Felix Alexander Andreae
MSc Thesis

Analysis of changes in producers' surplus of pig producers in the Netherlands, North Rhine-Westphalia and Lower Saxony due to supply shocks caused by highly contagious pig diseases

Student:	Felix Alexander Andreae
Reg.-No. WUR	880403-015-050
Reg.-No. Uni Bonn	2512908

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1st Supervisor:	Dr. ir. H.W. Saatkamp
University:	Wageningen University, The Netherlands
Chair Group:	Business Economics

2nd Supervisor:	Prof. Dr. T. Heckelei
University:	University of Bonn, Germany
Chair Group:	Economic and Agricultural Policy

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Abbreviations

AC	Aftermath costs
AD	Aujeszky's disease
CM	Control measure
CS	Consumers' surplus
CSF	Classical swine fever
DC	Direct costs
DCC	Direct consequential costs
DK	Denmark
DUPIMA	Dutch pig market
EC	European Commission
EEC	European Economic Community
E-EUR	East Europe
eq.	Equation
ES	Export supply
EU	European Union
FMD	Foot and mouth disease
GER	Germany
HCLD	Highly contagious livestock disease
ICC	Indirect consequential costs
ID	Import demand
ISP	InterSpread Plus
kg	Kilogram
LEI	Landbouw-Economisch Instituut Wageningen
LS	Lower Saxony
MRZ	Movement restriction zone
NL	The Netherlands
NL-NRW-LS	EU region Netherlands, North Rhine-Westphalia and Lower Saxony
NRW	North Rhine-Westphalia
OIE	World Organization for Animal Health
P	Price
PE	Partial equilibrium
PS	Producers' surplus
PVE	Productschappen Vee, Vlee en Eieren
Q	Quantity
S-EUR	South Europe
USA	United States of America
VAT	Value added tax
WTP	Willingness to pay

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Abstract

Outbreaks of highly contagious livestock diseases (HCLD) can go along with severe economic impacts for livestock producers. The cross-border region Netherlands, North Rhine-Westphalia and Lower Saxony (NL-NRW-LS) is a region of very intensive and specialized pig production. Thus, contagious pig diseases like Classical Swine Fever (CSF) and Aujeszky's Disease (AD) are an economic threat to the pig producers in NL-NRW-LS. The economic costs of HCLD can be categorized in direct costs (DC), direct consequential costs (DCC), indirect consequential costs (ICC) and aftermath costs (AC). ICC and AC are caused by price and quantity changes that occur during and after HCLD outbreaks. For pig producers ICC and AC are equivalent to changes in producers' surplus (PS). The aim of this study was to identify the PS changes associated with CSF and AD outbreaks in the cross-border region NL-NRW-LS.

To fulfill the research aim several steps were taken. CSF and AD control measures in NL-NRW-LS were identified and analyzed with respect to their impact on economic costs of CSF and AD epidemics. Control scenarios for CSF and AD that differ with respect to the diseased region, movement restrictions, trade status of the affected country and implemented vaccination strategies were set up. Based on the control scenarios a theoretical elaboration on economic welfare effects was conducted and equations to calculate changes in PS were identified. Data on supply shocks was taken from nine CSF and three AD outbreak simulations. Price estimation workshops with experts were held to acquire data on price changes associated with the supply shocks. The workshops were set up in a structured way to allow for reliable and verifiable price estimations.

Due to impracticability of price estimations no quantitative results could be obtained during the expert workshops. Therefore, the aim of this study changed into providing a thorough qualitative description of the factors influencing the market effects during CSF and AD outbreaks in NL-NRW-LS. During the workshops the experts mentioned assumptions and expectations that provide insight into the functioning of the pig market during CSF and AD epidemics. Furthermore, detailed qualitative descriptions of market effects during CSF and AD epidemics and semi-qualitative price change indications have been obtained from the expert workshops.

The theoretical elaboration in this thesis suggests that research on ICC on HCLD epidemics has to take into account different levels of product and market separation. During epidemics the pig market is separated spatially and economically. Vaccination and movement restrictions cause differences in products that implicate the emergence of temporary submarkets. This study revealed differences in the emergence of economic impacts during CSF and AD outbreaks. Moreover, differences between market effects in net importing and net exporting countries were disclosed. The experts' assumption that supply and demand shocks quickly level out across the EU market was identified as crucial. This assumption calls for further research on the EU market effects and on the responses of EU trading partners during disease outbreaks.

Keywords

Highly Contagious Livestock Diseases, Classical Swine Fever, Aujeszky's Disease, Indirect Consequential Cost, Producers' surplus

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1 Introduction

1.1 Background

Highly Contagious Livestock Diseases (HCLD) such as Classical Swine Fever (CSF) and Aujeszky's Disease (AD) can have huge veterinary, social and economic consequences (Mangen, 2002; Bosman et al., 2013; Dürr et al., 2013). Particularly, regions with high livestock farming density are likely to suffer from HCLD outbreaks (Mangen et al., 2002). The cross-border region Netherlands, North-Rhine Westphalia and Lower Saxony (NL-NRW-LS) is a highly specialized and inter-dependent pig farming region and an outbreak in one of the sub-regions would have consequences for the others (Hop et al., 2012). Longworth et al. (2012) categorize the economic consequences of HCLD epidemics into direct costs (DC), direct consequential costs (DCC), indirect consequential costs (ICC) and aftermath costs (AC). They define ICC and AC as costs that are caused by market disruptions during and after HCLD epidemics. Hop et al. (2012) point out that ICC "result from supply and/or demand shocks of livestock commodities (i.e. price effects)".

1.2 Problem Statement

During CSF and AD epidemics disruptions on the markets for piglets and slaughter pigs occur. These *temporary* market disruptions cause *temporary* price changes and consequently lead to changes in the producers' surplus (PS) of pig farmers. The changes in PS that occur to pig farmers during and after HCLD epidemics make up the ICC and AC that they have to defray. In previous literature, changes in PS and ICC have either been disregarded (e.g. Meuwissen et al., 1999) or not been fully considered (e.g. Berentsen et al., 1992a, b). Furthermore, the constant advancement of control measures and changing market structures call for a constant re-evaluation of disease control strategies. The global aim of this thesis is to analyze the changes in PS that arise to piglet and slaughter pig producers during CSF and AD epidemics under different control strategies. To provide a definite research area the research is delimited to piglet and slaughter pig producers in the EU region NL-NRW-LS. The focus on the region NL-NRW-LS allows the consideration of cross-border aspects of control strategies in a highly inter-dependent pig production area. To keep complexity at bay PS changes in other EU regions as well as changes in consumers' surplus (CS) are disregarded.

1.3 Research Objectives

Based on the aim of this study and the problem statement described above several research objectives and questions are defined.

1. To provide a qualitative and quantitative description of the NL-NRW-LS pig market:
   What are the trade relations between NL, NRW and LS (e.g. traded products, trade volume, value etc.)? What are the trade relations between the regions NL-NRW-LS and other regions?
2. To provide a description of different disease control strategies:
   What are possible disease control strategies in NL, NRW and LS? In which way do they differ between NL, NRW and LS? What are the implications for ICC and AC?
3. To estimate data on supply shocks and price effects by scenario analyses:
   How do supply shocks emerge in different outbreak and control strategy scenarios? What are the trade effects (in terms of volume) and the price effects during and after outbreaks?
4. To analyze the data, particularly with respect to the effects of CSF and AD outbreaks on PS, and the factors that influence the magnitude of PS changes.

1.4 Relevance of Study

The results of this study are relevant for policy makers and pig farmers the results create awareness of the economic impact of CSF and AD epidemics under different control strategies. Moreover, the consideration of cross-border disease control aspects provides insights in the economic advantages of bilateral disease control. These insights can be helpful for cross-border collaboration in disease control in the highly interdependent EU pig markets.

1.5 Research Context

This thesis is complementary to the studies of PhD candidates G. Hop and K. Bosman who study the cross-border aspects of control mechanisms for epidemics of CSF (Hop, G.) and AD (Bosman, K.). To allow a better comprehension of the research conducted, Figure 1 provides a general overview of the research project.

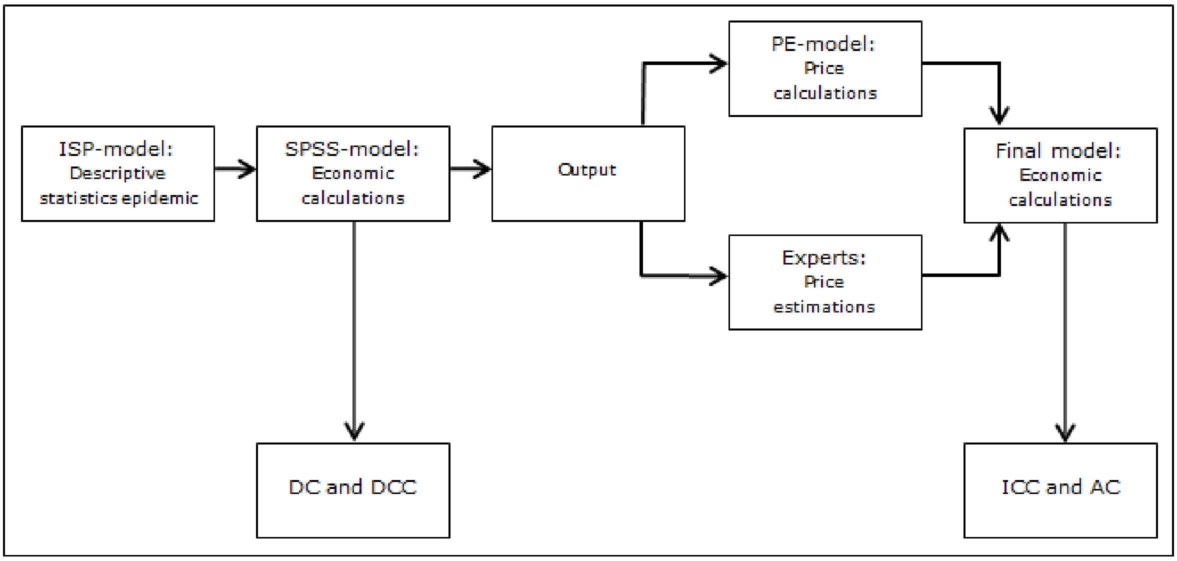


Figure 1. Overview of research project and relations between models and calculations.

Starting point of the research project are simulations of a CSF or AD epidemics. The descriptive statistics of the disease simulations are used in a SPSS-model to calculate DC and DCC of the respective epidemic (see Hop et al., submitted; Bosman et al., forthcoming a). Furthermore, the descriptive statistics provide the basis for subsequent calculations of the epidemics' ICC. To estimate price changes, that are necessary to calculate changes in PS, either a partial equilibrium (PE) model or price change estimations by experts can be used. In this thesis the latter approach is used.

1.6 Structure of Thesis

The second chapter consists of a literature review on HCLD economics literature. The third chapter describes economic effects associated with different disease control measures. The fourth chapter connects trade and welfare economic theory with economic aspects of disease control. Moreover, equations for the calculation of PS changes in different control scenarios are deduced. In the fifth chapter the expert workshops, that were conducted to gather data on price effects, are described. In the sixth chapter the results of the research are presented. In the seventh and eighth chapter the results and applied methods are discussed and a conclusion is drawn.

2 Literature Review

This literature review gives an overview of current HCLD economics literature. As this paper's objective is to investigate the changes in producers' surplus, special attention is paid to articles that consider indirect costs or ICC[1]. In the first section a general overview of literature on HCLD economics is given. In the second section a closer look is taken on studies that concern ICC. The third section presents a critique of the available literature.

2.1 HCLD

The literature on epidemiological and economic effects of HCLD is diverse. Numerous authors have published in the field of animal health economics. Among others Meuwissen et al. (1999), Buijtels and Burrell (2000) and Mangen (2002) analyzed the consequences of HCLD outbreaks in the Netherlands. Boklund et al. (2009) investigated different CSF control strategies in Denmark. Niemi et al. (2008) conducted an economic analysis of CSF outbreaks in Finland. Mahul and Durand (2000) investigated economic consequences of Food and mouth Disease (FMD) control in France. Dürr et al. (2013) analyzed CSF outbreaks in Switzerland.

In most cases the papers focus on one specific disease. The effect of FMD outbreaks are analyzed by Berentsen et al. (1992b). Buijtels and Burrell (2000) economically assess the consequences of AD outbreaks, while the economic effects of CSF epidemics are investigated by Meuwissen et al. (1999), Mangen (2002), Mangen et al. (2002 & 2004), Mangen and Burrell (2003), Niemi et al. (2006 & 2008), Bergevoet (2007), and Bruijnen and Saatkamp (2008). Longworth et al. (2012) research the economic impact of Avian Influenza epidemics. The aims and objectives of these studies differ. Some authors aim to calculate the total cost of past outbreaks (i.e. Meuwissen et al., 1999) and others compare the epidemiological and economic impact of different control strategies by simulating outbreaks (e.g. Mangen et al., 2002; Boklund et al., 2009).

Some authors investigate the influence of certain epidemiological and demographic characteristics on the epidemics' costs, like the duration of the high risk period (van Asseldonk et al., 2005) or the pig density in the region of the initial outbreak (Mangen et al., 2002; Boklund et al., 2009). Other studies focus on economic effects of trade bans (i.e. Buijtels and Burrell, 2000) or on inclusion of vaccination in control strategies (i.e. Mangen et al., 2001; Bergevoet et al. 2007). Van Asseldonk et al. (2005) aim to provide a decision making tool for policy makers.

Most of the above mentioned studies contain calculations of the direct costs of the researched epidemics, i.e. costs that are directly associated with disease control. However, only a few of them concern ICC, i.e. the costs that are a consequence of quantity and price effects that are triggered by HCLD epidemics and the related control measures. In the following section the most relevant studies that address or calculate ICC of HCLD epidemics are described.

2.2 ICC

The first authors who describe the theoretical background of ICC occurring during HCLD outbreaks are Berentsen et al. (1992a, b). In their first paper the authors review pre-existing studies on FMD outbreaks with respect to their economic methodology. As basis for their review the authors explain economic principles that are important for the economic analysis of HCLD. They suggest that at

[1] Previous authors have introduced different definitions of indirect costs. In the remainder of this thesis all types of indirect cost are referred to as ICC.

national level a distinction has to be made between producers, consumers and the government. The authors define producers' surplus as "gross returns (quantity times price) minus the variable costs (the area under the supply curve)" (Berentsen et al., 1992a). Furthermore, the authors argue that in livestock production the short-run supply curve can be assumed to be vertical. In a subsequent paper Berentsen et al. (1992b) economically assess and compare preventive and control strategies for FMD. The authors focus especially on ICC resulting from export bans that are introduced due the use of preventive vaccination. The paper uses an epidemiological, a disease-control and an export model. With the latter model the authors aim to calculate ICC that occur to the government, to consumers and to producers. The authors argue that export bans have a decreasing effect on domestic and export prices. Mangen (2002) points out that Berentsen et al. (1992b) only considered a sub-set of the ICC.

Buijtels and Burrel (2000) analyze the effects of export restrictions due to AD existence and vaccination in the Netherlands. In their analysis they econometrically develop a PE model of the Dutch pig market. The authors investigate the effects of export bans on product prices, outputs and producer revenue. In the model they recognize the price interactions between markets. Different trade ban scenarios are analyzed that take into account different disease statuses of trading partners. The authors conclude that there is a high pressure to achieve and maintain AD-free status, as complete trade bans can lead to price falls with large economic impact.

Saatkamp et al. (2000) present a framework to assess the economics of CSF epidemics in the EU. The authors give a description of EU control strategies and their economic impact. Special attention is given to the comparison of vaccination and non-vaccination strategies. Furthermore, the authors elaborate on ICC of CSF epidemics and describe market disruptions going along with CSF epidemics and the associated control measures. According to Saatkamp et al. (2000), the impact of a market disruption is influenced by several factors like the size of affected region, the duration of the epidemic, the net export of the affected region and price elasticities of supply and demand. The authors conclude that direct costs of an epidemic can be quickly outweighed by ICC. They also point out that ICC have to be considered in economic calculations, if an affected country is facing foreign trade responses.

Mangen in collaboration with other authors published several articles concerning the epidemiological and economic effects of CSF outbreaks in the Netherlands (Mangen, 2002; Mangen et al., 2002; Mangen and Burrell, 2003; Mangen et al., 2004). In the papers the authors focus on several factors influencing the economic impact of CSF outbreaks. Mangen (2002) investigates the welfare effects of small, medium and large scale epidemics. Mangen et al. (2002) analyze the effect of pig density on economic welfare changes during CSF epidemics. Mangen and Burrell (2003) use a sectoral market model and a stochastic epidemiological model to calculate economic effects of CSF in NL. Mangen et al. (2004) do an ex post calculation of the welfare effect of the 1997 CSF outbreak in NL. In the different studies a modeling framework developed by Mangen (2002) is used to calculate welfare effects. ICC of the simulated epidemics are calculated by a PE-model called DUPIMA (Mangen, 2002; Mangen et al., 2002, Mangen and Burrell, 2003). Like in Berentsen et al. (1992a, b), the Dutch piglet supply is assumed to be completely inelastic in the short-run.

Schoenbaum and Disney (2003) use computer simulations to compare control strategies for FMD outbreaks in the USA. They apply a cost-minimization approach to evaluate the control strategies that are based on vaccination or slaughter policies. To measure the economic impact a welfare analysis is conducted. It is assumed that the total costs of a FMD outbreak consist of government costs for control and eradication as well as of changes in PS and CS. The authors point out that the change in PS comprises "… the net change in PS in FMD-affected product markets (cattle, hogs, sheep, dairy, beef, pork) due to the supply effect of an FMD outbreak, combined with the change in PS in FMD-affected product markets due to the loss of export markets, and the indirect change in PS in all related markets (poultry meat, feed grains, etc.)" (Schoenbaum and Disney, 2003). To calculate PS and CS changes the authors use a multi-commodity, price-endogenous spatial equilibrium model.

The aim of van Asseldonk et al. (2005) is "… to conduct an integrated analysis of epidemiological, economic and socio-ethical aspects of (potential) control strategies". The authors use a multi-criteria analysis to support decision making in the complex issue of disease control. Van Asseldonk et al. (2005) study selected areas in six EU member states, including net importing and net exporting countries. Their economic analysis comprises a calculation of direct costs and ICC to farmers and a calculation of the net income effects on the rest of the economy. The authors point out that ICC occur due to a decrease of economic activities and give a clear indication which costs are included in the ICC.

Niemi et al. (2006 & 2008) conduct calculations of epidemiological and economic impact of CSF outbreaks in Finland. Niemi et al. (2006) analyze the income losses that occur to pig producers and slaughterhouses. The study mainly focuses on the effects of a decrease in export demand of meat products. The authors aim to investigate the effect of supply and demand shock on the Finnish pig sector and calculate production costs and profits. Unlike previous authors, Niemi et al. (2006) allow for adjustment of the production decision of pig farmers after the shock has been observed assuming a cost minimization behavior. The authors conclude that an export ban on meat could have a large financial impact on the Finnish pig sector. Niemi et al. (2008) also simulate the impact of a CSF epidemic in Finland. Their analysis is based on epidemiological and economic simulations and assumes profit maximizing behavior of producers and a reduction in export demand. Niemi et al. (2008) conclude that the responses of export markets to the CSF outbreak and the number of farms affected by control measures determines the economic impact of the epidemic.

Bruijnen (2008) provide a calculation of AC of the 1997 CSF outbreak in the Netherlands. In the analysis the author focuses on the period after the epidemic has been eradicated. The author conducts a quantitative analysis of the price and quantity effects in the time after the epidemic is under control. The author concludes that the economic impact after the epidemic is of similar dimension as the direct costs that occur during the outbreak. Bruijnen (2008) is the first who quantifies the AC of an epidemic.

Boklund et al. (2009) compare epidemiological and economic effects of control strategies against CSF in Denmark. The authors compare nine different control strategies using an InterSpread Plus (ISP) model and analyzing public costs, industry costs and export losses. The authors come to the result that although CSF epidemics in Denmark are likely to be of moderate size, they have a high economic impact due to export losses.

Longworth et al. (2012) describe the parameterization of an ISP model to conduct epidemiological and economic analysis of control strategies for Avian Influenza in the Netherlands. In their paper Longworth et al. (2012) aim to answer the question whether epidemiological modeling is a suitable basis for economic analysis of Avian Influenza control strategies. In the description of the economic framework the authors provide clear definitions of different cost categories associated with HCLD outbreaks. They define two subcategories of direct and indirect cost. According to Longworth et al. (2012), DC and DCC per definition originate from virus control and from avoiding further spread of the virus. ICC and AC arise because of market disruption during and after the outbreak.

2.3 Critique

The literature on ICC of HCLD outbreaks is scarce and some deficiencies can be pointed out in the available literature. In this section shortcomings of the current literature are described. The major points of criticism on the available studies can be based on:

a. missing theoretical economic framework
b. the level of market aggregation
c. insufficient cost definitions
d. the single country focus of current research

So far research has mainly been focused on the simulation of HCLD epidemic and their economic consequences. However, only few theoretical assessments of the underlying economic effects of HCLD epidemics have been conducted. Thorough examinations of theoretical frameworks and explanations of the underlying economic effects are missing, although a good understanding of the underlying market effects is crucial for the selection of appropriate disease control measures. The absence of well-structured theoretical frameworks complicates the understanding of the underlying models and assumptions in many studies. Exceptions are Berentsen et al. (1992a, b), Schoenbaum and Disney (2003) and Longworth et al. (2012) who provide detailed descriptions of the underlying economic theory.

