FCC Consortium

Analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in slaughter pigs

for

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Health and Consumers Directorate-General

SANCO/2008/E2/036

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Abbreviations

AIAO	All in/All out
ALC	Agri-Livestock Consulting Ltd
BCR	Benefit cost ratio
CBA	Cost-benefit analysis
CEA	Cost Effectiveness Analysis
COI	Cost of illness
DALY	Disability-adjusted life year
DG SANCO	Health and Consumers Directorate-General
EC	European Commission
EFSA	European Food Safety Authority
EU	European Union
FBD	Food Borne Disease
FCC	Food Control Consultants Ltd
FCR	Feed conversion ratio
FEFAC	European Feed Manufacturers' Federation
FSS	Farm Structure Survey
GE	Gastroenteritis
GHP	Good Hygiene Practice
GMP	Good Manufacturing Practice
GP	General Practitioner
HACCP	Hazard Analysis and Critical Control Points
HHC	Human Health Care
IID	Infectious Intestinal Disease
IRR	Internal rate of return
MS	Member State
na	Not available
NPV	Net present value
PDO	Protected Designation of Origin
PRRS	Porcine Reproductive & Respiratory Syndrome
spp.	species
QALY	Quality adjusted life year
QMRA	Quantitative microbial risk assessment
RVC	Royal Veterinary College
ToR	Terms of Reference
US	United States
USDA	United States Department of Agriculture
VLA	Veterinary Laboratories Agency
WHO	World Health Organisation
WtP	Willingness to pay
YLD	Years Lived with Disability
YLL	Years of Life Lost

Executive Summary

Introduction

The FCC Consortium has been awarded a contract by DG SANCO to provide the European Commission with an analysis of the costs and benefits in the EU of setting a target for the reduction of *Salmonella* infections in slaughter pigs.

The methodology used to develop this study is based around a cost-benefit analysis model structured so that it can capture the costs of pre-harvest *Salmonella* control interventions and the benefits in terms of reductions of human health and animal health costs. Data were collected through literature reviews, questionnaires sent to Member States, country visits and key informant interviews. The team has also worked closely with the EFSA *Salmonella* working group, the consortium who carried out the quantitative risk management assessment and the industry. Given the limit on resources and time, no primary data collection has been carried out.

Pig sector overview

The EU pig sector is dynamic responding to changes in demand for pig products and also variation in costs of inputs, particularly labour across the Member States. For Member States outside the Euro zone there has also been a strong influence of currency fluctuations, perhaps the most dramatic change having taken place in the UK where a strong pound sterling has affected the competitiveness of its pig sector and led to significant reductions in pig populations. In addition the speed of adoption and strengthening of enforcement of legislation might have influenced the competitive advantage of Member States and created shifts in pig populations, pig meat production and transport links. The most striking change over the last ten years has been the rapid expansion of the Spanish pig sector, which is of particularly interest to this study as Spain has reported high prevalence of *Salmonella* in slaughter pigs.

Salmonella in pigs

Salmonella infections are evident in the pig sector across Europe, but there is great variation. Countries with long standing control programmes have brought the disease down in slaughter pigs to low levels and in the case of Finland, it appears to have removed the infection completely. However, important pig producing countries such as France, Germany, Italy, Spain and the UK have levels of infection in slaughter pigs that would imply some risks to human health and a need to control and manage the disease and reduce that risk. It is important to recognize that not all *Salmonella* found in pigs would lead to human infections; data presented indicates that around a half are S. Typhimurium which is the second most important *Salmonella* infection reported in humans across the EU. The second most important pathogenic servovar found in pigs is S. Derby. Assessments using carcass swabs also indicate that *Salmonella* risks can be reduced by good and hygienic slaughter processes. Further analysis of the attribution of human infection suggests that the pig is an important reservoir of *Salmonella* infections.

Human health impact of *Salmonella* in pigs

The project has made an assessment of the economic impact of *Salmonella* in the Member States of the EU. A Cost of Illness model was developed using a two stage methodology. The model estimated the total number of cases using a pyramid of illness, an understanding of incidence and severity of disease. With this as a scale factor, various costs were estimated in terms of: productivity costs (loss of labour); healthcare costs and premature death (and excluding chronic sequelae). Stage 1 of the model, reported here, estimates that the total annual costs for *Salmonella* as a whole are approximately €600 million, not all of which are attributable to *Salmonella* in pigs. Based on published sources, an attribution of 15% was applied across all Member States, giving an estimate of the total annual human health losses due to *Salmonella* in pigs to be approximately €90 million. Stage 2 (to be reported in the Breeding Pig study SANCO/2008/E2/056) will refine the assumptions following consultation with Member States.

Given the scale of these losses it is important to ask how to minimize the risks to humans of *Salmonella* infections from pigs and how to reduce the economic impact of this disease in society.

Pre-harvest interventions and their costs

Information is presented on possible pre-harvest interventions to control and manage *Salmonella* in pigs. Seven different categories of costs associated with the control of *Salmonella* in pigs have been identified: feed; breeding pig and replacement stock; farm-level; transport; slaughterhouse; monitoring and a support unit. The consortium has carried out a thorough review of the literature, both peer reviewed and gray, on these different categories and presents summaries of what the practical interventions are and what they would cost if implemented.

A cost intervention model was developed to determine the costs of the interventions in individual Member States and also across the EU. The model is deterministic, but allows users to modify input parameters by intervention and also by member state, and therefore can be used to carry out sensitivity analysis. The model output presents an overall sum of the costs of interventions and a breakdown by intervention category and by member state. In addition some cost-effectiveness measures are also presented in terms of cost per pig slaughtered and cost per person year.

Based on what is known about the potential impacts of these interventions on pre-slaughter *Salmonella* prevalence in pigs, four scenarios were developed and placed into the model to determine their costs. All the scenarios described are plausible, ranging from: small scale interventions of a support and monitoring unit relying on the existing structures of the pig industry and public sector; to a targeted selection of interventions prioritized on the basis of the QMRA; and finally a wholesale level of interventions. The costs vary from €287 million for the smallest set of interventions through to €1 458 million for most comprehensive programme.

Cost-benefit analysis

The project developed a cost-benefit analysis model to test the economic profitability of the *Salmonella* control interventions in slaughter pigs. In addition to the human health benefits from the control of this disease, benefits associated with improved pig productivity have also been included. The model was used to perform a cost-benefit analysis on four intervention scenarios:

1. An establishment of a support unit and some increased sampling
2. Scenario 1 plus improvement of:
    a. feed practices at feed mill and farm-level
    b. farm-level biosecurity
3. Scenario 1 plus targeted interventions according to country *Salmonella* levels
    a. High prevalence – countries with slaughter pig prevalence's above the EU average:
        i) Clean replacement pigs
    b. Low prevalence – countries with slaughter pig prevalence's below the EU average:
        i) Feed control measures
4. Scenario 3 plus all transport and slaughterhouse measures.

The results of the analysis demonstrate that scenario 1 is superior to all others, but none of the scenarios show an economically profitable return. It is recognized that the analysis lacks the ability to examine the impact on the markets of *Salmonella* control interventions, in particular a market shock if people perceive pig products to be more risky than alternatives sources of protein and modify their consumption behaviour accordingly.

The main task outlined by the terms of reference was to make an assessment of a 50% and 90% reduction of *Salmonella* in slaughter pigs. This task has been made difficult, if not impossible, with the clear lack of attribution on how much a particular intervention or group of interventions has on *Salmonella* lymph node prevalence. However the analysis performed would equate that a 50% reduction in *Salmonella* would be scenario 2 and a 90% reduction scenario 4. Neither of these scenarios was positive even if it is assumed that the interventions they represent could eliminate immediately and maintain free the pig population from *Salmonella* and that all *Salmonella* in humans that has its origin in pigs could also be removed immediately.

Discussion and conclusions

On the basis of the available data and the assumptions made, the cost-benefit analysis did not show an economic benefit from any of the intervention scenarios. Sensitivity analyses did not change the results markedly, although did offer some possible direction for the development of *Salmonella* control at producer level.

The EU-wide benefit-cost ratio (BCR) was less than 1 (so that the economic benefits were lower than the costs) in all scenarios. Sensitivity analyses did not markedly change the results, although benefits would accrue to individual Member States under certain conditions, and to the EU in one instance.

Scenario 2 corresponds to a 50% reduction in *Salmonella* prevalence at EU level and shows a negative return with a BCR of 0.28 (Table 65). Scenario 4 corresponds to a 90% reduction in *Salmonella* prevalence and shows a slightly better, but still negative, return with a BCR of 0.50.

Scenario 1 produced the most favourable outcome, albeit still with a low benefit cost ratio. However, a sensitivity analysis (Scenario 1+ in Table 65) based on optimistic assumptions of a constant rate of reduction of 6% in human health losses plus a 6% constant rate of reduction in pigs affected by *Salmonella*, did show a small positive BCR of 1.07 and an NPV of €21 million. Whilst this is a very modest return under rather optimistic assumptions, it may indicate the most cost-effective way forward for *Salmonella* control in slaughter pigs.

The analysis suggests that there is some economic rationale (albeit based on strong assumptions) for a gradual introduction of *Salmonella* control measures, starting with the establishment of surveillance measures. Further interventions would be targeted according to the surveillance results.

Table 1: Summary of cost-benefit analysis of four scenarios

Scenario	Description	Discounted Costs (million €)	BCR Human health	BCR Human health and pig production	Cost per slaughter pig (€)
1	Establish support unit and increased sampling (varying rate of reduction of human health losses)	287	0.44	0.66	0.11
1+	Scenario 1 (but constant rate of reduction in human health costs and increase in pig productivity of 6%)	287	0.66	1.07	0.11
2	Scenario 1 plus feed practices and farm-level biosecurity	1 089	0.17	0.28	0.43
3	Scenario 1 plus targeted MS interventions, based on high and low prevalence	752	0.38	0.61	0.29
4	Scenario 3 plus transport and slaughterhouse measures	1 458	0.31	0.50	0.57

The results have to be qualified by the lack of precise data and information to make accurate assumptions. The lack of available data may be partly due to the nature of *Salmonella* infection in both pigs and humans. This may explain why many studies have failed to come up with more than very broad findings and general conclusions.

In this light, the most appropriate interpretation of the results may be that they failed to demonstrate a positive economic benefit from setting targets to reduce *Salmonella* in slaughter pigs. However, it would be premature to conclude that the cost-benefit will be negative under all circumstances and it is worthwhile continuing the investigations to explore possible ways forward.

The FCC Consortium will continue to implement a complementary study to analyse the costs and benefits of setting a target for the reduction of *Salmonella* infection in breeding pigs. This contract runs until December 2010. The study will extend the same cost-benefit model to include breeding pigs, which will enable refinement of the current findings as more information becomes available. In this regard, we propose further close consultation with EFSA, DG SANCO, the industry and institutions to review the current findings and facilitate further analysis.

1 Introduction

1.1 Background to the project

The FCC Consortium (comprising Food Control Consultants Ltd. and Agri-Livestock Consultants Ltd.) was awarded a contract (Tender SANCO/2008/E2/036) by the European Commission Health and Consumers Directorate-General (DG SANCO) to undertake an analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in slaughter pigs.

This contract is closely connected to a contract to analyse the costs and benefits of setting a target for the reduction of *Salmonella* in breeding pigs (Tender SANCO/2008/E2/056), which was also awarded to the FCC Consortium. Both contracts are 18 months in length. The slaughter pigs contract runs from 23 December 2008 until 23 June 2010, and the breeding pigs contract runs from 9 July 2009 to 8 January 2011. The FCC Consortium has developed synergies between the two projects to avoid duplication of work and enhance the overall outputs.

The work has been carried out in close coordination with DG SANCO, the European Food Safety Authority (EFSA), its working groups and subcontractors as well as industry representatives and the University of Veterinary Medicine, Hannover.

The project team comprised:

Expert	Organisation	Role
O. Oddgeirsson	Food Control Consultants Ltd.	Team Leader
J. Rushton	Royal Veterinary College*	Animal Health Economist
T. Crilly	Crystal Blue Consulting*	Public Health Economist
D. Dewar	Food Control Consultants Ltd.	Contract Manager
A. Cook	Veterinary Laboratories Agency*	Veterinary Epidemiologist
M. Bennett**	University of Liverpool*	Zoonoses Research Specialist
H. Clough**	University of Liverpool*	Risk Analyst

* Although not members or sub-contractors of the FCC Consortium, these organisations contributed resources to support the project team.

** Participated in initial stages of project only.

Project team members have regularly attended DG SANCO and EFSA meetings throughout the project period.

In 2008, salmonellosis was again the second most reported zoonotic disease in humans in the European Union (EU), accounting for 131 468 confirmed human cases. The statistically significant decreasing trend in the notification rate of the salmonellosis cases continued in the EU for the fifth consecutive year[1] (see Table 2 below).

[1] The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and food-borne outbreaks in the European Union in 2008, The EFSA Journal (2010), 1496.

Table 2: Reported *Salmonella* cases in humans 2004-008

Year	2004	2005	2006	2007	2008
Salmonella cases	195 947	174 544	164 011	151 998	131 468

The EFSA Journal 2010 - 1496

The decreasing trend may reflect improved *Salmonella* status of laying hen flocks following the introduction of new control programmes.

EU wide monitoring of *Salmonella* prevalence in pig populations is relatively recent, but demonstrates the presence of *Salmonella* at different levels across Member States and indicates a potential risk to human health. For this reason and with the apparent success of layer hen control programmes, the European Commission has considered setting targets for the reduction of *Salmonella* prevalence in the EU pig herd. Part of that process is to perform a cost-benefit analysis to determine the costs and benefits of pre-harvest interventions. The report presents the analysis of this problem in pigs with results detailed on human health impacts of *Salmonella* infections, costs of pre-harvest interventions and cost-benefit analysis of the reduction in pig *Salmonella* prevalence.

1.2 Requested work from the European Commission

In accordance with Regulation (EC) No 2160/2003 on the control of *Salmonella* and other specified food-borne zoonotic agents, the European Commission issued a call for tenders to carry out a cost-benefit analysis for the control of *Salmonella* in the pre-harvest stage of slaughter pig production. The tender was won by FCC Consortium. The requirements of the Terms of Reference (ToR) are outlined below:

1.2.1 Purpose of the contract

The purpose of the contract is to provide the Commission with an analysis of the costs and benefits in the EU of setting a target for the reduction of *Salmonella* infections in slaughter pigs.

Regulation (EC) No 2160/2003 requires that Community targets are established for the reduction of the prevalence of *Salmonella* in different poultry and pig populations. Community targets for poultry populations have been set. When defining a Community target for *Salmonella* in slaughter pigs, the Commission shall provide an analysis of its expected costs and benefits.

1.2.2 Work to be carried out

The tender specifications require the undertaking of a cost-benefit analysis. The analysis should

- take into account the criteria laid down in paragraph 6(c) of Article 4 of Regulation (EC) No 2160/2003 with regard to *Salmonella*, in particular:
  - i) its frequency in animal and human populations, feed and food;
  - ii) the gravity of its effects for humans;
  - iii) its economic consequences for animal and human health care and for feed and food businesses;
  - iv) epidemiological trends in animal and human populations, feed and food;

v) scientific advice;

vi) technological developments, particularly relating to the practicality of the available control options; and

vii) requirements and trends concerning breeding systems and production methods.

- use the outcome of the baseline survey on slaughter pigs as reference values to estimate the costs of respectively a 50% and 90% reduction of the mean prevalence at EU level, based on bacteriology of ileo-caecal lymph nodes over a period of 5 to 10 years;
- co-ordinate with the EFSA and its working group preparing an opinion concerning a quantitative risk assessment on *Salmonella* in slaughter and breeding pigs, in particular as regards the expected benefits and expected reduction by the most important control options. In this view the contractor should participate as an observer to at least 3 working group meetings in Parma (Italy) or elsewhere in the EU.

1.3 Report structure

The report has a total of eight Chapters including this one and has the following structure:

Chapter 2	Methodology
Chapter 3	Pig sector overview
Chapter 4	*Salmonella* in pigs and humans
Chapter 5	Human health impact of *Salmonella* in pigs
Chapter 6	Pre-harvest interventions and their costs
Chapter 7	Cost-benefit analysis
Chapter 8	Discussion and conclusions

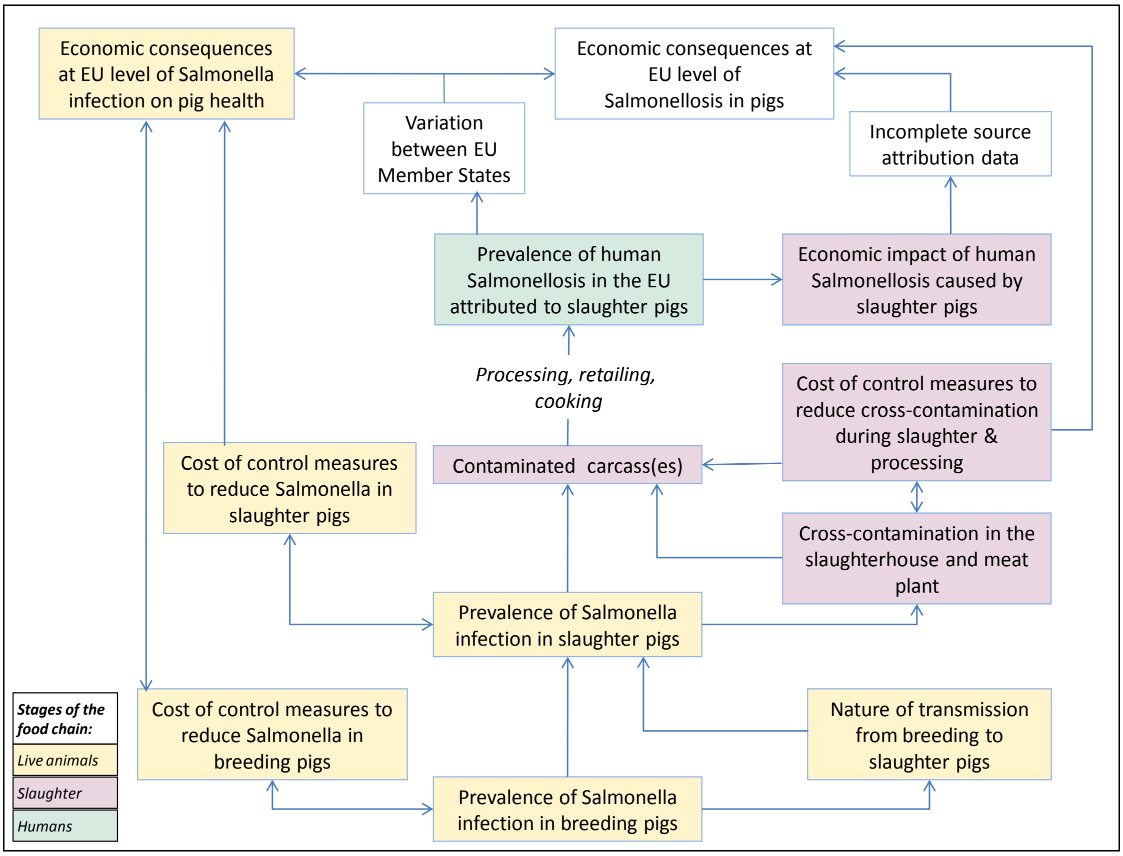
The information presented aims to be as objective as possible, taking into account acknowledged information gaps regarding the impact in humans of *Salmonella* in pigs. The intention is to provide information that will help the allocation of resources for animal health in the improvement of food safety across the European Union.

2 Methodology

2.1 Introduction

Initially the team developed a problem tree for the relationship between the various issues regarding *Salmonella* in the pig meat food chain which is shown in Figure 1.

Figure 1: Problem tree regarding *Salmonella* in the pigmeat food chain



The project was concerned only with the estimation of costs to reduce *Salmonella* infection in slaughter pigs, albeit this is linked to the control of *Salmonella* in breeding pigs. It also involved the assessment of the economic impact of *Salmonella* from pigs in the human population. It has not considered the costs of controlling *Salmonella* contamination of carcasses and/or meat post-harvest, and at present has only limited information on the costs of control of *Salmonella* in breeding pigs. The analysis presented in this report, therefore, does not cover all aspects of Figure 1.

2.2 Analytical structure

Cost-benefit analysis (CBA) is the framework that has been used for the project. CBA was developed to assess the economic profitability of interventions that generate costs and benefits in different time periods. Refined CBAs for livestock sector interventions are based on a solid understanding of the livestock sector within which an intervention will be applied. The current study aimed to assess the impact of interventions in the pig sector to reduce the prevalence of *Salmonella* infection in slaughter pigs.

2.2.1 Costs

The costs for the CBA were collected for interventions pre-harvest in the production of slaughter pigs. These covered the input supplies, farm level interventions, transport and slaughterhouse lairage. They also included information on the need to monitor the disease once a control programme has begun and the costs of staff to coordinate the campaign. Chapter 6 presents detailed information on the type of interventions assessed and also how the costs of the interventions were estimated.

2.2.2 Benefits

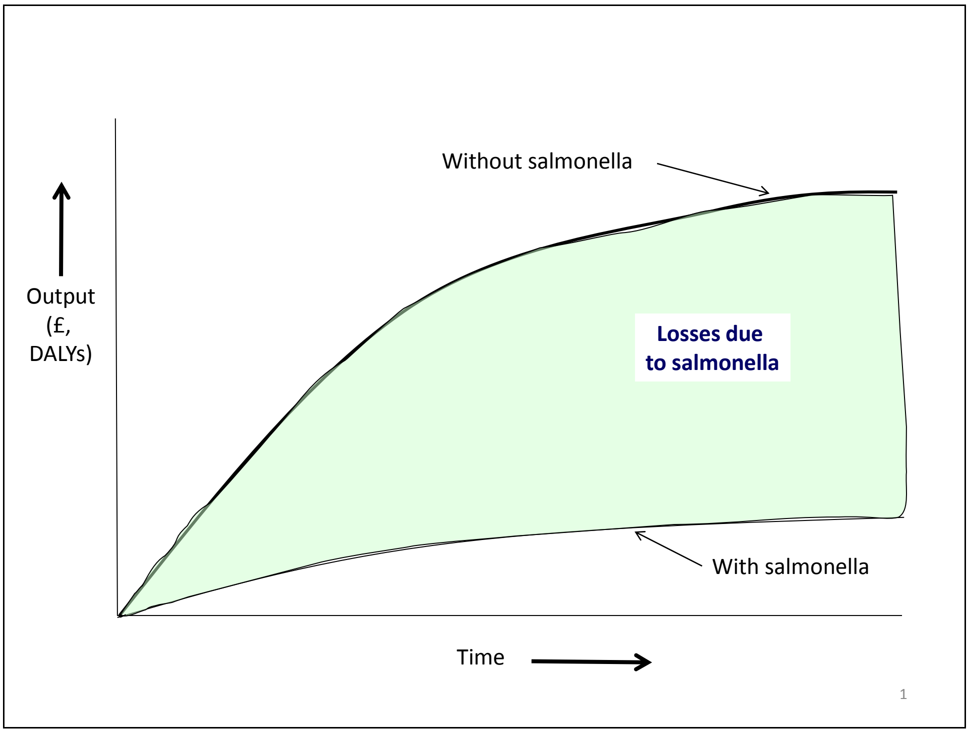
The main benefits considered by the project are related to the costs saved from reducing the impact of *Salmonella* from pigs on human health. Initially, estimates were made of the total impact of *Salmonella* from pigs on human health by Member State and across the EU (see Chapter 5 for full details on the human health impact assessment). The annualized human health losses estimated were used as a basis for calculating benefits from implementing pre-harvest *Salmonella* control interventions in pig herds (see Chapter 7 for details on the different scenarios).

At a later stage the cost-benefit analysis model has included the possibility that *Salmonella* control will improve pig productivity. The team has also discussed in the document the benefits from avoiding market shocks. These areas are discussed in more detail in Chapters 7 and 8

2.2.3 Overall assessment

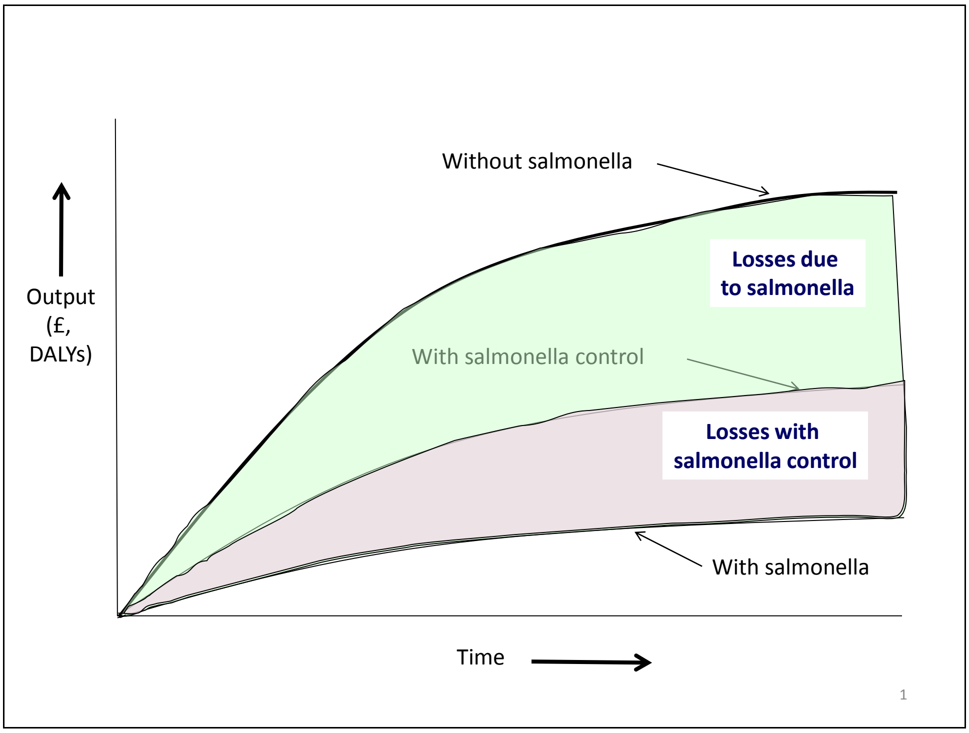
As mentioned above the initial work on the benefits was to look at the overall impact of *Salmonella* that comes from pigs on human health. This estimate of the impact of the disease can be done over a time period as shown in Figure 2.

Figure 2: Estimating the impact of *Salmonella* over time.



However, with a disease such as *Salmonella* it is unlikely that it can be eradicated and therefore there will always be some disease present. In this case there is a need to estimate the difference between output without *Salmonella* and with a control programme to estimate the losses with a control programme in place (see Figure 3).

Figure 3: Impact of a control programme over time and the reduction in losses.



The losses with the control programme are equivalent to the benefits (or termed the avoidable losses) that can be achieved through interventions. The analysis has been performed with two different levels of interventions that can reduce slaughter pig prevalence by 50% and 90% in a 10 year timeframe. Each set of interventions has a set of costs both in amount and in time, i.e. they are not equal in each year. There is then a need to determine the impact of the reductions in *Salmonella* prevalence on the reduction in human *Salmonella* cases, to look more carefully at the benefit streams produced. Again these benefits do not occur equally each year, it is likely that initially there will be few benefits and that they will increase over time.

In order to compare costs of interventions and the benefits generated in different time periods it is necessary to discount each amount in each year to generate a present value. Present values can then be used to estimate the economic value of a set of intervention in terms of:

- Net present value (NPV) – total present value of benefits minus total present value of costs.
  - If the value is greater than zero then the interventions are economically profitable
- Benefit cost ratio (BCR) – total present value of benefits divided by total present value of costs.
  - If the value is greater than one then the interventions are economically profitable
- Internal rate of return (IRR) – the discount rate that generates a NPV equal to zero

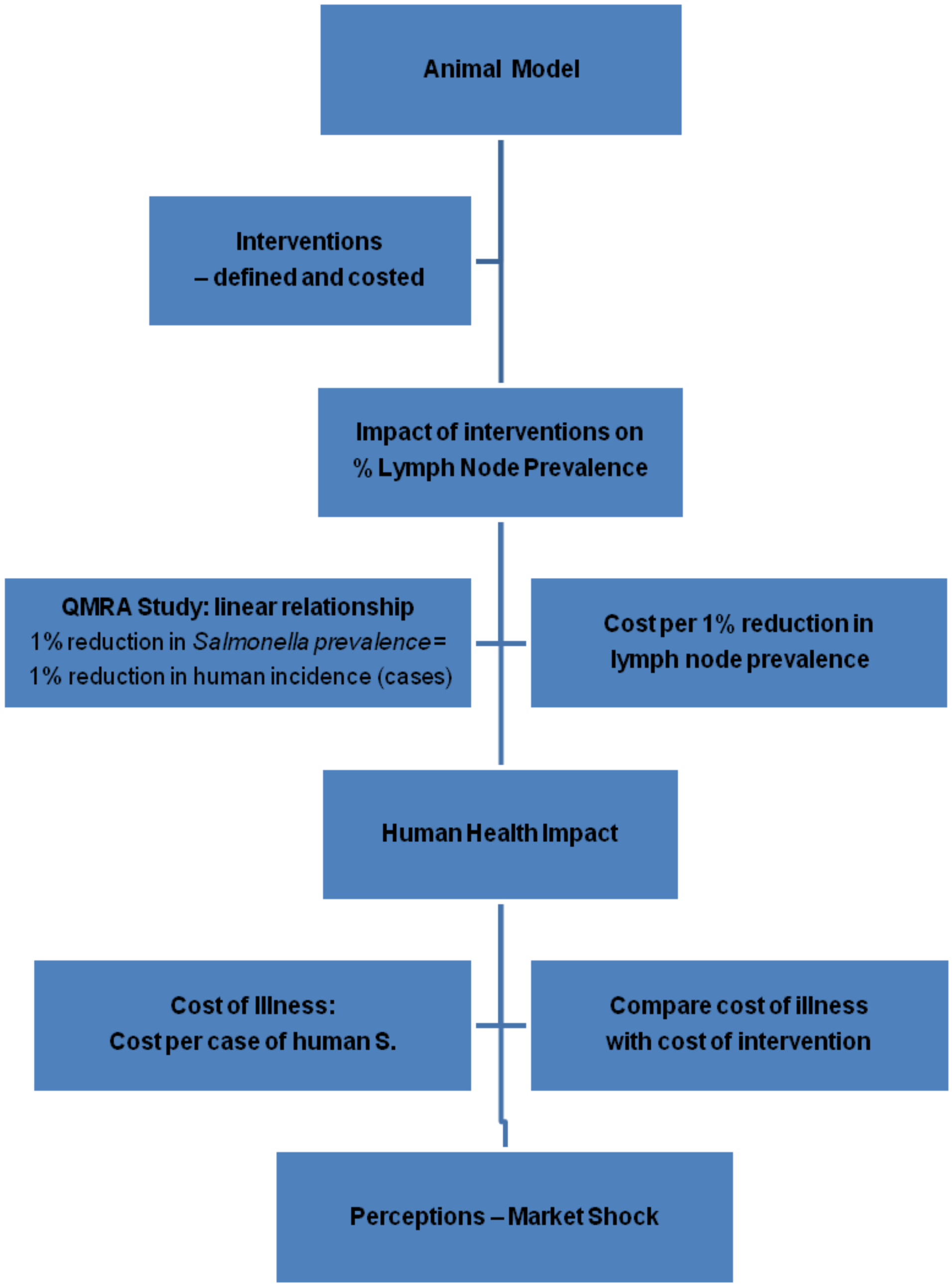
- An IRR greater than the expected return of capital in the economy is considered a good public investment. The criteria may differ for private investments.

The measures of project worth have been calculated in the model developed and used to assess the overall worth of the different investments.

The method described above is the classic method of carrying out a cost-benefit analysis, but in the case of the analysis of the *Salmonella* control interventions that were assessed none of the results generated a positive outcome. Therefore, a number of other outcomes were generated to provide the policy makers with a better means of making future decisions. Further details can be found in Chapter 7.

An overall summary of the process can be seen in Figure 4 below

Figure 4: Different components of the analytical structure.



2.3 Data collection

The present study has not been asked to look in or beyond the slaughterhouses so no detail has been defined in the downstream or post harvest part of the pig and pig product supply chain.

It is noted that the distinction between the pre and post harvest (or upstream and downstream) is taken to be at the point in the slaughterhouse where the prepared carcass moves from the slaughter line into the cold store.

An in-depth review of selected Member States was carried out as described below.

2.3.1 The pig sector and *Salmonella* control measures

For collection of data on the pig sectors and *Salmonella* control measures the team prioritised the countries in relationship to:

- Pig sector size
- Prevalence
- Contribution to EU *Salmonella* pig prevalence
- Representation with regards *Salmonella* control strategies
- Availability of secondary information
- Published articles
- Grey literature
- Contacts with key organisations and people

The following countries were chosen for in-depth work:

- Belgium
- Bulgaria
- Denmark
- Estonia
- Finland
- France
- Germany
- Netherlands
- Spain
- Sweden
- UK

Data were collected through a combination of country visits, collection of secondary data and key informant interviews (summary of data collected can be found in Chapter 4 and in supplementary annexes available with the final report).

2.3.2 Pre-harvest *Salmonella* control intervention

Data were collected through a literature search and through contact and interviews with key informants (full details can be seen in Chapter 6).

