark	2012	1.0
"Towards one economic livestock production Euregio of the Netherlands – North Rhine Westphalia – Lower Saxony"	International SafeGuard Conference, Wageningen, the Netherlands	2012	1.0

"Contagious livestock disease control in a Dutch-German cross-border context"	NZV, Wageningen, the Netherlands	2013	1.0
Safeguard project workshops		2009-2013	2.0
Teaching and supervising activities			
Supervising MSc Students	BEC, WUR	2012-2013	2.0
Computer labs: Veterinary Epidemiology and Economics		2012	0.5
Computer labs: Food Safety Economics		2011	0.5
Lecture: Economics of Animal Health and Food Safety		2013	0.5
Career related competences / personal development			
WASS PhD Council, incl. chair, organisation of PhD Days and Career Events; member of Wageningen PhD Council	WASS	2011-2012	7.0
Career assessment	WGS	2013	0.3
Voice Matters - Voice and Presentation Skills Training	BEC, WUR	2010	0.5
Total			**63.8**

1 WASS = Wageningen School of Social Sciences; WGS = Wageningen Graduate Schools; WUR = Wageningen University and Research Centre; AEP = Agricultural Economics and Rural Policy Group; BEC = Business Economics Group; ECH = Economics of Consumers and Households Group; IWFAHE = International workshop on Farm Animal Health Economics; ISVEE = International Symposium on Veterinary Epidemiology and Economics; NZV = Nederlandse Zoötechnische Vereniging.

2 One ECTS is equivalent to 28 hours of course work.

Acknowledgements

Acknowledgements

According to Horace's remarkable words *'nec scire fas est omnia'*, it is impossible to know and do everything yourself, and I simply agree with these words. I am indebted to many people who directly or indirectly contributed to the shaping of my ideas, to putting them on paper and to creating a pleasant working environment. Several people deserve special mention.

First of all, I wish to express my gratitude to Prof. Dr Alfons Oude Lansink. Alfons, thanks for offering the opportunity of writing this dissertation and for the professional and constructive support during the years of the project. A huge 'thank you' to Dr Helmut Saatkamp and Dr Monique Mourits. Helmut, thanks for your ongoing optimism, enthusiasm and vision, and your inspiring dedication to initiating and researching cross-border contagious livestock disease management. Monique, thanks for your continual encouragement, your down-to-earth 'no beating around the bush' support and your ability to put things into perspective. I benefited greatly from all three of you and I have been privileged to work with you.

This research is part of the project SafeGuard (GIQS), which is financed within the INTERREG IV A programme Deutschland-Nederland by the European Regional Development Fund. Their financial support is gratefully acknowledged. I express my gratitude to GIQS, and particularly to Dr Oliver Breuer, for their support.

A special note of appreciation is due to the numerous experts who contributed to this project over the years, especially those from the Ministry of Economic Affairs and PVE (the Netherlands) and from BMELV, Tierseuchenkasse Nordrhein-Westfalen and Niedersächsische Tierseuchenkasse (Germany). Without their help, it would have been a difficult and even more time consuming endeavour. I hope this research benefits them in some way. This appreciation is extended to the students who contributed to this project.

Special thanks go to my past and present office mates, other colleagues and the secretariat at the Business Economics Group who have shared in this experience with me. The laughter, excitement and article writing stress we shared over all those coffee breaks made my PhD a far more enjoyable and less solitary experience. Thanks Daphne Verreth and Wilma Steeneveld for sharing our office in the last year, for all the chats and gossip and for being my paranymphs! Thanks Koenraad Bosman for sharing the burden of parameterising disease simulation models, for all the brainstorming and the non-work related talks. Thanks Annet Velthuis for persuading me to start this PhD trajectory; looking back on this adventure I can honestly say 'I did the right thing and enjoyed it'! Thanks WASS PhD Council members for offering me some real diversionary action! Thanks Anne Wientjes for all the chats and fun during our weekly squash matches.

I am grateful to my family, my in-laws, and my friends – here and abroad – for providing all kinds of support, friendship and understanding over the years, and for knowing when to stop asking 'Is it finished yet'?
Finally, I wish to thank my better half – Jochem. Thanks for your constant stream of support, encouragement and care. You have helped me in ways beyond words. I so appreciate everything you have done for me over this period of hard work: I am truly grateful!

Colophon

The research described in this dissertation was financially supported by the European Regional Development Fund (INTERREG IV A programme Deutschland-Nederland).

Financial support from the Business Economics Group (Wageningen University) for printing this dissertation is gratefully acknowledged.

Cover photo Jochem Hop (Fredericton Railway Bridge, New Brunswick, Canada)
Cover design & layout Promotie In Zicht
Print Gildeprint