As most studies fail to explain the causal chain of events in outbreak and control scenarios, some economic consequences of HCLD epidemics are overlooked. Since most of the presented studies aim to quantify the costs that occur to the industry or to the society as a whole, the level of market aggregation is rather high. In contrast to Niemi et al. (2008) who explicitly point out the difference between effects on the affected and the unaffected market, other authors (i.e. van Asseldonk et al., 2005; Boklund et al., 2009) take into account the welfare changes in the entire pig and/or agribusiness industry and attached sectors instead of focusing on submarkets. In order to get a better understanding of the economic impact of different control measures on the PS it is necessary to analyze the markets on a lower level of aggregation. Market disaggregation should be conducted with respect to market location, farm type, product quality and time phase of epidemic.

Furthermore, it is important to differentiate between piglet farms and fattening farms, because differences in economic impact can occur. Niemi et al. (2006) for example conclude that fattening farms potentially benefit from low piglet prices during CSF outbreaks. Also quality differences in products like overweight or vaccination can have an impact on ICC. As movement and export restrictions can change during the course of an epidemic, a temporary disaggregation of the market effects is necessary for a thorough analysis of ICC.

Another shortcoming of the available literature is the unclear definition of the costs related with disease outbreaks. The most advanced and most useful cost definition can be found in Longworth et al. (2012). In literature prior to Longworth et al. (2012), van Asseldonk et al. (2005) and Boklund et al. (2009) make attempts to define the costs of epidemics. While Boklund et al. (2009) distinguish between public costs, industry costs and export losses, van Asseldonk et al. (2005) separate direct costs and ICC. Van Asseldonk et al. (2005) list following ICC that occur to farmers:

a. "Effects of price differences on farms in and outside the infected area, both during the outbreak and after the transportation ban has been lifted;
b. Farmers' loss resulting from temporary vacancy of stables;
c. Farmers' loss resulting from the movement restrictions inside movement standstill areas;
d. Farmers' loss of the market value of vaccinated animals that are sold" (van Asseldonk et al. 2005).

In this thesis the cost definitions of Longworth et al. (2012) are used. The authors distinguish cost categories by their origin (i.e. virus control, prevention of virus spread, market disruptions during outbreak and market disruptions after outbreak). According to Longworth et al. (2012), ICC are determined by factors such as the size of the epidemic, the net export situation, the type of control strategies and the responses of trade partners. AC are additionally influenced by e.g. the size of lost export volume, the way of restocking and the degree of temporary undercapacity.

A last point of criticism is made with respect to the single country focus of previous studies. As setting up contingency plans and controlling outbreaks is the responsibility of national governments, most research conducted in this field is focused on individual countries. Saatkamp et al. (2000) elaborate on economic aspects of HCLD in an EU context. Since the pig market of the EU is highly interdependent across national borders the evaluation of control strategies on EU level is necessary.

Based on the identified shortcomings in previous papers recommendations for future research can be made. Besides focusing on the economic consequences of disease outbreaks, future research should also concentrate on providing a sound theoretical framework of economic effects of HCLD outbreaks. By disaggregating the livestock markets on different level economic consequences of disease outbreaks can be analyzed in more detail. Disaggregation helps to disentangle the economic effects of different control measures that are implemented and it allows analyzing the impacts that disease outbreaks have on different stakeholders. Moreover, future economic analyses of HCLD outbreaks in the EU should include the effects on the EU market.

3 Epidemiological Background

The objectives of this chapter are to give an overview of the current CSF and AD control measures and to elaborate the economic consequences associated with these control measures. CSF and AD are contagious pig diseases that are strictly controlled in EU member states. Both diseases are listed in council directive 64/432/EEC and are compulsory notifiable according to EU regulations and national contingency plans (see Anonymous, 1964, 1988, 2001, 2005, 2011 & 2012). In the contingency plans the disease control measures that are to be implemented in the event of a disease outbreak are specified. The national contingency plans contain country specific measures and are not equivalent across member states. For example, Bosman and Saatkamp (2010) point out that the German AD contingency plan contains culling of infected animals as a control measure for AD, while the Dutch contingency plan does not. In the following the disease control measures for CSF and AD are presented. Table 1 shows the control measures that are used during CSF and AD epidemics.

Table 1. Control measures in the contingency plans for CSF and AD in Europe, NL and GER.

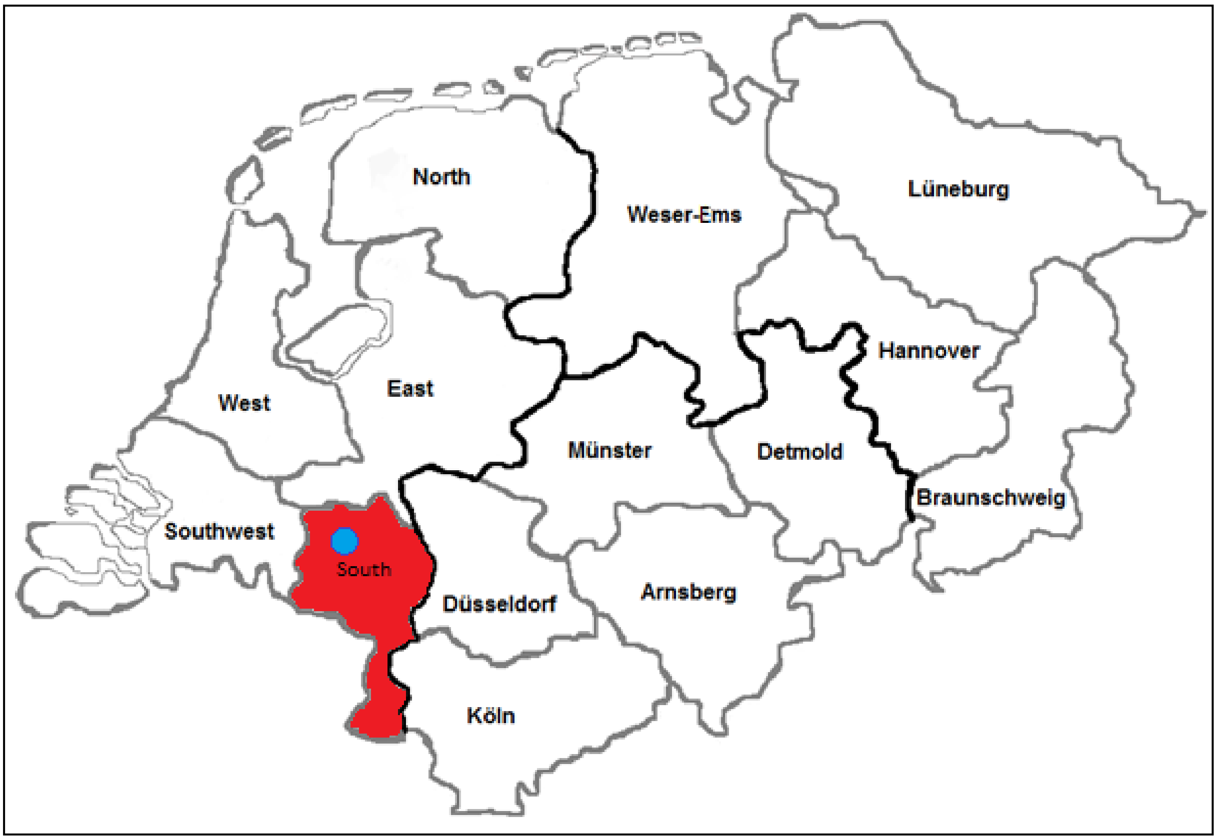
	CSF	AD	AD
Control Measure	**EU Minimum**	**NL**	**GER**
Emergency culling on infected holding	Mandatory	No	Mandatory
Nationwide 72 hour standstill	No	Mandatory	Mandatory
Pre-emptive culling on contact holdings	Optional	No	Optional
Movement Restrictions	Mandatory	Mandatory	Optional
Welfare slaughter	Optional	No	No
Repopulation ban in MRZ	Mandatory	No	No
Breeding ban	Optional	No	No
Emergency vaccination	Optional	Mandatory	Optional

Based on Anonymous (1964, 1988, 2001, 2005, 2011 & 2012), Elbers et al. (1999), Pluimers et al. (1999), Saatkamp and Bosman (2010).

3.1 CSF Control Measures

CSF control strategies in EU countries include emergency culling, a 72 h country wide movement standstill, pre-emptive culling, movement restrictions, welfare slaughter, repopulation bans, breeding bans and emergency vaccination (Anonymous, 2001). Emergency culling of affected herds and 72 h movement standstill are introduced immediately after outbreak detection. Pre-emptive culling of neighboring and contact holdings in a 1 km radius is an optional measure to the EU minimum measures (Mangen and Burrel, 2003). To prevent disease spread, two zones with different radii are installed around infected holdings. These zones are specified in the EU directive 2001/89/EC (see Anonymous, 2001). The protection zone has a radius of at least 3 km around infected holdings while the surveillance zone has a radius of at least 10 km. Movement of pigs is prohibited within the two zones and no pig is allowed to leave the zones. These two zones constitute the movement restriction zone (MRZ).

In addition to the movement restrictions in the MRZ, movement is restricted in the regions that contain infected holdings. In Figure 2 an example of an outbreak in region South of NL is presented. The MRZ is indicated by a spot inside the diseased region. In the MRZ and the diseased region movements are restricted, while there are no movement restrictions outside in unaffected regions. The underlying principle of separating a country into different regions is called regionalization (Anonymous, 1994). This principle is applied in the EU and it describes the division of a country's animal population in different subpopulations with distinct health statuses (Saatkamp et al., 2000; Scott et al., 2006; Anonymous 2007). The separation is mainly based on geographical criteria (OIE, 2007). Besides limiting movement restrictions to few regions of the affected country, regionalization allows continuation of trade from subpopulations that maintained the disease free status. For more information on regionalization see Saatkamp et al. (2000), Gemmecke et al. (2008) and Junker et al. (2009).



Source: Author's illustration.

Figure 2. Regions of NL, NRW and LS; disease outbreak in region South (NL).

When a disease outbreak lasts long, welfare slaughter schemes are introduced to avoid animal welfare problems (e.g. overpopulation of farms) and to cope with possible illegal transportation of pigs (Mangen and Burrel, 2003). Also prohibition of farm restocking and breeding bans may be implemented by the authorities. According to Pluimers et al. (1999), breeding bans help to decrease overpopulation of piglets in the MRZ and thus mitigate animal welfare problems. CSF control strategies in the EU are based on the principle of non-vaccination (Elbers et al., 1999; Saatkamp et al., 2000). While the preventive vaccination of pigs against CSF is forbidden in the EU, the use of emergency vaccination in densely populated livestock areas is allowed (Ribbens et al., 2012). The circumstances that allow emergency vaccination are described in Annex VI of the directive 2001/89/EC (see Anonymous, 2001).

3.2 AD Control Measures

In the national contingency plans of NL, NRW and LS emergency culling, 72 h country wide movement standstill, pre-emptive culling, MRZs and vaccination occur. In Germany the infected pigs and pigs that are suspected to be infected are culled. Additionally, the responsible authority can order the culling of all remaining pigs (Anonymous, 2005). According to Bosman and Saatkamp (2010), culling is not used as a control measure in the Netherlands. Like in the case of a CSF outbreak a nationwide 72 hour standstill after the confirmation of an AD outbreak is installed in NL and

Germany. In NRW and LS the authorities can order the pre-emptive culling of contact holdings (Anonymous, 2005).

If the epidemiological situation requires more measures, the German authorities can impose a movement restriction zone around the affected holding. The size of the MRZ is not determined by law. In the Netherlands a MRZ is imposed around the affected holding in which no movement is allowed until at least two weeks after the entire herd has been vaccinated twice (Bosman and Saatkamp, 2010). In the case of an AD outbreak in NL or Germany, the authorities can order an area wide vaccination of pigs to control the outbreak (Anonymous, 2005). According to German law, vaccinated pigs have to stay at their holding for a minimum of 21 days after vaccination (ibid., 2005). Exceptions can be made for slaughtering purposes.

In NL all animals that are not removed from the holdings have to be vaccinated twice. However, vaccination leads to the loss of the most favorable AD status. EU law makes a distinction between two AD statuses (Anonymous, 1964 & 2008). EU member states are categorized into provable AD-free member states and regions (so called Article 10 areas) and member states that have an approved AD control and eradication plan (Article 9 areas). Export of pigs from Article 9 to Article 10 areas is only possible under provision of additional guarantees. A thorough explanation of the categorization of the member states and the guarantees that have to be provided is given in “Guidance to Commission Decision 2008/185/EC” (Anonymous, 2009). Vaccination cannot be used preventively or for disease control without losing the Article 10 status. Buijtels and Burrell (2000) showed that the absence of Article 10 status has large negative effects on the Dutch pig sector.

3.3 Economic Effects of Control Measures

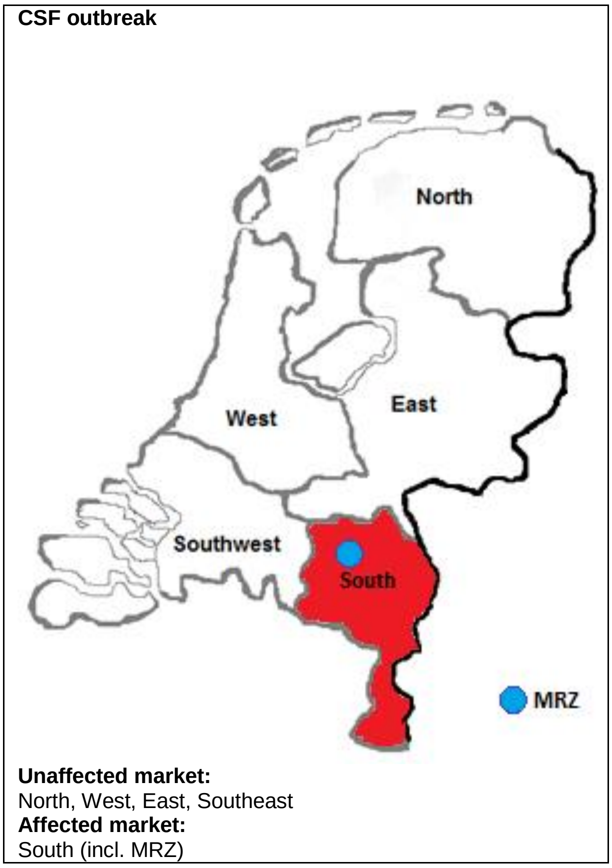
In their paper Bosman and Saatkamp (2010) and Hop et al. (2012) distinguish between veterinary and economic control measures. The authors state that the aim of the veterinary measures to eradicate a disease outbreak as soon as possible potentially conflicts with economic and socio-ethical goals. In Figure 3 a causal chain of consequences of HCLD epidemics is shown. The first link in the causal chain is the primary confirmation of the presence of a contagious disease. In order to eradicate the disease, veterinary control measures are implemented. As Modisane (2009) points out, disease control measures often cause unintended effects. Veterinary disease control measures have undesirable economic consequences such as large revenue losses (e.g. Elbers et al., 1999; Bosman and Saatkamp, 2010) and socio-ethical consequences such as the mass culling of animals (e.g. van Asseldonk et al, 2005; Bergevoet, 2011; Brosig, 2012). To mitigate these undesired effects additional economic and socio-ethical control measures are introduced (Bosman and Saatkamp, 2010). Ultimately, the final economic effects of the disease and the related control measures can be observed.

Based on Bosman and Saatkamp (2010).
Figure 3. Causal chain of consequences after an initial outbreak of a HCLD.

The final economic effects of HCLD outbreaks can be expressed in terms of economic costs. According to Longworth et al. (2012), these economic costs can be categorized into DC, DCC, ICC and AC. During an epidemic every veterinary, socio-ethical and economic control measure has influence on these cost categories. While veterinary control measures are aimed at disease eradication, economic control measures aim at mitigating the negative economic consequences caused by veterinary measures. In the following the economic effects of CSF and AD control measures and measures to mitigate these effects are described.

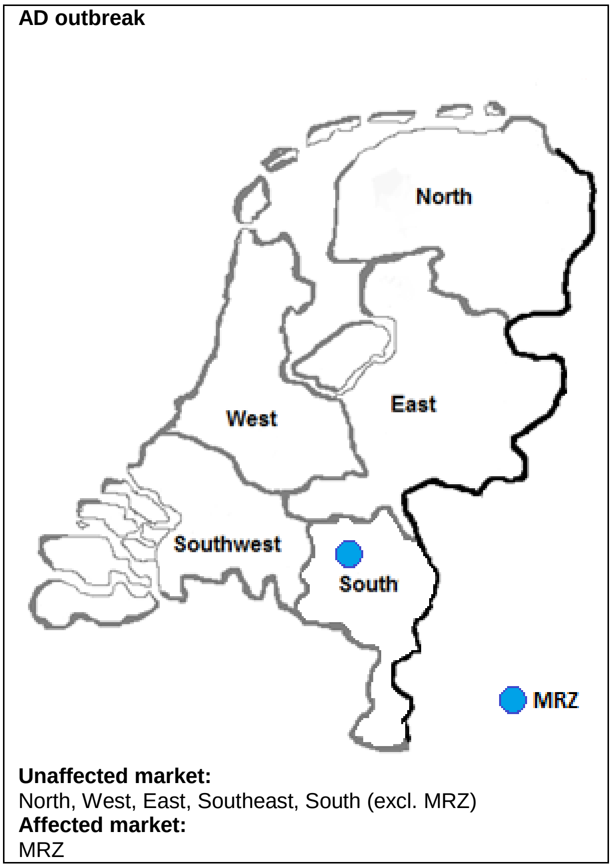
3.3.1 Movement Restrictions

By implementing movement restrictions the affected country is separated into two spatially and economically separated markets: the affected market, which is subject to movement restrictions, and the remaining, unaffected market. The part of the market underlying movement restriction faces different quantity and price effects than the unaffected market. In case of CSF outbreaks movements are restricted in the MRZ and in the affected region. In accordance with the regionalization principle, there are no movement restrictions outside the affected region (Anonymous, 1994). Figure 4 shows the market separation during a CSF outbreak in NL. Region South is the affected region. Within the region South movements are restricted during the outbreak. In Figure 4 South including the MRZ constitutes the affected market. In Figure 5 the market separation during an AD in NL is shown. During AD outbreaks movements are only restricted in the MRZ, therefore the affected market consists just of the MRZ.



Source: Author's illustration.

Figure 4. Market separation during CSF outbreak in NL.



Source: Author's illustration.

Figure 5. Market separation during AD outbreak in NL.

Inside the affected market the movement restrictions have severe consequences. Bosman et al. (2013) point out that inside the affected market large surpluses can build up. Farms inside the affected market lose access to the sales markets resulting in revenue losses. These losses are DCC that occur to farms inside the movement restriction area (Longworth et al., 2012). Moreover, farms inside the affected market will get problems with overweight and overage animals (Pluimers et al., 1999; Bosman et al., 2013). These animals are of reduced quality and will yield a reduced price as soon as market access is regained. Market access can be regained through channeling or after lifting the movement restrictions.

In the unaffected market the movement restrictions cause shortages because supply from pig holdings inside the affected market is missing. This causes a supply shock on the unaffected market. The supply shock causes price effects and supply problems outside the affected market and thus increases ICC. Among other factors, the size of the supply shock depends on the characteristics of the movement restrictions. In their paper Bosman et al. (2013) define three types of movement restrictions: strict movement restrictions, movement restrictions allowing movements within the affected market and movement restriction with in- and outside movement. For the price and quantity effect in the unaffected market it is important whether products can leave the affected or not. The former case can be referred to as movement restrictions with channeling to the unaffected market. By using channeling as an economic control measure the negative animal welfare and negative economic effects of a MRZ can be reduced (Bosman et al., 2013). The authors define channeling as the “transportation of pigs under certain conditions and to specific destinations”. In addition, channeling reduces the supply shock on the unaffected market and thus mitigates the negative economic impact of the veterinary control measures.

3.3.2 Welfare Slaughter

As Meuwissen et al. (1999) point out movement restrictions lead to welfare problems because animals become too big and the holdings become too crowded in the affected market. To mitigate the welfare problems, welfare slaughter schemes can be implemented. Welfare slaughter tackles the socio-ethical problems of overpopulation. However, welfare slaughter is not without negative socio-ethical consequences itself as many animals are killed and destroyed (van Asseldonk et al., 2005). The destruction of slaughter pigs and piglets reduces the supply quantity on the market and increases the ICC. Channeling can make welfare slaughter obsolete as no overage and overweight animals occur when channeling is allowed.