2.3.3 Human health impacts

Secondary data were collected via a thorough literature review and also a questionnaire circulated to Member States in April 2010. The questionnaire was designed around the analytical model developed to estimate the cost of illness of *Salmonella* in the human population at Member State level (full details can be found in Chapter 5). The questionnaire findings are reported in Chapter 8. The full impact of Member State responses will be brought into Stage2 of the human health model to be reported in SANCO/2008/E2/056 on breeding pigs.

2.3.4 Input data limitations

In order to determine beforehand farmers' expenses related to control interventions, the direct measurement of compliance costs (sometimes called accountancy or engineering approaches) is a solid approach when carrying out a cost-benefit assessment. This procedure allows the identification of each stage of pig production and the changes needed to meet a proposed reduction in *Salmonella* prevalence at farm level. This then permits the allocation of values on those changes and sums them (Traill et al., 2009).

Ideally, calculations of the costs of interventions are based on consultation of pig industry organisations and firms to ensure that the survey is large enough to be representative of companies of different sizes, and using different production techniques.

This Consortium team recognised the great variety of the pig productive systems and the large amount of bodies linked with the swine industry across the Member States. Efforts were made to take into account that the pig sector in the European Union is not homogenous, but made up of a variety of input industries, production systems and processing and retailing units. Within each system various support industries are identified and the modern intensive system is broken down into breeding, multiplying and fattening herds. In addition interactions between Member States and with third countries should be taken into account to avoid the partial analysis of the pig sectors in each Member State.

Bearing in mind the different levels of accuracy or availability of Member State-specific data, a selection of information sources was used to ensure the most representative data. However, difficulties with obtaining specific data for each Member State necessitated some estimating of values for data inputs to the predictive animal model. The estimates are to some extent supported by peer review studies, governmental agencies' databases and opinions from the scientific and pig industry community.

The lack of precise data must be taken into account when making inferences about which control measures are most cost-effective in the pre-harvest stage of the production of pig meat in the EU.

2.4 Project approach

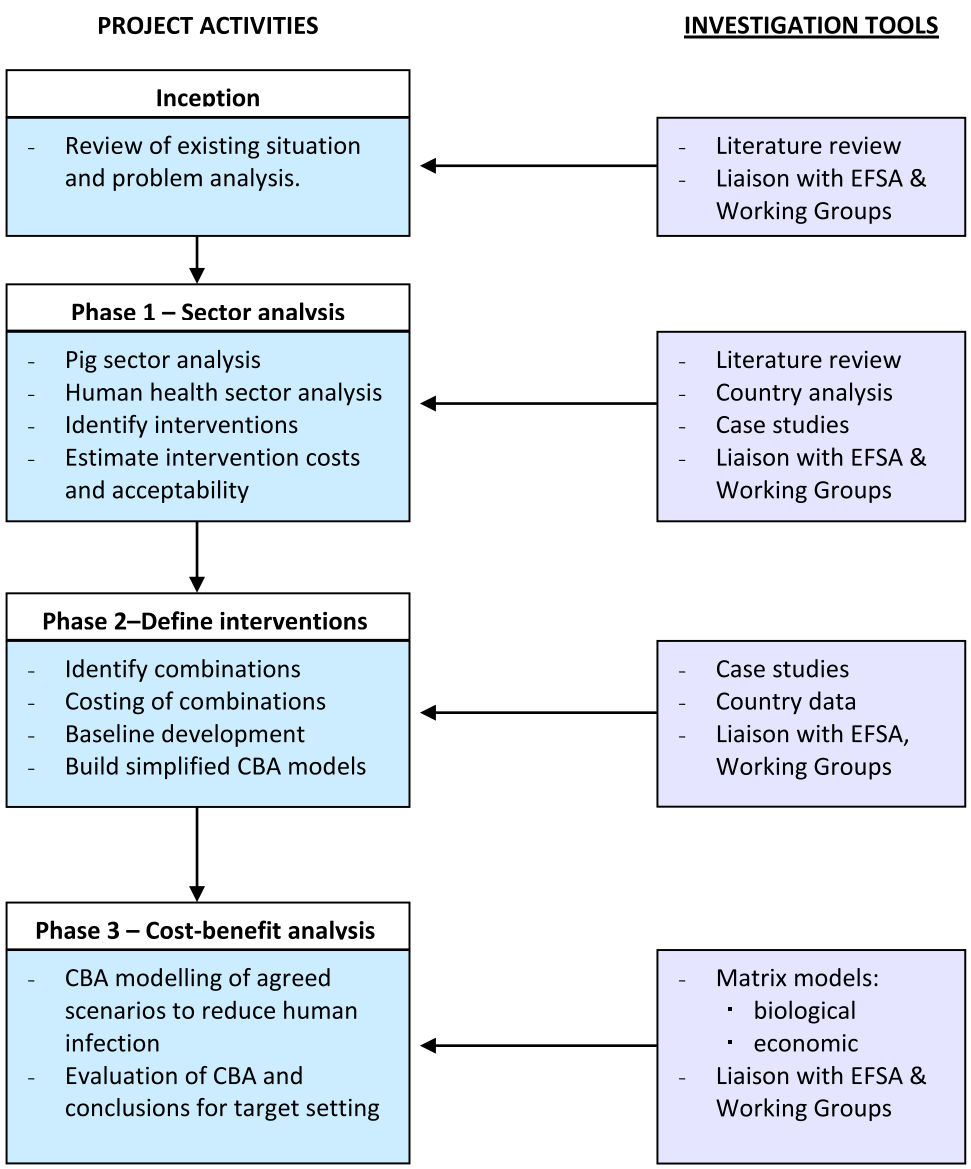
The overall order of how the project team has approached the task of the cost-benefit analysis is shown in Figure 5.

2.5 Summary

The methodology used to develop this study is based around a cost-benefit analysis model structured so that it can capture the costs of pre-harvest *Salmonella* control interventions and the benefits in terms of reductions of human health costs. Data were collected through literature reviews, questionnaires sent to Member States, country visits and key informant interviews. The team has also worked closely with EFSA *Salmonella* working group, the consortium who carried out the quantitative risk management assessment and the industry. Given the limit on resources and time, no primary data collection has been carried out. The following chapters present:

- more detailed methodologies for each component;
- the results of the data collected;
- the benefit and costs calculations; and
- the overall cost-benefit analysis of the control of *Salmonella* in slaughter pigs.

Figure 5: Project approach



3 Pig sector overview

3.1 Introduction

In order to give an insight into the European pork sector, an overview was made of the pig sector of eleven selected European Member Estates (Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Netherlands, Spain, Sweden and UK).

Moreover, the selected group includes the two major European producers, one in Northern Europe (Germany) and one in Southern Europe (Spain), two big exporting countries (Denmark and the Netherlands), a small pork producer (Estonia), and one of the most recent EU accession countries (Bulgaria).

3.1.1 Overview

There are enormous differences between members of the EU regarding the pig sector. An increasing concentration is foreseen in the different links of the pork chain. Southern and Eastern European countries are following this trend that started 10-15 years ago in Northern European countries like the Netherlands, Germany, and Denmark. However, there seems to be room for regional products that focus on niche markets (e.g. Jamón Ibérico in Spain).

Especially in North-Western Europe, the slaughterhouse link in the pork chain has been consolidated. Two principal examples are the largest European companies; *Danish Crown* and the *Dutch-German Vion Food Group*. However, in the Netherlands and Germany pig farmers have remained independent from the slaughterhouses (coordination takes place through quality and information systems). In Southern Europe there is much more fragmentation and competition between companies in different stages of the pork chains.

Quality management systems in North-Western Europe increasingly cover the whole chain, and are supported by chain-wide information systems. Southern European countries are following suit, while Eastern European countries have just started to catch up with EU legislative quality demands (Trienekens et al., 2008)

3.1.2 Quality systems

One of the core findings is the fact that in many countries quality systems are emerging that cover all processes in the pork chain. These systems encompass tougher measures for the reduction of *Salmonella* than the ones currently dictated by the general EU regulations.

Holdings that produce under these extra standards are subjected to external bodies that undergo regular inspections focused on feed, medicine use, hormones, hygiene, as well as animal welfare and transport. The systems also include a range of possible penalties including warnings, fines, or in the case of repetitive non-compliance, exclusion from the quality system.

Northern European countries like the Netherlands, Denmark, and Germany are in front in implementing these kinds of systems. In Southern countries like France and Spain, larger companies are following the Northern European trend, but an interesting development has also emerged towards Protected Designation of Origin (PDO) products and regional specialties. Special attention is given in these countries to (further) development of regulations and standards to protect the brand names of these products. Another clear trend is towards less use of medicines, increased use of organic feeds, etc. However, organic pig production is moving forward quite slowly and currently only accounts for a limited (niche) market share of 0-2% in most countries (Trienekens et al., 2008).

3.1.3 Pig Sector Main Players

One of the main characteristics of the European pork sector is the strong trend towards concentration of all links of the chain.

Feed industry

The biggest EU pig producer, Germany, has 10 companies that control almost 50% of the market. Similarly in the Netherlands the largest 10 companies have more than 65% market share. In Spain, 15 large companies dominate the Spanish market.

The Eastern European countries have a high number of small feed producers, but feeding stuffs are increasingly imported (Trienekens et al., 2008).

Farrowing/Finishing

Many small farrowing/finishing companies still exist, especially in Southern Europe, but also in the southern part of Germany. In the Netherlands there are currently about 8 000 farrowing/finishing farms. This number is falling. Spain has more than 96 000 farms, many of which are small. This also includes 13 500 extensive production farms that produce Iberian pork and other special meat products (Trienekens et al., 2008).

Breeding

The breeding market is also strongly concentrated. the Netherlands, Germany, and Denmark have the largest breeding companies, which deliver to the whole of Europe (including Spain).

3.1.4 Integration

Different management structures can be found at different stages in the supply chain, and major differences can also be found between chains and between countries. Rather than through written contracts, vertical relations are achieved by means of product and process standardisation: widely accepted or private quality standards. Wever and Wognum pointed out in 2008 the integration of finishing and farrowing production in diverse chains, with the aim of reducing animal health and food safety risks caused by the transportation of animals.

In Northern Europe farmer cooperatives still play an important role in the pork sector, such as in the Netherlands where the principal abattoir is the property of farmer cooperatives, and in Germany where strong cooperative organisations still persist. Germany has 121 marketing cooperatives (about 2/3 focused on fattening-slaughter and about 1/3 on breeding-fattening) as well as 150 producer associations. This makes the German pork sector one of the most strongly cooperative in Europe (Trienekens et al., 2008)

In Spain cooperatives cover 20% of production and 10% of the market (cooperatives between farmers and feed industries, cooperatives for trade in live animals, and cooperatives for trade of fresh meat).

In Germany, the Netherlands, France, and Denmark developments towards chain-wide information systems can be recognised. The most modern systems are chain-wide systems that include breeding, farrowing, finishing and slaughtering stages.

3.1.5 Innovation

Technological improvement has also helped the pig sector. In the breeding stage ongoing research is focusing on stress-free animal breeds and certification for specially bred sows and semen. In the feed industry new feeding concepts are being developed to reduce piglet mortality and also novel types of raw material are being introduced. At the farmer stage, housing and facilities are being adjusted to meet legislative and/or private labelling demands.

Moreover, in farm management computers and hand-held devices are increasingly used to track health and weight data of animals and to analyse farm performance, as in the Netherlands, Germany, and France. Furthermore, transportation methods have improved for live animals (well-ventilated vehicles with automatic drinking water installations) Furthermore, inter-organisational information systems between slaughterers and farmers are being developed in various countries (Trienekens et al., 2008)

3.1.6 Future

A large challenge for the European pork sector is to improve its image. In some European countries, like the Netherlands and Denmark, consumers are critical with regard to industrial meat production and concerned about issues like animal welfare, environmental pollution, etc. Competition from mass producers inside and outside the EU, such as Brazil, could become another potential challenge in the near future. Within Europe, competition is emerging between producers from the “new’’ countries (like Poland) and producers from the ‘’old’’ countries, like the Netherlands. This competition will further re-structure the European pork sector and push it towards low-cost production. On the other hand, the high productivity of in particular Northern European countries can help them keep or gain a strong position in international markets, while their strong knowledge base and technology can help them export knowledge and technology and/or start collaboration or joint ventures with foreign mass producers (Trienekens et al., 2008)

In summary there is a range of approaches towards *Salmonella* in the EU. At one extreme are the Scandinavian countries in particular Sweden and Finland with long programmes of control and they have been joined by the Danes, with a programmes that incentivise farm-level changes. There are similar programmes, but with much less support and organisation in the UK, France, Germany, Spain and Italy. The effectiveness of these programmes can be questioned with the results of the slaughter pig survey. Finally the Eastern European countries do not have a consistent history of checking and trying to manage *Salmonella*.

3.2 Input information

The data collection recognises that the pig sectors in the European Union are not homogenous, but made up of input industries, production systems and processing and retailing units that vary. Within each system various support industries are identified and the modern intensive system is broken into breeding, multiplying and fattening herds. The present study has not been asked to look in or beyond the slaughterhouses so no detail has been defined in this downstream or post harvest part of the pig and pig product supply chain (see Figure 6). It is noted that the distinction between the pre and post harvest (or upstream and downstream) is taken to be at the point in the slaughterhouse where the prepared carcass moves from the slaughter line into the cold store.

Figure 6: Schematic representation of the pig sector in EU

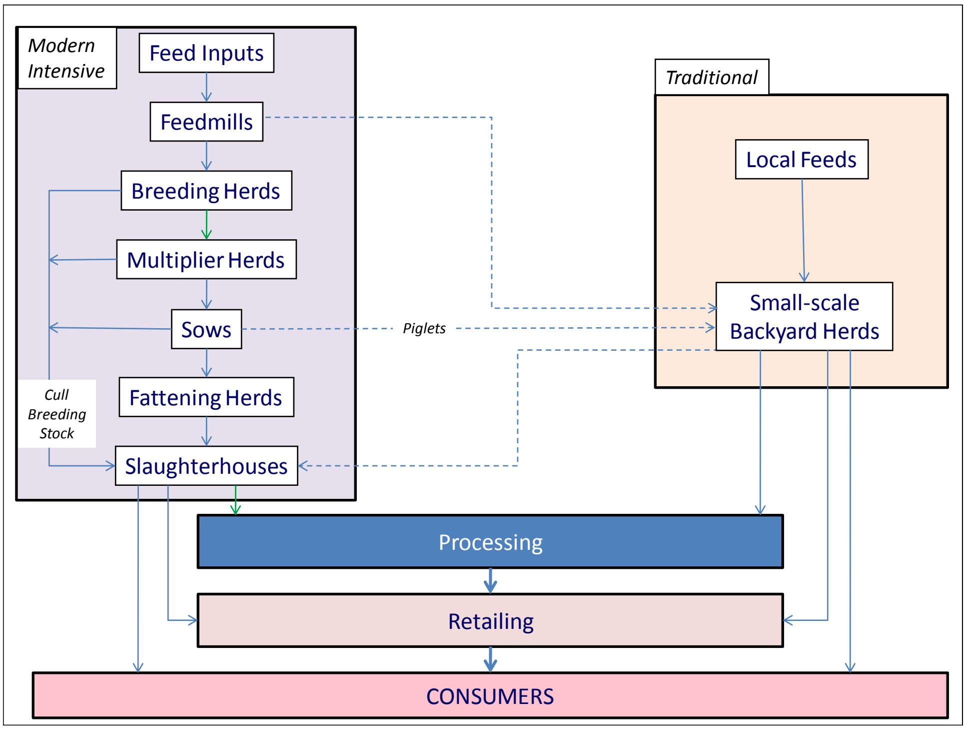


Figure 6 does not give details of other aspects of the input industries that can also affect *Salmonella* control, details of these are provided in the following sections.

3.3 Input industries

The present study focuses on the production of slaughter pigs, which has three important input industries associated with it:

- Feed
  - Feed supply
  - Feed mills
- Industries to assist in the prevention and control of *Salmonella*
  - Pharmaceutical
  - Veterinary services
  - Cleaning and disinfection services
  - Building / design & maintenance e.g. ventilation engineers, slurry systems, automated feed delivery
  - Pest control
- Breeding stock

The following section covers some of the more general information available on these input industries.

3.4 Feed industry

3.4.1 Current feed legislation

The animal feed industry is covered by a range of EU legislation of which the most important is as follows:

- The General Food Law Regulation ((EC) No 178/2002)
- The Feed Hygiene Regulation ((EC) No 183/2005)
- The Marketing of Feed Regulation ((EC) No 767/2009/EEC)
- The Official Control Regulation ((EC) No 882/2004)
- The Directive on the Circulation of Feed Materials (96/25/EEC)
- The Additives Regulation ((EC) No 1831/2003)
- The Certain Constituents Directive (82/471/EEC)
- The Dietetic Feeds Directive (93/74/EEC)
- The Directive on Packaging and Packaging Waste (94/62/EC)
- The Directive on Undesirable Substances in Animal Nutrition (2002/32/EC including Commission Directive 2009/8/EC)
- The Decision establishing a list of materials whose use is prohibited (2004/217/EC)
- The Regulation laying down the rules for the prevention, control and eradication of certain transmissible spongiform encephalopathy ((EC) N. 999/2001)
- Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation.
- The Medicated Feed Directive (90/167/EEC)

Of greatest overall relevance to the control of *Salmonella* in pigs the European animal feed related legislation assigns the responsibility of each operator in the feed and food chain to implement good practices to ensure the safety of the goods produced. In addition to these public regulations there is a range of private standards and international guidelines that apply to animal feed production:

- “HACCP” Guidelines - CODEX Alimentarius Food Hygiene Basic Texts
- “HACCP” Handbook
- EU Commission guidance document for the implementation of procedures based on the HACCP principles and facilitation of the implementation of the HACCP principles in certain food businesses.
- CODEX Code of Practice on Good Animal Feeding

It is recognised that many farms also have systems of mixing their own feeds.

3.4.2 Animal feed production in Europe

3.4.2.1 The European Feed Manufacturers' Federation (FEFAC)

The European Feed Manufacturers' Federation (FEFAC) is the only independent spokesman of the European compound feed industry at the level of the European Institutions. FEFAC holds observer status in CODEX Alimentarius.

The European Feed Manufacturers' Federation was founded in 1959 by five national compound feed associations from France, Belgium, Germany, Italy and the Netherlands. FEFAC today consists of 21 national associations with 20 EU Member States as full members. In addition the feed associations of Switzerland, Turkey, Norway and Croatia have observer/associate member status. See Appendix 1 for further details on FEFAC.

3.4.2.2 Feed production and consumption

The constant increase in animal production at the EU level has been followed by an increase in the amount of feeding stuffs produced and given to animals. The industrial compound feed sector is a significant link in the production chain of food products from animal origin. Delivering a safe final product is a question of good management practices at each stage of the animal feed processing.

Compound feeds are manufactured from a mixture of raw materials designed to achieve pre-determined performance objectives among animals. These raw materials are obtained from a wide variety of sources. Hence, the industry provides a major market for EU cereals, oilseeds and pulses. Some raw materials are obtained from the by-products of the food industry. Other important ingredients that cannot be grown in sufficient quantity in the EU are imported from third countries. These diverse sources of raw material supplies are an important factor in the industry's ability to manufacture feeds of both high quality and at competitive prices for livestock farmers

Animal feed is the most important production cost when rearing livestock for food production. In intensive livestock farming, the share of feed in total production costs ranges from 40% to 60%. In 2007 and 2008 feeding costs rose due to drastic increases in raw materials prices on the global market, exacerbated in the EU by the European regulations that prohibit the purchase of non-EU approved GMOs (52^{nd} FEFAC Annual General Meeting, 2009.

Farm animals in the EU-27 were estimated to consume 467 million tonnes of feed in 2008, of which 150 million tonnes were produced by the compound feed manufacturers (see Table 3).

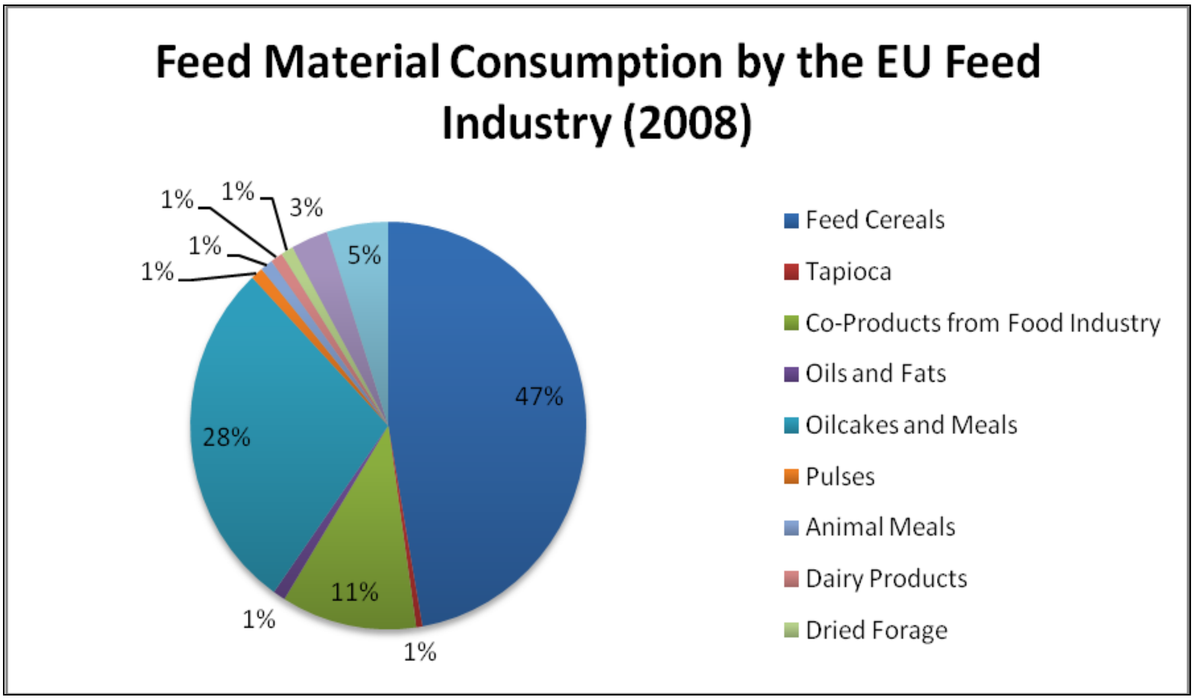
Table 3: EU-27 Livestock feed sourcing in 2008

EU-27 Livestock sourcing in feed	Million tonnes
Forages	228
Home-grown cereals	51
Purchased straight feeding stuffs	38
Industrial compound feed	150
TOTAL	467

Source: (52^{nd} FEFAC Annual General Meeting, 2009)

The value of all feeding stuffs used by EU livestock producers including forages produced on the farm is estimated at €89 billion in 2008. This accounts for 39% of all inputs and 56% of the turnover in livestock production. Purchases of compound feed amounted, in 2007, to €42 billion or 53% of the value of all used feeding stuffs (FEFAC website[1]). The European compound feed industry is estimated to employ over 110 000 persons at approximately 4 500 production sites. The production sites are often in rural areas.

Figure 7: Feed Material Consumption by the EU Feed Industry in 2008



excluding Greece, Malta and Luxembourg

Germany is the leading cattle feed producer, whereas Spain is the leader for pig feed and France for poultry feed production. European compound feed production represents 21% of global production (approx. 700 millions tones) The European level of production is equivalent to that in USA. Feed production is heavily reliant on imports of basic raw materials (see Table 4).

Table 4: Feed raw material imports into the EU

Raw material	2007	2008
	'000 tonnes	
Feed Cereals	13 500	10 000
Tapioca	1 238	1 250
Corn Gluten Feed	706	215
Maize Germ Meal	0	0
Oilcakes and Meals	27 639	27 259
Pulses	273	114
Fishmeal	527	493
Citrus Pulp	1 181	1 024
Dried Beet Pulp	574	395
Molasses	2 320	2 943
DDGS	442	221
Others	1 175	1 339
TOTAL	49 575	45 253

Source: FEFAC Feed and Food Statistical Yearbook, 2008

In terms of self sufficiency of feeding stuffs, Table 5 presents data on the origin of protein rich materials used to produce compound feeds. Only around a third of these feeding stuffs were produced in the EU in 2006/07, the rest being imported. The protein rich materials are of particular relevance for the assessment as they are reported to be problematic with regards to *Salmonella* contamination (personal communication Martin Wierup).

Table 5: Self-sufficiency EU-25 protein rich materials production in 2006/2007

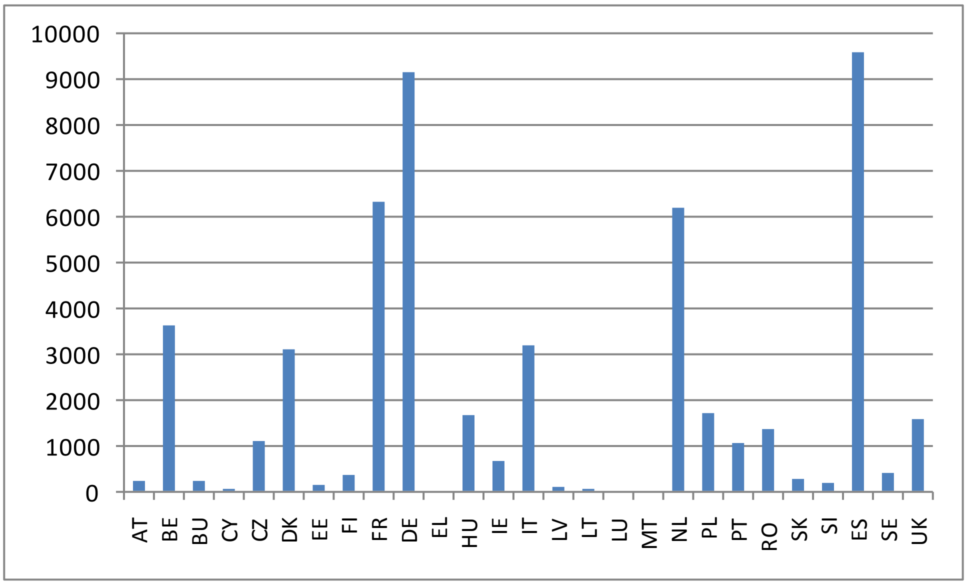
Feed stuff	EU-25		
	Production ('000 tonnes)	Consumption ('000 tonnes)	Self-Sufficiency (%)
Soyabean meal	983	36 050	3
Sunflower meal	3 386	4 975	68
Rapeseed meal	9 191	9 825	94
Cottonseed meal	476	258	184
Copra-Palm meal	0	3 130	0
Pulses	2 910	3 145	93
Dried Forage	3 828	3 600	106
Corn gluten feed	2 311	3 189	72
Fishmeal	443	800	55
Others	392	812	32
TOTAL	23 920	65 784	36

Source: FEFAC Feed and Food Statistical Yearbook, 2008

3.4.2.3 Pig feed in Europe

In 2008, EU-27 compound feed production decreased slightly due to a reduction on the pig feed demand by 1.4%. In the same year, the EU-27 industrial compound pig feed production represented 35% of the total animal feed production and remains the most important compound feed production in EU (52nd FEFAC Annual General Meeting).

Figure 8: Production of pig feed by country in the EU in 2008 ('000 tonnes)



Within the EU the Spain, Germany, France, the Netherlands, Belgium, Italy and Denmark are the biggest producers of pig feed. These countries alone produced 79% of the pig feed produced in 2008 (Table 6).

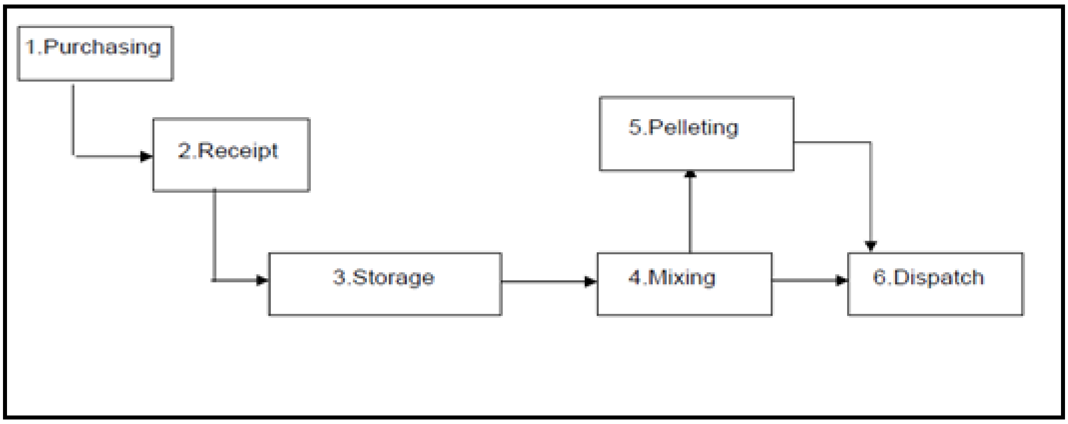
Table 6: Industrial pig feed production estimates in the EU by Member State in 2008.

Country		Feed ('000 tonnes)				
Name	Code	Piglets	Fatteners	Breeding	Others	Total
Austria	AT	na	na	na	na	237
Belgium	BE	814	2 824	0	0	3 638
Bulgaria	BU	na	na	na	na	220
Cyprus	CY	12	0	0	0	12
Czech Republic	CZ	na	na	na	na	1 093
Denmark	DK	620	1 799	710	0	3 129
Estonia	EE	na	na	na	na	141
Finland	FI	45	205	60	65	375
France	FR	780	4 459	1 077	0	6 316
Germany	DE	1 805	5 643	1 290	445	9 183
Greece	EL	na	na	na	na	Na
Hungary	HU	na	na	na	na	1 690
Ireland	IE	na	na	na	na	648
Italy	IT	na	na	na	na	3 175
Latvia	LV	na	na	na	na	100
Lithuania	LT	18	35	16	8	77
Luxembourg	LU	na	na	na	na	Na
Malta	MT	na	na	na	na	Na
Netherlands	NL	827	4 047	1 329	0	6 203
Poland	PL	na	na	na	na	1 700
Portugal	PT	152	675	215	18	1 060
Romania	RO	na	na	na	na	1 380
Slovak Republic	SK	23	197	45	10	275
Slovenia	SI	na	na	na	na	172
Spain	ES	na	na	na	na	9 604
Sweden	SE	na	na	na	na	402
United Kingdom	UK	69	1 098	389	16	1 572
EU	**EU-27**	**na**	**na**	**na**	**na**	**52 402**

3.4.3 Pig feed manufacturing process

The animal feed sector is linked to a number of other sectors that supply feed ingredients, either as a primary product or a by-product. These include the foodstuff sector, the chemicals sector, the fermentation industry, the mining industry and the primary agricultural sector (arable farming).

Figure 9: Animal feed production basic flow chart



3.4.4 Pharmaceutical industry

Other input industries potentially provide means to prevent and control *Salmonella* in the pig finishing units. The pharmaceutical industry can provide inputs to prevent a pig being infected such as the use of vaccination, competitive exclusion, pre-biotics/pro-biotics/organic acids for administration via feed or water. These industries can also produce drugs for the treatment of clinical salmonellosis if it occurs. Their ability to deliver such prevention and control measures is dependent on the level of technology development of their range of vaccines and drugs to deal with *Salmonella* in the pigs, and their contact network with pig farmers and their veterinarians using prophylactic and preventive treatments.

3.4.5 Veterinary services

In a similar vein the finishing pig farmers are dependent on advice from veterinary services, both public and private, in development and implementation of management strategies that limit the risks of entry of *Salmonella* on the farm (bioexclusion) and the management of disease if it enters (biocontainment). Therefore the knowledge of the animal health specialists in *Salmonella* control and management at farm-level is a critical aspect of *Salmonella* control in finishing pig units. It is also recognised that better knowledge of these specialists improves their willingness and motivation to engage in the activities of the pig sector. Their number, level of training and their ability to work with farmers is seen as an important aspect of a *Salmonella* control programme, and in turn an important cost aspect of any programme.

3.4.6 Cleaning and disinfection suppliers

Support industries that provide capital equipment, products and services to clean and disinfect pig facilities are an important part of managing risk of *Salmonella* in the environment. Therefore the availability of such cleaning and disinfection products and knowledge to pig farmers needs to be known as a baseline for future actions. For example, fumigation of emptied accommodation is highly effective but technically demanding and is also subject to stringent health and safety regulation due to the risk to operatives and is consequently seldom employed

3.4.7 Summary for input industries

Information on the general structure of the input industries to the pig finishing units is required to develop a baseline for the cost-benefit analysis. Such information will also allow the development of an understanding of the strengths and weakness of such industries and allow the analysis to refine what type of interventions and actions are required to upgrade the slaughter pig value chain to achieve reduced prevalence of *Salmonella* in pigs. Specific details of the data required about these industries can be found in Appendix 1.