3.3.3 Ban on Breeding and Repopulation

During CSF epidemics farms inside affected markets may be subjected to bans on repopulation and breeding (Pluimers et al., 1999). Because of the bans on repopulation and breeding farms suffer revenue losses due to idle production factors (Meuwissen et al., 1999; Pluimers et al., 1999). According to Longworth et al. (2012), revenue losses due to idle production factors can be classified as DCC. Repopulation bans influence the AC of a disease outbreak because as soon as movement restrictions and repopulation bans are lifted many farms are allowed to repopulate the barns again. In the sector the demand and price for piglets is likely to escalate. The price effect will be reinforced by breeding bans as they increase the supply shortage in piglets after the epidemic. Saatkamp et al. (2000) point out that massive restocking causes short-term price fluctuations.

3.3.4 Culling

During CSF and AD epidemics culling can occur in the forms of pre-emptive and emergency culling of entire herds (Anonymous, 2001 & 2005). Pre-emptive and emergency culling leads to DC and DCC, as holdings are depopulated and idle (cf. Longworth et al., 2012). By contributing to the supply shock culling has an effect on the ICC of an outbreak. Furthermore, pre-emptive culling has negative socio-ethical consequences as it is publically undesired to cull great numbers of animals (e.g. Backer et al., 2013). Vaccination can be used as an alternative to pre-emptive culling and decreases the number of pre-emptively culled animals (e.g. Greiser-Wilke and Moenning, 2004, Anonymous, 2007) Thus, vaccination decreases the supply shock.

3.3.5 Vaccination

The economic effect of emergency vaccination[2] is ambiguous. On the one hand vaccination decreases the number of culled animals (Greiser-Wilke and Moenning, 2004), and thus affects the DCC and ICC of the epidemic. On the other hand vaccination creates quality differences in products and can result in the loss of export markets. The loss of export markets results in ICC and AC, because it causes quantity and price effects in the affected country.

When vaccination is used as a disease control measure a quality difference in products is created. Vaccinated products may yield lower prices than non-vaccinated products (e.g. Saatkamp et al., 2000; Bergevoet, 2007; Backer et al., 2013). Therefore, farms inside vaccination areas may receive lower revenue. The price effects that are caused by the differences in the products raise the ICC of the epidemic. Moreover, the vaccination strategy of a country affects its disease status (OIE, 2013) and influences access to international trade (Greiser-Wilke and Moenning, 2004; Backer et al., 2013). With export bans formerly exported supply has to be sold on the domestic market, causing an excess supply on the national market. Therefore, vaccination co-determines the direction of the supply shock by determining the disease status of the country. When vaccination is used export bans might be imposed by trade partners. In net exporting countries export bans prevent excess supply from being sold on the international market. The quantity effects caused by export bans influence the prices on the domestic market. These effects have an impact on the ICC of the disease outbreak. The persistent loss of export markets can cause long run AC. In order to avoid export bans channeling could assure that products from vaccination zones are processed only domestically provided that the trade partners accept this practice.

3.3.6 Summary

Table 2 summarizes the cost effects of CSF and AD control measures. It shows which cost categories are affected by the veterinary control measures and which mitigation measures can be introduced to reduce the negative effects of the veterinary control measures. From the elaboration on the cost effects of disease control measures it can be concluded that channeling and vaccination can be used as mitigation control measures.

[2] Preventive vaccination is not considered in this study, since it is forbidden in the EU (van Asseldonk et al., 2005).

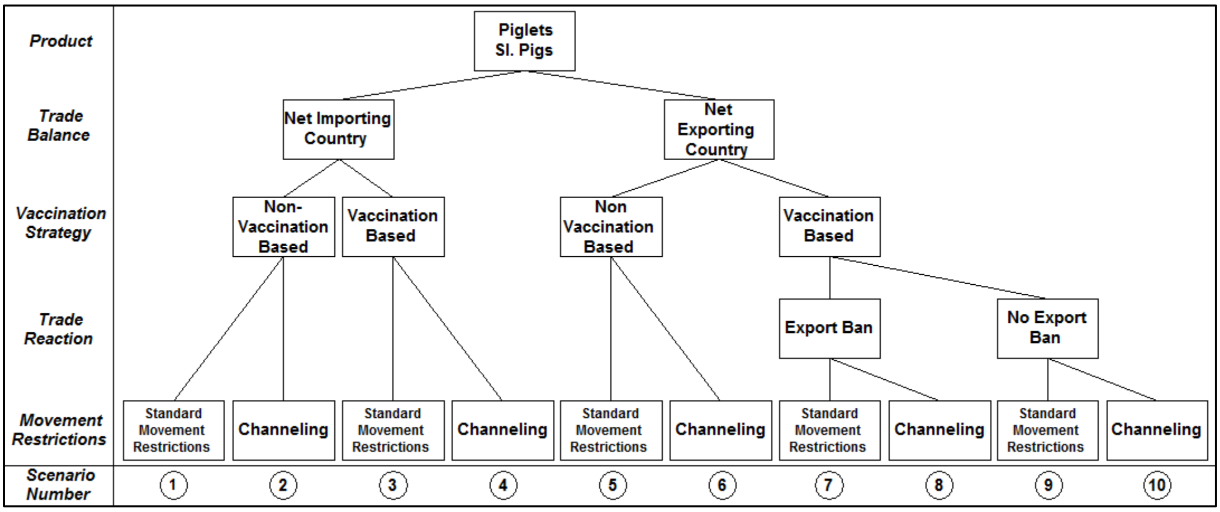
Table 2. Veterinary CSF and AD control measures and related mitigation control measures.

Veterinary CM	Consequences of the veterinary CM	Mitigation CM	Effect of Mitigation CM	Cost Categories
Movement restrictions	1. Loss of sales markets for farms inside MRZ.	Channeling	Allows farms to access the market.	DCC
	2. Supply shock.	Channeling	Decreases supply shock.	ICC
	3. Differences in products (Overweight pigs and piglets).	Channeling	Allows for earlier disposal of animals at optimal weight. Differences in products (Origin inside or outside MRZ).	DCC & ICC
Welfare slaughter	Increases supply shock.	Channeling	Reduces welfare slaughter.	ICC
Ban on repopulation and breeding	Revenue losses due to idle production factors.	-	-	DCC & AC
Culling	1. Depopulation of farms.	Vaccination	Decreases the number of culled farms.	DC & DCC
	2. Increases supply shock.	Vaccination	Decreases supply shock.	ICC
Vaccination	1. Differences in products (Vaccinated and non-vaccinated products).	Channeling	Mitigates economic impact.	ICC
	2. Export ban.	Channeling	Avoid export bans.	ICC & AC

Based on Meuwissen et al. (1999), Pluimers et al. (1999), van Asseldonk et al. (2005), Bosman and Saatkamp (2010), Hop et al. (2012), Longworth et al. (2012) and Bosman et al. (2013).

4 Theoretical Elaboration on Economic Welfare Effects

In this chapter the economic effects of the disease control measures are linked to economic welfare effects that occur to pig producers. The objectives of the theoretical elaboration on economic welfare effects are to identify factors that influence pig producers' PS and to come up with equations to calculate PS in different control scenarios. Based on the presentation of disease control measures in the previous chapter several disease control scenarios can be described. The scenarios consist of different combination of disease control measures, trade partners' responses, affected country characteristics and product types. Figure 6 provides an overview of the scenarios.



Source: Author's illustration.

Figure 6. Overview of disease control scenarios.

The PS effects of CSF and AD epidemics are primarily determined by five factors. The factors are shown on the left hand side of Figure 6. The first factor that plays a role is the type of concerned product (piglet vs. slaughter pig). An aggregated consideration of live pigs would conceal economic effects that occur specifically to piglet or slaughter pig producers. Therefore, a distinction is made between welfare effects occurring to piglet producers and slaughter pig producers.

Moreover, a country's trade balance is an important factor for the determination of welfare effects (net importing vs. net exporting). While an HCLD epidemic in a net exporting region will theoretically lead to a shortage of animals on the world market and to a surplus accumulation in the affected country, an outbreak in a net importing region will theoretically have opposite effects. The EU pig market has a highly specialized production structure and within the EU specialized production areas have evolved (Marquer, 2010). Piglet producers for example are predominantly located in NL and Denmark, while Germany imports large quantities of piglets and slaughter pigs (ibid., 2010). The specialization leads to an unbalanced production structure, e.g. NL produces much more piglets than demanded for domestic slaughter pig production.

The third and the fourth factor that influence the PS changes are the vaccination strategy (non-vaccination vs. vaccination) and as a consequence thereof the presence of export bans (export ban vs. no export ban). When export bans are implemented by trade partners, surpluses build up in affected net exporting countries. Unbalanced production structures in the affected country can amplify the surplus generation. Since the use of vaccination causes the loss of the disease free status (OIE, 2013), distinction is made between control strategies based on vaccination and strategies based on non-vaccination. In vaccination scenarios distinction is made between scenarios with and without export ban.

The fifth factor influencing ICC is the type of the implemented movement restriction. The type of movement restrictions (standard movement restrictions vs. channeling) influences the size of the supply shock in the unaffected market. Furthermore, channeling allows producers in the affected market to access the unaffected market. Thus, channeling allows them to generate PS.

4.1 Trade Theoretical Concerns

From a trade theoretical perspective there are two relevant factors for the welfare economic implications of the disease control scenarios. In trade theory it is distinguished between large scale and small scale countries. Koo and Kennedy (2005) point out that “a small importing country faces a perfectly elastic export supply function, because the country’s imports are not large enough to influence the world price”. Similar reasoning holds for small exporting countries. They face a perfectly elastic import demand and have too little supply to influence the world market price. The authors argue that small exporting countries are price takers. Accordingly, Gandolfo (2014) assumes that what happens in a small country has a negligible effect on the rest of the world.

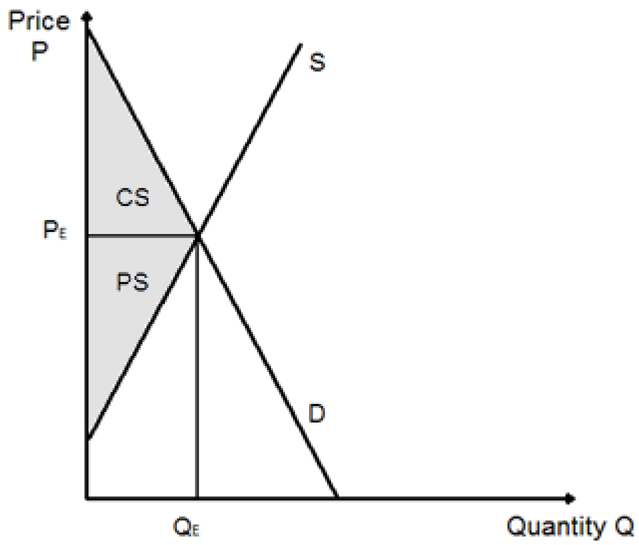
In contrast, large countries have an effect on the world market. These effects cannot be neglected. According to Koo and Kennedy (2005), the world market price is exogenous for small countries. In the large country case prices and other variables of the world market are endogenous. Hence, a change in quantity supplied or demanded by a large country has an effect on the world market price. Contrary, a change in a small country’s supplied or demanded quantity has no effect on the world market price. The scale of a country (or the size of an outbreak) is of importance for the economic impact on an epidemic, because an outbreak in a small scale country would have no effect on the product prices in the world market.

In the remainder of this thesis the term ‘EU price’ will be used instead of ‘world market’ price, since the focus is on the European market for live piglets and slaughter pigs. Given the small amount of trade in live pigs between EU countries and non-European countries, this denotation is sensible. Furthermore, transportation costs are neglected in the succeeding analysis. The EU free trade zone and the proximity of EU member states allow disregarding these costs.

4.2 Welfare Economic Concerns

Partial equilibrium approaches like welfare or economic surplus analysis can be used “to asses price distortions and market impacts for a single commodity” (Upton, 2009). With the help of welfare analysis it is possible to analyze the impact of policies on the net gain or loss of consumers, producers and government (ibid., 2009). Koo and Kennedy (2005) define CS as “the difference between what consumers are willing to pay and the market price that they actually pay”. In Figure 7 the CS is shown by the triangle between demand curve and price line. Berentsen et al. (1992a) point out that the area under the demand curve D equals the willingness to pay (WTP) for the demanded quantity Q_E.

According to Koo and Kennedy (2005), PS is “the difference between the price that sellers could receive and the market price they actually receive”. Upton (2009) argues that the supply curve S represents the marginal costs of production and the area below the supply curve S shows the total variable costs. The difference between the total revenue ($Q_E * P_E$) and the total variable costs is the PS (ibid., 2009). As shown in Figure 7, the PS consists of the triangle above supply curve S and below the price line. In the following the concept of economic surplus is related to the pig market.



Source: Author's illustration.
Figure 7. Long-run equilibrium situation in the pig market.

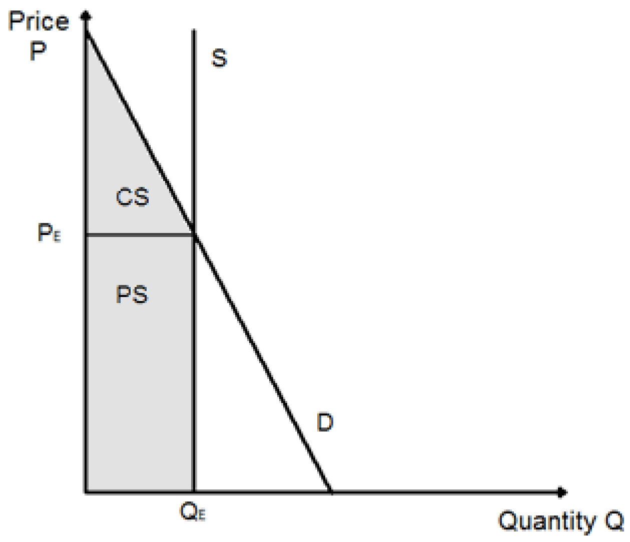
Researchers traditionally assign price inelastic supply and demand curves to food products (e.g. Koester, 1981; Berentsen et al., 1992a; Dijkhuizen and Morris, 1997). Thus, changes in the product prices do not cause large changes in supplied and demanded quantity. Also in the pig market it is reasonable to assume a steep supply curve (Burrel, 2002).

As shown by Koester (1981) short-run supply curves are less elastic than long-run supply curves, because variable inputs become fixed in the short term. In the short-run market situation pig holders cannot quickly adjust their production output, because of the time lag between production decision and production output (Upton, 2009). Once pig breeders and pig fatteners have made the decision to produce they will have a certain output at the end of the production period. This holds for fattening farms, piglet producers as well as for breeding stock producers. Berentsen et al. (1992a) point out that this implies that in the short-run all production factors of the pig holdings are fixed, resulting in a completely inelastic supply in the short-run. Upton (2009) points out that "… supply response by livestock producers is generally subject to significant time lags". Consequently, pig producers cannot adapt their production during a HCLD epidemic as long as the epidemic only lasts for a relatively short period (Berentsen et al., 1992a).

As shown in Figure 8, the completely inelastic supply curve suggests that all production factors that are variable in the long-run are fixed in the short-run, i.e. pig breeders and fatteners are not able to adjust their production to current prices. Since the short-run supply is completely inelastic, the producers' surplus in the short-run equals to the aggregate revenue that the producers generate. The calculation of the short-run producer's surplus PS_{SR}[3] is:

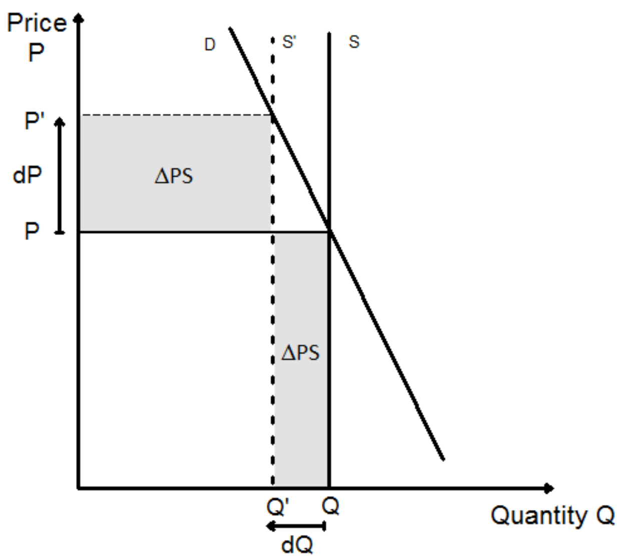
$$PS_{SR} = Q_E * P_E \tag{1}$$

[3] In the following text short-run producers' surplus PS_{SR} will simply be denoted as PS.



Source: Author's illustration.
Figure 8. Short-run equilibrium situation in the pig market.

When a supply shock occurs on the market the intersection of demand curve and new supply curve determines the new equilibrium price P'. This situation is shown in Figure 9. The shift of the supply curve S to S' occurs, because movement restrictions are implemented and animals are culled or slaughtered for welfare reasons. The supply shock dQ is composed of two components. First, all animals that are culled or slaughtered for welfare reasons drop out of the market. Second, the supply retained in the affected market because of the movement restrictions contributes to the supply shock.



Source: Author's illustration.
Figure 9. Price and quantity effect caused by a supply shock.

If it is assumed that the demand curve is not subject to a shift during the epidemic, the change in the producers' surplus ΔPS is calculated as[4]:

$$\Delta PS = dP * Q' + dQ * P \tag{2.1}$$

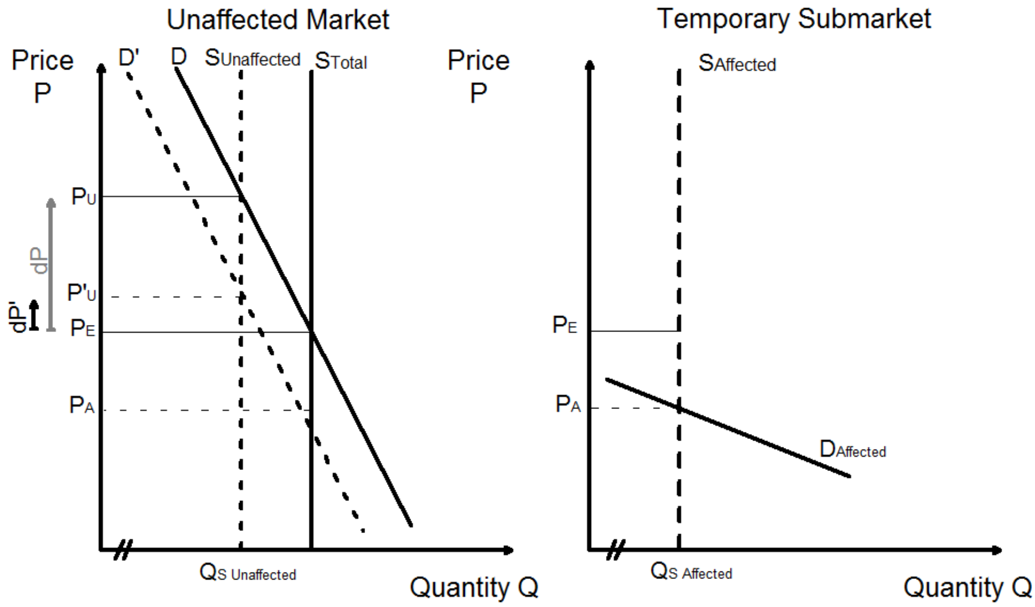
$$\Delta PS = (P' - P) * Q' + (Q' - Q) * P \tag{2.2}$$

The first parts [$dP * Q'$, respectively $(P' - P) * Q'$] of equations 2.1 and 2.2 relate to the change in PS that occurs to the producers in the part of the market that is not subjected to movement restrictions. The surplus of the producers in this part of the market changes, because of the price change dP that is induced by the supply shock caused by the epidemic. The second parts of equations 2.1 and 2.2 [$dQ * P$, respectively $(Q' - Q) * P$] refer to the affected producers who drop out of the market and thus cause the supply shock dQ. From equations 2.1 and 2.2 it follows that the change in producers' surplus depends on the pre-shock level of the price P, the post-shock level of the supply quantity Q' and on the changes in price dP and quantity dQ. The size of dP depends on demand curve D and the size of supply shock dQ.

Depending on the control strategy quality differences in products can occur. When channeling to the outside of the affected market is allowed or when movement restrictions are lifted, differences between affected and unaffected products are of importance. Overweight, overage and vaccinated animals are products of lower quality. Therefore, the WTP for these affected products will be lower than for unaffected products. The results of Coibion et al. (2007) suggest that the equilibrium demand elasticity is higher for low quality products. The existence of lower quality products has some economic implications.

In Figure 10 a temporary submarket for affected products is shown. Temporary submarkets emerge, when channeling is allowed or movement restrictions are lifted. The temporary market will exist as long as affected, low quality products are available. Affected products are substitutes for unaffected products. Therefore, the demand curve in the unaffected market is subject to a shift. Koester (1981) argues that the existence of substitute products has an effect on the price elasticity of demand. In Figure 10 this effect is shown by the shift of the demand curve in the unaffected market from D to D'. Consequently, the price change in the market of the unaffected products will be only dP' instead of dP. Since affected producers generate a producers' surplus $PS_{Affected}$ ($PS_{Affected} = P_A * Q_{S\,Affected}$), the total change in the producers' surplus ΔPS will turn out lower than in the case where affected producers are not able to sell their products.