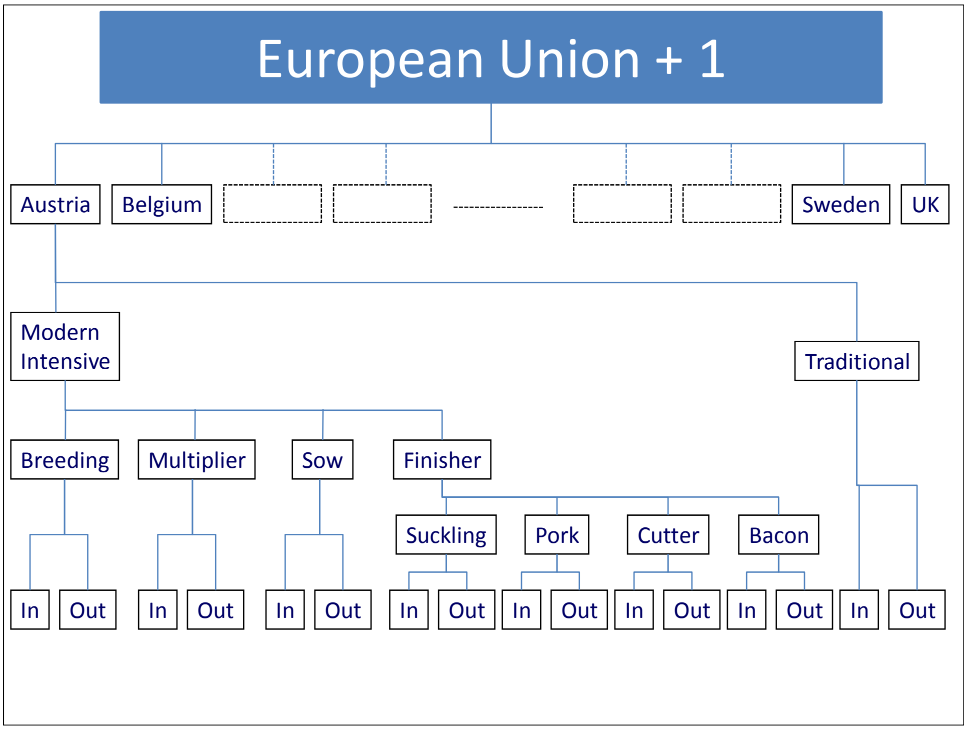
3.5 Pig production systems

In order to simplify the data collection process for the project a simple classification framework has been defined for the production units that separate pigs into:

- Modern Intensive systems
    - Breeding stock
    - Multiplier stock
    - Sow stock
    - Finishing stock
- Traditional systems

The intention for the work was to develop models that represent each Member State breaking the data down into the production and input units described above (see Figure 10).

Figure 10: Development of the model structure to represent the EU pig sector.



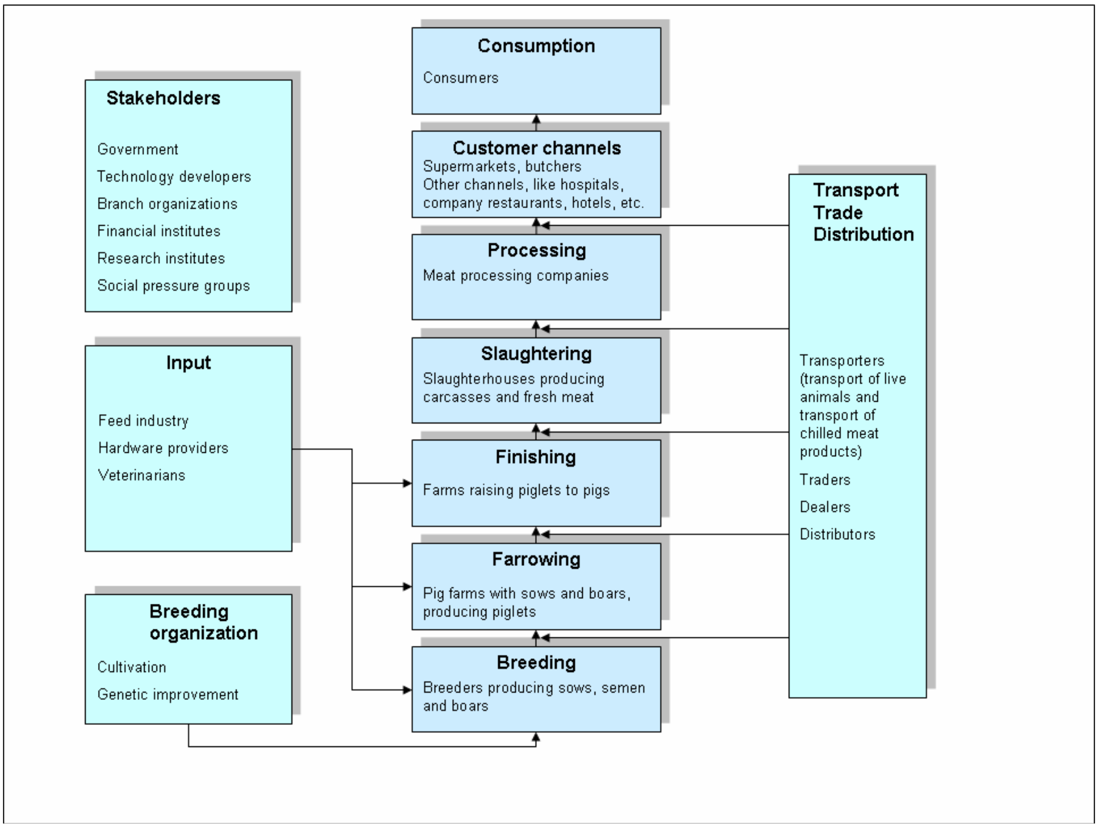
Where possible data have been collected by production systems and information has been sort on:

- Number of units
- Pig population
- Where possible the geographical location of the units (for finishing units the concentration of the units, for the breeding units the location)
- Average gross margin

- Average fixed costs
- Average labour inputs

The overall pork chain covers the following processes: Breeding – Farrowing – Finishing – Slaughtering –Processing – Retail. In most European pork chains these processes are performed by separate organisations. However, there are also many chains in France, Spain, and Greece, for example, in which farrowing and finishing are performed by the same company. Moreover, further integrated chains exist in which slaughtering and processing are also integrated. In addition to these chain actors, there are also major input providers, like the feed industry (extremely important for the pork chain as feed is one of the major cost components in pork production), transporters, etc., and stakeholders such as the government and branch organisations. Figure 11 pictures the pork chain as a network of interacting organisations aiming at the delivery of pork meat products to consumers (Trienekens et al., 2008)

Figure 11: A schematic representation of pork production chains in Europe



from Trienekens et al., 2008

A brief summary of the overview data is provided in the following section. More specific data are provided in Country Annexes for the specific countries that have been more thoroughly covered (Available with the final report)

3.5.1 Population and production

Table 7 presents the data on the number of pigs in the EU by Member State together with slaughter statistics and the level of self-sufficiency.

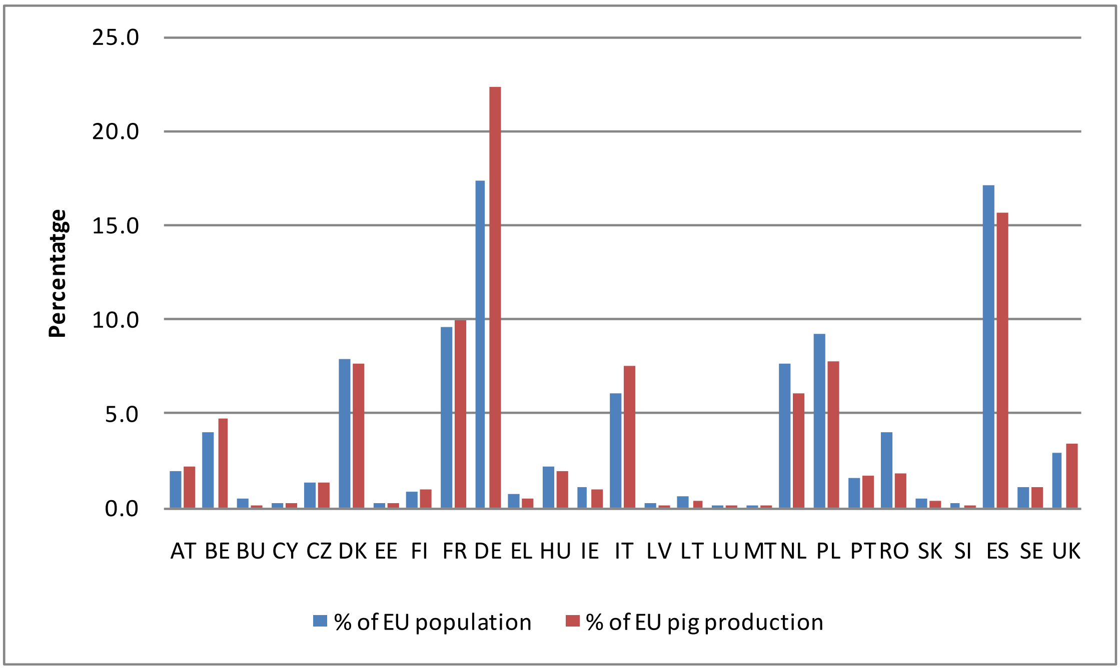
Table 7: Structure of the EU pig industry by Member State

Country		Pig population (2008)		Slaughter (2008)		Self Sufficiency in 2007 (base 100)	Surplus exported (+) / Shortfall imported (-)
Name	Code	Number (head)	% of EU population	Total (tonnes)	% of EU pig production		
Austria	AT	3,064,200	2.0	494,235	2.2	102	8,954
Belgium	BE	6,207,600	4.1	1,052,395	4.8	206	541,962
Bulgaria	BU	783,700	0.5	38,425	0.2	35	-69,901
Cyprus	CY	464,900	0.3	58,198	0.3	106	3,176
Czech Republic	CZ	2,135,000	1.4	288,356	1.3	85	-51,760
Denmark	DK	12,195,000	8.0	1,699,967	7.7	699	1,456,849
Estonia	EE	364,900	0.2	42,360	0.2	87	-6,351
Finland	FI	1,399,500	0.9	206,334	0.9	103	5,543
France	FR	14,810,000	9.7	2,212,568	10.0	102	48,955
Germany	DE	26,718,600	17.5	4,943,986	22.4	110	453,129
Greece	EL	1,061,000	0.7	104,909	0.5	41	-152,836
Hungary	HU	3,383,000	2.2	437,807	2.0	102	7,375
Ireland	IE	1,604,600	1.0	210,944	1.0	106	11,502
Italy	IT	9,252,400	6.0	1,669,317	7.6	66	-871,284
Latvia	LV	383,700	0.3	40,018	0.2	67	-19,849
Lithuania	LT	897,100	0.6	75,425	0.3	71	-31,031
Luxembourg	LU	77,800	0.1	7,764	0.0	90	-863
Malta	MT	65,500	0.0	10,344	0.0	39	-15,946
Netherlands	NL	11,735,000	7.7	1,343,763	6.1	133	331,092
Poland	PL	14,242,300	9.3	1,721,023	7.8	101	17,926
Portugal	PT	2,339,700	1.5	371,120	1.7	71	-147,952
Romania	RO	6,173,700	4.0	416,032	1.9	74	-143,287
Slovakia	SK	748,500	0.5	88,555	0.4	92	-7,778
Slovenia	SI	432,000	0.3	31,275	0.1	67	-15,705
Spain	ES	26,289,600	17.2	3,470,474	15.7	120	570,771
Sweden	SE	1,702,600	1.1	248,822	1.1	79	-66,249
UK	UK	4,550,000	3.0	756,152	3.4	47	-858,404
EU	**EU-27**	**153,081,900**	**100.0**	**22,040,568**	**100.0**	**102**	**432,168**

Source Eurostat

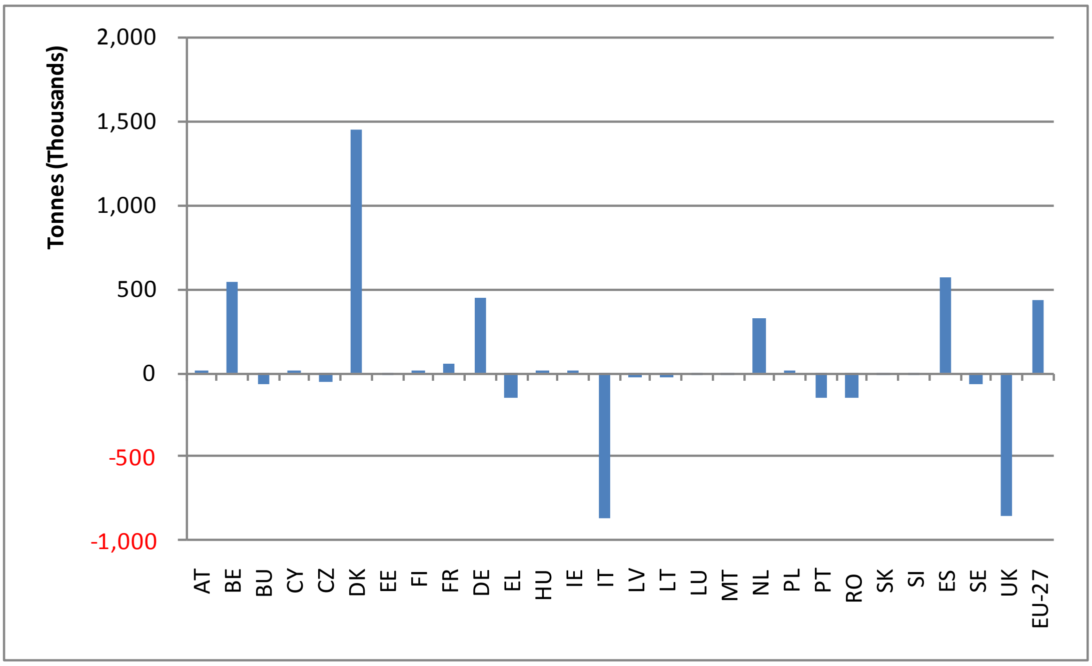
Similar to the feed data the largest herds are found in Germany, Spain, France, The Netherlands, Italy, Belgium and Denmark. The slaughter of pigs shows some slight variations in importance reflecting mainly the movement of rearer and finished pigs within the EU and to a lesser extent the differences in pig productivity (see Figure 12). This will be discussed in more detail below.

Figure 12: Percentage of pig population and meat production in the EU by Member State



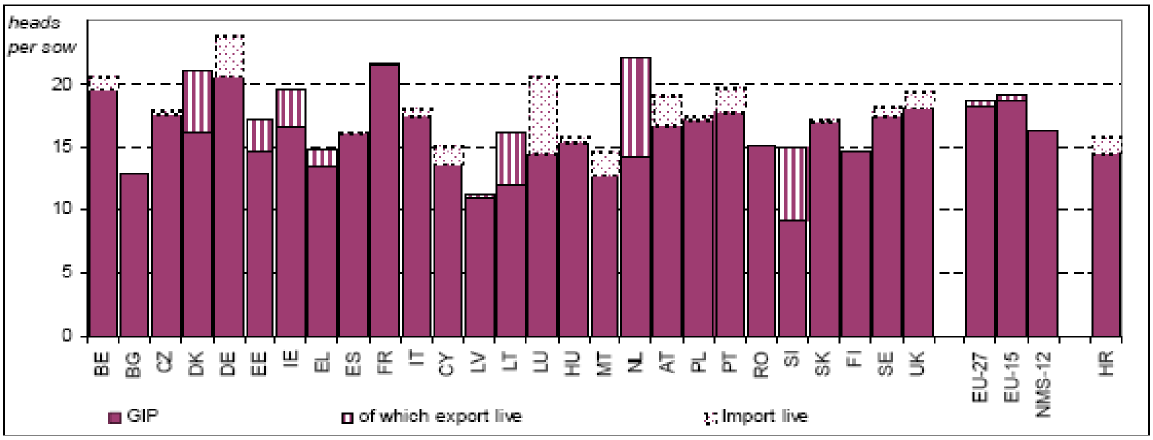
The largest importers in terms of absolute quantities of pig meat in the EU are Italy and the United Kingdom (see Figure 13). However 15 out of the 27 Member States have a deficit in pork production, with four of these importers producing less than half their own national needs for pork. This implies that the majority of Member States are reliant on others countries for pork meat supplies and hence are exposed to risks of *Salmonella* in pigs of these other countries.

Figure 13: Estimated import and export of pig meat in the EU by Member State.



As mentioned above there are variations in the productivity of pig herds between Member States. One measure is the production of pigs per sow with an EU average around 18 with countries such as Denmark, Germany, France and the Netherlands achieving rates above 20. This reflects the significant levels of investment in infrastructure, pig health care, feed and management in these countries and in the case of Denmark and the Netherlands the need to compete in international markets for pig products. It can also indicate that pigs are finished at lower weights, so for example the relatively low number of pigs per sow produced by Italy does not take into account that the finished pigs from this Member State have a high weight. Countries with much lower production levels per sow probably have far less intensive systems of production and their cost structures will be very different (see Figure 14).

Figure 14: Estimates of production of slaughter pigs per sow by Member State in 2008



Source: Eurostat

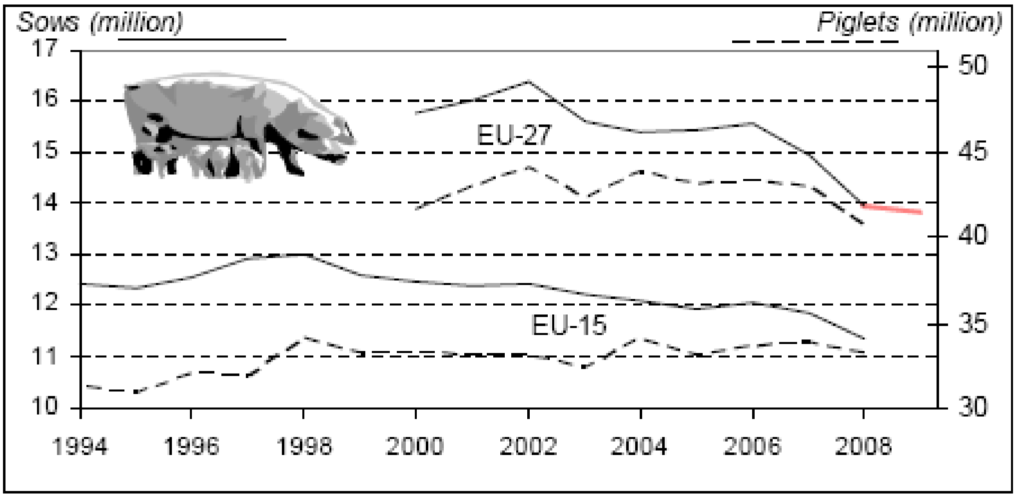
Rational interpretation of such data requires additional information on mortality and fertility rates, feed conversion ratios and finish weights before judgements can be made on the relative productivity of the different pig sectors. Many of these factors have been used in the model to estimate the costs of *Salmonella* control interventions.

3.5.2 Structural changes over time

Pig sectors and their associated populations are not static. Many have described the pig cycle which represents a constant fluctuation in pig numbers and pork numbers in attempts to match supply with demand. These market driven changes can also be influenced by technology changes and in market access. In addition, there will be an influence in costs of key inputs such as feed and labour and the impact of legislation and its enforcement. In the EU the changes seen recently in the pig sector reflect many of these factors and interpretation is not straightforward.

The pig population in the EU27 has recently declined (Eurostat, 2010). Between 2006 and 2008, the number of sows fell by 10%. This reduction was steeper in the EU12 New Member States (-27%) than in the older EU15 Member States (-6%), which may relate to sourcing of piglets and pork from outside these Member States as they integrate into the Union. It could also reflect the adoption of different pig production technologies, which an overall increase in some measures of productivity in these Member States implies. There have also been structural changes with a general concentration of the industry in the largest herds and disappearance of smaller herds. These structural and productivity changes have been particularly strong in the EU12 and are predicted to continue.

Figure 15: Change in sow and piglet numbers between 1994 and 2008 in the EU15 and EU27



Source: Eurostat

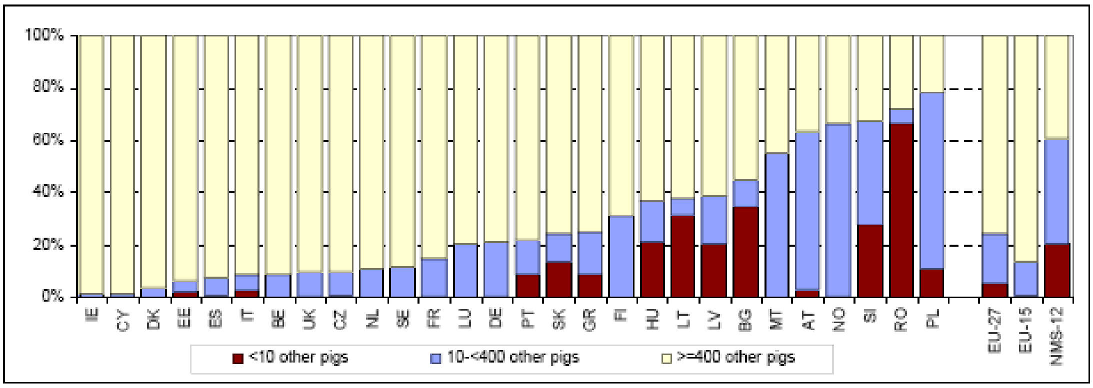
The Farm Structure Survey data from Eurostat has been analysed and distinguishes three types of national trend:

- **Concentration** – In 15 Member States the number of sows is increasing on large farms with over 200 sows, mainly at the expense of medium size farms with 20 – 199 sows. The countries affected are Austria, Belgium, Bulgaria, Cyprus, Denmark, Estonia, Finland, Germany, Greece, Italy, Latvia, Luxembourg, Netherlands, Portugal, Sweden. These states accounted for 52% of the EU sow herd in December 2008.
- **Abandonment** – In nine Member States there is an overall decrease in the number of sows in all pig farms. The countries are Czech Republic, France, Hungary, Ireland, Malta, Slovenia, Slovakia, Spain and UK. These accounted for 36% of sows in the EU.
- **Restructuring** – In three Member States (Lithuania, Poland and Romania) the number of sows is falling sharply in small herds (less than 10 sows) and increasing in larger herds, particularly those with over 200 sows. These countries make up 12% of the EU sow herd.

Pig breeding and fattening is highly concentrated in a small number of Member States. As mentioned above, seven countries (Germany, Spain, Poland, France, Denmark, Netherlands and Italy) accounted for 78% of EU pig production by weight. However, there are major differences between Member States in the structure of pig farms.

Figure 16 shows the distribution of 'other pigs' (pigs other than breeding sows and piglets, comprising mainly fattening pigs but also including boars and cull sows) by herd size in each Member State:

Figure 16: Distribution of "other" pigs (fatteners, cull sows and boars) by herd size

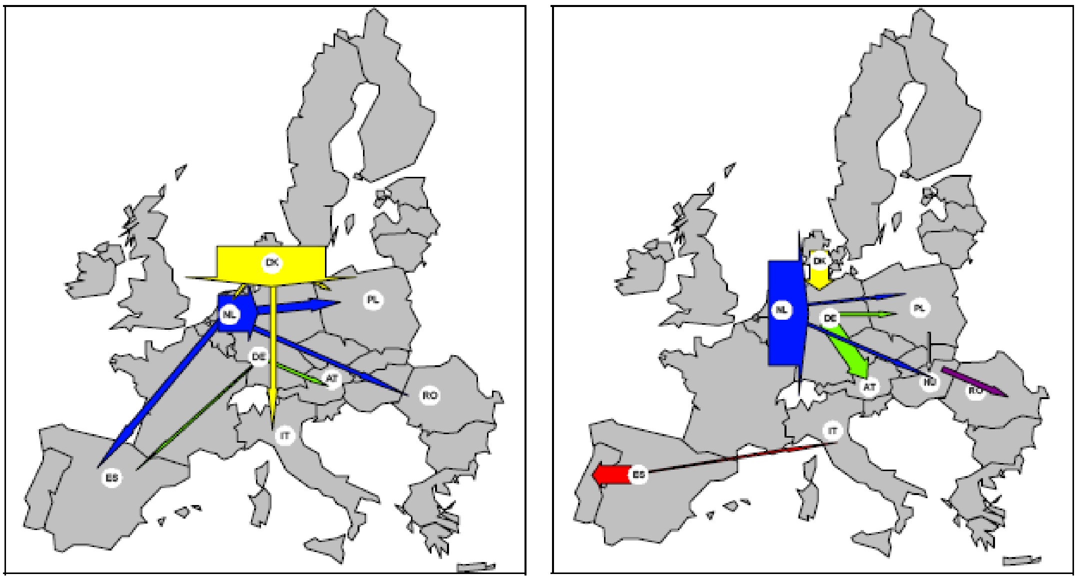


Source: Farm Structure Survey, 2007

At EU level, over 75% of other pigs are kept in herds of at least 400 other pigs. These comprise only 1.5% of pig farms. Of these approximately half are specialist fattening farms and half are breeding and fattening farms. At the other extreme, units of less than 10 other pigs hold 5.3% of other pigs but account for 86% of pig farms. More than half (57%) of the small fattening farms are in Romania.

The differences between the levels of productivity, cost structures and processing facilities mean that there is much movement of young and slaughter pigs across the Member States. It is estimated that the largest movements of young pigs is from Denmark and the Netherlands to southern and eastern Member States. For slaughter pigs, the Netherlands, Spain, Denmark and Germany export significant numbers, much of it to the eastern Member States (see Figure 17).

Figure 17: Estimated movement of young pigs (left map) and slaughter pigs (right map) in the EU in 2008



Source: Eurostat

In addition to these more recent trends in pig numbers and movement, there have been major changes in the pig population and production over a 10 to 15 year period. The UK herd has reduced by a half since the mid 90s reflecting that this Member State:

- did not adopt the Euro and its currency has been strong against the euro for an extended period. Recent changes in currency values would suggest that UK pig production may again become more competitive;
- introduced a Private Members Bill in Parliament to ban the use of sow crates in the UK. This was done before EU legislation and has placed the UK pig sector at a competitive disadvantage;
- has suffered a number of animal disease setbacks.

This range of issues has placed the UK pig sector at a competitive disadvantage to other member with a consequence that the UK pig population has reduced and pork imports have increased.

The other large change has been the growth in the pig sector in Spain. Traditionally the Spanish pig sector had its biggest concentration to the west of Madrid but in the last 10 years there has been a rapid expansion of the pig herd and pig production in the south-eastern corner of the country around Catalan. This growth in the sector seems to have been stimulated by:

- access to a port that can handle imported feeding stuffs;
- lower labour costs than northern European Member States;
- less rigorous application of environmental and welfare legislation;
- strong entrepreneurial spirit.

The entry of Spain as a leading, perhaps the leading, producer of pigs and pork in Europe has been relatively rapid. It has been driven by market forces and the ability of the pig sector to seek and exploit cost variations in the EU. The sector has also exploited the quality of transport links across the Community and the free movement of animals and goods across the Member States. This is a success of the EU in terms of there being equivalent animal health status for contagious diseases and for the existence of a free market. However, there is potential that such relatively dramatic changes can create problems for *Salmonella* control and these will be touched on in later sections.

3.6 Transport and handling facilities

Transport and handling of pigs can cause stress and provoke carrier pigs to excrete *Salmonella* again. *Salmonella*-infected pigs are most often subclinical carriers of *Salmonella* and will only intermittently excrete the bacteria in their faeces (Schwartz, 1999). However, stress may induce carriers to shed *Salmonella* at a higher rate and increase the susceptibility of *Salmonella*-free pigs to infection (Williams and Mulder).

During transportation, pigs are subjected to many stress factors such as noise, smells, mixing with pigs from other rearing pens or farms, high stocking densities, long duration of transport, change of environmental temperature and a general change of environment (Warriss et al., 1992). Therefore, stress imposed by transportation and handling can significantly amplify the number of pigs excreting *Salmonella* upon arrival at the abattoir (Williams; Berends and Rajkowski).

During transportation to the abattoir, *Salmonella*-negative finishing pigs may be infected from previously contaminated trucks that have not been thoroughly cleaned, or from *Salmonella*-infected pigs loaded on the same truck (Williams; Childers; Fedorka and Rajkowski). Furthermore, contaminated trucks may act as a source of infection for other farms or abattoirs (Fedorka; Rajkowski; Isaacson and Isaacson).

Data required for the study are detailed in Annex 3

3.7 Slaughterhouses

After transport to the abattoir, pigs are usually kept in lairage before killing. The lairage is a place where cross contamination and infection of *Salmonella* clean pigs can take place. Stress of pigs within the lairage may also result in *Salmonella* excretion, putting many pigs at risk. Frequent moving of pigs between pens may also result in increased *Salmonella* transmission (Berends et al., 1996; Isaacson et al., 1999). Facilities and systems of management in the slaughterhouses therefore are a critical aspect of *Salmonella* control and an important link between *Salmonella* in animals and humans.

The baseline survey carried out recently indicated a poor relationship between the prevalence of *Salmonella* in live pigs (lymph nodes) and surface contamination. This supports the view that contamination on a pig surface does not necessarily originate from that same animal, but is rather an indication of the general contamination of the slaughter environment. *Salmonella* could be isolated from swine lymph nodes and caecal and rectal contents 3 hours after infection from other pigs or the environment either by the oral or nasal route (Fedorka-Cray et al., 1995). Lairage time should be kept to an absolute minimum, at least for pigs from *Salmonella*-negative herds (Swanenburg et al., 2001). Lairage pens should be cleaned between batches of pigs and at the end of the slaughter day, since it has been showed that microbial contamination often remains in lairage holding pens after routine cleaning operations (Small et al., 2007)

Although the slaughter pig *Salmonella* prevalence does not depend on the operations carried out on the slaughter floor, they must be taken into account when attempting to assess the impact on human health.

3.8 Summary

The EU pig sector is dynamic responding to changes in demand for pig products and also variation in costs of inputs, particularly labour across the Member States. For Member States outside the Euro zone there has also been a strong influence of currency fluctuations, perhaps the most dramatic change having taken place in the UK where a strong pound sterling has affected the competitiveness of its pig sector and led to significant reductions in pig populations. In addition the speed of adoption and strengthening of enforcement of legislation has influenced the competitive advantage of Member States and created shifts in pig populations, pig meat production and transport links. The most striking change over the last ten years has been the rapid expansion of the Spanish pig sector, which is of particularly interest to this study as Spain has reported high prevalence of *Salmonella* in slaughter pigs.

The following Chapter will discuss in more detail *Salmonella* in the pig herds of Europe and how this can in turn affect the rates of *Salmonella* in humans.

4 *Salmonella* in pigs

4.1.1 Introduction

Representatives of the genus *Salmonella* are found worldwide as infectious agents. They have been found in almost all vertebrate animals and include around 2 500 serovars (Schwartz 1999; Selbitz 2002; Kamphues et al 2007).

Salmonella are mainly found in the intestinal tract of numerous hosts, both cold blooded and warm blooded animals. They are distributed in many different ways, including by latent infected carrier animals and have the ability to survive for a long period in the environment (Schwartz 1999).

Salmonella bacteria have been divided into epidemiological groups in accordance with their pathogenicity (Selbitz 2002).

1. Serovars adapted to humans:
    - S. typhi and S. paratypi with no importance for animals
2. Serovars adapted to particular animals:
    - S. dublin (cattle), S. cholerasuis (pig), S. gallinarium (poultry), S. abortusequi (horses), s. abortusovis (sheep). These serovars are responsible for clinical symptoms in their hosts.
3. Serovars not adapted to particular animals but with certain ability of infecting their hosts:
    - S. enteritidis and S. typhimurium. Both these serovars are responsible for clinical symptoms in humans, however are rarely in animals where in the infection is normally latent.
4. Serovars with no adaptation to particular animals and only exceptionally with the ability to infect their hosts.
    - This group represents the majority or about 2 000 serovars. These serovars are of almost no relevance for humans and animals where infections are normally latent and clinical symptoms only sporadic.

4.1.2 *Salmonella* in pigs

4.1.2.1 Nature of infection and excretion

Salmonellosis in pigs can be divided into two main groups: with and without clinical symptoms. The former is based on infection with pig adapted serovars, such as S. cholerasuis and S. typhisuis although both are not common today in Western Europe (Waldmann and Wendt 2004).

The main problem with *Salmonella* in pigs is due to infection with non-adapted serovars, which show no clinical symptoms in pigs but are in some cases responsible for clinical cases in humans, being zoonotic agents in most cases through food-borne infections. Both S. enteritidis and S. typhimurium belong to this group. If clinical symptoms appear at all following S. typhimurium infection in pigs, it is normally between weaning and 4 months of age, resulting in fever and enteritis for 3 - 7 days and in some cases fluctuating enteritis for few weeks. The clinical symptoms disappear in most cases but a proportion of these animals become carriers excreting *Salmonella* for many months (Swartz 1999).

As for the status of excretion of *Salmonella*, the following differentiation is frequently used (Wray and Sojka 1977):

STATUS OF *SALMONELLA* INFECTION IN PIGS

Actively excreting animals

Infected animals excrete *Salmonella* for months or even years following a clinical infection

Passive carriers

The animals take in *Salmonella* (e.g. with feed) and excrete them again without being infected at all

Latent carriers

The animals are infected via feed, the bacteria persist e.g. in mesenterical lymph nodes resulting in fluctuating excretion.

4.1.2.2 Prevalence studies

One of the first systematic investigations of the prevalence of *Salmonella* was in Denmark in the 1990s, followed later by investigations in Germany (Czerny et al. 2001). A control system for *Salmonella* was introduced in Germany within the scope of a quality system in April 2003 (Blaha 2004). This rule was extended to all pig farms in Germany in March 2007, establishing a surveillance programme based on serology (determination of *Salmonella* antibodies in meat juice of slaughtered animals) and categorising the farms into three risk groups.

Von Altrock et al. (2000) carried out a large epidemiological investigation on the prevalence of *Salmonella* in breeding, weaner and fattening herds in Germany using serological testing. They found 9.2% of breeding animals, 4.5% of the weaners and 7.3% of the fattening pigs as positive. Sixty farms were included of which 28.3% where positive.

Bacteriological results from pig herds in Germany in 2005 indicated that 5.56% were positive for *Salmonella*, a minor reduction from 2004 (5.60%), while 3.55% of the individual animals were positive (samples size 20 000), a slight increase from 2004 (3.12%), Hartung (2007). S. typhimurium was isolated in 70% of the cases, but S. enteritidis only in 5 out of the 736 positive samples.

There was however a large increase in positive samples from breeding animals, from 2.15% in 2004 to 7.58% in 2005. But, at the same time the number of samples taken from these types of animals doubled. The sampling of breeding animals was done more on herd bases in 2005 where most of these positive animals were found (most S. typhimurium).

To ensure comparability among Member States, EFSA (2006) proposed a baseline study for the prevalence of *Salmonella* in fattening pigs. This study has been undertaken and followed by a similar study in breeding pigs (see section on EFSA studies below).

4.1.2.3 Types of testing of live pigs

Most of the European *Salmonella* programs in pigs are based on serological testing, except for Sweden and Finland which use bacteriology.

The farms are checked by serology tests and in most cases categorised into three different categories, either by testing meat juice at slaughter or by blood sampling. Typical categorisation could be as follows:

- Category I < 20% of samples positive
- Category II 20-40% of samples positive
- Category III >40% of samples positive

This system of evaluating and categorising the farms is in accordance to their contribution to the risk in the slaughterhouse. It is used to initiate additional hygiene measures such as logistics in transport and slaughtering animals from category III farms at the end of the day, as well as measures during slaughter including separation in lairage, increased cleaning and disinfection and increased singeing of carcasses. Other measures could include selection of carcasses for processing according to risk, e.g. using carcasses from category III farms for products which are heat treated. The long term impact of this system is to be used for price differentiation.

4.1.3 *Salmonella* in feed and water

Feeding stuffs have been considered as one of the possible sources of *Salmonella* in pig and pig meat. About 48 million tons of compound feed is used annually in the EU-27 for pig feed. The major feed materials used (percent of total) are: 47% feed cereals, 27% oil seed residues (cakes and meals), 13% by-products from the food industry, 3% minerals and additives. The production of compound feed and the number of feed mills in the Member States is related to the size of their animal food production. The largest producers are France with 21.6%, Germany with 20.0%, Spain with 19.8%, the United Kingdom with 14.2% of the total production in the EU (EFSA 2008).

Feeding stuff contamination with *Salmonella* has been found to occur at all stages of production through vectors such as dust, vermin, insects and even humans (Marciorowski et al. 2006). A further infection could occur on the farm through storing; however up-to-date technology in farm management, such as use of closed silos, should minimise the contamination on farms.

Numerous studies have demonstrated the presence of *Salmonella* in many different types of feeding stuffs, in particular in high protein materials of animal origin such as fishmeal (also meat and bone meal when it was still in use). Salmonellosis in humans in the 1980s and 1990s was, to a large extent, due to *S. Enteritidis* and *S. Typhimurium*, both of which were frequently isolated in fishmeal and meat and bone meal. The ban on the use of feeding stuffs of animal origin as ingredients for the production of feed for food producing animals as from 2000 has however eliminated this source.

Salmonella has also been found in feeding stuffs of plant origin, such as grain and protein concentrates, which could therefore be an entry port to the food chain for *Salmonella*. Köhler (1993) carried out a detailed study of *Salmonella* contamination on different types of feeding stuffs of plant origin, finding contamination in 2-4% of the samples. S*. Typhimurium* was however not found.

Salmonella can be found in feeding stuffs, even though authors point out that these are not the serovars found in human cases (*S. Enteritidis and S. Typhimurium*) (Bisping 1993). Other authors however do not support this view, such as Marciorowski et al. (2006), who still consider feedingstuffs to be an important source of *Salmonella* on farms and in the food chain.

The EFSA report (2008) on microbiological risk assessment in feeding stuffs for food-producing animal states that in regions with low prevalence status, where endemic infection is well controlled or absent, *Salmonella* contaminated feed is the major source for introducing *Salmonella* into the animal food production. In other regions with high prevalence, although it is difficult to quantify, the relative importance of feed as compared to other sources of *Salmonella* may be lower. Although the most common *Salmonella* serotypes occurring in humans are seldom found in animal feeding stuffs in most countries, some serotypes found in feed are also found in humans.

In the 2005 zoonoses report (EFSA, 2006), data is presented on *Salmonella* in animal derived feed materials, where all countries report *Salmonella* from meat and bone meal every year. Fish meal has the potential to the spread *Salmonella*; however fishmeal seems to be somewhat less contaminated than other animal derived protein feed.

As for vegetable protein, *Salmonella* was isolated from in average 30% of unprocessed soya beans imported to Norway in 1994-2007, mainly from South America (EFSA 2008). Available data from the EFSA zoonoses report (2005) also support oil seeds such as soya bean products, as a risk factor for introducing *Salmonella* into the feed chain (EFSA, 2006). Similar results were achieved by a Dutch study, finding 12% extracted rape seed meal as positive in 2002, and 7% in 2003. *Salmonella* has also been found in grain but rarely.

Salmonella is also found in compound feeding stuffs in up to 6% in some countries (EFSA 2006). Incidence of *Salmonella* in feed was studied in a Spanish surveillance program on feed during 2007. A total of 700 feed mills were visited, with 2 100 feed materials and 2 100 compound feed batches sampled. Preliminary results from 308 feed mills showed a 3.5% incidence in feed materials and 3.5% incidence in compound feed (for all *Salmonella* serotypes) (Sobrino, 2008).

The EFSA report (2006) considers also the different serotypes found in feeding stuffs. A wide range of serotypes is found with a range of infectivity for humans. It is concluded that the reason for so many different serotypes identified in vegetable protein is not known.

It has been observed in some cases that some of the serotypes so far considered to be non-pathogenic develop affinity to a certain species, e.g. to pigs and spread further from there along the food chain.

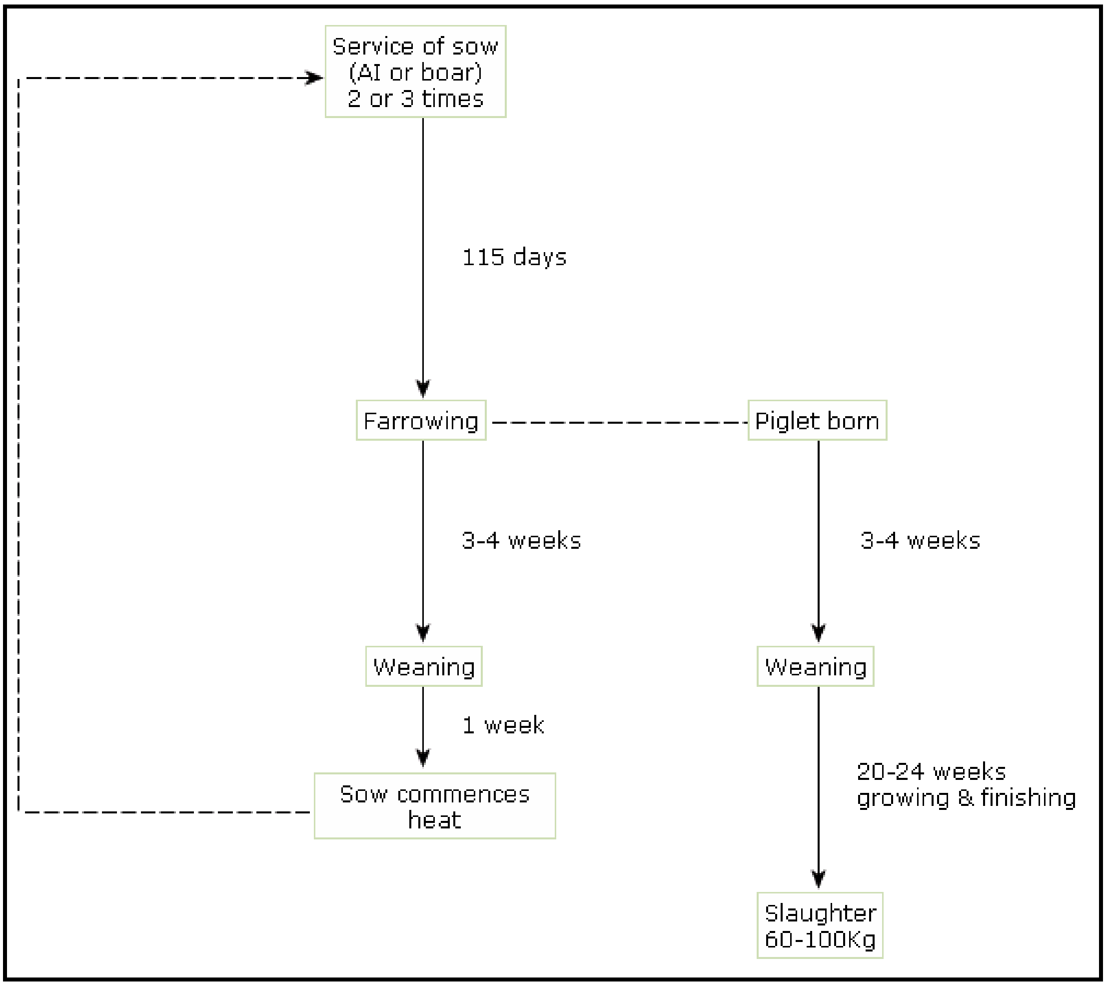
Several studies have shown strong links between contamination of feeding stuffs or feed mills and infections of groups pigs (Newell et al., 1959; Kranker et al., 2001; Davies et al., 2004; Österberg et al., 2006).

Drinking water has also been tested for *Salmonella*, e.g. Grosse Austing (2005) found one positive sample out of eleven and Meyer (2004) one out of 95 samples, but Offenberg (2007), Visscher (2006) and Battenberg (2003) did not find any positive sample out of the total of 202. Drinking water can be seen as a minimal risk according to these results.

4.2 Epidemiological trends in animals, feed and food

4.2.1 Epidemiology of *Salmonella* on pig farms

Figure 18: Typical sow farrowing cycle



Arrival of new animals is considered to be one of the main routes of entry of *Salmonella* into pig farms. Exacerbating factors include transport stress, the introduction to new housing and rearrangement of established groups, resulting in further horizontal infection within a farm of destination.

Visscher (2006) studied several fattening herds in Northern Germany and concluded that the main source of infection was not feeding stuffs or drinking water or environmental parameters, but new stock introduced to the farm. Several animals were tested using faecal samples for bacteriological analysis within the first three days of arriving in the fattening farm. Almost 60% of the animals were positive for *Salmonella*. In 14 of the 18 groups of about 100 animals at least one animal was positive and in one third of the groups more than 10% of the animals were positive. These results from Visscher (2006) support the frequently presented result that new stock is the main reason for new *Salmonella* infection on farms. (Steinback and Kroell 1999, Selbitz 2001, Lo Fo Wong et al. 2002, Blaha 2005).

Grosse Austing (2005) tested weaner farms and the corresponding fattening farms and found the same range of serovars in both cases, indicating that *Salmonella* is transferred from one production level to another.

Offenberg (2007) carried out a field study on *Salmonella* in positive weaner farms using conventional feeding practise, taking rectal and pooled samples at the end of the flat deck phase (25-27 kg). Three per cent of the rectal samples and 16% of the pooled samples were positive for *Salmonella*. This indicates that the weaners are already positive before transfer to the fattening herds. Offenberg emphasized however that the pigs tested positive after they arrived in the fattening farm, even if the farm of origin had been negative, an experience similar to the one in Denmark (Offenberg 2007).

Other vectors such as pests, bird excrement and flies may contribute to the *Salmonella* load. Leyk et al. (2004) tested these vectors and found *Salmonella* in 11% of the flies and 23% of vermin (mice and rats). In a study of 95 mice in a large farm with a severe *Salmonella* problem, 30 % of the mice were positive, out of which 84.4% with *S. typhimurium* and 15.6% with S. Agona. (Mauke 2002). Seblitz (2002) studied other parameters on farms and found *Salmonella* in 2%-27% in pigeons and 4% of rats.

4.2.2 EFSA studies

The current study, sponsored by DG SANCO, is one of a series of EFSA sponsored reports dating back to 2006 that includes:

Risk assessment and mitigation options:

Opinion of the Scientific Panel on Biological Hazards on "Risk assessment and mitigation options of Salmonella in pig production", The EFSA Journal (2006), 341, 1-131

Baseline survey of slaughter pigs:

Report of the Task Force on Zoonoses Data Collection on the analysis of the baseline survey on the prevalence of Salmonella in slaughter pigs, Part A, The EFSA Journal (2008) 135, 1-111

Report of the Task Force on Zoonoses Data Collection on the Analysis of the baseline survey on the prevalence of Salmonella in slaughter pigs, Part B, The EFSA Journal (2008) 206, 1-11

Source attribution

Scientific Opinion of the Panel on Biological Hazards on a request from the European Commission on a quantitative microbiological risk assessment on Salmonella in meat: Source attribution for human salmonellosis from meat. The EFSA Journal (2008) 625, 1-32

Feed

Scientific Opinion of the Panel on Biological Hazards on a request from the Health and Consumer Protection, Directorate General, European Commission on Microbiological Risk Assessment in feedingstuffs for food producing animals. The EFSA Journal (2008) 720, 1-84

Baseline survey of breeding pigs:

Analysis of the baseline survey on the prevalence of Salmonella in holdings with breeding pigs, in the EU, 2008, Part A: Salmonella prevalence estimates, EFSA Journal 2009; 7(12):1377

Quantitative Microbial Risk Assessment:

Quantitative Microbiological Risk Assessment on Salmonella in Slaughter and Breeder pigs: Final Report, Published 19 April 2010. VLA in consortium with DTU and RIVM

EFSA Panel on Biological Hazards; Scientific Opinion on a Quantitative Microbiological Risk Assessment of Salmonella in slaughter and breeder pigs. EFSA Journal 2010; 8(4):1547.

4.2.3 Risk assessment

The EFSA 2006 report "Risk assessment and mitigation options of *Salmonella* in pig production" laid the basis for a series of studies and reports that lead up to the setting of Community targets for reducing the prevalence of *Salmonella* serovars with public health significance in pig herds.

EFSA (2006) recognised that *Salmonella* spp. is one of the major causes of food-borne illness in humans with the contribution from pork varying between countries and production systems. All *Salmonella* serovars from pork are to be regarded as a hazard for public health. The most common serovar at EU level causing human food-borne infections from pork is S. typhimurium, although there have been significant outbreaks caused by other serovars. There was found to be a lack of the comprehensive data needed to put in place Community targets and implement appropriate control measures.

Two main options exist for detecting *Salmonella*, based on immunology and bacteriology. Immunology is used for mass screening of blood and other samples. Bacteriology is used for more specific testing of individual animals and strain isolation.

Risk mitigation options have been identified according to three lines of defence formulated by the World Health Organisation (WHO):

1. Pre-harvest control, focusing on *Salmonella* in the food-producing control.
2. Harvest control, concerning with hygiene improvement during slaughter and meat processing.
3. Post-harvest control concentrating on measures during the final preparation of food.

In general control measures should be based on actions taken throughout the production chain. No universal mitigation option was identified and a combination of measures aimed at preventing horizontal and vertical transmission is likely to be the most effective.

At the pre-harvest level measures can be addressed to:

i) the prevention of introduction of *Salmonella* into the herd;

ii) the prevention of in-herd transmission; and

iii) the increase of resistance to infection.

The report emphasises that *Salmonella* is a pathogen and not a ubiquitous bacterium or normal inhabitant of the intestinal flora of domestic animals. If the spread of *Salmonella* is to be reduced, it is of fundamental importance that monitoring programmes are set up to identify *Salmonella*-infected herds and animals, and prevent further spread. The primary and main source of *Salmonella* infection in the pig production food chain is the *Salmonella*-infected food producing animal. The ultimate objective is to produce *Salmonella*-free animals.

Bringing infected pigs into a herd is likely to be the most common means of introduction of *Salmonella*. In the EU, sourcing pigs from *Salmonella*-free herds is only likely to be a practical option in Denmark, Sweden and Finland. Elsewhere, other methods have to be used to limit the risk of introducing *Salmonella* by incoming animals. These include: introducing pigs from herds with the same or higher health status; integrated production chains; networking between producers; and isolation of incoming animals.

Hygiene and husbandry measures are important to minimise the spread of *Salmonella* within a farm and their preventive effects towards other infectious diseases can increase cost-effectiveness. All-in/all-out systems, batch production, closed pens and implementation of

Good Hygiene Practice (GHP) reduce the spread of *Salmonella* through a herd. It has also been found possible to rear *Salmonella*-free growers and finishers that originate from *Salmonella*-infected sow herds.

Outdoor pig husbandry systems present an increased risk of infection with *Salmonella* and control can be very difficult due to continuous exposure to infective agents.

Separation of batches and optimisation management during transport and slaughter can lead to incremental reductions of the pathogen load in live pigs at each stage of the food chain.

Control of *Salmonella* in feed is considered an essential part of pre-harvest control. Feed may be a major source of infection in countries with a low prevalence of *Salmonella* due to the potential for spread to a large number of farms.

EFSA (2006) Conclusions on risk mitigation options at pre-harvest level

In general, the control has to focus on the implementation of preventive actions in each phase of the entire production chain because there is no "silver bullet" through which the level of *Salmonella* contamination can be reduced. The control of *Salmonella* can follow those general rules that have been successfully applied to the control of other infectious diseases.

More specifically, the following measures are required to be followed:

- Prevention of introduction of *Salmonella* into the herd:
  - by infected animals, being the primary and major source of infection,
  - by feed, being a continuous risk for new introduction to herds in all MS,
  - from a contaminated environment (e.g. rodents) and by equipment and visitors.
- Prevention of in-herd transmission:
  - implementation of optimal hygienic and management routines; e.g. all-in/all-out systems, batch production with thorough cleaning and disinfection between batches,
  - identification and removal or isolation of *Salmonella* infected animals or group of animals,
  - control of vectors such as rodents and birds.
- Increase resistance to infection:
  - support good health and good management e.g. by reducing predisposing factors like the occurrence of other infectious diseases, e.g. dysentery (Brachyspira hyodysenteriae), Aujeszky´s disease and Porcine Reproductive and Respiratory Syndrome and worm infections,
  - the use of vaccine is a suitable option in a control programme depending on several factors, e.g. aim of the control plan (reduction or eradication), prevalence of *Salmonella*, etc. However, vaccination alone cannot eliminate *Salmonella* spp. from a herd,
  - the use of antimicrobials for *Salmonella* control in pigs should be discouraged due to public health risks associated with development, selection and spread of resistance. Their use should be limited and subjected to the approval of competent authority in defined conditions that would minimize the risk for the public health,
  - the use of fermented liquid feed and acidifying compounds in feed and drinking water generally is found to have a *Salmonella* reducing effect.
- Strategies for interventions:
  - an initial monitoring is required in order to establish a basis, the true picture of the current situation from a public health point of view,

- focus intervention for the control and elimination of all certain serovars associated with pigs and pork, as there is no scientific basis for focusing on certain serovars,
- in medium and high prevalence countries interventions required to be based on a successive implementation of *Salmonella* reducing steps as specified (in Chapter 6.2. of EFSA 2006) The results to be achieved require to be assessed based upon a long term perspective,
- at regularly controlled intervals the interventions required to be evaluated to ensure compliance and efficacy and necessary modifications undertaken. It is considered that while these interventions will considerably reduce the *Salmonella* prevalence at pre-harvest level, it remains to be seen if this strategy alone can result in a relatively *Salmonella*-free primary production system comparable to those systems that currently exist in the low prevalence countries,
- low prevalence countries require to ensure that the favourable *Salmonella* situation achieved to-date is maintained by the continuous use and, where possible, cost effective improvement of current monitoring and intervention strategies,
- for all MS a supporting monitoring programme is required to be in place and modified so as to meet the objectives and to apply appropriate strategies consistent with the status of the MS or region under consideration, as described above.

▪ Intervention in breeding or finisher production:

- a holistic approach from breeding to slaughter and processing is required in order to reduce the risk to human health from *Salmonella* in pigs and pork**.** An emphasis on the measures taken at the finisher phase has been shown to result in a greater and more rapid reduction in *Salmonella* prevalence in pigs and pork than emphasis on measures taken at the sow level.

Meat or carcass decontamination maybe considered in specific situations although EFSA (2006) does not consider decontamination to be a substitute for other recommended measures.

Monitoring at harvest level was considered to be of relevance in regard to both process hygiene evaluation and evaluation of the current *Salmonella* status of the entire food chain.

A proposal for a baseline study on the prevalence of *Salmonella* in fattening pigs was suggested.

4.2.4 Baseline survey of slaughter pigs

Annex III of The EFSA Journal (2006)[2] proposes a baseline study on the prevalence of *Salmonella* in fattening pigs in the EU. The scientific reasoning behind the recommendations includes the following points:

- The purpose of the survey is to determine a baseline for human exposure to *Salmonella* infection. The most appropriate baseline is the prevalence at the point of slaughter.
- The use of mesenteric lymph nodes and carcass swabs taken during slaughter are considered the most readily available and repeatable sampling points to ensure comparability among Member States and over time.

[2] Annex III of The EFSA Journal (2006), 341, Opinion on "Risk assessment and mitigation options of *Salmonella* in pig production"

- Carcass swabs are also recommended as transport, lairage and the slaughter process considerably influence the final contamination of the carcass and therefore the risk to public health. A Member State might end up in situations where the prevalence in the national herd has decreased through pre-harvest controls and a target has been achieved but no effect can be seen in pork (as contamination at slaughter might still occur) and therefore on human exposure. Such an event would be a severe drawback on the continuation of pre-harvest controls.
- Baseline versus monitoring: it might be emphasised that the most appropriate methods for establishing the baseline national prevalence were not necessarily the most appropriate for on-going monitoring of a control programme. Certain Member States, including United Kingdom, The Netherlands, Republic of Ireland and Denmark, have successfully used serological methods for such purposes.
- Lymph nodes are taken because they are less likely to be affected by contamination during sampling, transport and lairage compared to caecal contents and will therefore better reflect the status of the pig sent to slaughter than caecal contents.

4.2.4.1 Lymph node prevalence

Twenty five Member States participated in the survey[3], which found a Community observed lymph node prevalence of *Salmonella*-positive slaughter pigs of 10.3%, ranging between Member States from 0.0% to 29.0%. This infection may have arisen on the farm of orgin or at any time during transport to slaughter, or in lairage.

Table 8 shows weighted prevalence estimates and 95% confidence intervals for the *Salmonella* positive lymph node samples in slaughter-pigs by outcome variable, in the EU and Norway, 2006-2007 (Source: Table VII.2. EFSA, 2008)

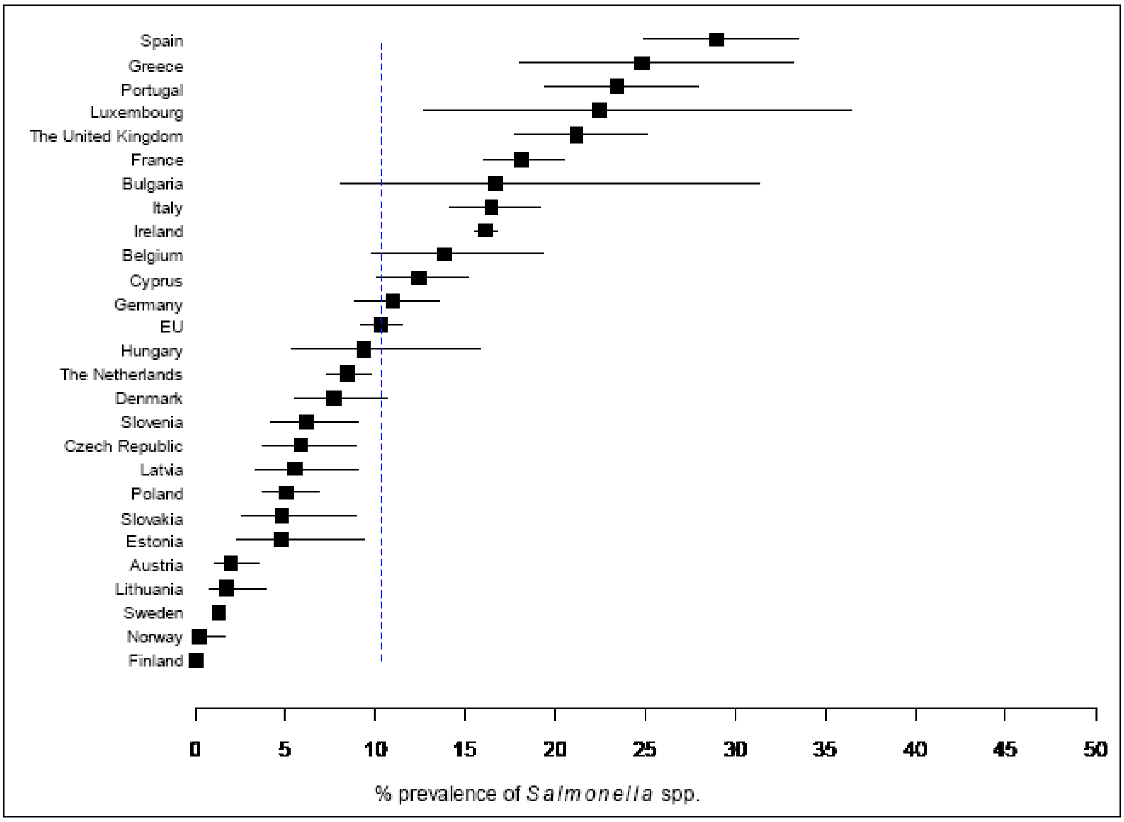
[3] Report of the Task Force on Zoonoses Data Collection on the analysis of the baseline survey on the prevalence of *Salmonella* in slaughter pigs, Part A, The EFSA Journal (2008) 135, 1-111.

Table 8: Weighted *Salmonella* prevalence estimates in slaughter pigs

	Salmonella spp.			*S.* Derby			*S.* Typhimurium			Other *Salmonella* serovars		
Country	Estimate	LB	UB	Estimate	LB	UB	Estimate	LB	UB	Estimate	LB	UB
Austria	0.020	0.011	0.036	0.003	0.001	0.011	0.007	0.002	0.020	0.011	0.005	0.023
Belgium	0.139	0.098	0.193	0.013	0.004	0.036	0.078	0.053	0.115	0.049	0.030	0.079
Bulgaria	0.167	0.081	0.314	0.049	0.013	0.164	0.018	0.006	0.049	0.101	0.049	0.197
Cyprus	0.124	0.101	0.152	0.000			0.010	0.008	0.013	0.115	0.091	0.145
Czech Republic	0.058	0.038	0.089	0.014	0.005	0.041	0.016	0.008	0.033	0.027	0.016	0.045
Denmark	0.077	0.055	0.107	0.013	0.008	0.022	0.045	0.034	0.059	0.020	0.014	0.030
Estonia	0.047	0.023	0.094	0.000			0.011	0.006	0.021	0.038	0.017	0.083
Finland	0.000			0.000			0.000			0.000		
France	0.181	0.160	0.205	0.065	0.056	0.074	0.071	0.054	0.095	0.045	0.032	0.063
Germany	0.109	0.088	0.135	0.012	0.008	0.018	0.061	0.047	0.078	0.043	0.034	0.055
Greece	0.248	0.180	0.332	0.038	0.016	0.088	0.034	0.016	0.071	0.172	0.117	0.246
Hungary	0.093	0.053	0.158	0.015	0.004	0.052	0.029	0.014	0.059	0.047	0.029	0.076
Ireland	0.161	0.156	0.167	0.024	0.023	0.025	0.091	0.090	0.092	0.036	0.020	0.064
Italy	0.165	0.141	0.191	0.054	0.038	0.077	0.016	0.009	0.026	0.096	0.077	0.121
Latvia	0.056	0.033	0.091	0.019	0.006	0.060	0.003	0.001	0.020	0.034	0.017	0.066
Lithuania	0.018	0.008	0.038	0.000			0.013	0.005	0.038	0.005	0.002	0.015
Luxembourg	0.224	0.127	0.364	0.015	0.007	0.028	0.161	0.088	0.276	0.040	0.016	0.096
Poland	0.051	0.037	0.069	0.001	0.000	0.002	0.014	0.008	0.025	0.035	0.025	0.049
Portugal	0.234	0.194	0.280	0.025	0.013	0.047	0.084	0.061	0.115	0.121	0.103	0.142
Slovakia	0.048	0.026	0.089	0.011	0.004	0.027	0.008	0.003	0.021	0.036	0.018	0.068
Slovenia	0.062	0.042	0.091	0.006	0.001	0.026	0.007	0.002	0.020	0.051	0.034	0.075
Spain	0.290	0.249	0.335	0.028	0.018	0.043	0.106	0.086	0.131	0.161	0.135	0.191
Sweden	0.013	0.012	0.015	0.000			0.012	0.005	0.027	0.005	0.003	0.009
The Netherlands	0.085	0.073	0.098	0.013	0.008	0.021	0.049	0.047	0.050	0.021	0.014	0.032
The United Kingdom	0.212	0.178	0.250	0.048	0.036	0.063	0.138	0.119	0.158	0.038	0.025	0.055
EU	**0.103**	0.092	0.115	**0.021**	0.018	0.026	**0.047**	0.041	0.053	**0.050**	0.044	0.057
Norway	0.003	0.000	0.016	0.003	0.000	0.016	0.000			0.000		

LB = lower bound of 95% confidence interval / UB = upper bound of 95% confidence interval
The '*S.* Typhimurium', '*S.* Derby' and '*Salmonella* serovars other than *S.* Typhimurium and *S.* Derby' prevalence estimates do not add up to the '*Salmonella* spp.' prevalence estimates due to some rounding errors in the estimation process.

Figure 19: Observed prevalence of slaughter pigs infected with *Salmonella* spp. in lymph nodes in the EU and Norway, 2006-2007



The ileo-caecal lymph node test indicates *Salmonella* infection of slaughter pigs at the level of primary production and is a sensitive test at individual animal level. Infected pigs may become carriers and excrete *Salmonella* in their faeces intermittently; therefore the lymph node test provides the best evidence of infection. False positive results are rare although there may be false negative results.

It is possible for pigs to become infected and for that infection to transfer to the intestinal lymph nodes within hours. Therefore a positive lymph node result may reflect infection on the farm of origin, or during transport or lairage.

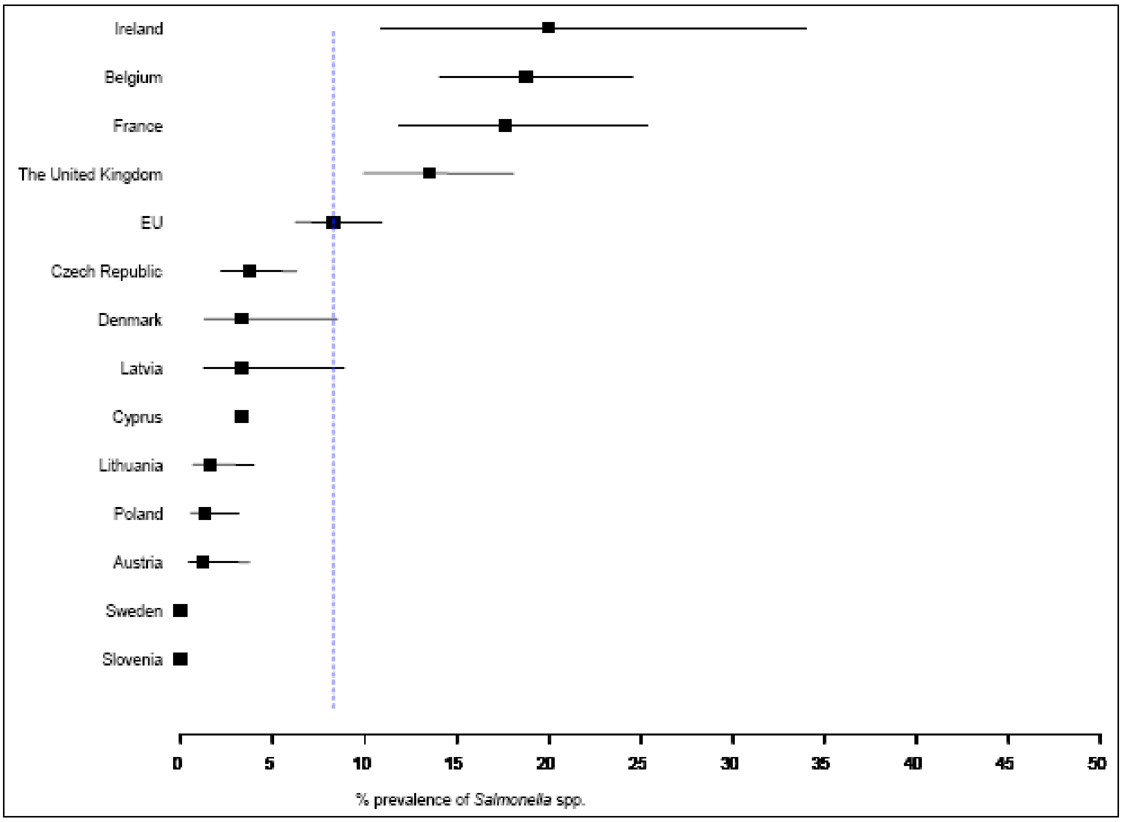
It is possible for pigs to ingest *Salmonella* bacteria, which transit passively through the gut without establishing active infection.