[4] Assumptions: dQ drops out of the market completely and the economy is not engaged in any trade relationship.



Source: Author's illustration.

Figure 10. Unaffected market and temporary submarket market for affected products.

4.3 Theoretical Elaboration on PS Effects

In the following the PS effects of the control scenarios will be described and equations for calculating ΔPS will be deduced. As shown in Figure 6, the control scenarios differ with respect to the market situation (import vs. export), the vaccination strategy (vaccination vs. non-vaccination), the trade response (export ban vs. no export ban) and the characteristic of the movement restrictions (standard vs. channeling). Emergency culling on infected holdings and movement restrictions around infected holdings (i.e. MRZs) are part of every control strategy. The standard movement restrictions are determined by the EU minimum measures. As Pluimers et al. (1999) describe for the 1997 CSF outbreak in NL, the characteristics of control measures (i.e. change from strict movement restrictions to channeling) as well as trade responses (e.g. lifting of an export ban) can change during the course of an epidemic. Therefore, the factors influencing and the calculation of ΔPS might differ during the course of an epidemic.

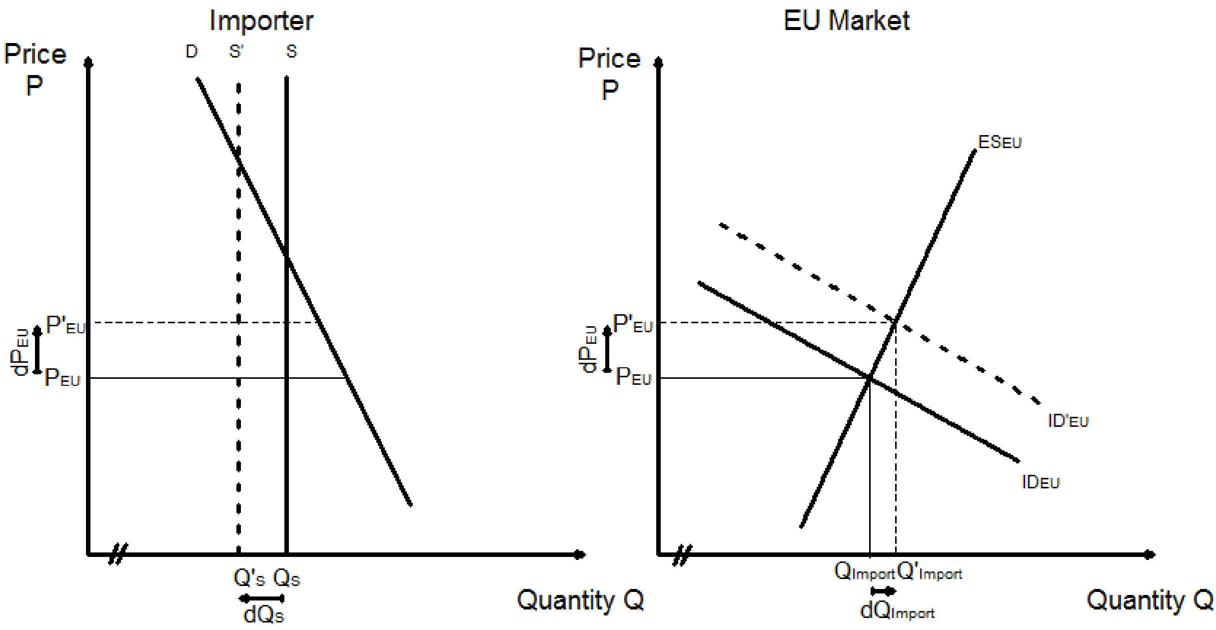
4.3.1 Net Importing Country

4.3.1.1 No. 1: Non-Vaccination Strategy with Standard Movement Restrictions

4.3.1.1.1 Quantity Effect

Figure 11 shows the impact of an epidemic on the market of an importing country with standard movement restrictions. Standard movement restrictions imply that dQ_S is completely cut off from the market. The supply shock dQ_S equals to the amount of supply that is cut off from the market by the movement restrictions plus the amount of culled animals. The cut off causes supply curve[5] S to shift left to S'. The decrease in supplied quantity from domestic producers consequentially leads to an increase in the import demand of the affected country. The import demand curve ID shifts to ID', resulting in an increase in imported quantity Q_{Import}.

[5] In the following the term supply curve describes the *short-run* supply curve.



Source: Author's illustration.

Figure 11. Net importer, non-vaccination with standard movement restrictions.

4.3.1.1.2 Price Effect

In absence of export bans the price that producers receive is determined on the EU market. Therefore, the price effect dP depends on the price response of the EU market. Depending on whether the affected country is large or small in trade theoretical terms, the shift in the domestic supply curve causes a shift in the EU market price P_{EU}. The shift of the ID curve on the EU market determines the new EU market price P'_{EU}. Under the assumption that the affected country is large an outbreak causes an increase in the EU price from P_{EU} to $P'_{EU.}$ The new EU price P'_{EU} will apply in the importing country. If the country is small, the producers' price will remain at P_{EU}.

4.3.1.1.3 PS Effect

The size of ΔPS depends on the size of the change in the supplied domestic quantity dQ_S and on the change in EU market price dP_{EU}. Since the price effect depends on the scale of the affected country, also the change in PS depends on whether the country is large or small. The ΔPS in the large country case is calculated as:

$$\Delta PS = (P'_{EU} - P_{EU}) * Q'_S + (Q'_S - Q_S) * P_{EU} \tag{3}$$

In the small country case or in cases where dQ_S is too small to affect P_{EU} the EU market price and the price in the importing country remain constant. The change in the PS in the small country scenario equals to:

$$\Delta PS = (Q'_S - Q_S) * P_{EU} \tag{4}$$

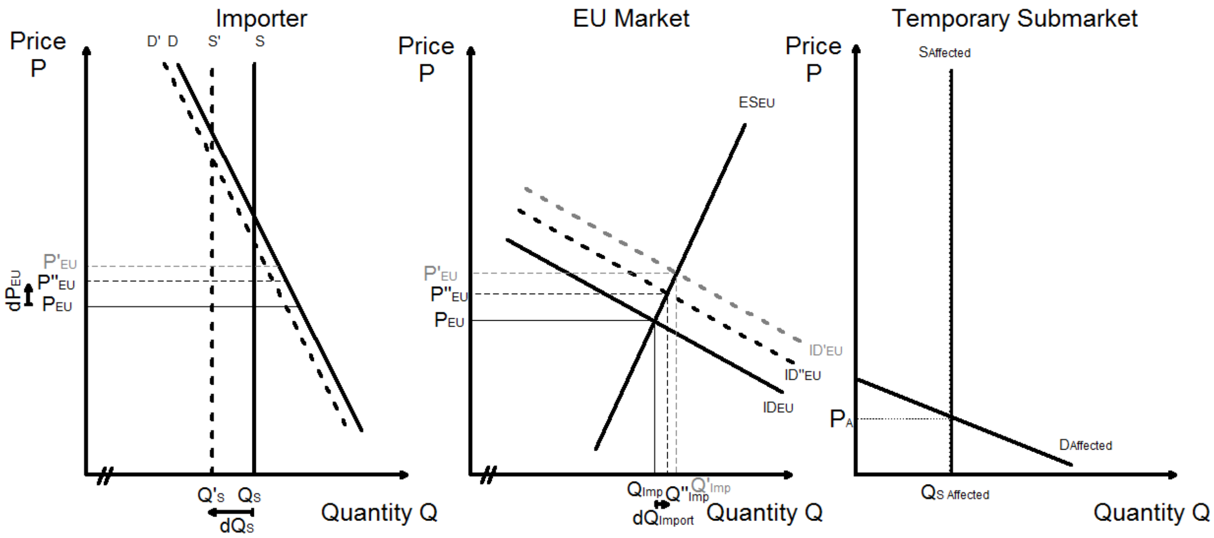
In the small country case the producers in the unaffected market do not gain or lose PS, because the EU market price P_{EU} remains constant. Affected farms lose PS as they are cut off from the market.

4.3.1.2 No. 2: Non-Vaccination Strategy with Channeling

The welfare effects in control scenario 2 depend on the quality differences between unaffected and channeled products. Two situations can be distinguished. In the first situation demand for the channeled products is equal to the demand for unaffected products. With equal demand the supply shock on the unaffected market dQ_S equals to the quantity that has been culled plus the supply that is cut off from the market by movement restrictions minus channeled supply. In the calculation of the PS there is no difference between control scenario 1 and scenario 2 with channeling and equal demand for affected and unaffected products. Subsequently the situation with unequal demand for channeled and unaffected products is described.

4.3.1.2.1 Quantity Effects

If channeled products are of lower quality than unaffected products, a temporary submarket for the affected products will emerge (Figure 12). The supply shock dQ_S on the unaffected market will equal to the quantity cut off by the movement restrictions plus the culled animals. Channeling does not decrease dQ_S, because of the quality difference between channeled and unaffected products. The channeled quantity is $Q_{S\,Affected}$.



Source: Author's illustration.

Figure 12. Net importer, non-vaccination with channeling with difference in demand.

4.3.1.2.2 Price Effects

The affected product is a substitute product of the unaffected product. Therefore, a leftward shift in the demand curve for the products in the unaffected market occurs. The demand shift leads to price changes. In the small country case the producers' price will be at the pre-epidemic level P_{EU}. In the large country case the producers' price will equal to P''_{EU}. The supply shock dQ_S causes a shift of the import demand ID to ID' while the demand shift in the importing country causes ID' to decrease to ID''. P''_{EU} is lower than the producers' price in the first scenario, because the import demand of the country is lower than in the first control scenario ($Q''_{Imp} < Q'_{Imp}$).

4.3.1.2.3 PS Effect

In the small country case the price received by the producers remains at P_{EU}, regardless of the demand shifts. In the large country case the demand shift and dQ_S matter, since large countries influence P_{EU}. In the net importer scenario, the equations for the ΔPS in the large country (eq. 5) and in the small country scenario (eq. 6) are as follows:

$$\Delta PS = (P''_{EU} - P_{EU}) * Q'_S + (Q'_S - Q_S) * P_{EU} - P_A * Q_{S\,Affected} \tag{5}$$

$$\Delta PS = (Q'_S - Q_S) * P_{EU} - P_A * Q_{S\,Affected} \tag{6}$$

In both cases the producers that drop out of the market lose PS in the amount of $\left(Q'_S - Q_S\right) * P_{EU}$. This is PS that they lose in the unaffected market. However, the producers who are affected by movement restrictions generate PS, because they can access the market via channeling. Their additional PS equals to ($P_A * Q_{S\,Affected}$).

4.3.1.3 No. 3: Vaccination strategy with standard movement restrictions

The changes in producers' surplus ΔPS in scenario 3 are calculated in the same way as in scenario 1 (eq. 3 and eq. 4). As pointed out in section 3 vaccination can lead to export bans. However, an export ban theoretically has a limited effect in net importing countries. If export bans are imposed, quantities that cannot be exported anymore will be sold on the domestic market. Thus, the gross import demand will be reduced. The impact of an export ban on the supply shock dQ_S is assumed to be negligible, because no surpluses will accumulate on the domestic market. Furthermore, the differences in products that are caused by vaccination are of no importance as long as movement restrictions are strict.

4.3.1.4 No. 4: Vaccination strategy with channeling

The PS effects of scenario 4 follow the same reasoning as in scenario 2. Changes in producers' surplus ΔPS are calculated by eq. 5 and eq. 6, respectively. The only difference between scenario 2 and 4 is that in scenario 4 channeled animals are vaccinated.

4.3.2 Net exporting country

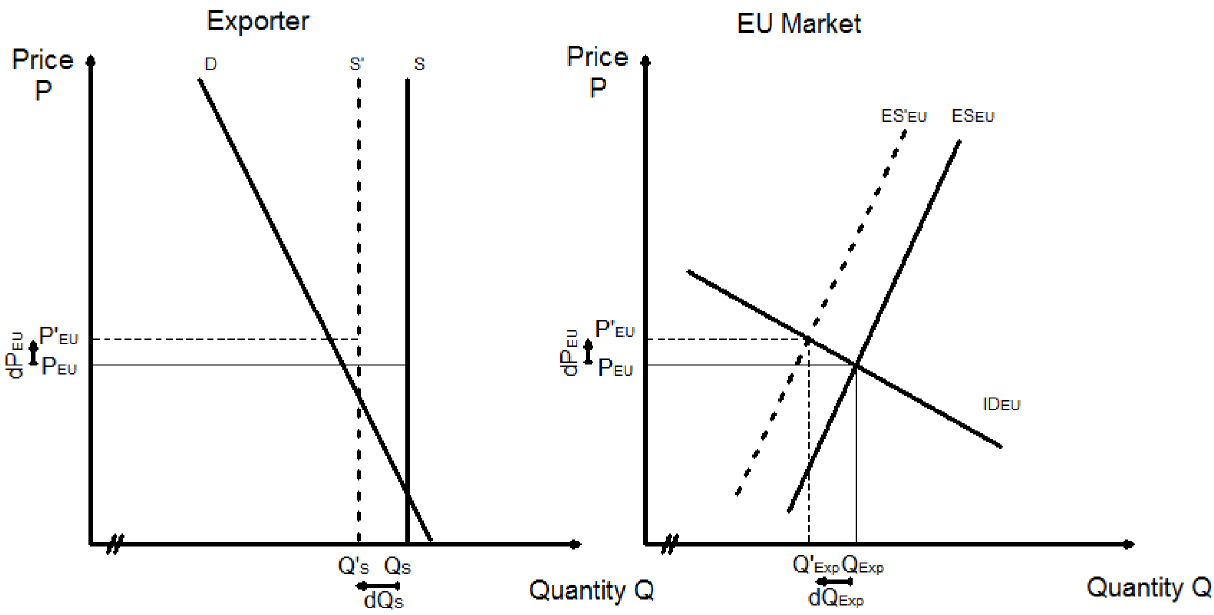
4.3.2.1 No. 5: Non-vaccination with standard movement restrictions

4.3.2.1.1 Quantity Effect

Figure 13 shows the impact of a CSF or AD epidemic in a net exporting country with standard movement restrictions. Standard movement restrictions imply that dQ_S completely drops out of the market. The supply shock dQ_S equals to the amount of supply that is cut off from the market by the movement restrictions plus the amount of culled animals. The quantity reduction causes the supply curve S to shift leftward to S'. The decrease in supplied quantity from domestic producers will lead to a decrease in the export supply of the affected country.

4.3.2.1.2 Price Effect

In a trade situation the price that the producers receive is determined on the EU market. Therefore, the price effect of the supply shock dQ_S depends on the response of the EU market. Depending on whether the country is large or small in the trade theoretical meaning, the shift in the domestic supply curve causes a change in the EU market price P_{EU}. In the large country case the EU market price increases from P_{EU} to P'_{EU}. If the country is small, the producers' price will remain at P_{EU}.



Source: Author's illustration.

Figure 13. Net exporter, non-vaccination, with strict movement restrictions, no export ban.

4.3.2.1.3 PS Effect

Depending on whether the country is large or small it has an impact on the EU market price P_{EU}. Therefore, also ΔPS depends on the scale of the affected country. In the large country case the supply shock dQ_S causes the EU market price to increase to P'_{EU}. The change in PS in a large country is given by:

$$\Delta PS = (P'_{EU} - P_{EU}) * Q'_S + \left(Q'_S - Q_S\right) * P_{EU} \qquad (7)$$

As dP_{EU} is equal to zero the change in PS in the small country case is given by:

$$\Delta PS = \left(Q'_S - Q_S\right) * P_{EU} \qquad (8)$$

4.3.2.2 No. 6: Non-vaccination without export ban with channeling

Like in scenario 2, the welfare effect of control scenario 6 depends on the quality differences between unaffected and channeled products. If the demand for unaffected and channeled products is identical, the supply shock dQ_S is decreased by the channeled supply. Ergo, the PS effects follow the same reasoning as in scenario 5. In the following the situation with unequal demand for channeled and unaffected products is described.

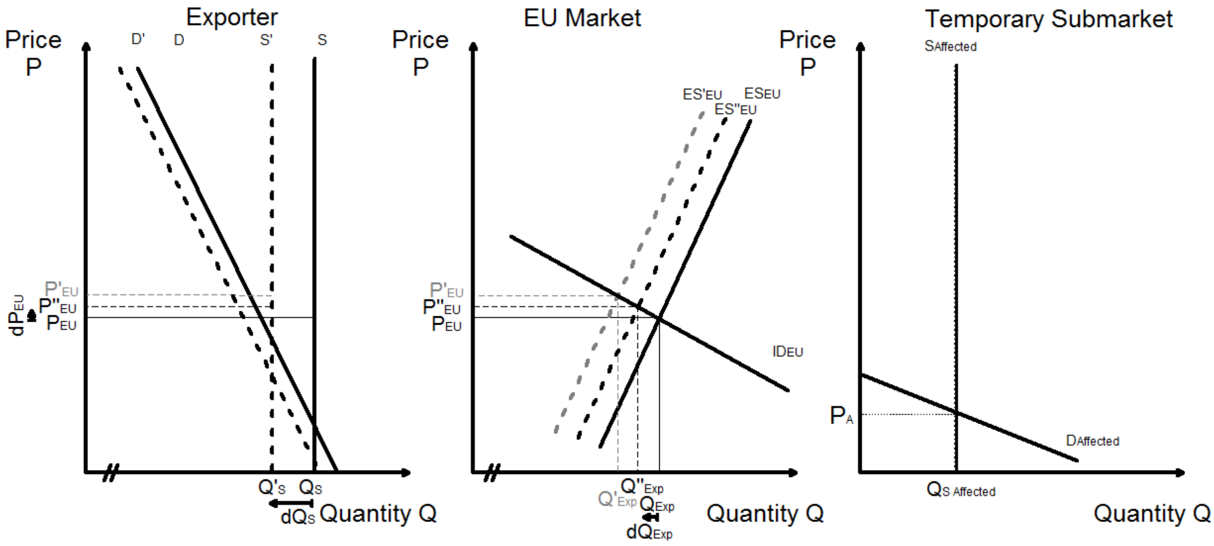
4.3.2.2.1 Quantity Effects

If channeled products are of lower quality than unaffected products, a temporary submarket for the affected products will occur (Figure 14). The channeled products are substitutes that become available outside of the areas underlying movement restrictions. The supply shock on the unaffected market will be dQ_S. It consists of the quantity that is cut off by movement restrictions plus culled quantities. The channeled quantity is $Q_{S\,Affected}$. This is the quantity that is sold on the temporary submarket. The shock on the EU market is dQ_{Exp}. It is lower than in scenario five, because the channeled products compensate for lost excess supply in the affected country.

4.3.2.2.2 Price Effects

In the small country case the producers' price will be the pre-epidemic price P_{EU}. In the large country case the producers' price will equal to P''_{EU}, because of the shift of the export supply ES via ES' to

ES''. P''_{EU} is higher than in the case with channeling and equal demand for channeled and unaffected products. Ceteris paribus, P''_{EU} is lower than the producers' price in the fifth scenario, because the export supply of the country is higher than in the fifth control scenario ($Q''_{Exp} > Q'_{Exp}$).



Source: Author's illustration.

Figure 14. Net exporter, non-vaccination with channeling with different demand, no export ban.

4.3.2.2.3 PS Effect

In the small country case the price received by the producers is P_{EU}, regardless of the effect of differences in demand for affected and unaffected products. In the large country case changes in demand matter, since P_{EU} is affected. In a net export situation with channeling with differences in demand the equations for the ΔPS in the large country (eq. 9) and in the small country scenario (eq. 10) are as follows:

$$\Delta PS = (P''_{EU} - P_{EU}) * Q'_S + (Q'_S - Q_S) * P_{EU} - P_A * Q_{S\,Affected} \tag{9}$$

$$\Delta PS = (Q'_S - Q_S) * P_{EU} - P_A * Q_{S\,Affected} \tag{10}$$

In both cases producers facing movement restrictions lose PS in the amount of [$(Q'_S - Q_S) * P_{EU}$]. Like in scenario 2.2 the affected producers are able to compensate via channeling by generating PS equal to ($P_A * Q_{S\,Affected}$).

4.3.2.3 No. 7: Vaccination with export ban and standard movement restrictions

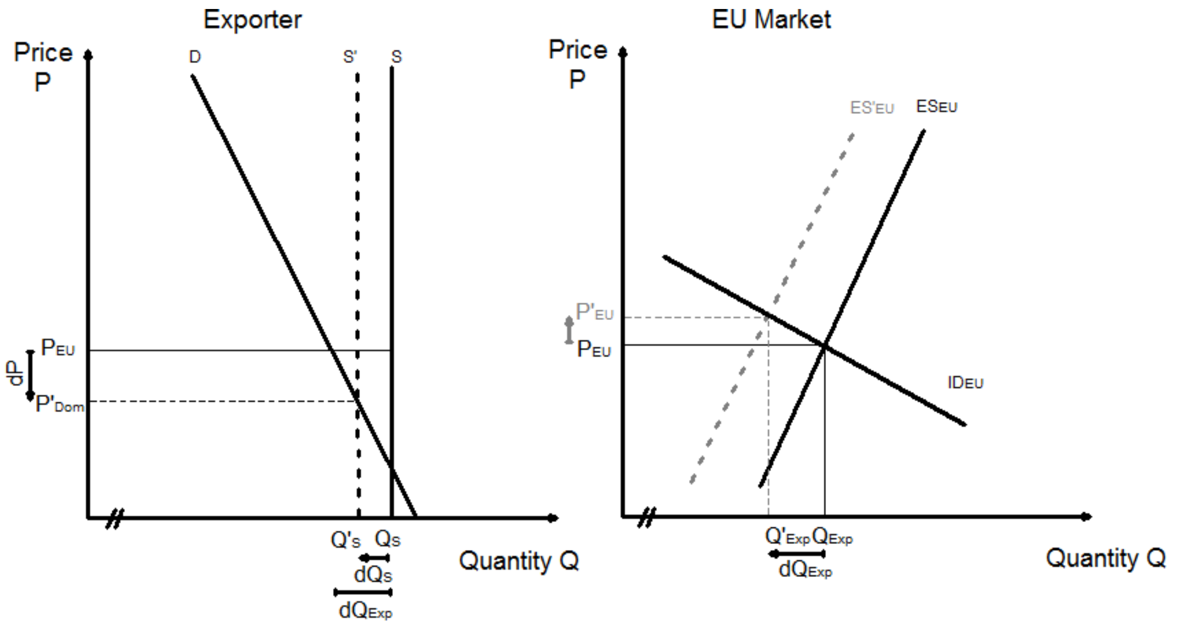
4.3.2.3.1 Quantity Effect

In scenario 7 vaccination is part of the control strategy. The supply shock dQ_S on the unaffected market consists of the culled animals plus the animals that are cut off from the market by the movement restrictions. The exported quantity from the affected country drops to zero due to the export ban. On the domestic market of the affected country oversupply accumulates, because excess supply cannot be exported anymore. Due to the export ban, the scale of the country is irrelevant for the calculation of PS changes in the affected country.

4.3.2.3.2 Price Effect

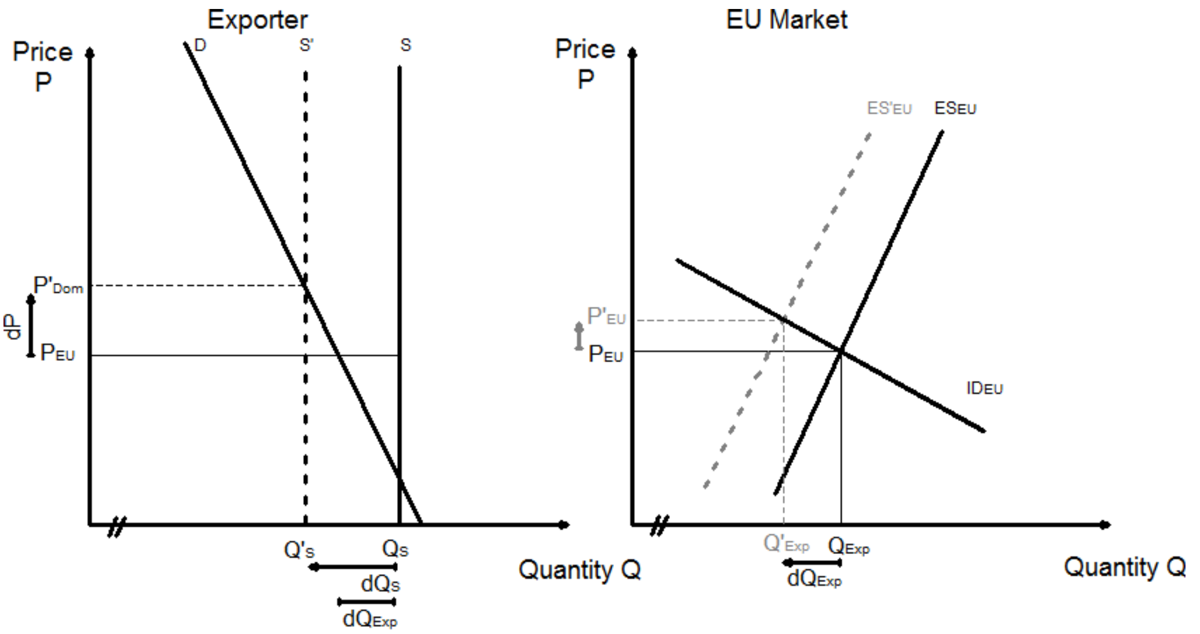
Because the export ban cuts off the affected country from the EU market, the producers' price in the affected country is not the EU price P_{EU} anymore. The new producers' price is the domestic price

P'_{Dom} that is determined on the unaffected market of the affected country. Whether the producers' price change dP is positive or negative depends on the size of the supply shock dQ_S. When dQ_{Exp} > dQ_S, then dP becomes negative as the new domestic price P'_{Dom} turns out smaller than pre-epidemic EU market price P_{EU}. This situation is presented in Figure 15. When dQ_{Exp} < dQ_S, then dP becomes positive (Figure 16). When dQ_{Exp} = dQ_S, then dP is zero.



Source: Author's illustration.

Figure 15. dQ_{Exp}>dQ_S. Net exp., vaccination with standard movement restrictions and export ban.



Source: Author's illustration.

Figure 16. dQ_{Exp}<dQ_S. Net exp., vaccination with standard movement restrictions and export ban.

4.3.2.3.3 PS Effect

The described quantity and price effects lead to a change in PS that can be calculated by:

$$\Delta PS = (P'_{Dom} - P_{EU}) * Q'_S + (Q'_S - Q_S) * P_{EU} \quad (11)$$

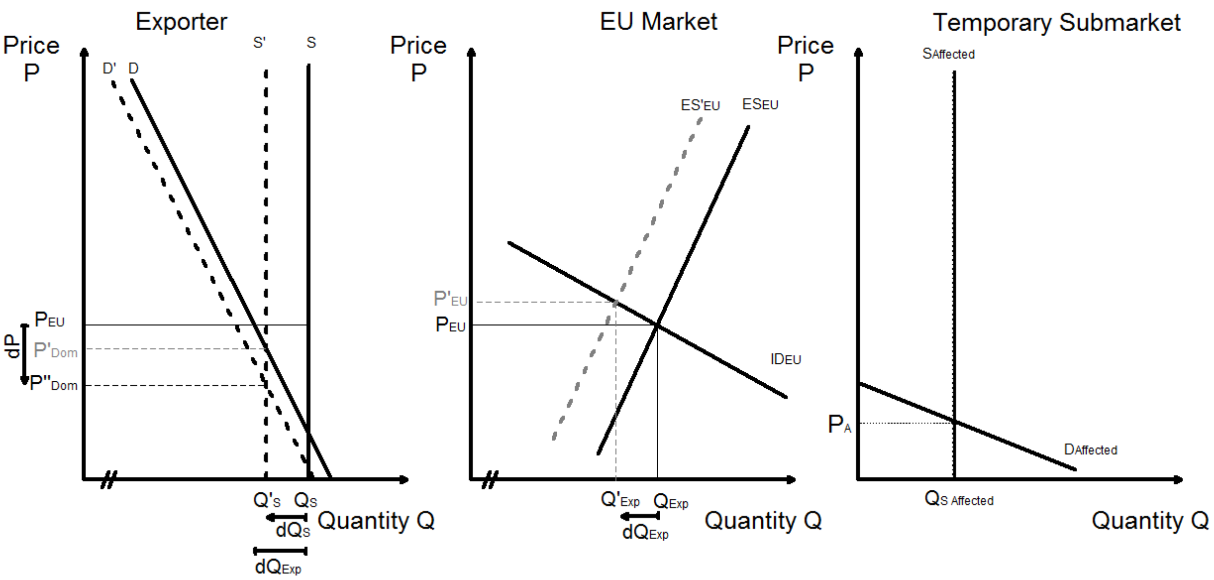
When $dQ_{Exp} > dQ_S$, the unaffected producers lose PS. When $dQ_{Exp} < dQ_S$ the unaffected producers gain PS.

4.3.2.4 No. 8: Vaccination strategy with export ban and channeling

Like in scenarios 2 and 6, the welfare effect of control scenario 8 depends on the quality differences between unaffected and channeled products. If there is no difference in the demand for unaffected and channeled products, the supply shock dQ_S is decreased by the channeled supply. In this case the PS effects will follow the same reasoning as in scenario 7. Below the PS effects that occur when demand for unaffected and channeled products differs are described.

4.3.2.4.1 Quantity Effects

As presented in Figure 17 a temporary submarket for affected products opens, when channeled and vaccinated products face a lower demand than unaffected products. The supply shock on the unaffected market will be dQ_S. It consists of the quantity that is cut off by movement restrictions and of the number of animals that are culled. The channeled quantity is $Q_{S\,Affected}$. Because of the export ban, the exported quantity from the affected country will drop to zero.



Source: Author's illustration.

Figure 17. Net exporter, vaccination with channeling with difference in demand and export ban.

4.3.2.4.2 Price Effects

The channeled products are substitutes for the unaffected products, therefore the demand curve D for the products in the unaffected market shifts leftward to D'. The combined effect of the shift in supply and in demand causes the domestic producers' price to drop to P''_{Dom}. Because of the demand shift on the unaffected market P''_{Dom} is lower than P'_{Dom}, which is, ceteris paribus, the producers' price in a scenario 7.

4.3.2.4.3 PS Effect

The calculation of ΔPS is similar to scenario 7, but due to channeling the producers affected by the movement restrictions generate PS:

$$\Delta PS = (P''_{Dom} - P_{EU}) * Q'_S + \left(Q'_S - Q_S\right) * P_{EU} - P_A * Q_{S\,Affected} \tag{12}$$

The affected producers lose PS in the amount of $[\left(Q'_S - Q_S\right) * P_{EU}]$. However, they also generate PS due to channeling. The PS generated by the affected producers is $(P_A * Q_{S\,Affected})$. Also in scenario 8 it is not definite whether the unaffected producers lose or gain PS. Like in the other scenarios with export bans imposed the price change dP can turn out positive or negative. Whether dP is positive or negative is determined by the size of the supply shock and the shift of the demand curve.

4.3.2.5 No. 9 and No. 10: Vaccination strategies without export ban

When no export ban is imposed against a country using vaccination the quantity, price and PS effects follow the same reasoning as in non-vaccination based scenarios. Therefore, the calculation of ΔPS in scenario 9 equals to the formulas of scenario 5. The calculation of ΔPS in scenario 10 equals to the formulas shown in scenario 6.

5 Description of Estimation Procedure

The third research objective of this thesis is to get insight into the emergence of supply shocks in different disease outbreak and control scenarios. Furthermore, it is aimed to quantify PS changes associated with supply shocks caused by CSF and AD outbreaks. In the previous chapter equations for the calculation of changes in PS during HCLD epidemics have been deduced. From the equations it can be seen that in order to calculate ΔPS data on price and quantity changes is required. Data on supply shocks has been taken from epidemiological simulations conducted by PhD candidates K. Bosman and G. Hop. To acquire information on price changes expert workshops have been conducted.

The expert workshops were set up in a structured way to provide a systematic framework for the estimation of price changes. According to van Audenhove (2007) experts are persons who have privileged access to information about processes and they "… have high insight in aggregated and/or specific knowledge". It was intended that the participating experts use their specific knowledge about the functioning of the pig market in order to provide price estimations. Pre-defined assumptions, a description of the default market situation and simulations of supply shocks were provided to facilitate the price estimations.

During the expert workshops it turned out that the original goal of quantifying price changes was not achievable. The experts argued that during HCLD epidemics there are too many uncertainties and too many unknown factors to give reliable price estimations. For example, the price volatility at the time of the epidemic and the trade responses of different EU countries are factors of uncertainty. Nevertheless, qualitative insights in the functioning of the pig market during epidemics have been obtained. Additionally, semi-qualitative indications of price changes have been compiled for different CSF and AD scenarios. Because the price estimations did not yield quantitative results, the global aim of this thesis changed into providing a thorough qualitative description of the consequences of CSF and AD outbreaks in NL-NRW-LS.

In the following the structure and the setup of the expert workshops are described in detail. This description will illustrate how the qualitative results have been obtained. Furthermore, insight into the structure of the expert workshops is given.

5.1 Basic Data for Estimation

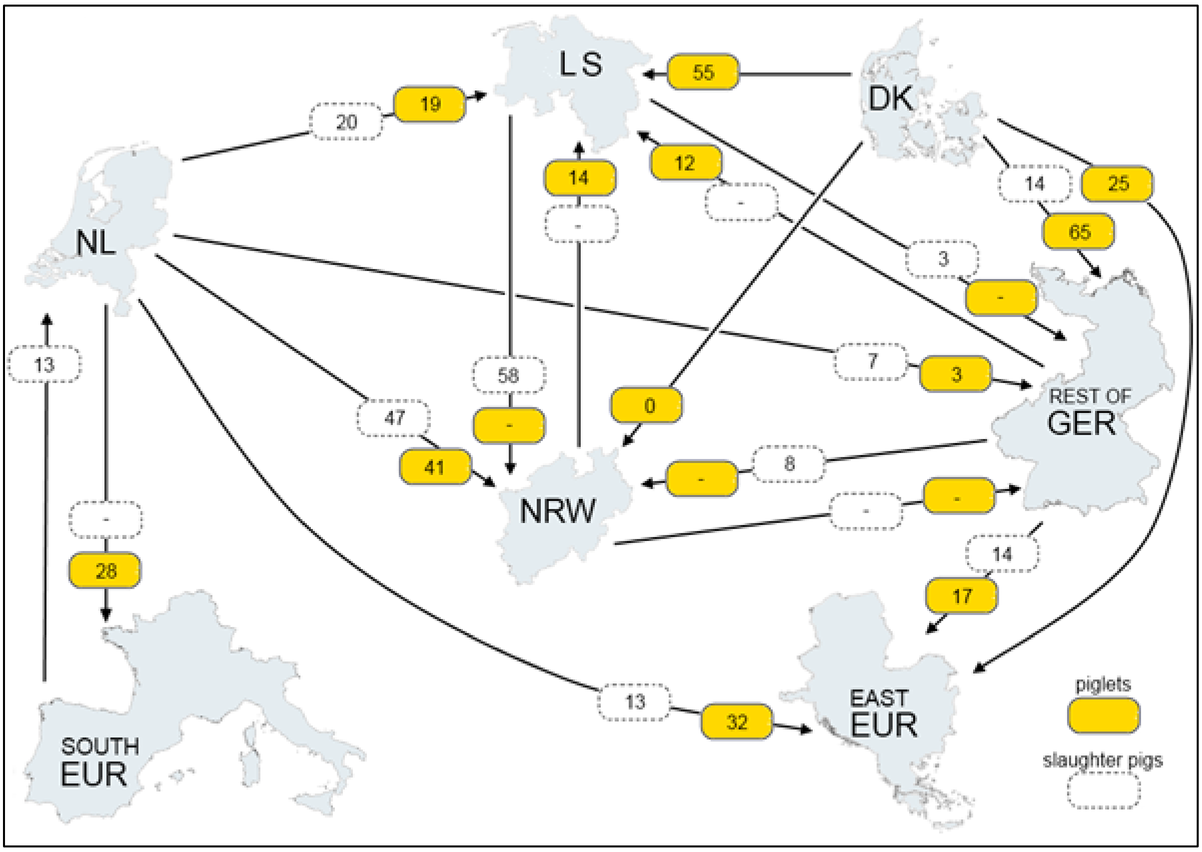
During the expert workshops the participants were supposed to estimate price changes in the markets for live piglets and slaughter pigs that occur due to supply shocks that are caused by CSF and AD outbreaks. To enable the participants to estimate price changes different information was required. First of all, a default market situation that the experts could base their estimations on was needed. Second, data on the supply shocks had to be prepared. Two data sets were provided to allow structured and verifiable price estimations:

1. Data on the default market situation
2. Data on supply shocks

In the following sections both data sets will be described.

5.1.1 Data on Default Market Situation

During the expert workshops the market situation in 2010 served as reference point. The default situation was provided as basis for price estimations. A detailed description of the market situation comprises data on several aspects. Data on piglet prices, piglet production, piglet import, piglet export, slaughter pig prices, slaughter pig production, slaughter pig import and export, the trade flows of live pigs and piglets between regions as well as slaughter capacity in the regions has been provided. Trade data from NL, NRW and LS as well as from all their trade partners within the EU has been provided. While the rest of Germany and Denmark were treated as independent trade entities, countries in the South and in East of the EU have been aggregated. This aggregation allowed a better overview of trade flows within the EU. In Figure 18 the weekly net trade flows of slaughter pigs and piglets within the EU are shown.



Based on Bosman et al. (forthcoming b) and Hop et al. (forthcoming); Data: Eurostat (2013).
Figure 18. Weekly net trade flows in 1,000 heads of slaughter pigs and piglets in the EU in 2010.

EU member states that are not indicated in Figure 18 do not play an important role in the trade of live pigs with NL-NRW-LS. Figure 18 shows *net* trade flows. Arrows in both directions indicate that there is trade in both directions, although only the net trade value between the regions is shown. The trade with the lower value is indicated by a minus sign (-) and the higher flow is indicated by the net trade value. A zero (0) indicates that the trade is marginal in the default situation, but can increase during an epidemic.

In addition to the trade flow map in Figure 18, a spreadsheet (Table 3) provided information on market prices for piglets and slaughter pigs. The prices shown in Table 3 are average prices in 2010. The indicated piglet price is the price for a piglet of 25 kg, excluding value added tax (VAT). Transport costs are deducted. Slaughter pig prices are in Euro per kg slaughter weight, also excluding VAT. Moreover, Table 3 shows the same weekly net trade of NL, NRW and LS with the regions as shown in Figure 18. To provide a better overview of the trade relations of NL, NRW and LS, the net imports and the net exports of each region are shown.

Table 3. Weekly net trade flow from and to NL-NRW-LS and average weekly price in 2010.

	Piglets				Slaughter Pigs			
	Default				Default			
	Exports		Imports		Exports		Imports	
NL	number	price[1]	number	price[1]	number	price[2]	number	price[2]
NL	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	n.a.
NRW	41	47.5	n.a.	n.a.	47	1.353	n.a.	n.a.
LS	19	47.5	n.a.	n.a.	20	1.353	n.a.	n.a.
rest of GER	3	46.5	n.a.	n.a.	7	1.353	n.a.	n.a.
DK	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	n.a.
S-EUR	28	45.5	n.a.	n.a.	-	1.338	13	1.310
E-EUR	32	45.5	n.a.	n.a.	13	1.370	n.a.	n.a.
Production	484				339			
LS	number	price[1]	number	price[1]	number	price[2]	number	price[2]
NL	n.a.	n.a.	19	47.5	n.a.	n.a.	20	1.353
NRW	-	41.5	14	41.5	58	1.353	-	1.353
LS	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
rest of GER	-	41.5	12	41.5	3	1.353	-	1.353
DK	n.a.	n.a.	55	47.5	n.a.	n.a.	n.a.	n.a.
S-EUR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
E-EUR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Production	278				389			
NRW	number	price[1]	number	price[1]	number	price[2]	number	price[2]
NL	n.a.	n.a.	41	47.5	n.a.	n.a.	47	1.353
NRW	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LS	14	41.5	-	41.5	-	1.353	58	1.353
rest of GER	-	41.5	-	41.5	-	1.353	8	1.353
DK	n.a.	n.a.	0	47.5	n.a.	n.a.	n.a.	n.a.
S-EUR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
E-EUR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Production	238				271			

1) Price: €/piglet of 25 kg (net prices, excl. VAT, transportation costs are deducted)
The listed prices for Exports from the Netherlands are for piglets with desired quality, batch size, genetics etc.
For piglets deviating from the norm (which may be the case during an outbreak), the prices will be lower: 41.50
2) Price: €/kg slaughtered weight, excl. VAT
Based on Bosman et al. (forthcoming b) and Hop et al. (forthcoming)

5.1.2 Data on Supply Shocks

Besides the market data, price estimations require data on supply shocks that they can be based on. To quantify trade shocks under different control strategy scenarios epidemiological simulations are necessary. Epidemiological simulations yield for example the number of affected farms and animals as well as the duration of a CSF or AD outbreak. In the expert workshops data from an ISP model were used. ISP is software that simulates epidemiological outcomes of HCLD outbreaks under different control strategies. According to Hop et al. (submitted) ISP models allow "… the parameterization of a stochastic, dynamic and spatially explicit epidemiological model …". For more detailed information on ISP models and the simulation of disease outbreaks see Hop et al., (submitted) and Bosman et al. (forthcoming a).

In the ISP model 9 CSF and 3 AD epidemics have been simulated. The simulated epidemiological scenarios differed with respect to the applied control strategy and the trade response of trade partners. With the simulations the weekly supply shocks in the market have been determined. The baseline scenarios for CSF and AD simulations were set up according to current legislation. Additionally, scenarios including control measures that are not yet part of current contingency plans (e.g. channeling) were simulated. Thus, the impact of epidemics under current and under alternative control strategies can be compared. In the following the CSF and AD disease scenarios that were composed for the expert workshops are described.