The presence of *Salmonella* infection in lymph nodes may only represent a limited public health threat as the intestinal lymph nodes are removed from the carcass and are not consumed.

4.2.4.2 Carcass swab prevalence

Thirteen Member States collected carcass swabs from pigs that had already been selected for sampling of lymph nodes in order to determine external contamination. The results showed an observed prevalence of carcass contamination of 8.3% overall, ranging from 0.0% to 20.0%. This estimation cannot be extrapolated to the EU level as the group of 13 Member States may not be representative of all Member States.

Figure 20: Observed prevalence of carcasses contaminated with *Salmonella* spp. in 13 Member States, 2006-2007



The carcass swab test reflects the surface contamination of the carcass. Presence of *Salmonella* infection in the pig need not result in carcass contamination, although it can easily occur through contact with faeces or leakage of gut contents during slaughter. The prevalence of positive carcass swabs is a product of the risk of infection within the pig, the risk that the infection is released to the exterior and the risk of cross-contamination from other carcasses or the slaughterhouse environment.

Salmonella may survive in slaughterhouse environments and result in contamination of carcasses and further cross-contamination to other carcasss. Carcass contamination can be reduced by slaughterhouse practices such as scalding and singeing as well as by special treatments such as hot water decontamination. A contaminated carcass is a risk to public health as the carcass is part of the food chain.

In 11 of the 13 Member States the prevalence of contaminated carcass swabs tended to be similar or lower than the lymph node *Salmonella* prevalence. In two Member States the carcass swab prevalence seemed to be higher than the lymph node prevalence. However, the report notes that sample sizes had not been designed for such calculations.

The Part B report of the slaughter pigs baseline survey[4] found that a *Salmonella* infected pig was twice as likely to yield a *Salmonella* contaminated carcass as an uninfected pig. Therefore, controlling the *Salmonella* prevalence in pigs during primary production would have a beneficial impact on *Salmonella* contamination of carcasss and pig meat. Additionally, there would be a likely reduction of the overall contamination of the slaughterhouse environment since incoming pigs are the primary source of *Salmonella* ingress to slaughterhouses.

Good slaughter hygiene is also vital in the prevention of *Salmonella* contamination of carcasss. The baseline survey found considerable variation in carcass contamination between slaughterhouses after taking into account other factors. The effect of the slaughterhouse and processing procedures may increase or decrease carcass contamination. However, the baseline survey was unable to estimate the association of factors related to rearing and processing with *Salmonella* infection of pigs or contamination of carcasss.

Carcass swab testing represents the closest of the sample points used in the baseline survey to consumer exposure. The carcass swab test may offer a valid complementary target in addition to the lymph node target and encourage Member States to consider whether on-farm interventions, slaughterhouse interventions, or a combination of both offer the optimum control strategy for their individual production systems.

4.2.4.3 Seroprevalence

Seroprevalence testing was undertaken by only nine Member States during the baseline survey and produced inconclusive results.

Seroprevalence (the presence of antibodies in meat juice or sera) is a measure of the prior exposure of the pig to *Salmonella* infection. It is a poor predictor of the *Salmonella* status of the individual pig or carcass. Their value probably lies in surveillance and identification of positive herds.

4.2.4.4 Recommendations of baseline survey of slaughter pigs

The recommendations of the baseline survey of slaughter pigs include the following points:

The *Salmonella* status of the pig (lymph node prevalence) and the slaughterhouse process were both shown to have a risk on carcass contamination.

[4] Report of the Task Force on Zoonoses Data Collection on the Analysis of the baseline survey on the prevalence of *Salmonella* in slaughter pigs, Part B, The EFSA Journal (2008) 206, 1-111

An integrated control programme that addresses both the primary production and the slaughter process may prove to be a feasible and cost-effective control option.

4.2.5 Source attribution

Source attribution is considered in Chapter 5 of this report concerning human health aspects.

4.2.6 Feed

The EFSA Panel on Biological Hazards has delivered a Scientific Opinion on Microbial risk assessment in feedingstuffs for food-producing animals[5].

Salmonella was identified as the major hazard for microbial contamination of animal feed. Animals can become infected when fed with *Salmonella*-contaminated feed. Transmission of *Salmonella* from animal feed to animals and to food products of animal origin has been shown.

The relative importance of different sources of animal infections in animals varies. In low prevalence regions, *Salmonella* contaminated feed is the major source for introducing *Salmonella* into animal food production. In regions of high prevalence, the relative importance of feed may be lower compared to other sources, although it is difficult to quantify. In all situations, there is a risk of introducing *Salmonella* into animal production via feed, which would compromise the results of other control measures. Although the most common *Salmonella* serotypes occurring in humans are seldom found in animal feeding stuffs, some serotypes found in feed are also found in humans.

Under EC legislation (Regulation EC No. 183/2005), feed business operators are required to implement procedures based on Hazard Analysis and Critical Control Points (HACCP) principles. There are safety benefits from the application of HACCP principles, Good Hygiene Practice (GHP) and Good Manufacturing Practice (GMP). The Panel on Microbiological Hazards has recommended the effective implementation of HACCP principles and GMP/GHP procedures should be ensured along the feed chain. This requires proper control of recontamination, which can occur during the production process as well as determination of effective heat treatment at individual plants.

Moist heat can effectively decontaminate feed materials and compound feed provided that sufficiently high temperatures and treatment times are used. The application of GHP/GMP practices minimises the risk of recontamination. The use of organic acids or formaldehyde can be effective in reducing contamination by *Salmonella* and other organisms. The aim is for the feed manufacturer to reduce continuously the occurrence of *Salmonella* in feed.

Establishment of microbiological criteria for *Salmonella* contamination along the feed chain is appropriate. Criteria based only on testing the feed end product would not be an effective way to ensure absence of *Salmonella* contamination. Common EU process hygiene criteria should be established on crushing plants, rendering plants and feed mills as an integral part of specific HACCP-based control programmes to maximise the control of *Salmonella* contamination. More information should be gathered with regard to home-mixed feed.

[5] Scientific Opinion of the Panel on Biological Hazards on a request from the Health and Consumer Protection, Directorate General, European Commission on Microbiological Risk Assessment in feedingstuffs for food producing animals. The EFSA Journal (2008) 720, 1-84

4.2.7 Baseline survey of breeding pigs

The issue of *Salmonella* in breeding pigs and the impact on slaughter pigs and human salmonellosis is being addressed in a complementary study to analyse the costs and benefits of setting a target for the reduction of *Salmonella* in breeding pigs. This study is also being undertaken by the FCC Consortium and will report in December 2010.

4.2.8 QMRA on slaughter and breeding pigs

EFSA has published a Quantitative Microbiological Risk Assessment on *Salmonella* in Slaughter and Breeder pigs. The EFSA Scientific Panel on Biological Hazards has delivered a Scientific Opinion on the QMRA[6], which includes the following points:

The fraction of human salmonellosis attributable in pigs will vary considerably between Member States and will depend mainly on i) the *Salmonella* occurrence (prevalence and numbers) in pigs and pig meat, ii) consumption patterns and preferences and iii) the relative importance of other *Salmonella* sources. Differences in the quality and sensitivity of the human reporting systems and testing methods between Member States make direct comparison of surveillance results between Member States difficult. A cautious estimate would be that around 10-20% of human *Salmonella* infections in the EU may be attributable to the pig reservoir.

From the QMRA analysis it appears that an 80-90% reduction of lymph node prevalence should result in a comparable reduction in the number of human cases attributable to pigs. However, there are data gaps and critical assumptions in the model. The Opinion concluded that setting prevalence targets for *Salmonella* in slaughter pigs based on the clustering of Member States as used in the QMRA and the opinion is not recommended.

To achieve control of *Salmonella* in slaughter pigs, the two major sources should be controlled: *Salmonella*-infected breeder pig herds and *Salmonella*-contaminated feed. Eliminating these sources may not be practically achievable but all efforts have to be directed at reducing the prevalence in breeder herds and the *Salmonella* contamination of feed, so as to minimise infection in slaughter pigs.

Breeder pig herd prevalence is a major determinant of slaughter pig lymph node prevalence at EU level. The importance appears to be more obvious in high prevalence countries. Theoretically, a 90% reduction of the breeder pig herd prevalence could result in a reduction of around two thirds of slaughter pig lymph node prevalence.

The Opinion describes a range of feed control measures to be applied on-farm as well as in crushing plants and feed mills.

The QMRA identifies the following theoretical scenarios:

a) by ensuring that breeder pigs are *Salmonella*-free, a reduction of 70-80% in high prevalence Member States and 10-20% in low prevalence Member States can be foreseen;
b) by feeding only *Salmonella*-free feeding stuffs, a reduction of 10-20% in high prevalence Member States and 60-70% in low prevalence Member States can be foreseen;

[6] EFSA Panel on Biological Hazards; Scientific Opinion on a Quantitative Microbiological Risk Assessment of *Salmonella* in slaughter and breeder pigs. EFSA Journal 2010; 8(4):1547.

c) by preventing infection from external sources of *Salmonella* (i.e. rodents and birds) a reduction of 10-20% in slaughter pig lymph node prevalence can be foreseen in both high and low-prevalence Member States.

A hierarchy of control measures is suggested: firstly to address a high prevalence in breeder pigs, followed by control of feed and then control of environmental contamination. Also according to the QMRA, for each Member State, a 99% reduction of *Salmonella* numbers on contaminated carcasss would result in a 60-80% reduction in the number of human salmonellosis cases attributable to pig meat consumption. Other sources of infection in slaughter pigs were not highlighted in the results of the QMRA including the internal and external environment of piggeries such as poorly managed herds, poor hygiene and wildlife.

Beyond compliance with EU legislation and GMP/GHP, it appears that control of *Salmonella* in pig meat for public health purposes should be based on the situations in individual Member States. General *Salmonella* control measures should always be applied, but the particular emphasis will depend on the epidemiological situation of the herd.

Control measures should include combinations of the following interventions: *Salmonella*-free (low risk) breeder pigs, *Salmonella*-free feed, cleaning-disinfection between batches both on-farm and during lairage, avoidance of faecal contamination during slaughter and decontamination of carcasss. Efficient vaccination will also be useful to control *Salmonella* on farm, but might interfere with test results. The QMRA results could give some guidance on appropriate combinations.

From the current evidence, it would appear that specific slaughterhouse interventions are, at present, more likely to produce greater and more reliable reductions in human illness, at least in the shorter timeframe, than can be achieved at the farm in high prevalence Member States. Unhygienic practices enabling direct and/or indirect faecal contamination during transport, lairage, and slaughter and dressing increase the risk of carcass contamination with *Salmonella*.

However the QMRA suggests that Member States can achieve more effective reductions in human cases by targeting both farm and slaughterhouse. Measures aiming at producing safe pig meat through decontamination of the carcass should not be perceived and used as a substitute to hygiene practices at earlier stages of the pig meat chain such as at pre-harvest.

4.3 Summary

Salmonella infections are evident in the pig sector across Europe, but there is great variation. Countries with long standing control programmes have brought the disease down in slaughter pigs to low levels and in the case of Finland appear to have removed the infection completely. However, important pig producing countries such as France, Germany, Italy, Spain and the UK have levels of infection in slaughter pigs that would imply some risks to human health and a need to respond to control and manage the disease and reduce that risk. It important to recognize that not all *Salmonella* found in pigs would lead to human infections, data presented indicates that around a half are S. Typhimurium which is the second most important *Salmonella* infection reported in humans across the EU. The second most important pathogenic servovar found in pigs is S. Derby. The carcass swab assessments also indicate that *Salmonella* risks can be reduced where good slaughter management and processing are practised. The next Chapter examines the human health impact of *Salmonella* from pigs across the EU.

5 Human health impact of *Salmonella* in pigs

This chapter considers the cost of human salmonellosis caused by pork and pork products. It uses a Cost of Illness approach, expressing the cost per case of illness in Euros for each EU-27 Member State. This marks the first of a two stage approach:

- Stage 1: generate a model and use common assumptions for all Member States based on literature and other published sources
- Stage 2: refine assumptions through further methodological development and consultation with Member States.

Stage 2 will be completed and reported in the next phase of work involving Breeding Pigs. This Slaughter Pig report documents the Stage 1 model.

5.1 Introduction – Setting up the model

The terms of reference (TOR) of the project refer to the impact of *Salmonella* on (a) animal populations, (b) human populations, (c) feed and (d) food. Here we address the parts of the brief that relate to (b) human populations, and go on to make the link with (d) food through the question of attribution between salmonellosis in humans and *Salmonella* in pork and pork products.. The TORs consider *Salmonella* and:

1. Its frequency in human populations
2. The gravity of its effects on humans
3. Epidemiological trends in human populations
4. Its economic consequences for human health care

The model is developed by addressing each of these terms of reference. It constructs the first link in the cost-benefit chain that connects (i) the cost of *Salmonella* in humans to (ii) the cost of interventions in the food chain to reduce *Salmonella* and (ii) the benefits that accrue from reducing *Salmonella* prevalence at specific points in the food chain.

The disease chain may be segmented in terms of humans and pigs which, for purposes of our exercise, represents outcome and source of *Salmonellosis* spp, summarised through the following links:

Outcome = Disease in the Human Population

1. Human population – infectious intestinal diseases (IID);
2. IID – salmonellosis, norovirus, campylobacter;

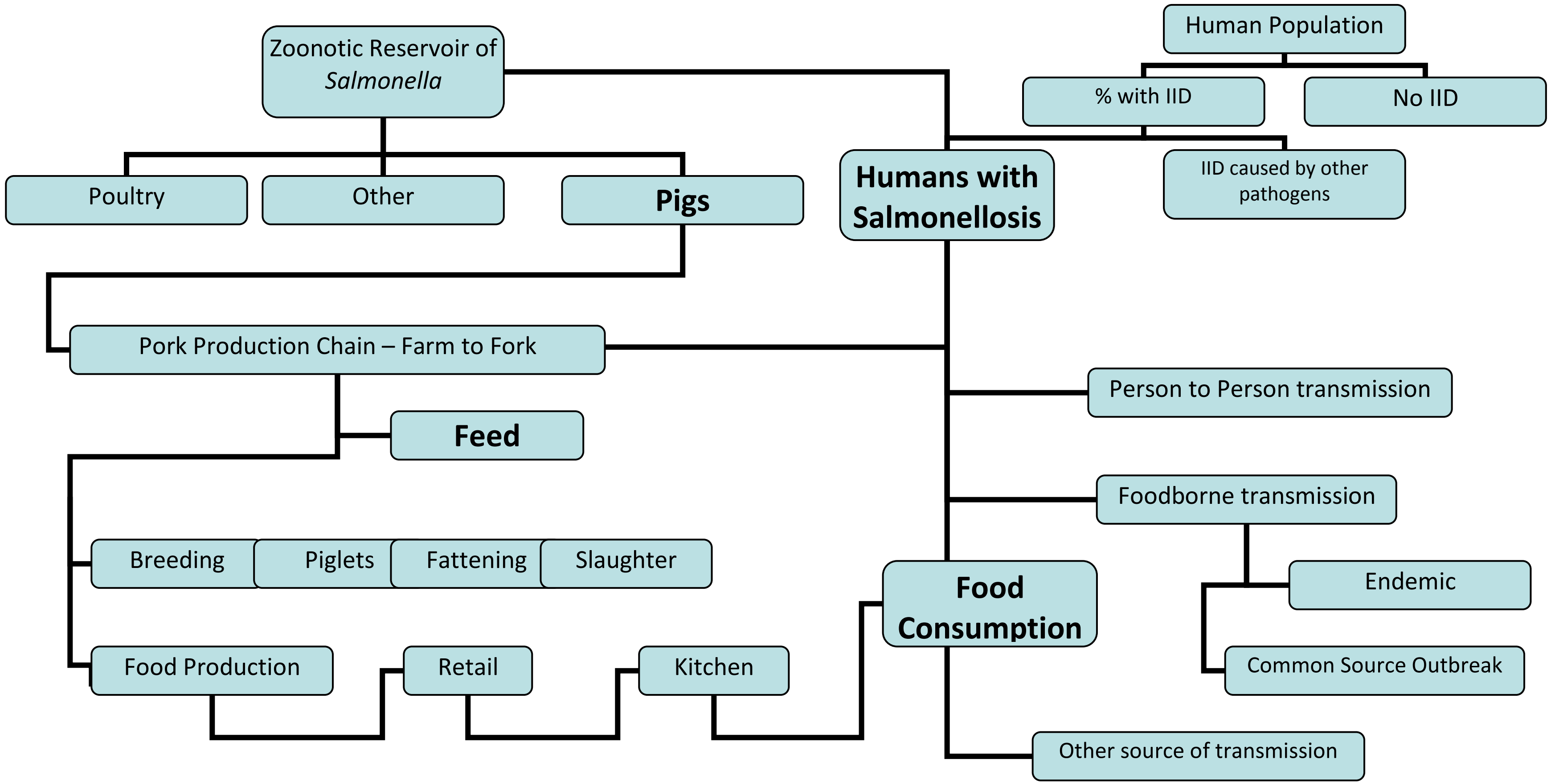
Source = Attribution to Pigs

3. Salmonellosis – source of transmission: zoonotic, foodborne, other causes;
4. Zoonotic reservoir – including pigs, poultry, beef;

5. Pig production chain – Farm to Fork – including feed, piglet, breeder, fattening, slaughter, food.

The linear relationship suggested by the Outcome-Source vector above is of course more complicated in practice. The human population is involved in the pig production chain through handling at every stage from farm to fork, and salmonellosis is endemic in the human population. Figure 21 below captures some of the relationships which are discussed more fully in this chapter and elsewhere in the report.

Figure 21: A schema showing transmission of salmonellosis relating to the human population



5.2 Frequency of *Salmonella* in human populations

5.2.1 Background

5.2.1.1 Epidemiological terminology

'Incidence' refers to the rate at which people contract a disease, i.e. cases per person per year, whereas 'prevalence' measures the total number of people sick at any given time, often referred to as 'point prevalence'. 'Endemic' gastroenteritis refers to illness which resides in the community and is always present in a population (i.e. never zero prevalence). An outbreak of gastroenteritis may lead to an epidemic disease which many people acquire over a short period (i.e. increasing incidence). *Salmonellosis* may arise from a single definable source, such as a batch of food prepared in a specific location, e.g. restaurant, bakery or nursing home. These common source outbreaks are not propagated from individual-to-individual. The disease may, however, continue to be endemic and perhaps epidemic as a consequence of contact with some typically geographically well-defined disease reservoir.

Mortality refers to the number of deaths or years of life lost (YLL) while morbidity is measured by prevalence or incidence of sickness which may be weighted by disability to give years lived with disability (YLD). Disability adjusted life years (DALYs) is a measure of burden of disease, similar in concept to quality adjusted life years (QALYs).

5.2.1.2 Description of Salmonella and its contribution to morbidity

Salmonella spp. refers to the *species pluralis* within the genus *Salmonella.* There are two species: S. bongori and S. enterica, the more common, which is divided into a further six sub-species, encompassing more than 2,500 serovars or serotypes. In the EU, *S* Enteritidis and *S.* Typhimurium are the serovars most frequently associated with human illness. "Human S. Enteritidis cases are most commonly associated with the consumption of contaminated eggs and poultry meat, while S. Tyhpimurium cases are mostly assocated with the consumption of contaminated pig, poultry, and bovine meat." (The EFSA Journal, 2010, p19).

Salmonella bacteria, if ingested, may cause *salmonellosis* in humans, which is an infectious intestinal disease (IID), commonly referred to as gastroenteritis (GE). The symptoms of gastroenteritis, for survey purposes, have been defined as "diarrhoea (at least twice a day) with two or more additional symptoms within a period of 7 days. The additional symptoms included: diarrhoea (at least twice a day), vomiting, fever, abdominal cramps, nausea, and blood or mucus in the stool" (De Wit et al, 2000, p714).

Gastroenteritis is one of the most common diseases throughout the world (Guerrant et al, 1990; Bern et al, 1992). In developed countries, associated mortality is low but morbidity is high; most episodes are brief and self-limiting, so that they do not require medical attention, but the high incidence places a significant social and economic burden on industrialised countries (De Wit et al, 2001; Hellard et al, 2003).

Salmonella is one of a range of causes of gastroenteritis. A study of outbreaks in England in 2002-3 (Lopman et al, 2004), for example, found that norovirus was the 'predominant etiological agent', detected in 63% of GE outbreaks. Campylobacter accounted for 0.8% (1/22) and *Salmonella* did not feature. However, in Britain in 1989, a series of national epidemics of foodborne infection with *Salmonella enteritidis* phage type 4 and *Listeria monocytogenenes*, led the UK government to initiate a major study to ascertain the true incidence of infectious intestinal disease in the community, together with the clinical course of the disease, its long-term sequelae and socio-economic costs. The study found that 20% of the population of England suffered IID in a year and 3% of the population presented themselves to their GP. Viruses accounted for 16% of cases in the community whereas bacterial pathogens were more common. Most cases suffered from infection with organisms that were spread from person to person rather than a common source or an identifiable foodstuff (IID, 2000).

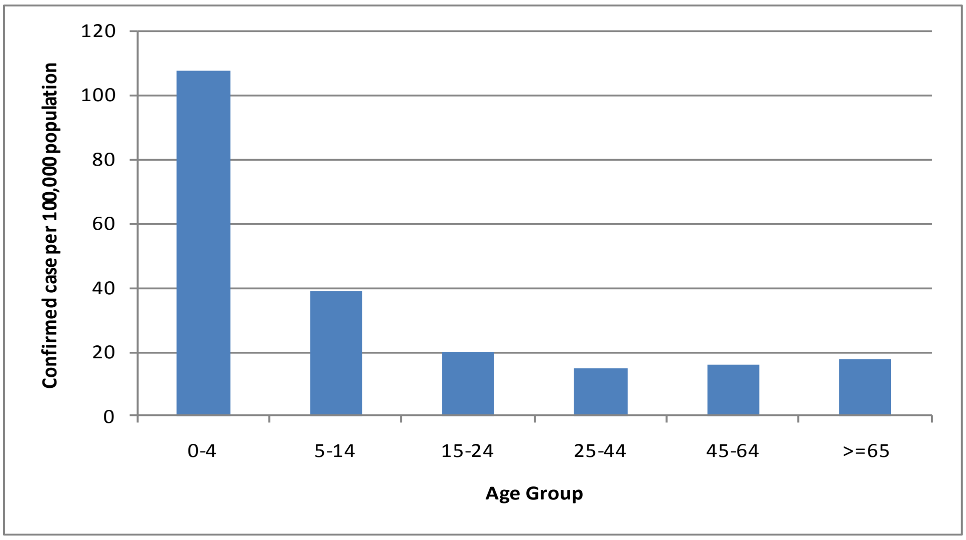
The English IID (2000) study was the first of its kind. The second GP-based national study was conducted in the Netherlands and reported by de Wit et al (2001a). It found that *Salmonella* spp. microrganisms were detected among 7.7% (65/857 – see Table 9 below) of patients with gastroenteritis and among 0.4% (2/574) control patients, representing the community at large.

Table 9: Micro-organisms detected in patients and controls (REF??)

Type	Patients (N=857)		Controls (N=574)	
	N	%	N	%
Salmonella spp	33	3.9	1	0.2
S. Enteritidis	12	1.4	0	0.0
S. Typhimurium	11	1.3	1	0.2
Other *Salmonellae*	9	1.1	0	0.0

Salmonella infections were largely due to *Salmonella enteritidis*, observed mainly in patients 15-60 years, and *Salmonella typhimurium*, found mostly in patients aged 0-4 years. De Wit *et al* linked the higher incidence seen among young patients to general factors such as hygiene and day care attendance, rather than age-specific risks. The incidence of salmonellosis across specific age groups is shown below for 24 Member States (The EFSA Journal, 2010, p24).

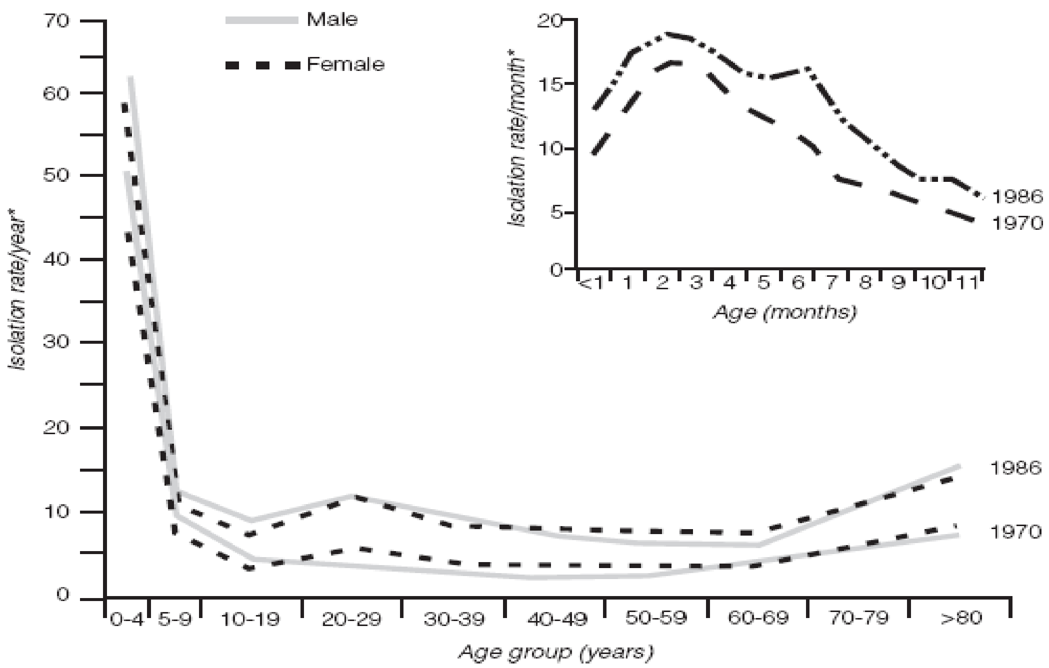
Figure 22: Age-specific distribution of reported confirmed cases of human salmonellosis, in Member States 2008.



Data from: all Member States except Bulgaria, Poland and Romania (N=112,367)

The distribution below, while similar to the current EU data above, shows more detail for the 65+ age group and indicates how incidence increases progressively with age.

Figure 23: Salmonellosis rates, by age and sex of patient and year, United States, 1970 and 1986



* Per 100,000 population

Source: Hargrett-Bean N., A. T. Pavia, and R. V. Tauxe. "*Salmonella* Isolates from Humans in the United States, 1984-86" *Morbidity and Mortality Weekly Report*, 37, SS-2 (1988): 25-31.

From Buzby et al, 1996, p15

De Wit et al (2001b) found that the incidence of gastroenteritis was 79.7 per 10,000 person years. Campylobacter was detected most frequently (10% of cases), followed by Giardia lamblia (5%), rotavirus (5%), Norwalk-like viruses (5%) and *Salmonella* (4%). A pathogen could be detected in almost 40% of patients (bacteria 16%, viruses 15%, parasites 8%).

5.2.2 Transmission of *Salmonella*

Salmonella is an enteric pathogen. *Enteric* is a general term for the intestines and microorganisms that inhabit the intestines are commonly known as enteric bacteria. The transmission of the pathogen *Salmonella* spp., like *Campylobacter* spp., occurs through the following routes:

- Foodborne transmission – a wide range of enteric pathogens and their toxins, including *Salmonella* spp., can be transmitted via food;
- Waterborne Transmission – similarly, a wide range of enteric pathogens, including *Salmonella* spp., can be transmitted via water;
- Zoonoses – as a foodborne pathogen, *Salmonella* spp. has its reservoir in animals. All *Salmonellae*, excluding *S. typhi* and some *S. paratyphi*, are zoonotic;
- Person-to-person spread – "most of the enteric pathogens can be transmitted by person-to-person spread, particularly in the very young and the elderly, those suffering from learning difficulties, and in circumstances where normal hygiene measures are difficult to maintain or ignored" (IID, 2000, p29).

Factors influencing transmission among humans include:

- Food hygiene practices – inadequate heating or storage of food can contribute to outbreaks and sporadic cases of food poisoning (Roberts 1982; Cowden et al, 1995);
- Infected food handlers – during the acute phase of illness, sufferers are excreting large numbers of micro-organisms and, if handling food, may cause contamination;
- Travel abroad – resulting in exposure to a wider range of pathogens;
- Gastric acid suppression – gastric acid is an effective barrier to the passage of gastrointestinal pathogens into the intestine from the stomach. Pharmaceutical agents may suppress acid production;
- Immune suppression – *Salmonella* septicaemia is an AIDS-defining illness. Immunosuppressive therapy associated with HIV, cancer or chemotherapy can leave individuals more susceptible to enteric pathogens.

Figure 24: Potential pathways of human exposure to pathogens found in animals

I. Direct contact with live food animal.
- Food animal bite.
- Contact with the skin, fur, tail, etc., and microorganisms found there.

II. Indirect contact with the live food animal.
- Aerosol contamination of the barn and air system.
- Contamination of the walls, floor, gates, etc.
- Animal waste.
- Bites by flies or fleas that had become disease vectors from previous contact with infected animals.

III. Direct contamination by the carcass.
- Penetration of the skin of the personnel handling meat by microorganisms.
- Entry of organisms through cuts and nicks on the hand of slaughterhouse or processing plant workers.

IV. Indirect contamination by the carcass.
- Aerosol contamination through pathogens released when the carcass is cut up and/or slapped onto the counter.
- Contact with knives, wiping clothes, sinks, etc., where pathogens have been deposited.

V. Cross contamination of other edible products from the environment, other foods, or pests.
- In the slaughterhouse, spreading from one contaminated carcass to others.
- Meat products in the processing plant.
    - Other raw or cooked foods in the kitchen of a private home or commercial feeding establishment.

VI. Consumption of meat, poultry, and dairy products.

VII. Person-to-person transmission.

Source: Economic Research Service, USDA, adapted from Roberts, T. "A Retrospective Assessment of Human Health Protection Benefits from Removal of Tuberculous Beef," *Journal of Food Protection* 49,4(April 1986):293-8.

From Buzby et al, 1996, p2

The figure above lists seven pathways of zoonotic disease, all of which contribute to the burden of foodborne disease. "Illnesses in farm families or slaughterhouse workers that arise from either direct or indirect contact with live animals are categorized here as illnesses from food sources, because these illnesses would not have occurred had these people not been exposed to this occupational hazard." (Buzby et al, 1996)

The EFSA Journal 2010 discusses domestic versus imported sources of *Salmonella* cases (extract in box below). Nordic countries experienced a high level of imported *Salmonella*. (De Jong et al (2006) have used notified cases from Swedish travellers as a means of estimating burden of disease in the EU.)

Domestic versus Imported Cases - The EFSA Journal 2010, p25

The proportion of *Salmonella* cases that were reported as domestically acquired in MSs and EEA/EFTA countries remained approximately the same in 2008 as in 2007 (63.6% versus

65.1%). The same observation was made for the proportion of imported cases or those acquired while travelling abroad, which in 2008 was 7.8% compared to 7.9% in 2007. While many MSs report a clear dominance of domestically acquired *Salmonella* infections, three of the four Nordic countries: Sweden, Finland and Norway, reported the highest proportions of imported cases of salmonellosis (82.1%, 83.2% and 83.6% respectively). As in previous years, Ireland and the United Kingdom showed ratios close to 1:1 between domestically and imported cases, which was not seen in other reporting countries. The proportion with an unknown location of origin still represented 28.6% of confirmed cases. Although data on domestic/imported cases are often incomplete and may not provide a true picture of the distribution between domestic and imported cases the continual repetitive results may indicate common cultural features in some geographical areas

5.2.3 Frequency of serovars in humans

5.2.3.1 Change 2005 – 2008

The two most common serovars found in humans are S. Enteritidis and S. Typhimurium. Table 10 below shows how frequency of *Salmonella* by serovar has changed between 2005 and 2008.

While the number of *Salmonella* reported in humans has reduced in the EU from 217 775 in 2005 to 127 296 in 2008 (see Table 10 below), the only identified serovar to consistently rise in number is S. Typhimurium. It accounted for 9.3% of known serovars in 2005 and rose to 21.9% in 2009, with the absolute numbers increasing from 15 058 to 26,423.

S. Enteritidis remains the major serovar in the human population, with 70,091 in 2008 compared to 26 423 confirmed cases of S. Typhimurium.

Table 10: *Salmonella* serovars reported in humans in the EU, CSR 2005-2008.