5.1.2.1 CSF Scenarios

The simulated CSF scenarios differed with respect to the affected country and region, vaccination strategy and movement restrictions during the outbreak. The CSF outbreaks and disease control scenarios are summarized in Table 4. In Table 4 the simulation scenarios are ordered according to the affected country (NL, NL+LS or NRW), movement and trade restrictions (baseline, extended trade ban or channeling) and vaccination strategy (non-vaccination or vaccination).

The farms of first virus detection (index farms) of the simulated epidemics are situated in different regions. In scenarios 1 to 4 the index farm is situated in region South of NL, i.e. South is the diseased region. Scenarios 1 to 4 are examples of outbreaks in a net exporting country. In scenarios 5 to 8 the infected farms are situated right at the border between region East in NL and Weser-Ems region in LS. Since the MRZ around the infected farm covers parts of both regions, East and Weser-Ems, both are considered diseased and underlie movement restrictions. This is in accordance with the national contingency plans (Anonymous, 1988 & 2012). Scenarios 5 to 8 are special cases, since a net exporting and a net importing region are affected by the disease simultaneously. Scenario 9 simulates a CSF outbreak in the region Münster (NRW). Münster is an importing region with a high demand for slaughter pigs and piglets.

In the CSF simulations different types of movement restrictions were considered. The baseline scenarios simulated the epidemics according to the contingency plans of NL-NRW-LS (see Anonymous, 1988 & 2012). Movement restrictions and export bans are part of every control scenario. In the first two weeks exports are banned in every CSF control scenario. In scenario 3 and 4 the export bans are extended to week six after the initial outbreak. For the first six weeks neither the producers in the free nor in the diseased region are allowed to export. In scenarios 7 and 8 channeling was simulated. The channeling strategy allows farms enclosed in the diseased regions to trade within the regions East and Weser-Ems from week three on. As East is a region with surplus in piglets and slaughter pigs and Weser-Ems is an importing region of both products, the effect of channeling is expected to be considerable.

Moreover, the CSF scenarios differed with respect to the vaccination strategy. Each simulated outbreak region and movement restriction combination was simulated under a vaccination and non-vaccination scenario. For example, the combination outbreak in NL with “baseline” movement restrictions was simulated with non-vaccination in scenario 1 and with vaccination in scenario 2.

Table 4. Overview of CSF control scenarios used during expert workshops.

Scenario no.	Scenario name	Weeks after first detection	Movement restrictions: Diseased region within country (affected market)	Movement restrictions: Free regions within country (unaffected market)
1	NL_baseline_novacc	Weeks 0-2: Weeks 3-6: Weeks >6:	• No movements allowed within region South • No movements allowed within region South • Domestic transport allowed to/from region South[2]	• 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
2	NL_baseline_vacc[1]	See NL_baseline_novacc (no change in demand)		
3	NL_exttradeban_novacc	Weeks 0-6: Weeks >6:	• No movements allowed within region South • Domestic transport allowed to/from region South[2]	• No export allowed to/from free regions within NL • Export allowed to/from free regions within NL
4	NL_exttradeban_vacc[1]	See NL_exttradeban_novacc (no change in demand)		
5	NL+LS_baseline_novacc	 Weeks 0-2: Weeks 3-6: Weeks >6:	NL: see NL_baseline_novacc LS: • No domestic transport allowed to/from region Weserems; movements within region allowed • Same as weeks 0-2 • Export allowed to/from region Weserems[3]	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
6	NL+LS_baseline_vacc[1]	See NL+LS_baseline_novacc (no change in demand)		
7	NL+LS_channeling_novacc	 Weeks 0-2: Weeks >3: Weeks 0-2: Weeks >3:	NL: • No movements allowed within region East • Channeling allowed with region Weserems; movements allowed within region East LS: • No domestic transport allowed to/from region Weserems; movements within region Weserems allowed • Channeling allowed with region East; movements allowed within region Weserems	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
8	NL+LS_channeling_vacc[1]	See NL+LS_channeling_novacc (no change in demand)		
9	NRW_baseline_novacc	Weeks 0-2: Weeks 3-6: Weeks >6:	• No domestic transport allowed to/from region Münster; movements within region allowed • Same as weeks 0-2 • Export allowed to/from region Münster[3]	• No export allowed from free regions within NRW; import piglets/sl.pigs allowed (except first 3 days) • Export allowed to/from free regions within NRW • Export allowed to/from free regions within NRW

[1] Veterinary strategies with vaccination do include additional transport restrictions for farms with vaccinated animals (farms within a 2 km radius from a detected farm), i.e., in case of marker vaccination (NL), export of vaccinated animals is not allowed and products from vaccinated animals need to be treated. In case of live vaccine vaccination (GER), animals are culled during / at the end of the outbreak.

[2] Piglets and slaughter pigs from a previously diseased region stay within NL, NRW or LS, respectively, as it was assumed that other EU countries do not want to buy piglets / slaughter pigs from a diseased region. From week 7 onwards, the diseased region reduces in size and after lifting the protection and surveillance zones at the end of the outbreak, the remainder of the diseased region is lifted as well.

[3] Piglets and slaughter pigs from an (previously) diseased region are partly exported to other EU countries and partly stay within NL, NRW or LS, respectively. From week 7 onwards, the diseased region reduces in size and after lifting the protection and surveillance zones at the end of the outbreak, the remainder of the diseased region is lifted as well.

Source: Based on Hop et al., (forthcoming)

5.1.2.2 AD Scenarios

The AD scenarios are less complex than the CSF scenarios. Three AD scenarios were simulated. Scenario 11 is situated in a net exporting region and scenarios 12 and 13 are in net importing regions. During AD epidemics movement and trade restrictions occur to the farms enclosed within the MRZ (Anonymous, 2005 & 2011). The supply and price effects caused by the movement restriction are therefore expected to be smaller than during CSF epidemics. The scenarios are summarized in Table 5.

Table 5. Summary of simulated AD outbreak and disease control scenarios.

Scenario no.	Scenario name	Weeks after first detection	Movement Restrictions
			Diseased region within country (affected market)
11	NL_baseline_vacc[1]	Weeks 0-end	• MRZ of 10 km radius around infected holding(s)
12	NRW_baseline_novacc	Weeks 0-end	• MRZ of 10 km radius around infected holding(s)
13	LS_baseline_novacc	Weeks 0-end	• MRZ of 10 km radius around infected holding(s)

[1] Vaccination is conducted in a radius of 10 km around infected holdings
Source: Based on Bosman et al. (forthcoming b).

In scenario 11 an AD outbreak in region South of NL is simulated. The baseline AD control strategy consists of a MRZ of 10 km radius around infected holdings. Vaccination is conducted within the radius of the MRZ. Scenario 12 and 13 only differ in terms of the location of the infected farms. In scenario 12 the epidemic occurs in NRW. In scenario 13 the infected farms are situated in LS. Contrary to the contingency plan of NL, the German contingency plan does not allow vaccination. Instead, the German contingency plan permits preventive depopulation of neighboring holdings. For AD no alternative control scenarios have been simulated.

5.1.3 Example Simulation Output

In order to estimate prices the experts were provided with scenario files containing the output of the epidemiological simulations. In the following an example of a scenario file is presented. Scenario 1, i.e. NL_baseline_novacc, serves as example (see Table 4). Each scenario file contained information about the affected country, the affected and unaffected market as well as the MRZ. In the scenario file information on piglet and slaughter pig production and export as well as the weekly number of slaughterings and piglet surplus in the respective area was provided. In Tables 6 to 9 the weekly averages for weeks 0-6 are shown. To reduce the number of estimations conducted by the experts the periods weeks 0-2 and weeks 3-6 were merged. Tables 7 and 8 show the weekly averages in the diseased and the free regions of NL. Table 9 shows the characteristics of the MRZ including duration of the epidemic, number of culled piglets and slaughter pigs in the MRZ, weekly production in MRZ, weekly piglet surplus in the MRZ and the number of vaccinated piglets and slaughter pigs. A map of the affected country, in which the affected region was colored, provided visualization (Figure 19).

Table 6. Default market situation total NL.

Total NL							
Weekly piglet production	**Weekly export of piglets**	**Piglet export in %**	**Weekly sl. pig production**	**Weekly export of sl. pigs**	**Sl. pig export in %**	**Baseline weekly no. of slaughterings**	**Weekly piglet surplus**
484	123	26%	339	93	28%	272	144

Source: Data based on ISP simulations (see Hop et al, submitted).

Table 7. Simulation output of scenario 1, weeks 0-6, characteristics of unaffected market.

Unaffected part of NL							
Weekly piglet production	**Weekly export of piglets**	**Piglet export in %**	**Weekly sl. pig production**	**Weekly export of sl. pigs**	**Sl. pig export in %**	**Baseline weekly no. of slaughterings**	**Weekly piglet surplus**
227	47	19%	181	63	32%	128	46

Source: Data based on ISP simulations (see Hop et al, submitted).

Table 8. Simulation output of scenario 1, weeks 0-6, characteristics of affected market.

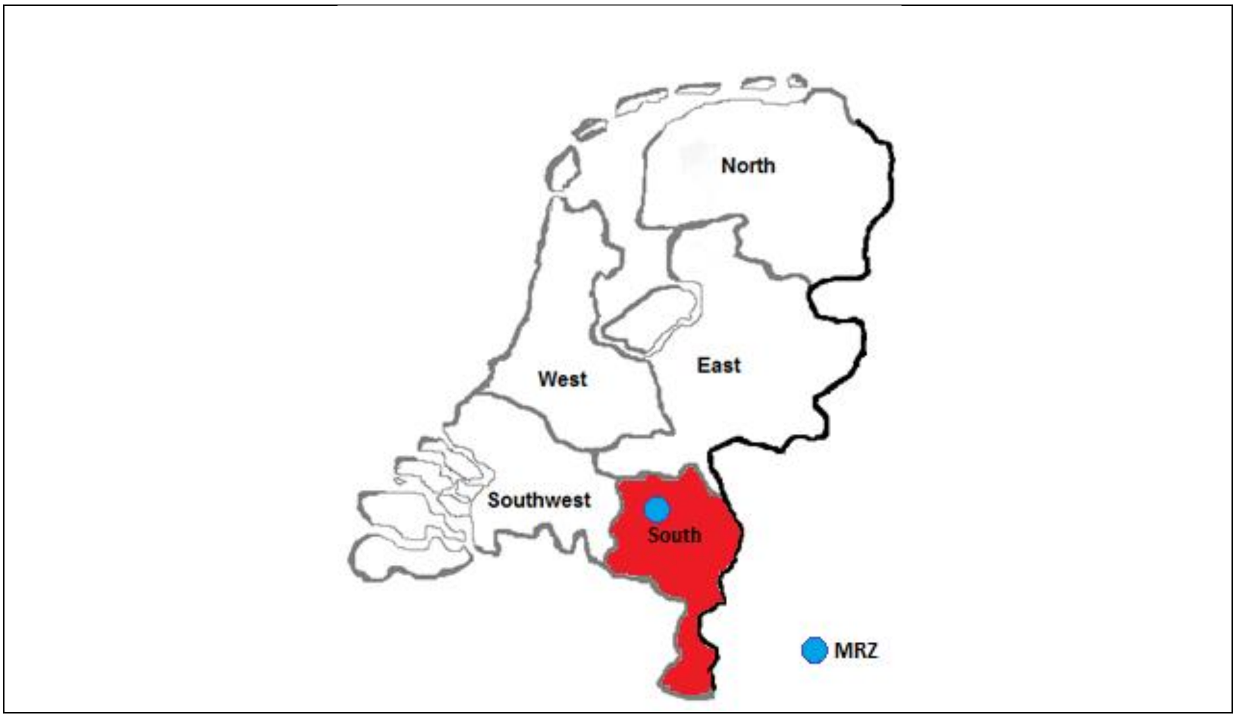
Affected region (South)							
Weekly piglet production	**Weekly export of piglets**	**Piglet export in %**	**Weekly sl. pig production**	**Weekly export of sl. pigs**	**Sl. pig export in %**	**Baseline weekly no. of slaughterings**	**Weekly piglet surplus**
256	76	30%	158	30	19%	143	98

Source: Data based on ISP simulations (see Hop et al, submitted).

Table 9. Simulation output of scenario 1, weeks 0-6, characteristics of MRZ.

MRZ							
Length of outbreak in weeks	**Weekly no. culled animals (1 km zone)**		**Weekly production in MRZ (10 km zone)**		**Weekly piglet surplus**	**Weekly no. of vaccinated animals (2 km zone)**	
Medium outbreak	**Piglets**	**Sl. Pigs**	**Piglets**	**Sl. Pigs**		**Piglets**	**Sl. Pigs**
15	6	3	41	28	13	7	8

Source: Data based on ISP simulations (see Hop et al, submitted).



Source: Author's illustration.

Figure 19. Map of the disease outbreak scenario 1 NL_baseline_novacc.

5.2 Price Estimation Workshops

In the following a short description of the expert workshops is given. In total three workshops with four participants took place. Between the individual workshops there was a gap of two to three weeks. The first meeting took place in mid-September 2013, the second at beginning of October 2013 and the third at the end of October 2013. The expert workshops were scheduled for approximately 2.5 to 3 hours each.

5.2.1 Participants

Four participants attended the three expert workshops. The selection of the participants was made purposely. The participants came from the industry, an association of the Dutch agribusiness and from a research institute. For the selection it was crucial that the participants' profiles and their fields of knowledge were complementary. Moreover, all participants were expected to have a deep insight into the European pig market and a good understanding of the price determining factors. R. Hoste, a pig production economist at Wageningen University, P. van Balkom, purchasing manager at Vion Food Netherlands and B. van Dam and P. Westra, pig market experts at PVE served as experts in the workshops. All experts were contacted via e-mail and telephone to obtain their collaboration. Although this study is potentially of great interest for the German pig industry, none of the contacted German experts was interested in participating.

5.2.2 Time Table of Expert Workshops

The following time table was intended for the meetings:

First meeting (17/09/2013)

- Presentation, explanation and discussion of the estimation approach;
- Issues for change, improvement, revision;
- First 'test-estimations' for basic scenarios.

In-between

- Revision of the approach.

Second meeting (04/10/2013)

- First set of estimations;
- CSF and AD;
- Different index regions in NL, NRW and LS;
- Default control strategy including default channeling possibilities;
- Some alternative control strategies (i.e. vaccination);
- Discussion/inventory of most important channeling options (for subsequent meeting).

Third meeting (25/10/2013)

- Second set of estimations.

An optional fourth meeting to reflect on and validate the results of the previous meetings was not held.

5.2.3 Assumptions and Starting Points

Price estimations as such are complicated, because a lot of factors influence the prices. In addition, interactions between these factors have to be taken into account. To facilitate price estimations some assumptions have been made and starting points have been defined:

1. The prices for primary producers are estimated (price for live piglets and fattening pigs).
2. Impacts for other stakeholders (e.g. slaughterhouses) are disregarded.
3. The estimations refer to the submarkets within the region NL-NRW-LS.
4. Effects on external markets are disregarded.
5. The reference market situation is the weekly average supply and price situation in 2010
    - Deviations from the supply and price averages are assumed to be the effect of the simulated epidemic.
6. Consumer demand for meat
    - CSF non-vaccination and AD: demand is assumed to remain unchanged during the outbreak.
    - CSF vaccination: demand might vary and vaccinated products might yield a lower price than non-vaccinated.
7. Demand for slaughter pigs is assumed to be derived from consumer demand for meat.
8. Demand for piglets
    - CSF and AD non-vaccination: demand is determined by placement possibilities.
    - CSF vaccination: demand might vary and vaccinated piglets might face a lower price than non-vaccinated.
    - AD vaccination: sales to NL or Article 9 areas with a reduced price.
    - The weight of piglets has an impact on their price. Overweight piglets yield a lower price and might be slaughtered directly.
9. The supply of unaffected producers is assumed to be inelastic during the course of the epidemic. The relatively short duration of the epidemic does not allow adaption of the supplied quantity.

5.2.4 Estimation Procedure

Supported by the data sets and the well-defined starting points and assumptions the participants were supposed to follow a strict estimation procedure during the workshops. The following steps were envisaged to be taken:

- Step 0: Presentation and explanation of the default situation of the piglet and slaughter pig market, explanation of assumptions and starting points.
- Step 1: Presentation and explanation of the input data sheet for a specific epidemiological scenario (quantitative shocks in supply and possible changes in market access); short discussion on accuracy and plausibility of this scenario and on the underlying assumptions.
- Step 2: Based on the scenario background and the quantitative input, a qualitative estimation of the changes in trade flows of animals (increase/decrease/unchanged) and changes in market access was intended to be made. The participants were animated to discuss their results to reach consensus on the qualitative estimation (i.e. the direction and magnitude of the changes).
- Step 3: Based on the qualitative estimation, a quantitative estimation of the supply quantities on the different submarkets of the different products was supposed to be made, in percentage compared to the normal/reference situation and absolute quantities. Besides the quantity changes in piglets and slaughter pigs, the experts were also asked to address the supply of

vaccinated and overweight animals. The estimations were to be filled into the respective sheet by each participant. For each scenario the estimation was scheduled to take circa 5 minutes. After the quantitative estimations of each scenario a discussion was envisaged in order to come up with consensus.

- Step 4: Based on the confrontation of the quantitative changes in supply and demand in the respective regions, an estimation of the prices of various products on different submarkets had to be made. The estimations were to be filled into the respective sheet by each participant within 5 minutes. Furthermore, after the price estimations of each scenario a discussion was envisaged in order to come up with consensus.

For CSF, steps 2-4 had to be done twice. One time for the 0-6 weeks estimation and a second time for the period thereafter. The procedure from step-1 to step-4 was aimed to be repeated in the 'estimation group' for each different scenario. The scenarios are primarily based on the *average/most likely* expected epidemiological impact. The cumulative situation at the end of the simulated epidemic was to be used as starting point. As basis for estimation the average weekly situation was provided. This could result in a (small) over-estimation of the epidemiological impact.

- Step-5: Once the prices and the quantities for the different products and submarkets were obtained, the changes in PS and the respective ICC were supposed to be calculated.

5.2.5 First Workshop

During the first workshop the research aim, the research approach, the assumptions, the outbreak scenarios and the market situation were presented and discussed. Examples of CSF outbreaks and AD scenarios provided the basis for discussion. Points of discussion were, among others, channeling strategies and the trade volumes shown in Figure 18. The participants identified inaccuracies in the trade data. Moreover, the experts asked for additional information on the key countries in the EU pig market (i.e. NL, NRW, LS and DK). For these regions the experts asked for background information on total trade volume, weekly domestic production and the main export destinations and trade partners. Furthermore, the general economic market effects and the causal chain of consequences after an initial outbreak were discussed. After the workshop the figures, volumes and prices were updated according to the suggestions of the experts.

5.2.6 Second Workshop

In the second workshop a summary of the general market effects that were discussed in the first workshop was presented (see chapter 6, Tables 12 to 14). These tables are important qualitative results of the workshop as they give an insight into the functioning of the piglet and slaughter pig market during AD and CSF epidemics. During the second workshop the content of tables was verified by the experts.

Moreover, a first attempt to conduct steps 2 and 3 of the estimation procedure (i.e. qualitative and quantitative estimation of trade flows) was made. However, there was consensus among the participants that no reliable estimations of trade flow changes could be given due to great uncertainties. The mentioned uncertainties included the volatile demand, the time of the outbreak and the price volatility at the time of the outbreak. There was agreement among participants that supply shocks will quickly level out over the EU market. Leveling-out describes the effect that if a supply shock occurs, the supply in all EU regions will be reduced by the same percentage. In scenario

1 and 2 for example, the piglet supply shock reduces the total EU supply by 1.59%. Due to the leveling-out effect the supply shock would lead to piglet supply reduction of 1.59% in all EU regions.

The experts agreed that the season of year in which the epidemic takes place has an influence on the economic impact, because price volatility differs across seasons. With respect to the impact of vaccination the experts' opinion was that vaccination would have no effect on the traded quantities, but on the prices of vaccinated piglets. As vaccinated piglets have to stay within the vaccination zone they have to be placed within that zone. If there are not enough places on fattening farms available, excess piglets will have to be slaughtered. It was noted that since the piglet producers have to sell their piglets urgently they are forced to lower their prices. Although products of vaccinated slaughter pigs must be labeled and treated before they are exported (Anonymous, 1964 & 2008), the experts assumed that the disposal of slaughter pigs will be less problematic as meat of vaccinated animals will end up in meat products. In the case of AD, the acceptance of live vaccinated animals in Article 10 (i.e. AD-free) countries was identified as a crucial price determining factor.