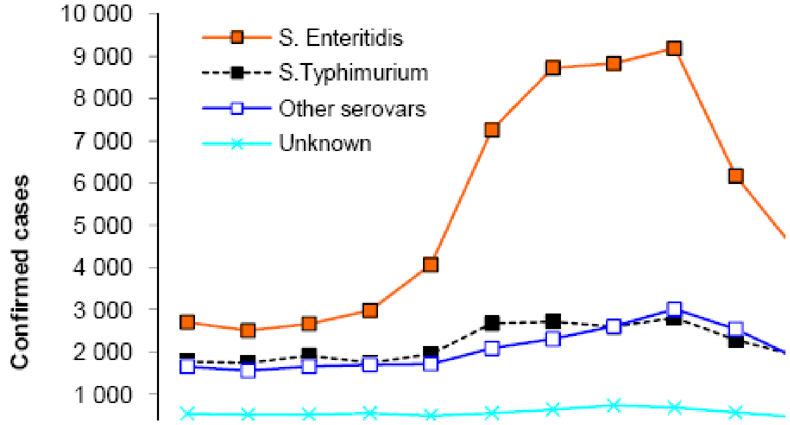
	Year							
	2005 (N=23 MS + 2)		2006 (N=24 MS + 4)		2007 (N=26 MS + 3)		2008 (N=26 MS + 3)	
Serovar	N	%	N	%	N	%	N	%
S. Enteritidis	86,536	53.7	90,362	71.0	81,472	64.5	70,091	58.0
S. Typhimurium	15,058	9.3	18,685	14.7	20,781	16.5	26,423	21.9
S. Infantis	1,354	0.8	1,246	1.0	1,310	1.0	1,317	1.1
S. Bovismorbificans	621	0.4		0.0		0.0	501	0.4
S. Hadar	577	0.4	713	0.6	479	0.4		0.0
S. Virchow	535	0.3	1,056	0.8	1,068	0.8	860	0.7
S. Newport	259	0.2	477	0.4	469	0.4	624	0.5
S. Derby	245	0.2	730	0.6	733	0.6	787	0.7
S. Stanley		0.0	522	0.4	589	0.5	529	0.4
S. Agona		0.0	367	0.3	387	0.3	636	0.5
S. Anatum	179	0.1		0.0		0.0		0.0
S. Goldcoast	173	0.1		0.0		0.0		0.0
S. Kentucky		0.0	357	0.3	431	0.3	497	0.4
Other	55,619	34.5	12,790	10.0	18,562	14.7	18,495	15.3
Total	**161,156**	**100.0**	**127,305**	**100.0**	**126,281**	**100.0**	**120,760**	**100.0**
Unknown	56,619		17,359		9,814		6,636	

Source: QMRA, 2009, p408

5.2.4 Seasonal variation

There is some seasonal variation in S. Typhimurium, but the increase during summer months is more prominent for S. Enteritidis. This is thought to be linked to temperature and behaviour (e.g. consumption of barbecued food). (EFSA 2010, p24).

Figure 25: Number of reported confirmed salmonellosis cases in humans by month and serovar, 2008

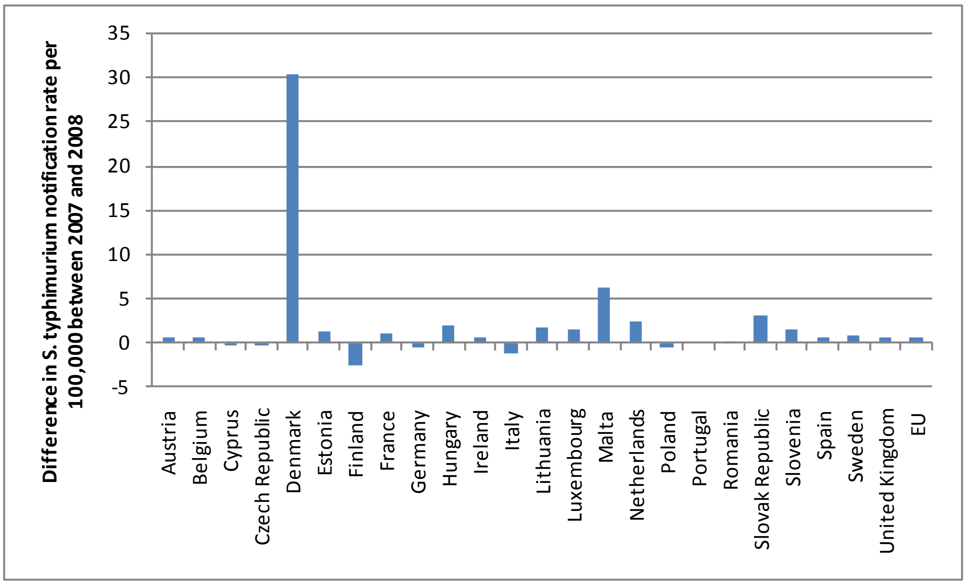


Source: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom (N=119,092).

5.2.4.1 Change between 2007 and 2008

The number of reported cases of S. Typhimurium increased by 27% (5,642) in a single year from 2007 to 2008 while reported cases of S. Enteritidis reduced by 14% (11,381 cases) over the period. Small absolute increases in S. Typhimurium were observed in every MS, but the largest movement is apparent in Denmark. “The increase in *S.* Typhimurium human cases observed in 2008 appears to be related to food-borne outbreaks, especially to a very large outbreak of *S.* Typhimurium U292 in Denmark where the source is still unknown.” In terms of phage-typing, U292 topped the list *S.* Typhimurium. EFSA noted that it was a “newcomer”, that was solely attributed to Denmark (2010, p83).

Figure 26: Difference in *Salmonella* Typhimurium notification 2007-2008 in the EU



All Member States except Bulgaria, Greece and Latvia

5.2.5 Attribution link between animals and humans

A range of methods are used to make the link between source of *Salmonella*, e.g in foodstuffs, and presentation in humans, (considered extensively in EFSA, 2006; EFSA, 2008; EFSA, 2008a; QMRA, 2009), including microbial subtyping, analytical epidemiology, use of outbreak data, comparative exposure assessment and structured expert opinion.

There are pros and cons to each approach. Outbreak data among humans provides a cause-effect audit trail but is particular and cannot with certainty reflect the sporadic or general endemic risk of *Salmonella* in the community. Microbiological sub-typing of serovars and phages focuses on the reservoir or source level in animals, and attributes pathology in animals to pathology in human patients: "the closer the resemblance of animal and food isolates with human isolates, the greater the likelihood that these were the sources of infection" (EFSA, 2008, p19). The method has the strength of focusing on the primary source of exposure but "does not provide any information on the transmission route" (EFSA, 2008, p22).

Microbiological Subtyping

The link between S. Typhimurium and pork and S. Typhimurium and humans leads analysts to attribute a large proportion of S. Typhimurium in humans to the reservoir in pigs. While S. Typhimurium is linked to pig meat and pork herds, S. Enteritidis is linked to poultry and eggs. Phage-typing through microbiological methods supports this. Van Duijkeren et al (2002) found that Serovar Typhimurium pt 510 was the most prevalent serovar Typhimurium phage type in both humans and pigs, while Serovar Enteritidis phage type 4 (pt 4) was the most common phage type in humans and chickens.

Data on human isolates (earlier) shows that S. Enteritidis is the most common and S. Typhimurium is the second most common serovar encountered in humans, accounting for 80% of identified cases altogether. EFSA reports that 33% of serovars in pig meat and 32% in pork herds are S. Typhimurium, forming the largest identifiable serovar in each (see tables below relating to pig meat and pork herds). Bovine meat is also an important reservoir of infection, since 26% of S. cases in bovine animals and 25% of S. cases in bovine meat are S. Typhimurium.

The spatial distribution of serovars gives a more nuanced picture, however. Among the named serovars found in pig meat, Slovakia and Latvia are weighted towards S Enteriditis and in the Czech Republic towards S. Derby. This implies that S. Enteritidis could be attributed to pigs rather than poultry in Slovakia, since the dominant serovar (40% of isolates) in pig meat is S Enteriditis.

Nevertheless, the EU-wide picture is presented in an uncomplicated fashion: "Overall, reported data from 2008 support the generally accepted perception that the main sources of *Salmonella* infections in humans are from different types of meat and eggs in the EU" (The EFSA Journal, 2010, p99).

Table 11: Distribution of the ten most common *Salmonella* serovars in pig meat, 2008

Country	Number isolates serotyped	% positives										
		S. Typhimurium	S. Derby	S. Agona	S. Infantis	S. London	S. Bredeney	S. Rissen	S. Enteritidis	S. Livingston	S. Brandenburg	Others nontypeable, unspecified
Total no. of isolates	1,417	469	280	55	49	48	46	37	21	20	9	383
Czech Republic	57	12.3	29.8	14.0	8.8	3.5			7.0			24.6
Denmark	199	44.2	28.1	1.0	5.5					3.0		18.1
Germany	197	29.7	1.5	0.5	0.5				0.5	1.5	3.0	42.6
Hungary	128	37.5	23.4	0.8	20.3	1.6	3.9	5.5	0.8	0.8		5.5
Ireland	201	47.3	11.4	17.4	2.5	8.0	6.0	0.5	1.0		0.5	5.5
Italy	532	19.4	27.6			5.3	3.6	4.9	0.9	0.6		37.8
Latvia	17	5.9	5.9				5.9		17.6			64.7
Netherlands	12	50.0	1.6						8.3	16.7	8.3	8.3
Romania	64	34.4	1.6	12.5	1.6		14.1	4.7		7.8		23.4
Slovakia	10	10.0	10.0						40.0		10.0	30.0
Proportion of serotyped isolates		33.1	19.8	3.9	3.5	3.4	3.2	2.6	1.5	1.4	0.6	27.0

Table 12: Distribution of the ten most common *Salmonella* serovars in pig herds, 2008

Countries	No. of isolates serotyped	% positive										
		S. Typhimurium	S. Derby	S. London	S. 1,4,5,12:i:-	S. Livingstone	S. Choleraesuis	S. Infantis	S. Enteritidis	S. Rissen	S. Anatum	Other serovars, non-typeable, and unspecified
Total no. of isolates	**4,897**	**1,544**	**646**	**177**	**154**	**127**	**119**	**118**	**112**	**109**	**101**	**1,690**
Austria	69	29.0	15.9	-	-	13.0	-	4.3	1.4	-	-	36.2
Belgium	1,010	48.8	15.7	0.8	-	3.4	-	3.0	0.4	3.8	2.2	22.0
Czech Republic	73	26.0	12.3	2.7	-	-	-	1.4	8.2	-	-	49.3
Estonia	21	9.5	-	-	-	-	33.3	9.5	9.5	-	-	38.1
Germany	1,318	33.1	7.1	1.6	-	0.9	0.5	1.5	2.1	-	1.1	52.0
Hungary	61	21.3	14.8	-	-	4.9	16.4	19.7	-	-	-	23.0
Ireland	18	72.2	11.1	-	-	-	-	-	-	-	-	16.7
Italy	634	17.7	16.7	-	24.3	1.4	9.9	-	0.5	-	-	29.5
Luxembourg	21	52.4	33.3	-	-	-	-	4.8	-	-	-	9.5
Netherlands	758	16.5	22.7	14.8	-	7.7	-	4.4	1.5	-	3.8	28.8
Poland	82	39.0	12.2	-	-	-	8.5	-	15.9	-	-	24.4
Romania	60	18.3	1.7	-	-	-	33.3	-	-	-	-	46.7
Slovakia	82	24.4	17.1	4.9	-	-	4.9	-	22.0	-	-	26.8
Slovenia	55	14.5	1.8	-	-	-	1.8	18.2	34.5	-	-	29.1
Spain	385	16.1	10.1	5.2	-	0.5	-	0.8	1.0	18.4	9.1	38.7
Sweden	31	64.5	-	-	-	-	-	6.5	-	-	-	29.0
United Kingdom	219	67.1	5.9	4.6	-	-	-	0.5	1.4	-	-	20.5
Proportion of serotyped isolates		**31.5**	**13.2**	**3.6**	**3.1**	**2.6**	**2.4**	**2.4**	**2.3**	**2.2**	**2.1**	**34.5**

Note: Data are only presented for sample size ≥10. Both clinical and monitoring isolates are included, and it should be noted that there can be some overlap of isolates between the two reportings and the sum of isolates does not correspond to the number of tested flocks.

1. The serovar distribution (% isolates) was based on the number of serotyped isolates, including non-typeable isolates. Ranking was based on the sum of all reported serovars.

5.2.6 Epidemiological trends

The audit trail between epidemiological evidence and control programmes appears to support the pig/poultry-human attribution links. *S*. Enteritidis decreased markedly in 2008, while an increase in *S*. Typhimurium cases was observed. The EFSA Journal (2010) has noted how the downward trend in S. Enteritidis in the human population marks a response to control measures in poultry through target-setting. Similar targets do not exist for pigs (since they are subject to this enquiry).

Impact of Control Programmes (EFSA, 2010)

An important decline in the prevalence of *S*. Enteritidis and *S*. Typhimurium in laying hens was observed in 2008 which was the first year when Member States implemented new control programmes in this animal population. The improved situation in laying hen flocks may have been reflected in the decrease of *S*. Enteritidis cases reported in humans, since eggs are an important source for these infections.

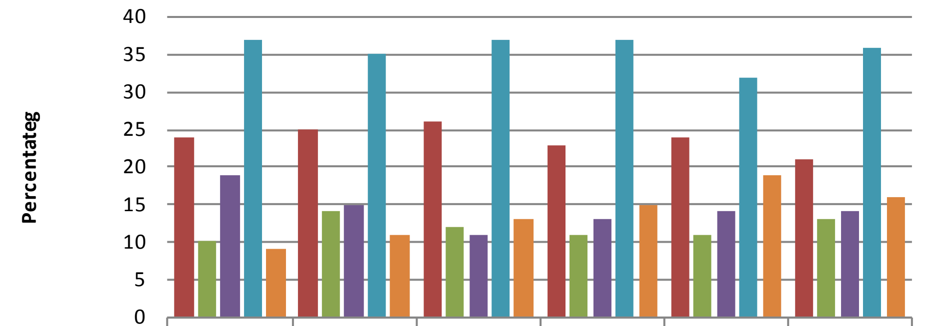
5.2.7 Outbreak analysis

In addition to sero- and phage typing, outbreak information is used to connect human cases of salmonellosis to different food stuffs. There were 490 verified outbreaks due to *Salmonella* in the EU in 2008, 91.6% of which allowed detailed investigation of foodstuffs. Eggs and egg products were the main culprit in 40.8% of cases (primarily S Enteritidis outbreaks) while pig meat was implicated in 7.1% of outbreaks (primarily S Typhimurium). Bakery products, mixed meals or buffet meals and broiler meat were responsible for a further 23.7% of outbreaks (mainly S. Enteritidis). “This date is generally in line with the observations made from the serovar distributions” (EFSA, 2010, p100).

5.2.8 Summary of attribution to pork/pigs

There are wide variations in the estimates of attribution. For example, one source of expert estimate (Vargas-Galindo, 2007) suggests that 55% of human salmonellosis is foodborne, whereas the US Department of Agriculture (ERS/USDA model) assumes that 95% of salmonellosis is foodborne. ESFA (2008) cite data from Van Pelt *et al.* (1999) and Valkenburgh *et al.* (2007) for estimates of the contributions of different reservoirs to laboratory confirmed salmonellosis in the Netherlands. This shows that the contributions of pigs to *Salmonella* infections is around a quarter for this country and dropping to 21% in 2006 (see Figure 27).

Figure 27: Percentage of contributions of different reservoirs to laboratory confirmed salmonellosis in the Netherlands



	1994-98	2001-2	2003	2004	2005	2006
Pig	24	25	26	23	24	21
Cattle	10	14	12	11	11	13
Chicken	19	15	11	13	14	14
Layers	37	35	37	37	32	36
Travel/other	9	11	13	15	19	16

Data cited by EFSA, 2008a

The most recent estimate of attribution is through the November 2009 QMRA report (QMRA, 2009) that suggests that 10%-20% of salmonellosis in humans can be attributed to pork.

The implication for the CBA model is that:

- We assume that 15% of human salmonellosis can be attributed to pork

The Table 13 below summarises the range of opinion (drawn mainly from EFSA, 2008a) about the proportion of S. in humans that is thought to be linked to pork consumption.

Table 13: Percentage attribution of pork to human salmonellosis – summarising the literature

Description	Source	%
*% of different reservoirs in Netherlands	Van Pelt et al., 1999, Valkenburgh et al., 2007, EFSA 2008	21%
*Denmark	DZC	10% - 21%, so 15% of all 20% of known
General	QMRA, 2009	10%-20%
*Netherlands	Vargas-Galindo, 2007	8% (14% of foodborne S. which is 55%)
* *Salmonella* outbreaks related to meat and meat products		6% (11/179)
*USA, expert estimate	Hoffman et al, 2006; 2007	6%
*USA, outbreak data	Hoffman et al, 2006; 2007	3%

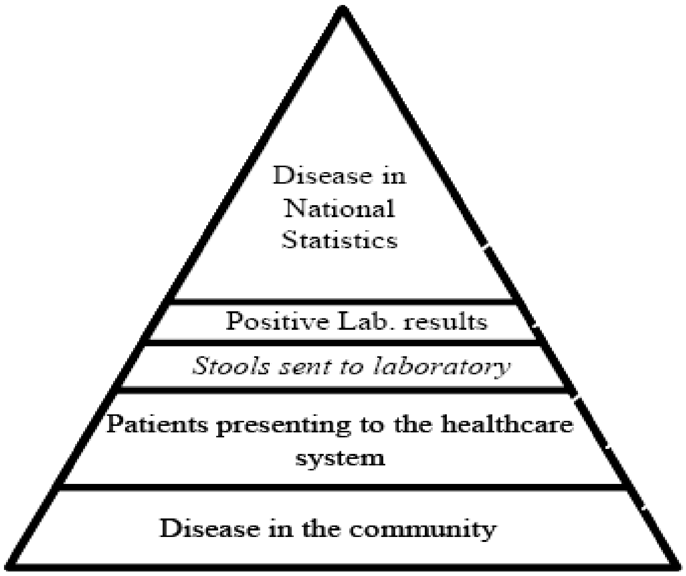
* Source: EFSA, 2008a

5.3 Burden of illness pyramid in humans

Salmonellosis is a notifiable disease, meaning that identified cases are reported to the public health surveillance bodies in each Member State. The numbers of cases that are formally reported each year are known, but represent a fraction of the cases that present to general practitioners. Patients who visit their GP with symptoms of gastroenteritis represent a sub-set of the people in the community who experience enteric distress, which may or may not be associated with *Salmonella* spp. The total number of cases in the community is unknown. Their mild nature means that there may be an economic consequence, e.g. as individuals take time off work or remain at home to care for sick children, but there is no medical record of the event. Even where the illness is severe or leads to death, the cause of death, e.g. salmonellosis, many not be investigated. “[U]nknown agents accounted for approximately 81% of foodborne illnesses in the United States and 64% of deaths” (Mead et al, 1999; quoted in Buzby et al, 2009, p1853).

EFSA (2008a) set out these relationships through the burden of illness pyramid below. The cause of the illness will only be established if a specimen (stool) is obtained (either by the GP or the hospital physician) and sent to a laboratory for analysis. Pathology services are linked into public health surveillance systems, so that the laboratory will notify the central body of the occurrence of the disease. In this way, public health systems can become aware of increases in incidence associated with epidemics.

Figure 28: Surveillance pyramid showing the multipliers for *Salmonella* in England and the Netherlands (EFSA, 2008a)



5.3.1 Relationship between reported cases and those in the Community

The potential scale of variation in these estimates is very large indeed, illustrated through the United States experience, documented by Mead et al (1999), who contrasts England's multiplier of 3.2 (Wheeler et al, 1999) with 38 found in the US. The current multiplier used by the USDA is 18 (Voetsch et al, 2004). The Dutch Sensor ratio of 13.9 community cases per reported case is nearer the current US estimate.

Special surveys are required to estimate the relationship between the top and bottom of the pyramid above. The England survey (IID, 2000) suggests that for every reported case of salmonellosis there are 3.2 cases in the community.

At the same time, the relationship between GP cases and reported cases is very similar between England and the US (2.3 and 2.2 respectively), and incidence data based on the number of reported cases at EU level (26.4 per 100 000 population in 2008) is also similar to the US picture (25.5 per 100 000). Estimates at the more severe end of illness are therefore comparable between the EU and US. The main area of divergence appears to be in the estimated (largely invisible) volume of mild salmonellosis cases in the community.

The variation in *Salmonella* estimates here may be due to (a) different levels of morbidity of (b) different methods of detection, or a combination of the two. In other words, we have no means of establishing for each Member State what the true incidence of *Salmonella* in the community may be. We can use the three published estimates, however, as a guide.

Table 14: Three pyramid of illness estimates

	England (IID, 2000)	Netherlands (Sensor)	USA
Reported cases	1	1	1
Positive by Routine Lab Investigation	1.2	NA	
Presenting to GP/physician	2.3	4.9	2.2
Community Cases	3.2	13.9	18 (Voetsch et al, 2004) 38 (Mead et al, 1999)

5.3.2 Implications for the Stage 1 model

In the first place, we are using the same selected multipliers across all MSs. It is possible to vary them subsequently (Stage 2) based on local data.

The selected multiplier is 2.3 for GP case per 1 reported case, based on the England ratio which is similar to the US ratio. The selected multiplier is 11.5 community cases per 1 reported case. This approximates the mean of the England, Netherlands and US ratios. It produces an 80%:20% relationship between mild (people who do not see a GP) and more severe (people who do see a GP) cases. In terms of our model it produces an 80%:20% relationship between Severity 1 and Severities 2+3+4 (discussed later).

Table 15: Pyramid of Illness Assumptions Used in CBA Model

	Selected Multiplier	Reason
Reported cases	1	1
Presenting to GP/physician	2.3	Commonality between England and US figures
Community Cases	11.5	Approximates mean of England, Netherlands and US multipliers

5.3.3 Reported cases of Salmonellosis

The annual number of reported cases is summarised in Table 16 below. *Salmonella* has 131 468 confirmed cases of human salmonellosis (TESSy) reported in the EU in 2008 and is the second highest out of 11 zoonoses. The highest is campylobacter. *Salmonella* rates have decreased by 13.5% between 2007 and 2008, following a trend of significant reduction over 5 years.

The EU notification rate was 26.4 cases per 100 000 population, ranging from 2.9 in Romania to 126.8 confirmed cases per 100 000 population in Slovakia. Germany, the United Kingdom and the Czech Republic accounted for half of all confirmed cases (49.5%) in 2008. As in previous years, *S.* Enteritidis and *S*. Typhimurium were the most frequently reported serovars (79.9% of all known serovars in human cases). (EFSA, 2010, p19)

Table 16: *Salmonella* reported cases in EU in 2008 (EFSA, 2010)

Country	*Salmonella* confirmed reported cases[7]	Incidence Report Cases per 100,000 Population	Population[8] 1st January 2008
European Union (27 countries)	131 468	26.4	497 645 455
Austria	2 310	27.8	8 318 592
Belgium	3 831	35.9	10 666 866
Bulgaria	1 516	19.8	7 640 238
Cyprus	169	21.4	789 269
Czech Republic	10 707	103.1	10 381 130
Denmark	3 669	67.0	5 475 791
Estonia	647	48.2	1 340 935
Finland	3 126	59.0	5 300 484
France	7 186	11.2	63 982 881
Germany (including ex-GDR from 1991)	42 909	52.2	82 217 837
Greece	1 039	9.3	11 213 785
Hungary	6 637	66.1	10 045 401
Ireland	447	10.2	4 401 335
Italy	3 232	5.4	59 619 290
Latvia	1 229	54.1	2 270 894
Lithuania	3 308	98.3	3 366 357
Luxembourg (Grand-Duché)	202	41.8	483 799
Malta	161	39.2	410 290
Netherlands[9]	1 627	15.5	16 405 399
Poland	9 149	24.0	38 115 641
Portugal	332	3.1	10 617 575
Romania	624	2.9	21 528 627
Slovakia	6 849	126.8	5 400 998
Slovenia	1 033	51.4	2 010 269
Spain	3 833	8.5	45 283 259
Sweden	4 185	45.6	9 182 927
United Kingdom	11 511	18.8	61 175 586

5.3.4 Incidence of *Salmonella* - Implication for human healthcare cost-benefit analysis model

The human healthcare (HHC) CBA model takes the number of reported cases as a starting point and estimates the total number in the community by attributing a burden of illness pyramid to the Member State. The model will assign a value for y and z to each Member State based on the best available survey data. In our Stage 1 Model y = 2.3 and z = 11.5. Member States will be able to alter these factors in the light of local knowledge.

Reported cases	1
Presenting to GP	1 * y
Community Cases	1 * z

[7] Source: The EFSA Journal 2010, p22

[8] Source: Eurostat

[9] Netherlands reported cases based on Sentinel system with estimated coverage of 64%; the incidence ratio reflects this. The EU total is based on reported cases (unadjusted for 64% in Netherlands).

5.4 Gravity of the effects of *Salmonella* in human populations

Among the pathogens that cause gastroenteritis, *Salmonella* (along with *Campylobacter*) infection causes the most severe illness, with raised temperature and bloody diarrhoea most frequently associated with the pathogen (IID, 2000, p146). In the England IID study, among the sample of adults infected by *Salmonella* who consulted their GP: “92% had abdominal pain, 94% loss of appetite, 20% bloody diarrhoea, 86% high temperature, 73% headache, 72% muscle ache and 59% faintness/dizziness” (IID, 2000, p140). Children presenting to their GP also had severe symptoms. Over 70% of adults and 50% of children had severe diarrhoea. There were insufficient *Salmonella* cases in the community component for analysis. In general, as one would expect, symptoms of IID were more severe, more frequent and of longer duration among those who visit their GP compared to those in the community (IID, 2000, p146).

5.4.1 Severity

5.4.1.1 Mild, moderate and severe disease

Severity of disease is linked to the pyramid of illness described earlier, and may be described as:

- Mild – those case in the community that are self-limiting. The outcome for this group is full recovery;
- Moderate – patients who feel sufficiently unwell to visit their general practitioner. The outcome for this group is full recovery (query chronic sequelae);
- Severe – patients who experience acute symptoms and may be hospitalised. The outcome for this group may be full recovery, chronic sequelae such as reactive arthritis, or death.

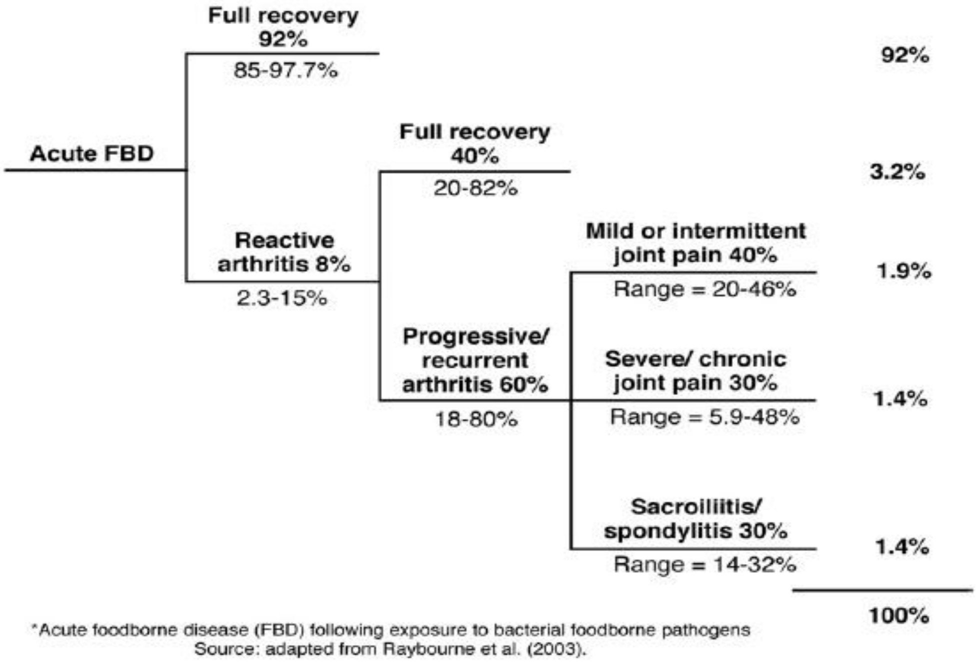
5.4.1.2 Chronic sequelae

The disease outcome tree of arthropathies (acute foodborne disease (FBD) after exposure to bacterial foodborne pathogens is shown below (Source: Raybourne et al, 2003; in Buzby et al, 2009). The model indicates that nearly 5% of people who suffer acute foodborne disease experience chronic sequelae in the form of joint pain.

Beltran-Fabregat et al (2006) conducted a *Salmonella*-specific study in Spain following a foodborne outbreak of *Salmonella* enteritidis phago type 14 b in a banquet in Castellon in 2004. They found incidence of reactive arthritis and musculoskeletal symptoms and concluded that infection by *Salmonella* supposes a risk for joint symptoms in the community.

Possible chronic complications from non-typhoid *Salmonella* identified by Buzby et al (1996) include abscesses, aortitis, arthritis, cholecystitis, colitis, endocarditis, epididymo-architis, meningitis, myocarditis, pericarditis, pneumonia, proderma or pyelonephritis, rheumatoid syndromes, septicaemia, reactive arthritis, Reiter syndrome, splenic abscesses, thyroiditis. The tree below suggests that 4.7% of acute foodborne disease could result in chronioc sequelae.

Figure 29: Acute foodborne disease tree



From Buzby et al, 2009

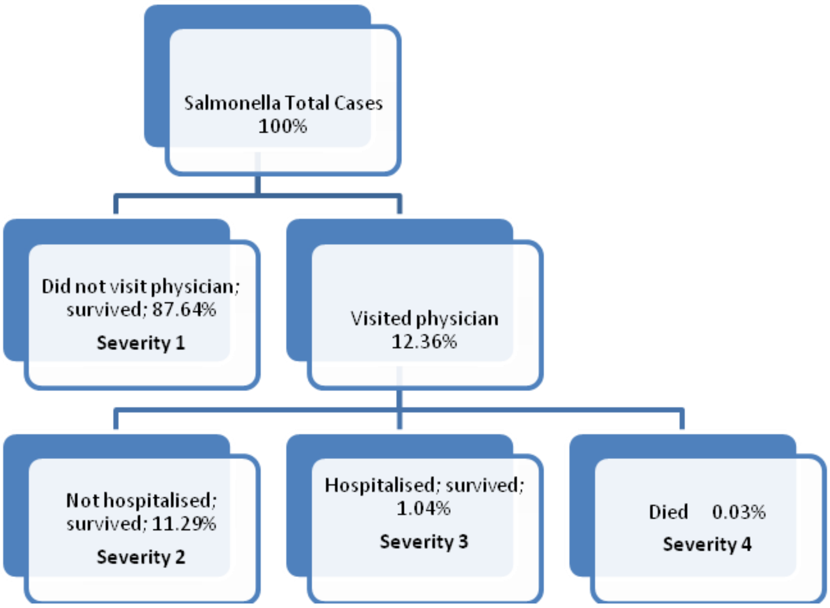
5.4.2 Outcome severity

The pyramid of illness considers reported : GP : community cases, and intuitively this links to severe : moderate : mild categories of illness and to utilisation levels of hospital or death: GP : no healthcare. In terms of measurement, utilisation data is the most easily observable, and is used as a proxy for severity. In accordance with the Economic Research Service (ERS) of the United States Department of Agriculture (USDA), we use four outcome severity levels:

- Severity 1: cases who do not visit a physician and recover fully;
- Severity 2: cases who visit a physician and recover fully;
- Severity 3: cases who are hospitalised and recover fully;
- Severity 4: cases who visit a physician and/or are hospitalised and die.

The cost of chronic sequelae are not included. Each case is considered in only one of the four categories, as set out in the tree diagram below, based on published sources (Frenzen et al, 1999; Mead et al, 1999; Voetsch et al, 2004).

Figure 30: Distribution of estimated US *Salmonella* cases by disease outcome



Source: ERS/USDA at www.ers.usda.gov (Updated 3rd May, 2007)

5.4.3 Outcome severity – implication for cost-benefit analysis Model

The pyramid of illness relationships described earlier are applied to the Outcome Severity classifications 1-4, adapting the ERS/USDA model[10].

At each level of outcome severity it is necessary to identify the volumes of healthcare utilisation:

- Primary care general practitioner (physician) visits
- Emergency room visits
- Outpatient clinic visits
- Hospital admission

While it is apparent that chronic sequelae impose a cost which may be significant (Buzby et al, 2009), we do not propose to factor it in directly, since incidence rates would be speculative. It is something to bear in mind when considering the sensitivity of the cost of illness calculations.