5.2.7 Third Workshop

In workshop two it was agreed that the interviewers compile information on quantity changes within different regions. Table 10, Table 11 and Figure 20 show examples of the compiled data. Based on the leveling-out assumption a spread sheet model to calculate changes in trade of each EU region was created. The output of this model is shown in Tables 10 and 11. Instead of quantifying the trade changes at the trade connection between two regions, the spread sheet model calculated the net import during the different epidemic periods (i.e. weeks 0-6 and 7-end) for all EU regions. The results were provided to substitute steps 2 and 3 of the estimation procedure. Besides data on trade changes the experts asked for detailed information on the piglet and slaughter pig surpluses and shortages that arise in the diseased region, the unaffected market and in the EU. Figure 20 shows the surpluses and shortages that arise during the course of a CSF epidemic in scenario 1. Despite all additional information that was provided the experts said that they are not able to reliably estimate prices. Instead the experts suggested in the third workshop to use semi-qualitative indicators, i.e. plus (+) and minus (-) signs, to indicate price effects. During the third workshop a first discussion on the plus and minus indication was held. It was agreed that signs will be filled in after the expert workshops and sent to the experts for verification.

Table 10. Input sheet for expert estimation of piglet prices.

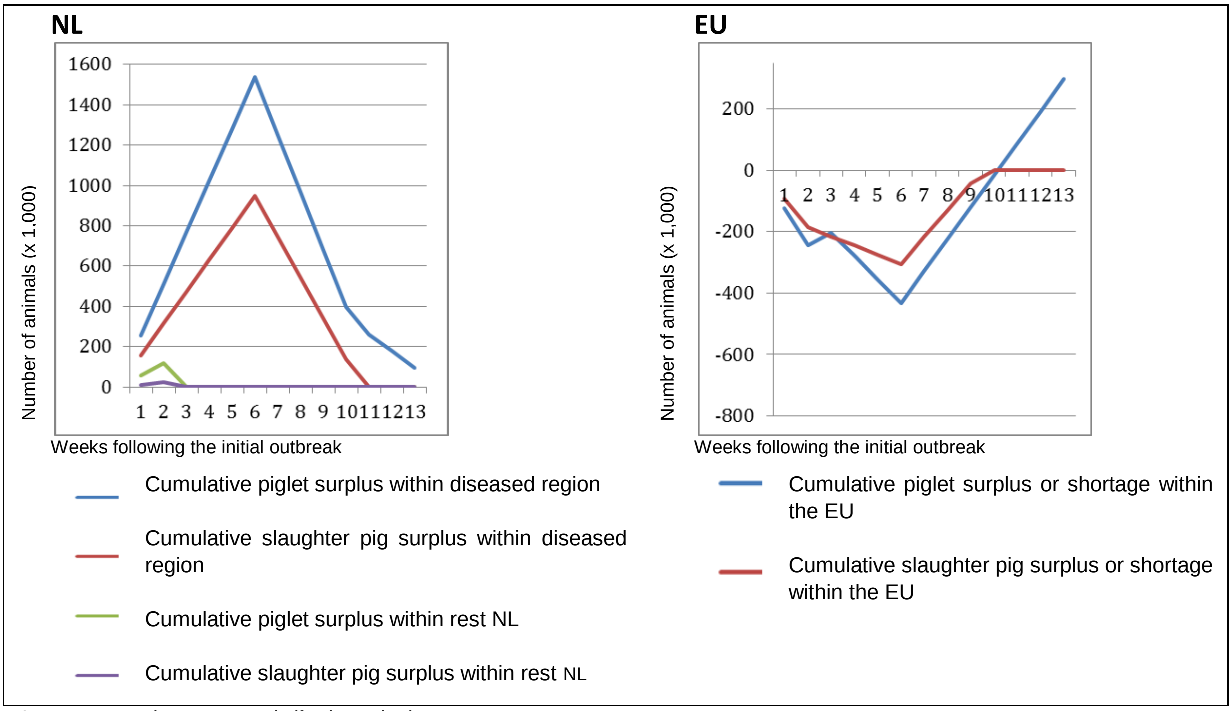
	Piglets						
	Default			Scenario weeks 0-6		Scenario weeks 7-end	
	Sl.pig demand[1]	Net import[2]		Net import[2]		Net import[2]	
	number	number	price[4]	number	price	number	price
NL	361	-123	46.5				
Rest				-51		-165	
South				0		0	
NRW	265	27	46.6	22		30	
LS	378	100	46.8	93		104	
rest of GER	415	39	46.2	32		43	
DK	380	-145	46.7	-152		-141	
S-EUR	1,838	28	45.5	-4		46	
E-EUR	903	74	45.5	58		83	

[1] Slaughter pig demand = piglet production – piglet export + piglet import
[2] Negative net import = export.
[3] Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import
[4] Price = average price for piglets going to/coming from several destinations (e.g., for NL piglets: ((19+41)*€47.5 + (28+32)*€45.5 + 3*€46.5) /123)
[5] Total import = -93 (so, in total, 93,000 slaughter pigs are exported).
Source: Based on data derived from spreadsheet model (see Bosman et al., forthcoming b).

Table 11. Input sheet for expert estimation of slaughter pig prices.

	Slaughter Pigs						
	Default			Scenario weeks 0-6		Scenario weeks 7-end	
	Slaughterings demand[3]	Net import[2]		Net import[2]		Net import[2]	
	number	number	price	number	price	number	price
NL	265	-74[5]	1.350				
Rest				-23		-74	
South				0		0	
NRW	384	113	1.353	108		113	
LS	348	-41	1.353	-45		-41	
rest of GER	361	2	1.340	-2		2	
DK	366	-14	1.353	-18		-14	
S-EUR	1,825	-13	1.310	-35		-13	
E-EUR	930	27	1.310	16		27	

[1] Slaughter pig demand = piglet production – piglet export + piglet import
[2] Negative net import = export.
[3] Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import
[4] Price = average price for piglets going to/coming from several destinations (e.g., for NL piglets: ((19+41)*€47.5 + (28+32)*€45.5 + 3*€46.5) /123)
[5] Total import = -93 (so, in total, 93,000 slaughter pigs are exported).
Source: Based on data derived from spreadsheet model (see Bosman et al., forthcoming b).



Source: Based on Hop et al. (forthcoming).

Figure 20. Cumulative surpluses and shortages in NL and EU during scenario NL_baseline_novacc.

6 Results

As described in the previous chapter, quantitative estimations were said to be not feasible. The applied method proved to be inadequate for estimating price changes. Nevertheless, the expert workshops did not end without results. They delivered qualitative information on the functioning of the pig market during disease outbreaks and semi-qualitative estimations of price changes. In this chapter the qualitative results of the expert workshops are presented.

6.1 Experts' Assumptions and Expectations

During the estimation workshops the experts stated several assumptions and expectations. These assumptions and expectations concern the driving forces that determine the size of the supply shock and the price changes. In the following the experts' expectations and assumptions are listed.

<u>CSF:</u>

- Supply shocks in pig market quickly level out across all EU regions.
- Seasonality in price volatility and volatility in demand for piglets and slaughter pigs co-determine the economic impact of epidemics.
- Vaccinated animals are expected to yield lower prices than unvaccinated animals.
- The changes in trade volumes are expected to be unaffected by vaccination. Hence, the trade volume is expected to be equal in vaccination and non-vaccination scenarios.
- The size of the economic damage depends on the export volume from affected area.
- Shortages and surpluses are expected to build up until lifting the movement restrictions or until channeling is allowed. Reducing these shortages and surpluses can take relatively long.
- Piglet producers are expected to face the biggest losses.

<u>AD:</u>

- AD epidemics are expected to have no significant effect on prices during the outbreak, because the area under movement restriction and the weekly supply shocks are relatively small.
- During AD epidemics the price and quantity effects in exporting countries are expected to be larger after the epidemic has ended. The occurring AC are expected to be larger than the ICC. The surplus that builds up within the MRZ is released at the end of the epidemic and causes a temporary oversupply situation.
- In NL a large quantity of vaccinated animal is released at the end of the epidemic.
- Vaccinated piglets and slaughter pigs will yield a lower price than non-vaccinated animals.
- From a European perspective the released peak supply after lifting the MRZ is small. Hence, the prices on the EU market are assumed to remain unchanged.
- In NL the economic damage for the affected producers is determined by the purchasing behavior of fatteners. If fatteners decide to buy vaccinated piglets from affected producers, the piglet prices are expected to drop less.
- AD outbreaks in Germany are expected to have no significant effect on trade volume and prices.

Based on the experts' opinions, expectations and assumptions further results have been deducted. During the workshops these results were thoroughly discussed and verified by the experts.

6.2 Tables on Market Effects

During the expert workshops there was demand for a detailed qualitative description of the market effects that follow an initial outbreak of CSF and AD. Tables 12 to 15 were compiled between workshop one and two. In the second workshop a thorough discussion on these tables followed. The tables were provided as an estimation support, but can also be regarded as a qualitative result of this thesis. They were well discussed with and verified by the experts. Tables 12 to 15 give an insight in temporal sequence of market effects that follow CSF and AD outbreaks. Tables 12 and 13 provide a qualitative description of the market effects during CSF outbreaks. In Tables 12 and 14 the market effects of CSF and AD epidemics in NL are summarized. Tables 13 and 15 provide summaries of the effects of CSF and AD outbreaks in LS. In addition to the qualitative market effects in the affected country, the qualitative market effects that occur to trade partners are presented.

In the case of an outbreak in NL (Table 12) surpluses build up in the affected country within weeks 0-2 and weeks 3-6. From week 7 until the end of the epidemic exports will be increased in order to get rid of accumulated surpluses. Within the first two weeks of a CSF epidemic in NL there will be a shortage of slaughter pigs and piglets in NRW, LS and other EU countries that are direct trade partners of NL. Indirect trade partners within the EU will not suffer from shortages in the first two weeks of a CSF outbreak in NL. In weeks 3-6 also indirect trade partners of NL will face shortages, because the supply shock levels out across the EU market. The duration of shortages in the EU market depends on the duration of export bans. Third countries outside the EU are assumed to keep their borders closed during the epidemic.

In Table 13 market effects of a CSF outbreak in Weser-Ems (LS) are shown. LS is a net importing market for piglets and a net exporting market for slaughter pigs. Due to trade bans in weeks 0-2 and weeks 3-6 a shortage in piglets, but a surplus in slaughter pigs will arise in LS. In order to cope with slaughter pig surpluses slaughter numbers will increase. In weeks 7-end imports of piglets will increase in LS in order to fill up piglet shortages. In NL a piglet surplus will arise in weeks 0-2 and 3-6, because LS piglet demand is discontinued. To overcome slaughter pig surpluses in NL slaughterings and exports to EU increase. In NRW a small piglet surplus and a small slaughter pig shortage will arise in weeks 0-6. In other net piglet importing markets piglet imports will increase slightly in weeks 0-6. In net piglet exporting markets exports will slightly decrease. In weeks 7-end exports of piglets from all trade partners of LS are increased.

Tables 14 and 15 concern AD outbreaks and include three periods (before, during, after outbreak). Since AC of AD epidemics are expected to be more relevant than ICC, Tables 14 and 15 also show the expected market effects after the epidemic. Table 14 describes the market effects of an AD epidemic in NL. During AD outbreaks no movements are allowed within MRZs. Within MRZs surpluses of vaccinated animals will accumulate. Supply shocks that occur to NRW, LS and other trade partners will level out across the EU market. After the epidemic vaccinated piglets that accumulated during the epidemic can either be sold in NL or in Article 9 areas. In Table 15 the market effects for an AD outbreak in LS are described. During outbreaks no movements are allowed in the MRZ without consent of authorities. Authorities can allow directed movements within the MRZ or to slaughterhouses for immediate slaughter. Because granting movement permission takes some time, small surpluses built up. After the outbreak has ended the market will quickly return to the default situation.

Table 12. Market effects of CSF outbreaks in NL.

Trade partners	Before outbreak (normal situation)	Outbreak: weeks 0-2[1,2]	Outbreak: weeks 3-6[1,2]	Outbreak: weeks 7-end[1,2]
NL: net exporting market for piglets and slaughter pigs	↑	Due to trade ban and movement restrictions: • large piglet and slaughter pig surpluses	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)
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 NL trade ban: • piglet shortages • decrease in slaughter pig export (no slaughter pig import from NL)	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)
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: decrease 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 realized; the same holds for the period of weeks 7 until the end of the outbreak.

Source: Based on Hop et al. (forthcoming).

Table 13. Market effects of CSF outbreaks in LS.

Trade partners	**Before outbreak (normal situation)**	**Outbreak: weeks 0-2**[1,2]	**Outbreak: weeks 3-6**[1,2]	**Outbreak: weeks 7-end**[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	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
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	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 lifting trade ban for diseased region LS: • Increased export of piglets
NRW: net importing market for piglets and slaughter pigs		Due to trade ban for diseased region LS: • small piglet surpluses • small slaughter pig shortages	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 increase in import (piglet surpluses) • net exporting piglet markets: decrease in export (piglet surpluses) • small slaughter pig shortages	Due to trade ban for diseased region LS: • net importing piglet markets: slight increase in import (piglet surpluses) • net exporting piglet markets: decrease in export (piglet surpluses) • small slaughter pig shortages • trade volume and price effects level out across the EU market	
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, new trade volume and price equilibrium will be realized; the same holds for the period of weeks 7 until the end of the outbreak.
Source: Based on Hop et al. (forthcoming).

Table 14. Market effects of AD outbreaks in NL.

Trade partners	Before outbreak (normal situation)	During Outbreak:	After outbreak:
NL (net exporting market for piglets and slaughter pigs)	↑	• No movements allowed to and from farms in MRZ for first 4 weeks after initial outbreak • Rest of NL as usual • After 4 weeks: within MRZ movement allowed, farms in MRZ can deliver to slaughterhouses for immediate slaughter	• Vaccinated piglets can be transported within NL or to Art. 9 areas
LS (net importing market for piglets and slaughter pigs)	All European markets (regions and countries) are related, but not all markets have direct trade relationships (there is an equilibrium).	Overall, increasing shortage of piglets and slaughter pigs: shock and price effects level out across the EU market. This means that some farms will not be able to buy piglets, i.e. the shock leads to higher prices. The exact price farmers are willing to pay for piglets also depends on the expected price for slaughter pigs. The farms that cannot buy piglets will therefore be the farms for which the gross margins become negative. These farms are present in all markets, not only in countries like Poland and Hungary, but also in the Netherlands and north-western Germany.	
NRW (net importing market for piglets / net exporting market for slaughter pigs)			
Direct trade partners	↓		
Indirect trade partners			
Third countries		No change	

Source: Based on Bosman et al. (forthcoming b).

Table 15. Market effects of AD outbreaks in LS.

Trade partners	Before outbreak (normal situation)	During Outbreak:	After outbreak:
LS (net importing market for piglets and slaughter pigs)	↑	• No movements allowed from farms in MRZ without consent of authorities • With consent movements only to farms within MRZ or to slaughterhouse for immediate slaughter • Small surpluses build up in the short term as consent granting takes time	↑
NRW (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 (there is an equilibrium).	No significant effects	• Default situation
Direct trade partners			↓
Indirect trade partners	↓		
Third countries		No change	

Source: Based on Bosman et al. (forthcoming b).

6.3 Price Change Indications

As final result of the expert workshops semi-qualitative price change indications have been generated. The aim was to provide illustration of the best guess on price changes related to supply shocks during CSF and AD epidemics. The indications are based on the information that was provided and compiled during the expert workshops. The price change indications refer to the cumulative surpluses and shortages that arise during CSF and AD epidemics (see Figure 21). To indicate the relative size of the price changes plus (+), minus (-) and neutral (o) signs have been utilized. Single plus (minus) signs indicate a slight increase (decrease) of the respective price. Two signs indicate a medium and three signs a large price response. The neutral sign indicates that no significant price responses are expected. An (x) indicates that no price is determined on the market, because of complete movement standstill in the affected region.

6.3.1 CSF Price Indications

In Tables 16 to 20 the expected price reactions for the different CSF scenarios are presented. To enable the indication of price changes the tables contain information about the default market price, the weekly demand, the trade volume in the default situation and the estimated trade volume during the epidemic. In Tables 16 and 17 price change indications for CSF scenarios 1 to 4 are presented. Table 16 refers to piglet prices. Table 17 refers to slaughter pig prices. In Tables 16 to 20 it can be seen that during the course of CSF epidemics price changes in regions outside the affected country are expected to be alike. The price changes inside the affected country differ between the affected and unaffected regions.

Table 16 indicates that during weeks 0-6 prices drop in the free regions of the affected country, while prices outside the affected country rise. In the diseased regions no market price is determined, due to complete movement standstill during weeks 0-6. During weeks 7-end prices drop, because large accumulations of surplus animals are released from the free regions in the affected country. Prices in the affected country drop further than in the other EU regions. When movements are allowed again, a price is determined in the diseased region. The price within the diseased region is lower than anywhere else. Since the producers in the diseased region are only allowed to trade domestically, traded quantity from the diseased region is indicated as zero. Differences between scenarios occur without (i.e. scenarios 1 and 2) and with (scenarios 3 and 4) extension in the export ban. In scenarios 1 and 2 export is banned only in weeks 0-2. In scenario 3 and 4 scenarios are banned in weeks 0-6. Therefore, shortages and prices in EU markets are higher during weeks 0-6 in scenarios 3 and 4. Between non-vaccination (scenarios 1 and 3) and vaccination scenarios (scenarios 2 and 4) differences in price change indications occur within the free regions of the affected country.

Table 17 contains the price change indications for slaughter pig prices in CSF scenarios 1 to 4. Price change indications differ between the affected country and EU trade partners. In weeks 0-6 prices rise in the EU regions. In the affected country prices rise in free regions in scenario 1 and drop in scenarios 2, 3 and 4. During weeks 7-end slaughter pig prices are indicated to be at the pre-outbreak level in the EU regions in scenarios 1 to 4. In the free regions of the affected country prices are at pre-outbreak level during weeks 7-end in scenario 1 and 3. In vaccination scenarios 2 and 4 prices are indicated to decrease during weeks 7-end.

In Tables 18 and 19 price change indications for CSF scenarios 5 to 8 are presented. Table 18 shows price change indications of piglet prices. Price changes differ between affected countries (NL and LS) and EU trade partners. During weeks 0-6 prices decrease in EU regions and in the free regions in NL.

In the diseased region in LS prices rise strongly and stay at pre-outbreak level in free regions in scenarios 5 and 6. In scenarios 7 and 8, where channeling is allowed, prices remain at pre-outbreak level during weeks 0-6. Inside the diseased region of NL no market price is determined, because of movement standstill. During weeks 7-end prices are at pre-outbreak level in all scenarios and in all regions. Table 19 shows price change indications for slaughter pig prices in CSF scenarios 5 to 8. During weeks 0-6 slaughter pig prices increase in EU regions and they decrease in the diseased region in LS in scenarios 5 and 6. In scenarios 7 and 8 slaughter pig prices are indicated to remain constant in all regions, except for the diseased region in NL. During weeks 7-end the prices are at the pre-outbreak level in all regions.

In Table 20 price change indications for CSF scenario 9 are summarized. Price changes are only indicated in NRW. In all other EU regions there are no price changes during the epidemic. In the diseased region piglet prices are increased in weeks 0-6 and weeks 7-end. Slaughter pig prices decrease in weeks 0-6 in the diseased region and increase in free regions within NRW. During weeks 7-end slaughter pig prices return to the pre-outbreak level.

Table 16. Piglet price change indications for CSF scenarios 1-4.

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			**Scenarios 3-4**			**Scenarios 1-2**			**Scenarios 3-4**		
	Quantity	*Quantity*	*Price*	*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]	
	in 1,000	*in 1,000*	*€*	*in 1,000*	*Scenario 1*	*Scenario 2*	*in 1,000*	*Scenario 3*	*Scenario 4*	*in 1,000*	*Scenario 1*[3]	*Scenario 2*[3]	*in 1,000*	*Scenario 3*	*Scenario 4*
NL	361														
▪ Rest country		-47	46.5	-51	-	-	0	-	- -	-227	- -	- -	-267	- -	- -
▪ South		-76	46.5	0	x	x	0	x	x	0	- - -	- - -	0	- - -	- - -
NRW	265	27	46.6	22	+	+	19	++	++	34	-	-	36	-	-
LS	378	100	46.8	93	+	+	89	++	++	109	-	-	113	-	-
Rest of Germany	415	39	46.2	32	+	+	27	++	++	49	-	-	53	-	-
Denmark	380	-145	46.7	-152	+	+	-156	++	++	-136	-	-	-132	-	-
South Europe	1,838	28	45.5	-4	+	+	-26	++	++	74	-	-	91	-	-
East Europe	903	74	45.5	58	+	+	47	++	++	96	-	-	105	-	-

[1] Slaughter pig demand = piglet production – piglet export + piglet import.
[2] A negative number for net import means export.
[3] Price = average price for piglets going to/coming from several destinations.
[4] Price changes are presented as higher (+, ++ and +++) or lower (-, - - and - - -) compared with the default situation.
Source: Based on Hop et al. (forthcoming).

Table 17. Slaughter pig price change indications for CSF scenarios 1-4.