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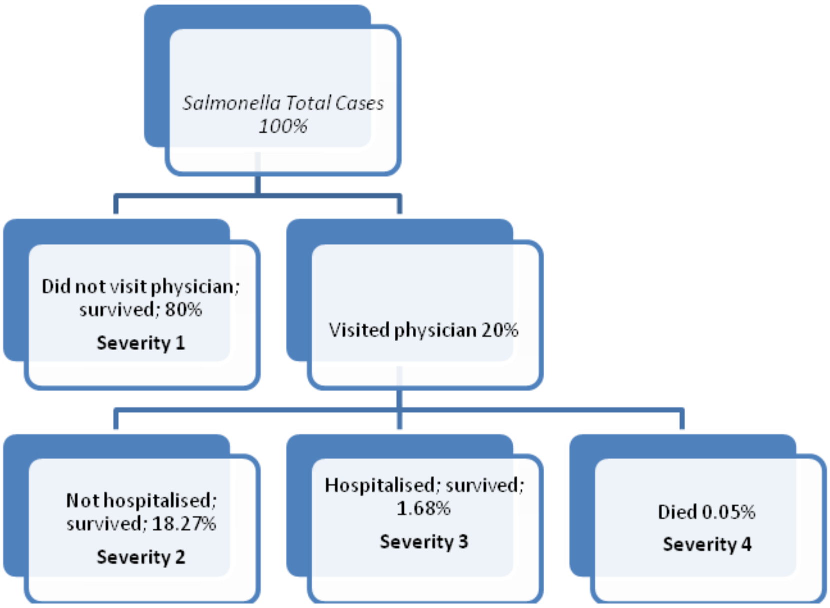
[10] Method:

- Multiplier A = 1 for reported cases
- Multiplier B, select multiplier for GP visits
  - maintain balance of relationships within 'visited physician' category, i.e. Severities 2, 3 and 4 based on USDA model
  - as multiplier for GP visits rises, so too do volumes in Severities 2, 3 and 4
- Multiplier C, select multiplier for community cases
- assign percentages across severity groupings
- Impact:
  - severities 2, 3 and 4 (GP, hospital, fatality) are dependent upon the GP multiplier B
  - Severity 1 is dependent upon community multiplier C

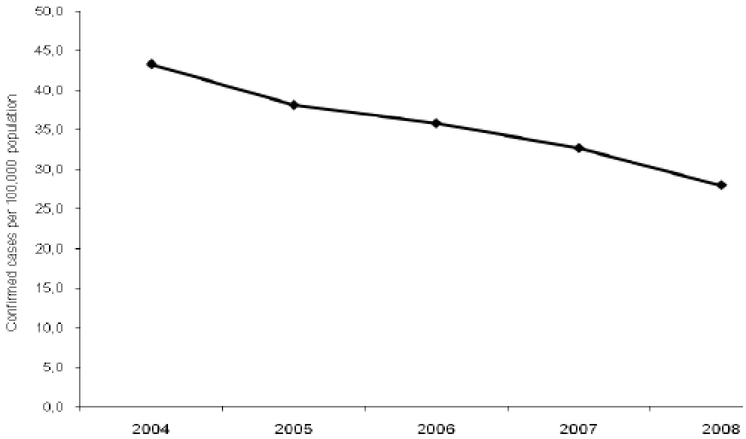
Figure 31: Adapting US severity outcome distribution to selected multipliers in burden of illness pyramid



5.5 Epidemiological trends in the human population

The best data relating to trends in the human population is available through "The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and food-borne outbreaks in the European Union" published annually by EFSA (EFSA, 2010; 2009). It shows a significant reduction in salmonellosis over a five year period.

Figure 32: Notification rate of reported confirmed cases of human salmonellosis in the EU, 2004-2008[11]



Source for EU trend: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

The trend data supports a policy connection between epidemiological trends and *Salmonella* control programmes.

[11] Includes total cases for 2004 and confirmed cases for 2005-2008, see The EFSA Journal 2010, p23

5.5.1 3.1 Trends and attribution to control programmes

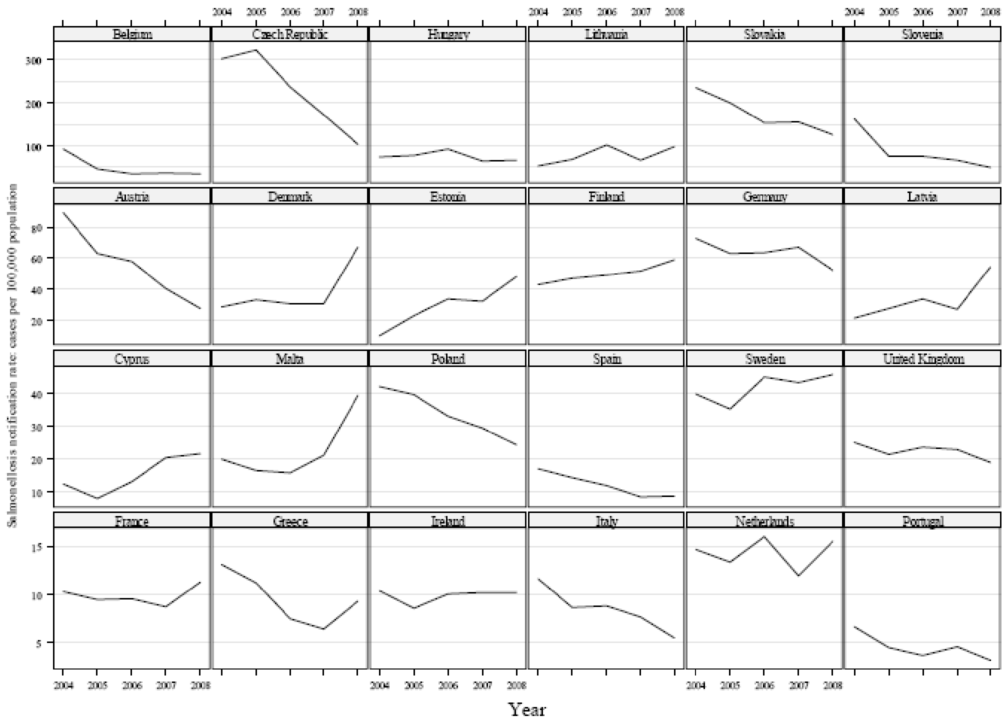
EFSA (2010) has given a strong message based on trend analysis:

- *Salmonella* control measures in animal populations are effective in reducing illness among the human population

The conclusion was substantiated through analysis of reduction in S. Enteritidis, connected to targets in poultry, and increase of S Typhimurium associated with absence of controls in pigs.

Member States are obliged to implement *Salmonella* control programmes in breeding flocks of fowl (*Gallus gallus)* and laying hen flocks. 19 MSs have met their relative *Salmonella* reduction targets for laying hen flocks. The MS specific targets are based on the MS prevalence reported in a baseline survey on the prevalence of *Salmonella* in laying hen flocks carried out in 2004-2005. In breeding flocks, MSs have to meet the Community target of ≤1% of flocks infected with the five target serovars by end 2009. 20 MSs have reported a prevalence lower than this target and six MSs reported prevalence only slightly above the 1% target. All MSs except one, that reported high levels of infection in 2007, have shown substantial improvements in 2008.

Figure 33: Salmonellosis notification rates in humans (cases per 100,000 population) in MSs,2004-2008



Note: MSs have been ranked according to the maximum value of the notification rate. A unique scale is used for MSs shown in the same row but scales differ among rows.

The EFSA Journal – 2010, p101

The data for 2008 suggests that the new *Salmonella* control programmes in poultry have had a positive impact on public health by reducing the number of human salmonellosis cases, particularly cases caused by the *S.* Enteritidis serovar. The reduction of *Salmonella* prevalence in laying hen flocks and the decrease in human reported cases in 2008 was particularly observed in the Czech Republic, Slovakia, and Germany.

5.5.2 3.2 Implication of trends upon policy

The trend analysis has lent support to programmes for improvement in food hygiene and safety in the EU. The EFSA report shows a predisposition to extend *Salmonella* reduction programmes to pig production and pork foodstuffs through targeting breeding and slaughter pigs.

> The results from the control programmes in breeding and laying hen flocks are promising and encourage considering broadening the intensified control efforts further to other animal populations, such as breeding and slaughter pigs.
>
> Community targets for the reduction of *Salmonella* in broiler and in turkey flocks have been laid down in the Community legislation in 2007 and 2008 and the first year of implementation of mandatory control programmes by MSs in these animal populations is 2009 and 2010, respectively. The *Salmonella* reduction targets for breeding and slaughter pigs are foreseen to be set up in the coming years.

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5.5.3 Trends – Implication for cost-benefit analysis

The trend data provides evidence of benefits for human health as a consequence of reduction in *Salmonella* prevalence among animals. The EFSA report (2010) also indicates that the EU is receptive to *Salmonella* reduction programmes as a public health measure. The analysis shows direction of trend, rather than a mechanistic or linear link between prevalence of serovars in animals and incidence in humans.

The trend data is therefore helpful in (a) ascertaining attribution and (b) confirming that potential benefits will accrue. At this stage it does not make a direct contribution to modelling.

5.6 Economic consequences for human health care

It is well documented that the economic consequences of *Salmonella* in particular and enteric diseases in general are substantial (e.g. Buzby et al, 2009; de Wit et al, 2000; Hellard et al, 2003; McNamara et al, 2003; Maki, 2009; Payment et al, 1991). Quantifying the economic consequences, however, is not an easy thing to do, and the challenges fall into two categories[12]:

- Epidemiological challenges
- Economic methodological challenges

5.6.1 Epidemiological challenges

The epidemiological complexities have largely been considered in earlier sections. In summary they include:

[12] Acknowledgement to Buzby & Roberts (2009) for the structure of this section

- Estimating the number of illnesses – the number of cases in the community is a multiple of the number of reported cases of *Salmonella*. The multipliers are estimated through special studies and vary from 3.2 to 18.
- Attributing *Salmonella* to particular sources – we are interested in pigs as a source of *Salmonella* and, specifically, the role that breeding/slaughter pigs play in the chain of transmission. A pragmatic approach is to estimate:
    - The proportion of human *Salmonella* cases that is foodborne
    - The proportion of foodborne *Salmonella* that can be attributed to pork foodstuffs

  Ultimately, the link that we need to establish is “what impact would a 1% reduction in *Salmonella* prevalence in breeding/slaughter pigs have on the incidence of salmonellosis among humans?”

- Estimating Acute Illness Outcome Severity – we have resolved to use the USDA approach which identifies four categories of severity outcome based on utilisation and mortality data:
    - Severity 1: cases who do not visit a physician and recover fully;
    - Severity 2: cases who visit a physician and recover fully;
    - Severity 3: cases who are hospitalised and recover fully;
    - Severity 4: cases who visit a physician and/or are hospitalised and die

  The US relationship between these severity classed is: (1) 87.64% : (2) 11.29% : (3) 1.04% : (4) 0.03%. We adopt a 80%:20% distribution between outcome severity (1) : severities (2, 3 and 4). The relationship between Severities 2, 3 and 4 are comparable to those of the USDA model.

- Estimating chronic complications – chronic sequelae of foodborne pathogens include paralysis, kidney failure, irritable bowel syndrome, Guillain-Barré syndrome (GBS) and arthritis. Buzby et al (2009) note that it is important to include these sequelae in cost studies relating to foodborne disease as they can result in high average and total costs. We propose to exclude chronic sequelae from our cost model. While acknowledging that it is potentially a large omission, the evidence that links *Salmonella* (as distinct from all enteric pathogens) to chronic sequelae is not sufficiently explicit for modelling purposes[13].

Unknown Costs of Chronic Sequelae of Salmonella, Buzby et al, 1996, p20

> These COI (Cost of illness) estimates do not include the costs of chronic medical conditions, which may be significant. The likelihood of such occurrences and associated costs are unknown. Archer (1984, 1985) estimated that 2 percent of salmonellosis patients will end up with reactive arthritis, an inflammation of the joints that lasts from a few days to 6 months. A fraction of these cases develop rheumatoid arthritis, a life-long inflammation of the joints.

[13] We follow the example of the US Department of Agriculture model which omitted the cost for *Salmonella* on the basis of insufficient data (but recognised the principle by including estimated costs of haemolytic uremic syndrome and end-stage renal disease as chronic sequelae for Shiga toxin-producing *E. coli* O157 (STEC O157)).

With better data on incidence and associated costs of chronic illnesses caused by salmonellosis, total costs of these chronic illnesses could be computed and added to estimated costs associated with acute salmonellosis.

- Variations in severity of outcome - severity of outcome may vary between individuals who are exposed to the same pathogen:
  - Immunity – immune system responses between people and between countries. The relationship between prevalence of *Salmonella* in pigs and incidence among people by country is weak, (with R^2 of only 23%[14]). The association between 'burden of disease' which takes into account the size of industry (*Salmonella* prevalence * heads slaughtered) and human *Salmonella* is even weaker (R^2 = 5%). Spain, for example has reported low incidence of 8.2 human cases per 100 000 population, but the highest *Salmonella* prevalence among pigs in the EU at 29%. Finland, on the other hand, has 51.9 human cases per 100 000 population and 0% prevalence among pigs. Sweden, too, has high incidence, most of which, like Finland's, is imported. While we might infer from these inverse relationships that exposure to *Salmonella* increases resistance, across MSs there is no clear picture. Poland has below average prevalence (5.1% pigs with *Salmonella*) and below average incidence (29.3 per 100 000 persons)[15].
  - Pathogen behaviour – linked to the question of immune responses, is the question of pathogen behaviour and virulence – comparing the impact of a single hit or cumulative doses.
  - Data capture – we cannot disentangle measured differences in morbidity from differences in reporting habits. Are fewer people infected or are fewer cases report, e.g. in Spain and Poland?
  - Prevention actions – Food storage, cooking and personal hygiene measures can prevent transmission of bacteria. High temperatures and hand-washing kill or remove *Salmonella*.

5.6.2 Methodological challenges

This study has been commissioned as a cost-benefit analysis (CBA) of setting *Salmonella* reduction targets in slaughter pigs. The aim is to measure the costs of intervention in the industry against benefits to pigs and to humans. Both the costs and the benefits may have both monetary and non-monetary values. For example, the cost of changing slaughter practices may be set against the benefit of reduced spending on medicines and healthcare.

Cost effectiveness analysis (CEA) also seeks to weigh the pros and cons of interventions, but is usually structured as a comparison of two or more programmes, e.g. the most cost-effective means to achieve a particular target, such as reduction in *Salmonella* prevalence or incidence. CBA in this case is measuring the benefits of intervention versus non-intervention.

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[14] Applying simple regression on the sample of 25 MSs, which excludes Malta and Romania where there is no reported prevalence among pigs

[15] This analysis appears to be inconsistent with the statement made in the recent QMRA report: "Breeding herd prevalence is a strong indicator for slaughter pig prevalence (validated in some part by the results of the EU-wide baseline surveys in breeding and slaughter pig surveys), which in turn is a strong indicator or human risk. Hence, by reducing breeding herd prevalence major reductions in the number of human cases can be achieved." (p392, VLA et al, 2009)

5.6.2.1 Choosing the method

There are several potential methods of estimating the economic burden of salmonellosis in humans : monetary techniques such as (i) contingent valuation, including willingness to pay (WtP) and revealed preferences, (ii) cost of illness (COI), or non-monetary measures of outcome such as (iii) Disability Adjusted Life Year (DALY) and (iv) Quality of Life Years (QALY).

(i) Contingent valuation is a survey-based economic technique for the valuation of non-market resources, which in this case is human health and the impact of contamination. Health states do not have a market price (since they are not directly sold). Typically the survey or choice experiment tries to ascertain the maximum amount of money that people would be willing to pay, sacrifice, exchange for a given health state (including death or near death). In this cost-benefit analysis, a WtP would try to establish how much people would pay to avoid salmonellosis at different levels of severity: mild, moderate, severe, fatal.

Buzby et al (2009) note that the US government regards WtP as the 'best practice' approach (OMB, 2003) in cost-benefit appraisals of proposed regulation. While it may be theoretically superior, and have the advantage of including valuation of pain and suffering, it has disadvantages:

- There are practical difficulties in designing a survey tool across diverse populations;
- 'Stated preference' or willingness to pay may not mirror the 'revealed preference' of a binding market transaction. Survey results are open to challenge;
- Survey tools need to be carefully designed and piloted and across large populations are resource-intensive.

(ii) Cost of Illness provides an inventory of the money spend on direct costs of health care, e.g. hospital services, and indirect costs, e.g. relating to lost productivity. Some arbitrary decisions may be made on inclusion and exclusion, e.g. whether to include the cost of pharmaceuticals. In economic terms, the productivity value attached to a day of absenteeism may not be identical to the daily wage, e.g. salaried workers may be paid for the day's absence and in some cases their workload can be deferred. The advantage of the approach is that it is easy to understand. A model can be readily designed and audited. Over time it can be improved as assumptions used to populate the model are refined through a growing evidence-base.

(iii) DALYs and QALYs are non-monetary currencies that may be used to compare the burdens of different diseases, e.g. diabetes in children compared to cataracts among older people. Their advantage is that they form an internally-consistent metric that allows healthcare priorities to be weighed. Their disadvantage is that the currency is opaque to general audiences; monetary values are easier to understand and are less context-dependent. QALY and DALY also involve subjective judgements on how to weight for age and disability which present ethical challenges.

The literature is dominated by Cost of Illness approaches, rather than WtP or QALY/DALY (Buzby et al, 2009). We have elected to use COI as the method that best suits the needs of this project on the basis that:

- It is pragmatic – given the task of estimation across 27 Member States with no unifying language;
- It draws on secondary (published) data rather than requiring primary fieldwork or surveys;

- The monetary evaluation can be readily understood by general and specialist audiences;
- The approach is supported by the body of evidence in the literature.

5.6.3 Selecting the value of a statistical life

The value of a statistical life is required if the cost of premature death is to be factored into an economic model. Roberts et al (1996) undertook a sensitivity analysis using estimates of $5 million per statistical life on the one hand or a range of $12 000 - $1 585 000 on the other depending upon age. Estimates of benefits over 20 years varied markedly.

The monetary assumptions relating to life-value can outweigh all other cost estimates, overshadowing the fine distinctions made on the cost of different parts of the treatment pathway where, for example, the cost of a GP visit might be 20 Euros.

5.6.4 Estimating the anticipated effect of a proposed rule

The problem of attribution between *Salmonella* in pigs and humans makes it difficult to know what would be the reduction in *Salmonella* cases due to increased food safety. We depend on the QMRA study and EFSA Opinion to arbitrate on this point.

5.7 The model and results for EU-27

The model is divided into 6 modules:

- **Module 1:** Total number of cases
  - Pyramid of Illness
  - Incidence
  - Outcome severity
- **Module 2:** Productivity costs
  - Labour market cost and participation
  - Days absent from work by outcome severity
- **Module 3:** Healthcare utilisation costs
  - GP visit
  - Emergency department
  - Outpatients
  - Hospital admission
- **Module 4:** Premature death
- **Module 5:** Total costs
- **Module 6:** Attribution to pork
  - Cases and costs associated with pork

5.7.1 Module 1: Annual number of cases

5.7.1.1 Pyramid of illness: reported and unreported cases

We take the number of reported cases and make an assumption about the number of unreported cases in the pyramid of illness.

Table 17: Method – Number of Cases

Data Item	EU-27 Total	Definition
Reported Cases	131,468	2008 confirmed cases; Source: EFSA 2010
Population	497,645,455	2008 population at 1st January from Eurostat
Incidence of Confirmed Cases	26.4	Reported Cases per 100,000 Population
Ratio of total : reported cases ('the community multiplier')	11.5	Approximates mean of England, Netherlands and US ratios
Total *Salmonella* cases	420,698	Community multiplier * reported cases
Community Incidence per 100,000 Pop	303.8	
Unreported Cases in the community	1,209,506	

The community multiplier of 11.5 is a major assumption. Reporting practices vary between MSs, and so it is likely that the multiplier between reported and community cases will also vary. This report (Stage 1 of the model) maintains a constant multiplier across all MSs.

5.7.1.2 Severity outcome

The variables we need to identify are: those who did not seek medical advice and then those that dispersed to GP, hospital or did not survive. In Stage 1 we are using the same selected multipliers across all MSs. It is possible to vary them subsequently based on local data.

The selected multiplier is 2.3 for GP case per 1 reported case, based on the England ratio which is similar to the US ratio. The selected multiplier is 11.5 community cases per 1 reported case. This approximates the mean of the England, Netherlands and US ratios. It produces an 80%:20% relationship between mild (people who do not see a GP) and more severe (people who do see a GP) cases. In terms of our model it produces an 80%:20% relationship between Severity 1 and Severities 2+3+4. Within the 20% of cases that see a GP, we estimate the following relationships (after the USDA outcome severities at March 2010):

Table 18:

Severity 2	see a GP and survive	18.27%
Severity 3	hospitalised	1.68%
Severity 4	die	0.05%

5.7.1.3 Attribution to pork consumption

The QMRA report (2009) estimates that 10-20% of *Salmonella* infection is attributed to pork consumption, but that this proportion is likely to vary between countries.

Two main epidemiological methods of attributing illness to source at population level are (a) using outbreak data and extrapolating foodborne disease sources to population morbidity and (b) using serovar and phage type analysis of human illness and cross-matching with dominant sources.

For purposes of this study we will use 15% as the proportion of salmonellosis caused by pork and pork products.

We apply the proportion at the end of the analysis (Module 6) – estimating the cost of all salmonellosis and then attributing a straight percentage of costs and cases to pork.

Table 19: Module 1 Results: Number of cases (all *Salmonella*)

Number of Cases

Min	161		1	2.3	11.5	0.8	0.2	18.27%	1.68%	0.05%		370	1,852	1,481	338	31	0.9	6.7	33.3	0.016
Max	42909		1	2.3	11.5	0.8	0.2	18.27%	1.68%	0.05%		98,691	493,454	394,763	90,147	8304	239.5	291.7	1458.3	0.708
		Assumptions :		2.3	11.5							Muliple	Multiple	Severity 1	Severity 2	Severity 3	Severity 4			
			Reporting Pyramid																	
geo/time	Salmonella reported cases 2008	Incidence Report Cases per 100,000 Population 2008	Reported cases	Presenting to GP	Community Cases	% of Cases that do not see GP Severity 1	% of Cases that do see a GP	% Severity 2	% of Cases Hospitalised Severity 3	% fatality Severity 4		Estimated cases presenting to GP	Estimated Cases in Community	Estimated cases in community who did not present to GP	Visited GP and survived	Hospital Cases	Fatalities	Incidence of GP cases per 100,000 pop	Community Incidence per 100,000 Pop	Fatality per 100,000 Population
European Union (27 countries)	131468	26.4										302,376	1,511,882	1,209,506	276,200	25,443	734	60.8	303.8	0.147
Austria	2310	27.8	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		5,313	26,565	21,252	4,853	447.0	12.9	63.9	319.3	0.155
Belgium	3831	35.9	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		8,811	44,057	35,245	8,049	741.4	21.4	82.6	413.0	0.200
Bulgaria	1516	19.8	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		3,487	17,434	13,947	3,185	293.4	8.5	45.6	228.2	0.111
Cyprus	169	21.4	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		389	1,944	1,555	355	32.7	0.9	49.2	246.2	0.120
Czech Republic	10707	103.1	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		24,626	123,131	98,504	22,494	2072.1	59.8	237.2	1186.1	0.576
Denmark	3669	67.0	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		8,439	42,194	33,755	7,708	710.1	20.5	154.1	770.5	0.374
Estonia	647	48.2	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		1,488	7,441	5,952	1,359	125.2	3.6	111.0	554.9	0.269
Finland	3126	59.0	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		7,190	35,949	28,759	6,567	605.0	17.5	135.6	678.2	0.329
France	7186	11.2	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		16,528	82,639	66,111	15,097	1390.7	40.1	25.8	129.2	0.063
Germany (including ex-	42909	52.2	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		98,691	493,454	394,763	90,147	8304.1	239.5	120.0	600.2	0.291
Greece	1039	9.3	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		2,390	11,949	9,559	2,183	201.1	5.8	21.3	106.6	0.052
Hungary	6637	66.1	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		15,265	76,326	61,060	13,944	1284.4	37.1	152.0	759.8	0.369
Ireland	447	10.2	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		1,028	5,141	4,112	939	86.5	2.5	23.4	116.8	0.057
Italy	3232	5.4	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		7,434	37,168	29,734	6,790	625.5	18.0	12.5	62.3	0.030
Latvia	1229	54.1	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		2,827	14,134	11,307	2,582	237.8	6.9	124.5	622.4	0.302
Lithuania	3308	98.3	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		7,608	38,042	30,434	6,950	640.2	18.5	226.0	1130.1	0.549
Luxembourg (Grand-Du	202	41.8	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		465	2,323	1,858	424	39.1	1.1	96.0	480.2	0.233
Malta	161	39.2	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		370	1,852	1,481	338	31.2	0.9	90.3	451.3	0.219
Netherlands	1627	15.5	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		3,742	18,711	14,968	3,418	314.9	9.1	22.8	114.1	0.055
Poland	9149	24.0	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		21,043	105,214	84,171	19,221	1770.6	51.1	55.2	276.0	0.134
Portugal	332	3.1	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		764	3,818	3,054	697	64.3	1.9	7.2	36.0	0.017
Romania	624	2.9	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		1,435	7,176	5,741	1,311	120.8	3.5	6.7	33.3	0.016
Slovakia	6849	126.8	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		15,753	78,764	63,011	14,389	1325.5	38.2	291.7	1458.3	0.708
Slovenia	1033	51.4	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		2,376	11,880	9,504	2,170	199.9	5.8	118.2	590.9	0.287
Spain	3833	8.5	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		8,816	44,080	35,264	8,053	741.8	21.4	19.5	97.3	0.047
Sweden	4185	45.6	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		9,626	48,128	38,502	8,792	809.9	23.4	104.8	524.1	0.254
United Kingdom	11511	18.8	1.0	2.3	11.5	80.00%	20.00%	18.27%	1.68%	0.05%		26,475	132,377	105,901	24,183	2227.7	64.3	43.3	216.4	0.105

5.7.2 Module 2: Productivity

5.7.2.1 Value of time lost from work

We need an estimate of the opportunity cost of labour, based on number of days lost due to illness, average daily earnings and the size of the labour market.

A cost index of earnings was developed for all MSs around the EU base of 1 for 2006 (the most recent complete year). Denmark has the highest gross earnings, with an index of 1.54 while Bulgaria has the lowest with an index of 0.07. Where there was no value available for 2006 we have made an assumption, based on (a) the index for the nearest available year, applied to the EU 2006 average, e.g. Greece uses the index for 2003; (b) substituting an index for a comparable MS, e.g. Estonia uses Latvia's index.

Prices have been inflated from 2006 to 2008. High levels of inflation in Eastern Europe, e.g. 61% Latvia and 40% Bulgaria, have altered the index. However, the ranking remains much the same as these countries were starting from a low price base.

Labour market participation is based on the proportion of the population that is aged 15-64 (according to Eurostat analyses) and the proportion of the working age population that is economically active. The working age population is 67% of the total, ranging from 65% in Denmark to 72% in Slovakia. The proportion of working age adults who are active in the labour market ranges from 59% in Malta to 82% in Denmark. The net employment factor, to be applied across the whole population, is 0.486 for the EU, ranging between 0.415 in Malta and 0.546 in the Netherlands.

Table 20: Method – Value of time lost from work

Data Item	Value for EU 27 MS	Definition
Average Daily Wage 2006	€ 120.39	Eurostat 2006 annual gross earnings divided by 260 days (52*5)
Cost Index for Member States 2006	1.00	
Average Daily Wage per EU MS 2006		Where there are gaps in the data, apply cost index to EU daily wage
Inflation over period	8%	Eurostat % labour cost inflation 2007 and 2008
Average daily wage 2008	€ 130.09	Applying MS inflation produces a new labour cost index for 2008
% Population 16 -64 % Population 15-64	66% 67%	Eurostat 2008 age profile
Labour Market participation rate	72%	Eurostat labour market date
Labour market factor	0.486	

5.7.2.2 Productivity costs

The main cost of cases in Severity 1 category are associated with lost productivity. These people who experience mild symptoms of salmonellosis do not seek medical advice but might take time off work.

The cost per case varies between MSs, in accordance with labour costs. Cost per mild case of salmonellosis averages about a quarter of the daily wage in each MS, since the employment factor approaches 50% and we are assuming 0.5 days absenteeism on average per case. The maximum is € 53.7 (Denmark) and the minimum is € 2.8 (Bulgaria).

People in Severity category 2 suffer more severe symptoms of illness and take themselves to a GP surgery or emergency department. The physician may also refer them on to hospital for an outpatient appointment and further tests.

People who are hospitalised or die (severity categories 3 and 4) combine days lost at home with days spent in hospital.

Table 21: Method – Productivity Costs – Due to Absenteeism caused by Salmonellosis

Value for EU 27 MS	Severity 1	Severity 2	Severity 3	Severity 4	Total
Days absent from work due to salmonellosis	0.5	1.6	4.5	4.5	
Days lost	1,209,506	219,763	56963	1642	579080
Productivity Cost	€ 3,458,334	€25,833,169	€6,692,827	€193,062	€68,070,915
Cost per Case	€ 29	€93.5	€263.1	€263.1	€45

Sensitivity: Total costs are driven by the assumptions on unreported cases in the community. Cost per case depends upon the rates of absenteeism and labour costs. We have good comparative data on labour costs across the EU. Absenteeism rates are more uncertain.

Table 22: Module 2. Productivity cost of all *Salmonella* in humans in EU-27

Productivity

	Earnings Cost Index 2006 or nearest year	Average Daily Wage (euros) 2006 equivalent	Wage inflation in 2007 and 2008 (as % of 2006)	Average Daily Wage at 2008 prices	New Index (2006 inflated to 2008)	15-64 pop	% employment (participation rate)	Employment factor	days per case absent from work	Severity 1 Cases	Days of productivity lost	Cost of Productivity	Cost per Case Severity 1
Min	0.07	€ 8	3.33	€ 12		65%	59%	41%	0.5	1,481	307	€ 18,651	€ 2.8
Max	1.54	€ 186	60.79	€ 199		72%	82%	55%	0.5	394,763	102,063	€ 16,028,739	€ 53.7
Assumptions:									**0.5**				
European Union (27 countries)	1.00	120.39	8.06	130.09	1.00	67%	72%	0.486		1,209,506	300,739	€ 35,351,856	€ 29.2
Austria	1.17	141.05	6.61	150.37	1.16	68%	76%	0.517	0.5	21,252	5,497	€ 826,538	€ 38.9
Belgium	1.20	144.90	7.74	156.12	1.20	66%	68%	0.446	0.5	35,245	7,865	€ 1,227,968	€ 34.8
Bulgaria	0.07	8.44	40.30	11.84	0.09	68%	69%	0.466	0.5	13,947	3,250	€ 38,480	€ 2.8
Cyprus	0.68	81.96	13.64	93.14	0.72	69%	76%	0.524	0.5	1,555	407	€ 37,916	€ 24.4
Czech Republic	0.26	31.86	16.42	37.09	0.29	71%	71%	0.502	0.5	98,504	24,728	€ 917,227	€ 9.3
Denmark	1.54	185.80	7.33	199.42	1.53	65%	82%	0.538	0.5	33,755	9,086	€ 1,811,821	€ 53.7
Estonia	0.17	20.04	36.79	27.41	0.21	68%	77%	0.520	0.5	5,952	1,548	€ 42,435	€ 7.1
Finland	1.09	131.08	8.04	141.61	1.09	66%	77%	0.511	0.5	28,759	7,348	€ 1,040,629	€ 36.2
France	1.00	120.65	6.09	128.00	0.98	65%	71%	0.463	0.5	66,111	15,315	€ 1,960,203	€ 29.7
Germany (including ex-	1.26	151.40	3.73	157.05	1.21	67%	78%	0.517	0.5	394,763	102,063	€ 16,028,739	€ 40.6
Greece	0.68	81.35	17.69	95.74	0.74	67%	68%	0.458	0.5	9,559	2,189	€ 209,577	€ 21.9
Hungary	0.25	30.25	18.37	35.81	0.28	69%	62%	0.425	0.5	61,060	12,989	€ 465,074	€ 7.6
Ireland	1.39	167.32	8.25	181.13	1.39	68%	74%	0.504	0.5	4,112	1,036	€ 187,573	€ 45.6
Italy	1.00	120.65	6.49	128.48	0.99	66%	64%	0.423	0.5	29,734	6,288	€ 807,833	€ 27.2
Latvia	0.17	20.04	60.79	32.22	0.25	69%	77%	0.535	0.5	11,307	3,025	€ 97,464	€ 8.6
Lithuania	0.17	20.04	41.69	28.40	0.22	69%	70%	0.479	0.5	30,434	7,296	€ 207,163	€ 6.8
Luxembourg (Grand-Du	1.39	167.77	5.67	177.29	1.36	68%	67%	0.455	0.5	1,858	423	€ 75,037	€ 40.4
Malta	0.49	58.76	3.33	60.71	0.47	70%	59%	0.415	0.5	1,481	307	€ 18,651	€ 12.6
Netherlands	1.30	156.92	7.02	167.93	1.29	68%	81%	0.546	0.5	14,968	4,085	€ 685,923	€ 45.8
Poland	0.22	25.93	23.21	31.95	0.25	71%	65%	0.458	0.5	84,171	19,266	€ 615,524	€ 7.3
Portugal	0.48	57.28	8.47	62.13	0.48	67%	79%	0.530	0.5	3,054	809	€ 50,247	€ 16.5
Romania	0.12	14.28	47.02	20.99	0.16	70%	66%	0.462	0.5	5,741	1,327	€ 27,852	€ 4.9
Slovakia	0.22	27.08	13.42	30.71	0.24	72%	69%	0.498	0.5	63,011	15,704	€ 482,314	€ 7.7
Slovenia	0.22	27.08	15.52	31.28	0.24	70%	73%	0.513	0.5	9,504	2,435	€ 76,185	€ 8.0
Spain	0.68	81.35	9.31	88.92	0.68	69%	73%	0.504	0.5	35,264	8,887	€ 790,272	€ 22.4
Sweden	1.12	134.94	6.19	143.29	1.10	66%	81%	0.532	0.5	38,502	10,246	€ 1,468,180	€ 38.1
United Kingdom	1.42	171.14	10.25	188.68	1.45	66%	78%	0.516	0.5	105,901	27,322	€ 5,155,032	€ 48.7