Region	Weekly slaughterings demand[1]	Weekly net import of slaughter pigs[2]													
		Default situation		**CSF outbreak**											
				Weeks 0-6						**Weeks 7-end**					
				Scenarios 1-2			**Scenarios 3-4**			**Scenarios 1-2**			**Scenarios 3-4**		
	Quantity	*Quantity*	*Price*	*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]	
					Scenario 1	*Scenario 2*		*Scenario 3*	*Scenario 4*		*Scenario 1*	*Scenario 2*		*Scenario 3*	*Scenario 4*
	in 1,000	*in 1,000*	*€*	*in 1,000*			*in 1,000*			*in 1,000*			*in 1,000*		
NL	265														
▪ Rest country		-51	1.350	-23	+	-	0	-	- -	-118	o	-	-154	o	-
▪ South		-23	1.350	0	x	x	0	x	x	0	-	- -	0	-	- -
NRW	384	113	1.353	108	+	+	106	++	++	117	o	o	120	o	o
LS	348	-41	1.353	-45	+	+	-47	++	++	-37	o	o	-34	o	o
Rest of Germany	361	2	1.340	-2	+	+	-4	++	++	6	o	o	9	o	o
Denmark	366	-14	1.353	-18	+	+	-20	++	++	-10	o	o	-7	o	o
South Europe	1,825	-13	1.310	-35	+	+	-45	++	++	6	o	o	22	o	o
East Europe	930	27	1.310	16	+	+	11	++	++	37	o	o	45	o	o

[1] Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import.
[2] A negative number for net import means export.
[3] Price = average price for piglets going to/coming from several destinations.
[4] Prices changes are presented as higher (+, ++ and +++) or lower (-, -- and ---) compared with the default situation.
Source: Based on Hop et al. (forthcoming).

Table 18. Piglet price change indications for CSF scenarios 5-8.

Region	**Weekly slaughter pig demand**[1]	**Weekly net import of piglets**[2]													
		Default situation		**CSF outbreak**											
				Weeks 0-6						**Weeks 7-end**					
				Scenarios 5-6			**Scenarios 7-8**			**Scenarios 5-6**			**Scenarios 7-8**		
	Quantity	*Quantity*	*Price*	*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]		*Quantity*	*Price*[3, 4]	
	in 1,000	*in 1,000*	*€*	*in 1,000*	*Scenario 5*	*Scenario 6*	*in 1,000*	*Scenario 7*	*Scenario 8*	*in 1,000*	*Scenario 5*	*Scenario 6*	*in 1,000*	*Scenario 7*	*Scenario 8*
NL	361														
▪ Rest country		-94	46.5	-70	-	-	-94	o	o	-153	o	o	-94	o	o
▪ East		-29	46.5	0	x	x	-29	x	x	0	o	o	-29	o	o
NRW	265	27	46.6	29	-	-	27	o	o	29	o	o	27	o	o
LS	378						100	o	o				100	o	o
▪ Rest country		12	46.8	12	o	o				175	o	o			
▪ Weser-Ems		88	46.8	0	+++	+++				0	o	o			
Rest of Germany	415	39	46.2	43	-	-	39	o	o	42	o	o	39	o	o
Denmark	380	-145	46.7	-141	-	-	-145	o	o	-142	o	o	-145	o	o
South Europe	1,838	28	45.5	45	-	-	28	o	o	42	o	o	28	o	o
East Europe	903	74	45.5	82	-	-	74	o	o	81	o	o	74	o	o

[1] Slaughter pig demand = piglet production – piglet export + piglet import.
[2] A negative number for net import means export.
[3] Price = average price for piglets going to/coming from several destinations.
[4] Prices changes are presented as higher (+, ++ and +++) or lower (-, -- and ---) compared with the default situation.
Source: Based on Hop et al. (forthcoming).

Table 19. Slaughter pig price change indications for CSF scenarios 5-8.

Region	Weekly slaughterings demand[1]	Weekly net import of slaughter pigs[2]													
		Default situation		CSF outbreak											
				Weeks 0-6						Weeks 7-end					
				Scenarios 5-6			Scenarios 7-8			Scenarios 5-6			Scenarios 7-8		
	Quantity	*Quantity*	*Price*	*Quantity*	*Price[3, 4]*		*Quantity*	*Price[3, 4]*		*Quantity*	*Price[3, 4]*		*Quantity*	*Price[3, 4]*	
	in 1,000	*in 1,000*	*€*	*in 1,000*	*Scenario 5*	*Scenario 6*	*in 1,000*	*Scenario 7*	*Scenario 8*	*in 1,000*	*Scenario 5*	*Scenario 6*	*in 1,000*	*Scenario 7*	*Scenario 8*
NL	265														
▪ Rest country		-28	1.350	-23	+	+	-28	o	o	-117	o	o	-28	o	o
▪ East		-46	1.350	0	x	x	-46	x	x	0	o	o	-46	o	o
NRW	384	113	1.353	108	+	+	113	o	o	117	o	o	113	o	o
LS	348	-41	1.353				-41	o	o				-41	o	o
▪ Rest country				-45	+	+				-37	o	o			
▪ Weser-Ems				0	-	-				0	o	o			
Rest of Germany	361	2	1.340	-2	+	+	2	o	o	6	o	o	2	o	o
Denmark	366	-14	1.353	-18	+	+	-14	o	o	-10	o	o	-14	o	o
South Europe	1,825	-13	1.310	-35	+	+	-13	o	o	6	o	o	-13	o	o
East Europe	930	27	1.310	16	+	+	27	o	o	37	o	o	27	o	o

[1] Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import.
[2] A negative number for net import means export.
[3] Price = average price for piglets going to/coming from several destinations.
[4] Prices changes are presented as higher (+, ++ and +++) or lower (-, -- and ---) compared with the default situation.
Source: Based on Hop et al. (forthcoming).

Table 20. Price change indications for piglets and slaughter pigs for CSF scenario 9.

Region	Weekly slaughter pig demand[1]	Weekly net import of piglets[2]						Weekly slaughterings demand[3]	Weekly net import of slaughter pigs[2]					
		Default situation		CSF outbreak					Default situation		CSF outbreak			
				Weeks 0-6		Weeks 7-end					Weeks 0-6		Weeks 7-end	
				Scenario 9		Scenario 9					Scenario 9		Scenario 9	
	Quantity[4]	*Quantity*[4]	*Price*[5]	*Quantity*[4]	*Price*[6]	*Quantity*[4]	*Price*[6]	*Quantity*[4]	*Quantity*[4]	*Price*[7]	*Quantity*[4]	*Price*[6]	*Quantity*[4]	*Price*[6]
NL	361	-123	46.5	-121	o	-125	o	265	-74	1.350	-75	o	-73	o
NRW	265							384						
▪ Rest country		-4	46.6	-4	o	-4	o		173	1.353	113	++	173	o
▪ Münster		31	46.6	0	++	58	+		-60	1.353	21	--	-78	o
LS	378	100	46.8	103	o	98	o	348	-41	1.353	-43	o	-39	o
Rest of Germany	415	39	46.2	42	o	36	o	361	2	1.340	0	o	4	o
Denmark	380	-145	46.7	-142	o	-147	o	366	-14	1.353	-16	o	-12	o
South Europe	1,838	28	45.5	42	o	16	o	1,825	-13	1.310	-23	o	-5	o
East Europe	903	74	45.5	81	o	68	o	930	27	1.310	22	o	31	o

[1] Slaughter pig demand = piglet production – piglet export + piglet import.
[2] A negative number for net import means export.
[3] Slaughterings demand = slaughter pig production – slaughter pig export + slaughter pig import.
[4] Number of animals (x 1,000).
[5] Price = average price for piglets going to/coming from several destinations. Price in €/kg slaughter weight.
[6] No difference between non-vaccinated and vaccinated slaughter pigs. Prices are presented as higher (+, ++ and +++) or lower (-, -- and ---) compared with the default situation.
[7] Price = average price for 1 kg / slaughtered weight going to/coming from several destinations.
Source: Based on Hop et al. (forthcoming).

6.3.2 AD Price Indications

According to experts' expectation, AD epidemics have no significant effect on prices during the outbreak because the area under movement restriction and the weekly supply shocks are small. Therefore, no price change indications for the time during the outbreaks are provided. Instead, price change indications are given for the aftermath of AD epidemics. Price changes in the aftermath of AD outbreaks are induced by the occurrence of large quantities of vaccinated animals. Considering the verified market effects described in Table 15, it is justifiable not to provide price change indications for NRW and LS. In NRW and LS AD outbreaks are expected to have only minor effects on supply of piglets and slaughter pigs.

Tables 21 and 22 present the estimated price trends for piglet prices after an AD epidemic in NL. To determine the aftermath price effects in NL two different behaviors of slaughter pig producers are considered, since their purchasing behavior play a key role in the aftermath pricing of piglets. After lifting the MRZ around the infected holding the cumulated piglet surplus from inside the MRZ is causing a shock on the Dutch market. Since in NL a vaccination based control strategy is used, the piglets from inside the MRZ are all vaccinated. These piglets must be sold quickly as they are too heavy and too old. Possible target markets for vaccinated piglets are NL or Article 9 countries like Spain, Italy and East EU countries. Since the breeders need to sell their vaccinated piglets their animals will yield a low price. The size of the price decrease is determined by the purchasing behavior of the Dutch fatteners. If many fatteners buy vaccinated piglets from the affected breeders (Table 21) the price drop will not be as large as in a situation in which the fatteners avoid buying vaccinated piglets (Table 22). As vaccinated piglets constitute a substitute product for non-vaccinated product in NL, the unaffected Dutch breeders are also expected to face a temporary price decrease for their products. Since the quantity of vaccinated piglets is only a minor share of total EU production, the breeders in the other EU countries are expected to face no significant price changes in either scenario.

Table 21. Piglet price change indications for AD scenario 11.

Piglets	**AD outbreak**
	Aftermath price changes
Region	Scenario 11
NL	
▪ Rest country	-
▪ MRZ	- -
Other EU countries	o

Source: Based on Bosman et al. (forthcoming b).

Table 22. Piglet price change indications for AD scenario 11, low demand for vaccinated piglets.

Piglets	**AD outbreak**
	Aftermath price changes
Region	Scenario 11
NL	
▪ Rest country	-
▪ MRZ	- - (-)
Other EU countries	o

Source: Based on Bosman et al. (forthcoming b).

7 Discussion

Originally, the aim of this thesis was to provide a quantitative analysis of changes in PS of pig producers in the cross-border region NL-NRW-LS caused by outbreaks of CSF and AD. However, due to difficulties in price estimation the aim of this thesis changed into providing a detailed qualitative elaboration of the economic effects of CSF and AD outbreaks in NL-NRW-LS. A theoretical framework for HCLD economic analyses has been provided and applied during expert workshops. The expert workshops delivered qualitative results on the economic impact of CSF and AD epidemics. In the following the theoretical framework, the price estimation workshops and the qualitative results of the workshops are discussed.

7.1 Discussion on Theory

The theoretical analysis of the disease control measures revealed differences in the emergence of supply shocks and economic effects during CSF and AD epidemics. Based on Meuwissen et al. (1999), Pluimers et al. (1999), van Asseldonk et al. (2005), Bosman and Saatkamp (2010), Hop et al. (2012), Longworth et al. (2012) and Bosman et al. (2013) the disease control measures were categorized into veterinary, socio-ethical and economic measures. Moreover, the cost effects associated with the control measures were identified.

Differences in the emergence of supply shocks between CSF and AD can be described. CSF outbreaks have an immediate impact in the pig market because large parts of the production are suddenly cut off from the market and animals are culled. The supply shocks primarily emerge due to movement restrictions in diseased regions. Emergency culling, pre-emptive culling and welfare slaughter contribute to the supply shock. In exporting countries export bans implemented by trade partners can exacerbate the supply shock. To mitigate the economic impact of veterinary control measures channeling and vaccination can be implemented as mitigation measures.

Supply shocks during AD outbreaks are caused by movement restrictions and vaccination. As shown in chapter 3 the area under movement restriction is considerably smaller than during CSF outbreaks. Therefore, the economic impact of AD outbreaks appears differently. When vaccination is used, vaccinated animals accumulate in the MRZ. This pool of vaccinated animals causes AC as soon as the movement restrictions are lifted. The results of Bosman et al. (2013) have shown that channeling can reduce shortages on the outside and surpluses on the inside of MRZs.

The welfare economic elaboration in this thesis showed that product and market differentiation during economic analysis of HCLD epidemics is important. During CSF and AD epidemics different temporary submarkets exist. As shown in Chapter 3, movement restrictions, regionalization and export bans temporarily separate the market for live piglets and slaughter pigs spatially and economically. Also Mangen et al. (2004) underline the importance of spatial and temporal disaggregation of effects during HCLD outbreaks. Economic effects in the diseased and free regions as well as on direct and indirect trade partners differ from each other. As shown in Figure 20 in Chapter 5 surpluses and shortages accumulate in various markets. The appearance of shortages and surpluses depends on the implemented control measures, on the response of trade partners and on whether the affected country is net importing or net exporting. Therefore, the size and direction of price effects differ across submarkets.

Moreover, the elaboration on economic welfare effects has shown that the market is separated on product level (product differentiation). Mangen and Burrel (2003) distinguish between breeders, slaughter pig producers and breeding stock producers and thus make a distinction on product level.

However, the authors do not take into account occurring quality differences. When channeling from diseased regions is allowed, overweight, overage and vaccinated animals are put on the market. This leads to market separation on product level. These affected products are substitutes for unaffected piglets and slaughter pigs. While van Asseldonk et al. (2005) and other authors recognize the decreased value of vaccinated products, they do not take into account that vaccinated products are substitutes for unaffected products.

In the welfare economic elaboration differences in the emergence of PS changes in net importing and net exporting countries were discussed. The price reactions that are triggered in net exporting countries differ from the price effects in net importing countries. In net exporting countries export bans cause price drops because of surplus accumulation in the domestic market. This finding is in line with the finding of van Asseldonk et al. (2005) and Boklund et al. (2009). They argue that producers in net exporting countries are more affected by export bans than producers in net importing countries. In the theoretical elaboration it was argued that when no export bans are implemented, producers' prices are determined on the EU market. Without export bans the supply shocks cause price increases in the affected country, because the total supply quantity in the EU is reduced. This holds for net importing as well as for net exporting countries.

7.2 Discussion on Method

The theoretical knowledge about PS changes was put into practice during expert workshops. As shown in Figure 1, estimations on PS changes can either be acquired by PE models or by expert workshops. The failure of the price estimations by experts puts the choice of the research method into question. However, PE models require input data that underlies uncertainty (e.g. price elasticities). This influences the reliability and validity of the outcomes of PE models. Furthermore, PE models are rather complex and it is time consuming to set them up.

In the theoretical elaboration of economic welfare effects the two following central assumptions were introduced: The assumption of completely inelastic short-run supply and the assumption of unchanged demand. These assumptions were also fundamental during the expert workshops. The assumption of completely inelastic short-run supply has been introduced by Berentsen et al. (1992a) and has been made in many subsequent papers (e.g. Mangen et al., 2004; Niemi et al., 2006 & 2008; Boklund et al., 2009). Technical and natural arguments support this assumption. The assumption of unchanged demand is more controversial. Schoenbaum and Disney (2003) argue that consumer demand might shift due to psychological effects. End consumers' reactions to CSF and AD outbreaks are difficult to anticipate, but can have great influence on ICC and AC of an epidemic. Boklund et al. (2009) point out that especially the market reaction to vaccination is not predictable. If the assumption of unchanged demand during CSF and AD outbreaks does not hold, the described market effects may be no longer applicable. Changing demand would add complexity to the economic situation during HCLD outbreaks.

7.3 Discussion on Results

To calculate PS changes associated with CSF and AD outbreaks data on supply shocks and on price changes were required. Data on supply shocks was delivered by epidemiological simulations of CSF and AD outbreaks using ISP models. To acquire quantitative data on price changes price estimation workshops with experts were held. For the price estimations a structured and verifiable estimation approach was developed. However, the experts stated that they were not able to reliably estimate price changes due to great uncertainty about market responses. Too many factors are simultaneously and inter-dependently influencing the market during CSF and AD epidemics. For example uncertainty about seasonality in price volatility and about demand volatility hampered the price estimations. While no quantitative data was generated during the workshops, the workshops gave qualitative insight in temporal market effects during CSF and AD outbreaks. The experts stated expectations and assumptions on market effects during CSF and AD epidemics. Moreover, semi-qualitative price change indications were generated.

During the workshops there was consensus about several assumptions and expectations concerning the market effects during CSF and AD epidemics. The most crucial assumption made by the experts is the leveling-out assumption. Leveling-out describes the effect that supply shocks will be disseminated across the EU market. Leveling-out leads to a dilution of the supply shock. Shortly after the emergence of the supply shock in the EU market, indirect trade partners of the affected country will also face economic consequences. Leveling-out leads to mitigation of the economic effects occurring to direct trade partners and the affected country. If the supply shocks do not level out across the EU market, the shock will mainly affect the affected country and its direct trade partners. Moreover, also the speed of leveling-out is crucial for the dissemination of the economic effects of HCLD epidemics. So far, no study has examined the responses of the EU pig market to disease outbreaks. Therefore, it is not possible to verify or falsify the experts' leveling-out assumption or to determine the speed of leveling-out.

The qualitative description of time-related market effects helps to understand market dynamics during CSF and AD epidemics. To get a detailed insight into the dynamics of market effects during epidemics it was necessary to separate the epidemic in different time periods, because movement and trade restrictions change during the course of the epidemics. The different periods during CSF and AD epidemics were qualitatively analyzed. Movement and trade restrictions proved to be the most important factors influencing the economic impact of CSF and AD outbreaks. They determine how supply shocks are distributed into the different markets. Particularly during epidemics in net exporting countries trade bans determine the size of the economic impact in the affected country. The effects of export bans in net exporting countries are also described by other authors (e.g. Niemi et al., 2006 & 2008; Bergevoet et al., 2007). The results of Bosman et al. (2013) reveal the importance of movement restrictions as they show that surpluses arise in diseased regions and shortages occur in disease free regions.

The semi-qualitative price indications that were compiled are only of illustrative value. They give a rough picture of the expected price effects during CSF and AD outbreaks. Due to the lack of quantitative data on price changes, no changes in PS were calculated. The obtained price indications show that price effects are expected to differ across submarkets and change during the course of the epidemic. In most scenarios the price change is expected to be largest in the affected country. While disease outbreaks in net exporting regions cause prices to drop in the affected country, outbreaks in net importing countries have the opposite effect. CSF and AD outbreaks in net importing regions are expected to have no observable effect in the EU market. In general the effects occurring during CSF outbreaks are more extensive than the effects of AD epidemics. In accordance with the experts' assumption, AD epidemics have no noticeable effect on the EU price for piglets and slaughter pigs.

The price change indications allow comparing the effects of different control strategies and trade ban scenarios. The results show that in scenarios with extended trade bans the price responses in the affected country as well as in the different EU trade partners are expected to be stronger than in scenarios without extended trade bans. The minor price changes in channeling scenarios indicate that channeling can be an effective economic control measure when a disease occurs in a cross-border context. The effectiveness of channeling has also been shown by Bosman et al. (2013). Furthermore, the price change indications reveal that vaccination has, ceteris paribus, no noticeable effect on price responses in the EU market. However, the price change indications should be interpreted with great care as they give only a rough picture of the price effects during CSF and AD epidemics.

In this thesis several delimitations have been made. The theoretical framework and the expert workshops were focused on PS changes that occur to breeders and fatteners. The PS effects occurring to other stakeholders and other industries have not been considered. Furthermore, to obtain a complete picture about the welfare changes caused by CSF and AD outbreaks also the costs occurring to the government and changes in CS have to be considered. In comprehensive welfare analyses changes in CS occurring to slaughter pig producers are of particular interest as they are caused by changes in piglet prices. Furthermore, this study did not take into account differences in epidemiological factors like the density of pig population, duration of the high risk period or length of the epidemic.

8 Conclusion

Despite the difficulties, most of the research objectives of this thesis have been fulfilled. In the context of the expert workshops qualitative and quantitative descriptions of the EU pig market have been provided. CSF and AD disease control measures used in NL-NRW-LS have been described and analyzed with respect to their impact on ICC. The economic effects of the disease control measures have been connected to welfare economic theory. The welfare economic elaboration gave insight in the emergence of PS changes under different disease control scenarios. It has been shown that for thorough PS analyses separation of markets and product differentiation are necessary in order to capture all relevant economic effects of HCLD epidemics. Changes in trade flows associated with CSF and AD outbreaks have been calculated based on the experts' assumption of leveling-out.

Due to the impracticability of quantitative estimation of price changes, no calculations on PS changes have been made. Instead, factors that influence the size of ICC and AC have been identified qualitatively. Movement restrictions and trade bans have been identified as the most important factors determining the economic impact during CSF epidemics. During AD outbreaks pools of vaccinated animals build up in the MRZ. Therefore, AC can be considerable for pig producers during AD epidemics. Net exporting countries like NL are hit hard by export bans, while in net importing countries export bans have less economic impact. The price change indications suggest that channeling can be an effective economic control measure during CSF outbreaks in a cross-border region.

The experts' assumption of leveling-out suggests that supply shocks and thus economic effects of CSF and AD outbreaks are disseminated across the EU market. The validity of this assumption could not be tested. Therefore, future research in the field of HCLD economics should be focused on the responses of the EU market to HCLD epidemics. Furthermore, consumers' acceptance of vaccinated animals and animal products should be researched because the use of vaccination can have great implications for the economic impact of CSF and AD epidemics.

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