Productivity

	days per case absent from work	Severity 2 Cases	Days of productivity lost	Cost of Productivity	Cost per Case Severity 2	days per case absent from work	Severity 3 Cases	Days of productivity lost	Cost of Productivity	Cost per Case Severity 3	days per case absent from work	Severity 4 Cases	Days of productivity lost	Cost of Productivity	Cost per Case Severity 4
Min	1.6	338	224	€ 13,629	€ 8.8	4.5	31	58	€ 3,531	€ 25	5	1	2	€ 102	€ 25
Max	1.6	90,147	74,582	€ 11,712,910	€ 171.8	4.5	8,304	19,323	€ 3,034,567	€ 483	5	240	557	€ 87,536	€ 483
Assumptions:	**1.6**					**4.5**					**4.5**				
European Union (27 countries)		276,200	219,763	€ 25,833,169	€ 93.5		25,443	56,936	€ 6,692,827	€ 263.1		734	1,642	€ 193,062	€ 263.1
Austria	1.6	4,853	4,017	€ 603,988	€ 124.5	4.5	447	1,041	€ 156,480	€ 350.0	4.5	13	30	€ 4,514	€ 350.0
Belgium	1.6	8,049	5,748	€ 897,331	€ 111.5	4.5	741	1,489	€ 232,479	€ 313.6	4.5	21	43	€ 6,706	€ 313.6
Bulgaria	1.6	3,185	2,375	€ 28,119	€ 8.8	4.5	293	615	€ 7,285	€ 24.8	4.5	8	18	€ 210	€ 24.8
Cyprus	1.6	355	297	€ 27,707	€ 78.0	4.5	33	77	€ 7,178	€ 219.5	4.5	1	2	€ 207	€ 219.5
Czech Republic	1.6	22,494	18,070	€ 670,258	€ 29.8	4.5	2,072	4,682	€ 173,650	€ 83.8	4.5	60	135	€ 5,009	€ 83.8
Denmark	1.6	7,708	6,639	€ 1,323,978	€ 171.8	4.5	710	1,720	€ 343,015	€ 483.1	4.5	20	50	€ 9,895	€ 483.1
Estonia	1.6	1,359	1,131	€ 31,009	€ 22.8	4.5	125	293	€ 8,034	€ 64.2	4.5	4	8	€ 232	€ 64.2
Finland	1.6	6,567	5,370	€ 760,434	€ 115.8	4.5	605	1,391	€ 197,012	€ 325.7	4.5	17	40	€ 5,683	€ 325.7
France	1.6	15,097	11,191	€ 1,432,407	€ 94.9	4.5	1,391	2,899	€ 371,106	€ 266.9	4.5	40	84	€ 10,705	€ 266.9
Germany (including ex	1.6	90,147	74,582	€ 11,712,910	€ 129.9	4.5	8,304	19,323	€ 3,034,567	€ 365.4	4.5	240	557	€ 87,536	€ 365.4
Greece	1.6	2,183	1,600	€ 153,148	€ 70.2	4.5	201	414	€ 39,677	€ 197.3	4.5	6	12	€ 1,145	€ 197.3
Hungary	1.6	13,944	9,491	€ 339,851	€ 24.4	4.5	1,284	2,459	€ 88,048	€ 68.5	4.5	37	71	€ 2,540	€ 68.5
Ireland	1.6	939	757	€ 137,068	€ 146.0	4.5	87	196	€ 35,511	€ 410.5	4.5	2	6	€ 1,024	€ 410.5
Italy	1.6	6,790	4,595	€ 590,319	€ 86.9	4.5	625	1,190	€ 152,939	€ 244.5	4.5	18	34	€ 4,412	€ 244.5
Latvia	1.6	2,582	2,210	€ 71,221	€ 27.6	4.5	238	573	€ 18,452	€ 77.6	4.5	7	17	€ 532	€ 77.6
Lithuania	1.6	6,950	5,331	€ 151,383	€ 21.8	4.5	640	1,381	€ 39,220	€ 61.3	4.5	18	40	€ 1,131	€ 61.3
Luxembourg (Grand-Du	1.6	424	309	€ 54,833	€ 129.2	4.5	39	80	€ 14,206	€ 363.4	4.5	1	2	€ 410	€ 363.4
Malta	1.6	338	224	€ 13,629	€ 40.3	4.5	31	58	€ 3,531	€ 113.3	4.5	1	2	€ 102	€ 113.3
Netherlands	1.6	3,418	2,985	€ 501,235	€ 146.6	4.5	315	773	€ 129,859	€ 412.4	4.5	9	22	€ 3,746	€ 412.4
Poland	1.6	19,221	14,079	€ 449,790	€ 23.4	4.5	1,771	3,647	€ 116,531	€ 65.8	4.5	51	105	€ 3,361	€ 65.8
Portugal	1.6	697	591	€ 36,718	€ 52.6	4.5	64	153	€ 9,513	€ 148.1	4.5	2	4	€ 274	€ 148.1
Romania	1.6	1,311	969	€ 20,352	€ 15.5	4.5	121	251	€ 5,273	€ 43.7	4.5	3	7	€ 152	€ 43.7
Slovakia	1.6	14,389	11,475	€ 352,448	€ 24.5	4.5	1,325	2,973	€ 91,312	€ 68.9	4.5	38	86	€ 2,634	€ 68.9
Slovenia	1.6	2,170	1,780	€ 55,672	€ 25.7	4.5	200	461	€ 14,423	€ 72.1	4.5	6	13	€ 416	€ 72.1
Spain	1.6	8,053	6,494	€ 577,487	€ 71.7	4.5	742	1,683	€ 149,615	€ 201.7	4.5	21	49	€ 4,316	€ 201.7
Sweden	1.6	8,792	7,487	€ 1,072,864	€ 122.0	4.5	810	1,940	€ 277,956	€ 343.2	4.5	23	56	€ 8,018	€ 343.2
United Kingdom	1.6	24,183	19,965	€ 3,767,010	€ 155.8	4.5	2,228	5,173	€ 975,953	€ 438.1	4.5	64	149	€ 28,152	€ 438.1

5.7.3 Module 3: Healthcare costs

Service utilisation assumptions are applied according to the ratios set out below (Source Frenzen et al, 1999).

Table 23: Utilisation per Case

	GP Visits	Emergency Department Attendance	Out Patient Attendance	Hospital Admittance
Severity 1 (do not visit GP)	0			
Severity 2 (visit GP and survive)	1.4	0.1	0.3	0
Severity 3 (hospitalised and survive)	0.7	0.3	0.2	1.0
Severity 4 (visit GP/hospitalised and die)	1.0	0.3	0.2	0.9

Cost of Services is currently a weak component of the model. The structure is logical and acceptable. The costing assumptions, however, need to be refined throughout Stage 2. (We have already collected data on cost variation between MSs which has informed the cost matrix below).

We are using notional costs on the basis of EU-27 = 1 and then applying the labour cost index. The notional costs are:

Table 24: Notional Cost Assumptions

	EU-27 Base	Notional Cost at Base 1
GP Visit	1	€ 25
Emergency Department Visit	1	€ 100
Outpatient Attendance	1	€ 150
Hospitalisation	1	€ 2,500

Table 25: Module 3. Healthcare utilisation and sub-components

GP Visit Module

Min	0.09	€ 2.28	1.40	474		0.70	22	€ 254	1.00	1	€ 10	496.2499	€ 5,790	€ 2.28
Max	1.53	€ 38.32	1.40	126,206		0.70	5,813	€ 175,438	1.00	240	€ 7,230	132258.3	€ 3,991,686	€ 38.32
Factors		**€ 25.00**	**1.40**			**0.70**			**1.00**					

	Labour Cost Index 2008	Cost per GP Visit	GP visit per case Severity 2	No. GP Visits Severity 2	Cost of GP Visit Severity 2	GP visit per case Severity 3	No. GP Visits Severity 3	Cost of GP Visit Severity 2	GP visit per case Severity 4	No. GP Visits Severity 4	Cost of GP Visit Severity 4	Total GP Visits	Total Cost GP Visits	Cost per Case
European Union (27 countries)	1.00	€ 25.00	1.40	386,680	€ 8,588,100	0.70	17,810	€ 395,555	1.00	734	€ 16,300	405,224	€ 8,999,955	€ 22.21
Austria	1.16	€ 28.90	1.40	6,794	€ 196,335	0.70	313	€ 9,043	1.00	13	€ 373	7,120	€ 205,750	€ 28.90
Belgium	1.20	€ 30.00	1.40	11,268	€ 338,072	0.70	519	€ 15,571	1.00	21	€ 642	11,808	€ 354,285	€ 30.00
Bulgaria	0.09	€ 2.28	1.40	4,459	€ 10,147	0.70	205	€ 467	1.00	8	€ 19	4,673	€ 10,633	€ 2.28
Cyprus	0.72	€ 17.90	1.40	497	€ 8,897	0.70	23	€ 410	1.00	1	€ 17	521	€ 9,324	€ 17.90
Czech Republic	0.29	€ 7.13	1.40	31,492	€ 224,487	0.70	1,450	€ 10,340	1.00	60	€ 426	33,002	€ 235,252	€ 7.13
Denmark	1.53	€ 38.32	1.40	10,791	€ 413,568	0.70	497	€ 19,048	1.00	20	€ 785	11,309	€ 433,401	€ 38.32
Estonia	0.21	€ 5.27	1.40	1,903	€ 10,025	0.70	88	€ 462	1.00	4	€ 19	1,994	€ 10,506	€ 5.27
Finland	1.09	€ 27.21	1.40	9,194	€ 250,221	0.70	423	€ 11,525	1.00	17	€ 475	9,635	€ 262,221	€ 27.21
France	0.98	€ 24.60	1.40	21,136	€ 519,897	0.70	973	€ 23,946	1.00	40	€ 987	22,149	€ 544,829	€ 24.60
Germany (including ex-	1.21	€ 30.18	1.40	126,206	€ 3,809,019	0.70	5,813	€ 175,438	1.00	240	€ 7,230	132,258	€ 3,991,686	€ 30.18
Greece	0.74	€ 18.40	1.40	3,056	€ 56,227	0.70	141	€ 2,590	1.00	6	€ 107	3,203	€ 58,924	€ 18.40
Hungary	0.28	€ 6.88	1.40	19,521	€ 134,328	0.70	899	€ 6,187	1.00	37	€ 255	20,457	€ 140,770	€ 6.88
Ireland	1.39	€ 34.81	1.40	1,315	€ 45,765	0.70	61	€ 2,108	1.00	2	€ 87	1,378	€ 47,959	€ 34.81
Italy	0.99	€ 24.69	1.40	9,506	€ 234,711	0.70	438	€ 10,810	1.00	18	€ 445	9,962	€ 245,967	€ 24.69
Latvia	0.25	€ 6.19	1.40	3,615	€ 22,384	0.70	166	€ 1,031	1.00	7	€ 42	3,788	€ 23,458	€ 6.19
Lithuania	0.22	€ 5.46	1.40	9,730	€ 53,095	0.70	448	€ 2,445	1.00	18	€ 101	10,196	€ 55,641	€ 5.46
Luxembourg (Grand-Du	1.36	€ 34.07	1.40	594	€ 20,243	0.70	27	€ 932	1.00	1	€ 38	623	€ 21,213	€ 34.07
Malta	0.47	€ 11.67	1.40	474	€ 5,525	0.70	22	€ 254	1.00	1	€ 10	496	€ 5,790	€ 11.67
Netherlands	1.29	€ 32.27	1.40	4,785	€ 154,439	0.70	220	€ 7,113	1.00	9	€ 293	5,015	€ 161,845	€ 32.27
Poland	0.25	€ 6.14	1.40	26,909	€ 165,217	0.70	1,239	€ 7,610	1.00	51	€ 314	28,200	€ 173,140	€ 6.14
Portugal	0.48	€ 11.94	1.40	976	€ 11,660	0.70	45	€ 537	1.00	2	€ 22	1,023	€ 12,219	€ 11.94
Romania	0.16	€ 4.03	1.40	1,835	€ 7,405	0.70	85	€ 341	1.00	3	€ 14	1,923	€ 7,760	€ 4.03
Slovakia	0.24	€ 5.90	1.40	20,145	€ 118,902	0.70	928	€ 5,476	1.00	38	€ 226	21,111	€ 124,605	€ 5.90
Slovenia	0.24	€ 6.01	1.40	3,038	€ 18,266	0.70	140	€ 841	1.00	6	€ 35	3,184	€ 19,142	€ 6.01
Spain	0.68	€ 17.09	1.40	11,274	€ 192,651	0.70	519	€ 8,873	1.00	21	€ 366	11,814	€ 201,890	€ 17.09
Sweden	1.10	€ 27.54	1.40	12,309	€ 338,968	0.70	567	€ 15,612	1.00	23	€ 643	12,899	€ 355,223	€ 27.54
United Kingdom	1.45	€ 36.26	1.40	33,857	€ 1,227,649	0.70	1,559	€ 56,544	1.00	64	€ 2,330	35,480	€ 1,286,522	€ 36.26

Module 3: Healthcare utilisation and sub-components

Emergency Department Visit

Min	0.09	€ 9.10	0.10	34		0.30	9	€ 436	0.30	0	€ 13	43.4	€ 2,028	€ 9.10
Max	1.53	€ 153.29	0.10	9,015		0.30	2,491	€ 300,750	0.30	72	€ 8,675	11577.8	€ 1,397,717	€ 153.29
Factors:		**€ 100.00**	**0.10**			**0.30**			**0.30**					

	Labour Cost Index 2008	Cost per Emergency Department Visit	ED visit per case Severity 2	No. ED Visits Severity 2	Cost of ED Visit Severity 2	ED visit per case Severity 3	No. ED Visits Severity 3	Cost of ED Visit Severity 2	ED visit per case Severity 4	No. ED Visits Severity 4	Cost of ED Visit Severity 4	Total ED Visits	Total Cost ED Visits	Cost per Visit
European Union (27 countries)	1.00	€ 100.00	0.10	27,620	€ 2,453,743	0.30	7,633	€ 678,094	0.30	220	€ 19,560	35,473	€ 3,151,397	€ 88.84
Austria	1.16	€ 115.59	0.10	485	€ 56,096	0.30	134	€ 15,502	0.30	4	€ 447	623	€ 72,045	€ 115.59
Belgium	1.20	€ 120.01	0.10	805	€ 96,592	0.30	222	€ 26,693	0.30	6	€ 770	1,034	€ 124,055	€ 120.01
Bulgaria	0.09	€ 9.10	0.10	318	€ 2,899	0.30	88	€ 801	0.30	3	€ 23	409	€ 3,723	€ 9.10
Cyprus	0.72	€ 71.59	0.10	36	€ 2,542	0.30	10	€ 702	0.30	0	€ 20	46	€ 3,265	€ 71.59
Czech Republic	0.29	€ 28.51	0.10	2,249	€ 64,139	0.30	622	€ 17,725	0.30	18	€ 511	2,889	€ 82,375	€ 28.51
Denmark	1.53	€ 153.29	0.10	771	€ 118,162	0.30	213	€ 32,654	0.30	6	€ 942	990	€ 151,758	€ 153.29
Estonia	0.21	€ 21.07	0.10	136	€ 2,864	0.30	38	€ 792	0.30	1	€ 23	175	€ 3,679	€ 21.07
Finland	1.09	€ 108.86	0.10	657	€ 71,492	0.30	181	€ 19,757	0.30	5	€ 570	843	€ 91,819	€ 108.86
France	0.98	€ 98.39	0.10	1,510	€ 148,542	0.30	417	€ 41,050	0.30	12	€ 1,184	1,939	€ 190,776	€ 98.39
Germany (including ex-	1.21	€ 120.72	0.10	9,015	€ 1,088,291	0.30	2,491	€ 300,750	0.30	72	€ 8,675	11,578	€ 1,397,717	€ 120.72
Greece	0.74	€ 73.60	0.10	218	€ 16,065	0.30	60	€ 4,440	0.30	2	€ 128	280	€ 20,632	€ 73.60
Hungary	0.28	€ 27.52	0.10	1,394	€ 38,379	0.30	385	€ 10,606	0.30	11	€ 306	1,791	€ 49,291	€ 27.52
Ireland	1.39	€ 139.24	0.10	94	€ 13,076	0.30	26	€ 3,613	0.30	1	€ 104	121	€ 16,793	€ 139.24
Italy	0.99	€ 98.76	0.10	679	€ 67,060	0.30	188	€ 18,532	0.30	5	€ 535	872	€ 86,127	€ 98.76
Latvia	0.25	€ 24.77	0.10	258	€ 6,396	0.30	71	€ 1,767	0.30	2	€ 51	332	€ 8,214	€ 24.77
Lithuania	0.22	€ 21.83	0.10	695	€ 15,170	0.30	192	€ 4,192	0.30	6	€ 121	893	€ 19,483	€ 21.83
Luxembourg (Grand-Du	1.36	€ 136.28	0.10	42	€ 5,784	0.30	12	€ 1,598	0.30	0	€ 46	55	€ 7,428	€ 136.28
Malta	0.47	€ 46.67	0.10	34	€ 1,579	0.30	9	€ 436	0.30	0	€ 13	43	€ 2,028	€ 46.67
Netherlands	1.29	€ 129.09	0.10	342	€ 44,125	0.30	94	€ 12,194	0.30	3	€ 352	439	€ 56,671	€ 129.09
Poland	0.25	€ 24.56	0.10	1,922	€ 47,205	0.30	531	€ 13,045	0.30	15	€ 376	2,469	€ 60,626	€ 24.56
Portugal	0.48	€ 47.76	0.10	70	€ 3,331	0.30	19	€ 921	0.30	1	€ 27	90	€ 4,279	€ 47.76
Romania	0.16	€ 16.14	0.10	131	€ 2,116	0.30	36	€ 585	0.30	1	€ 17	168	€ 2,717	€ 16.14
Slovakia	0.24	€ 23.61	0.10	1,439	€ 33,972	0.30	398	€ 9,388	0.30	11	€ 271	1,848	€ 43,631	€ 23.61
Slovenia	0.24	€ 24.05	0.10	217	€ 5,219	0.30	60	€ 1,442	0.30	2	€ 42	279	€ 6,703	€ 24.05
Spain	0.68	€ 68.35	0.10	805	€ 55,043	0.30	223	€ 15,211	0.30	6	€ 439	1,034	€ 70,693	€ 68.35
Sweden	1.10	€ 110.15	0.10	879	€ 96,848	0.30	243	€ 26,764	0.30	7	€ 772	1,129	€ 124,384	€ 110.15
United Kingdom	1.45	€ 145.04	0.10	2,418	€ 350,757	0.30	668	€ 96,932	0.30	19	€ 2,796	3,106	€ 450,485	€ 145.04

Module 3: Healthcare utilisation and sub-components

Outpatient Visit Module

Min	0.09	€ 13.65	0.30	101		0.20	6	€ 436	0.20	0	€ 13	108	**€ 7,553**	**€ 13.7**
Max	1.53	€ 229.94	0.30	27,044		0.20	1,661	€ 300,750	0.20	48	€ 8,675	28753	**€ 5,206,735**	**€ 229.9**
Assumptions:		**€ 150.00**	**0.30**			**0.20**			**0.20**					

	Labour Cost Index 2008	Cost per Outpatient Department Visit	OP visit per case Severity 2	No. OP Visits Severity 2	Cost of OP Visit Severity 2	OP visit per case Severity 3	No. OP Visits Severity 3	Cost of OP Visit Severity 2	OP visit per case Severity 4	No. OP Visits Severity 4	Cost of OP Visit Severity 4	Total OP Visits	Total Cost OP Visits	Cost per OP Visit
European Union (27 countries)	1.00	€ 150.00	0.30	82,860	€ 11,041,843	0.20	5,089	€ 678,094	0.20	147	€ 19,560	**88,095**	**€ 11,739,498**	**€ 133.26**
Austria	1.16	€ 173.38	0.30	1,456	€ 252,430	0.20	89	€ 15,502	0.20	3	€ 447	**1,548**	**€ 268,380**	**€ 173.38**
Belgium	1.20	€ 180.02	0.30	2,415	€ 434,665	0.20	148	€ 26,693	0.20	4	€ 770	**2,567**	**€ 462,128**	**€ 180.02**
Bulgaria	0.09	€ 13.65	0.30	955	€ 13,046	0.20	59	€ 801	0.20	2	€ 23	**1,016**	**€ 13,870**	**€ 13.65**
Cyprus	0.72	€ 107.39	0.30	107	€ 11,439	0.20	7	€ 702	0.20	0	€ 20	**113**	**€ 12,162**	**€ 107.39**
Czech Republic	0.29	€ 42.77	0.30	6,748	€ 288,626	0.20	414	€ 17,725	0.20	12	€ 511	**7,175**	**€ 306,862**	**€ 42.77**
Denmark	1.53	€ 229.94	0.30	2,312	€ 531,730	0.20	142	€ 32,654	0.20	4	€ 942	**2,459**	**€ 565,327**	**€ 229.94**
Estonia	0.21	€ 31.61	0.30	408	€ 12,889	0.20	25	€ 792	0.20	1	€ 23	**434**	**€ 13,704**	**€ 31.61**
Finland	1.09	€ 163.29	0.30	1,970	€ 321,713	0.20	121	€ 19,757	0.20	3	€ 570	**2,095**	**€ 342,040**	**€ 163.29**
France	0.98	€ 147.59	0.30	4,529	€ 668,438	0.20	278	€ 41,050	0.20	8	€ 1,184	**4,815**	**€ 710,672**	**€ 147.59**
Germany (including ex-	1.21	€ 181.09	0.30	27,044	€ 4,897,310	0.20	1,661	€ 300,750	0.20	48	€ 8,675	**28,753**	**€ 5,206,735**	**€ 181.09**
Greece	0.74	€ 110.40	0.30	655	€ 72,292	0.20	40	€ 4,440	0.20	1	€ 128	**696**	**€ 76,860**	**€ 110.40**
Hungary	0.28	€ 41.29	0.30	4,183	€ 172,707	0.20	257	€ 10,606	0.20	7	€ 306	**4,447**	**€ 183,619**	**€ 41.29**
Ireland	1.39	€ 208.85	0.30	282	€ 58,840	0.20	17	€ 3,613	0.20	0	€ 104	**300**	**€ 62,558**	**€ 208.85**
Italy	0.99	€ 148.14	0.30	2,037	€ 301,772	0.20	125	€ 18,532	0.20	4	€ 535	**2,166**	**€ 320,838**	**€ 148.14**
Latvia	0.25	€ 37.15	0.30	775	€ 28,780	0.20	48	€ 1,767	0.20	1	€ 51	**824**	**€ 30,598**	**€ 37.15**
Lithuania	0.22	€ 32.74	0.30	2,085	€ 68,265	0.20	128	€ 4,192	0.20	4	€ 121	**2,217**	**€ 72,578**	**€ 32.74**
Luxembourg (Grand-Du	1.36	€ 204.43	0.30	127	€ 26,026	0.20	8	€ 1,598	0.20	0	€ 46	**135**	**€ 27,671**	**€ 204.43**
Malta	0.47	€ 70.01	0.30	101	€ 7,104	0.20	6	€ 436	0.20	0	€ 13	**108**	**€ 7,553**	**€ 70.01**
Netherlands	1.29	€ 193.64	0.30	1,025	€ 198,564	0.20	63	€ 12,194	0.20	2	€ 352	**1,090**	**€ 211,110**	**€ 193.64**
Poland	0.25	€ 36.84	0.30	5,766	€ 212,422	0.20	354	€ 13,045	0.20	10	€ 376	**6,131**	**€ 225,843**	**€ 36.84**
Portugal	0.48	€ 71.64	0.30	209	€ 14,991	0.20	13	€ 921	0.20	0	€ 27	**222**	**€ 15,938**	**€ 71.64**
Romania	0.16	€ 24.21	0.30	393	€ 9,520	0.20	24	€ 585	0.20	1	€ 17	**418**	**€ 10,122**	**€ 24.21**
Slovakia	0.24	€ 35.41	0.30	4,317	€ 152,875	0.20	265	€ 9,388	0.20	8	€ 271	**4,589**	**€ 162,534**	**€ 35.41**
Slovenia	0.24	€ 36.07	0.30	651	€ 23,484	0.20	40	€ 1,442	0.20	1	€ 42	**692**	**€ 24,968**	**€ 36.07**
Spain	0.68	€ 102.53	0.30	2,416	€ 247,694	0.20	148	€ 15,211	0.20	4	€ 439	**2,568**	**€ 263,344**	**€ 102.53**
Sweden	1.10	€ 165.23	0.30	2,638	€ 435,816	0.20	162	€ 26,764	0.20	5	€ 772	**2,804**	**€ 463,352**	**€ 165.23**
United Kingdom	1.45	€ 217.56	0.30	7,255	€ 1,578,405	0.20	446	€ 96,932	0.20	13	€ 2,796	**7,713**	**€ 1,678,133**	**€ 217.56**

Module 3: Healthcare utilisation and sub-components

Hospital Admission Module

	Labour Cost Index 2008	Unit Cost	Hospital Admission per case Severity 2	No. Hospital Admission Severity 2	Cost of Hospital Admission Visit Severity 2	Hospital Admission per case Severity 3	No. Hospital Admission Severity 3	Cost of Hospital Admission Visit Severity 3	Hospital Admission per case Severity 4	No. Hospital Admission Severity 4	Cost of Hospital Admission Visit Severity 4	Total Hospital Admits	Total Cost Hospital Admits	Cost per Hospital Admit
Min	0.09	€ 228	0.00	0		1.00	31	€ 36,355	0.90	1	€ 944	**32**	€ 37,299	**€ 227.56**
Max	1.53	€ 3,832	0.00	0		1.00	8,304	€ 25,062,505	0.90	216	€ 650,661	**8520**	€ 25,713,166	**€ 3,832.37**
Assumptions:		**€ 2,500**	**0.00**			**1.00**			**0.90**					
European Union (27 countries)	1.00	€ 2,500.00	0.00	0	€ 0	1.00	25,443	€ 56,507,810	0.90	661	€ 1,467,030	**26,103**	**€ 57,974,840**	**€ 2,220.99**
Austria	1.16	€ 2,889.71	0.00	0	€ 0	1.00	447	€ 1,291,839	0.90	12	€ 33,538	**459**	**€ 1,325,377**	**€ 2,889.71**
Belgium	1.20	€ 3,000.31	0.00	0	€ 0	1.00	741	€ 2,224,442	0.90	19	€ 57,750	**761**	**€ 2,282,192**	**€ 3,000.31**
Bulgaria	0.09	€ 227.56	0.00	0	€ 0	1.00	293	€ 66,762	0.90	8	€ 1,733	**301**	**€ 68,495**	**€ 227.56**
Cyprus	0.72	€ 1,789.86	0.00	0	€ 0	1.00	33	€ 58,539	0.90	1	€ 1,520	**34**	**€ 60,059**	**€ 1,789.86**
Czech Republic	0.29	€ 712.84	0.00	0	€ 0	1.00	2,072	€ 1,477,074	0.90	54	€ 38,347	**2,126**	**€ 1,515,421**	**€ 712.84**
Denmark	1.53	€ 3,832.37	0.00	0	€ 0	1.00	710	€ 2,721,187	0.90	18	€ 70,646	**728**	**€ 2,791,833**	**€ 3,832.37**
Estonia	0.21	€ 526.80	0.00	0	€ 0	1.00	125	€ 65,962	0.90	3	€ 1,712	**128**	**€ 67,675**	**€ 526.80**
Finland	1.09	€ 2,721.47	0.00	0	€ 0	1.00	605	€ 1,646,401	0.90	16	€ 42,743	**621**	**€ 1,689,144**	**€ 2,721.47**
France	0.98	€ 2,459.79	0.00	0	€ 0	1.00	1,391	€ 3,420,805	0.90	36	€ 88,809	**1,427**	**€ 3,509,614**	**€ 2,459.79**
Germany (including ex-	1.21	€ 3,018.10	0.00	0	€ 0	1.00	8,304	€ 25,062,505	0.90	216	€ 650,661	**8,520**	**€ 25,713,166**	**€ 3,018.10**
Greece	0.74	€ 1,839.92	0.00	0	€ 0	1.00	201	€ 369,962	0.90	5	€ 9,605	**206**	**€ 379,567**	**€ 1,839.92**
Hungary	0.28	€ 688.12	0.00	0	€ 0	1.00	1,284	€ 883,847	0.90	33	€ 22,946	**1,318**	**€ 906,794**	**€ 688.12**
Ireland	1.39	€ 3,480.89	0.00	0	€ 0	1.00	87	€ 301,121	0.90	2	€ 7,818	**89**	**€ 308,939**	**€ 3,480.89**
Italy	0.99	€ 2,469.06	0.00	0	€ 0	1.00	625	€ 1,544,348	0.90	16	€ 40,094	**642**	**€ 1,584,442**	**€ 2,469.06**
Latvia	0.25	€ 619.24	0.00	0	€ 0	1.00	238	€ 147,284	0.90	6	€ 3,824	**244**	**€ 151,108**	**€ 619.24**
Lithuania	0.22	€ 545.70	0.00	0	€ 0	1.00	640	€ 349,352	0.90	17	€ 9,070	**657**	**€ 358,421**	**€ 545.70**
Luxembourg (Grand-Du	1.36	€ 3,407.09	0.00	0	€ 0	1.00	39	€ 133,192	0.90	1	€ 3,458	**40**	**€ 136,650**	**€ 3,407.09**
Malta	0.47	€ 1,166.81	0.00	0	€ 0	1.00	31	€ 36,355	0.90	1	€ 944	**32**	**€ 37,299**	**€ 1,166.81**
Netherlands	1.29	€ 3,227.29	0.00	0	€ 0	1.00	315	€ 1,016,173	0.90	8	€ 26,381	**323**	**€ 1,042,555**	**€ 3,227.29**
Poland	0.25	€ 613.97	0.00	0	€ 0	1.00	1,771	€ 1,087,093	0.90	46	€ 28,223	**1,817**	**€ 1,115,315**	**€ 613.97**
Portugal	0.48	€ 1,194.05	0.00	0	€ 0	1.00	64	€ 76,719	0.90	2	€ 1,992	**66**	**€ 78,711**	**€ 1,194.05**
Romania	0.16	€ 403.45	0.00	0	€ 0	1.00	121	€ 48,722	0.90	3	€ 1,265	**124**	**€ 49,986**	**€ 403.45**
Slovakia	0.24	€ 590.24	0.00	0	€ 0	1.00	1,325	€ 782,352	0.90	34	€ 20,311	**1,360**	**€ 802,663**	**€ 590.24**
Slovenia	0.24	€ 601.18	0.00	0	€ 0	1.00	200	€ 120,184	0.90	5	€ 3,120	**205**	**€ 123,304**	**€ 601.18**
Spain	0.68	€ 1,708.84	0.00	0	€ 0	1.00	742	€ 1,267,600	0.90	19	€ 32,909	**761**	**€ 1,300,509**	**€ 1,708.84**
Sweden	1.10	€ 2,753.79	0.00	0	€ 0	1.00	810	€ 2,230,333	0.90	21	€ 57,903	**831**	**€ 2,288,236**	**€ 2,753.79**
United Kingdom	1.45	€ 3,626.02	0.00	0	€ 0	1.00	2,228	€ 8,077,658	0.90	58	€ 209,708	**2,286**	**€ 8,287,366**	**€ 3,626.02**

5.7.4 Module 4: Premature death

There is a good case for omitting premature death from the financial calculation because any cost attached to a statistical life is (a) purely notional and (b) has a powerful impact upon the valuations, which puts too much of a burden on the data. We do not have a good estimate of the number of deaths in each EU MS, let alone a means of valuing life.

For the sake of completion, we have worked up a calculation here on the following basis:

- **Number of fatalities:** 1 in 80 (0.25%) of cases that visit the GP, equivalent in this model to 0.05% of all cases

This linear approach leads to a high estimated number of fatalities in Germany, with 240 cases (0.291 fatalities per 100 000 population). The pattern of incidence would follow that of reported cases, with the highest incidence of fatalities occuring in Slovakia (0.7 fatalities per 100 000 population).

We have not applied the pork attribution ratio yet. Using 15% as the assumed proportion of *Salmonella* cases attributed to pork, the estimated 734 deaths in the EU associated with salmonellosis (out of the population of nearly 500 million), then 110 of these would be connected to pork.

Cost of fatality: as an exploratory approach, we are using a productivity measure as a proxy for value, based on a number of years' earnings.

Advantage of this approach:

- it is consistent across Member States
- it introduces economic parity through use of the labour cost index for each MS
- like the rest of this model, it is transparent and easily refined

Disadvantage of this approach:

- any estimate of the value of a statistical life is merely speculative
- as a result, the values can vary enormously, e.g.
    - the USDA *Salmonella* cost-calculator imputes a value of over $5 million per life (in 2010) based on willingness to pay studies (e.g. Fisher et al, 1989; Viscusi, 1993) adjusted for age and morbidity (Mauskopf and French, 1991)
    - if we impute 20 years average earnings, then the minimum cost per premature death occurs in Bulgaria with a value of € 61k and the maximum cost per case is valued in Denmark at over € 1 million

Table 26: Results from Module 4. Premature death

Premature Death

Daily Wage	**€ 130.09**		
Annual Wage	€ 33,822.85	Min	€ 283,763	€ 61,573
		Max	€ 195,619,710	€ 1,036,975

Assumptions:	**No. Earning Years**	20	**1.00**

	Labour Cost Index 2008		**Premature Death per case Severity 4**	**No. Premature Death Severity 4**	**Cost of Premature Death**	**Cost per Case of Premature Death**
European Union (27 countries)	1.00	€ 676,457	1.00	734	€ 441,058,928	€ 600,961
Austria	1.16	€ 781,905	1.00	13	€ 10,083,159	€ 781,905
Belgium	1.20	€ 811,833	1.00	21	€ 17,362,378	€ 811,833
Bulgaria	0.09	€ 61,573	1.00	8	€ 521,096	€ 61,573
Cyprus	0.72	€ 484,304	1.00	1	€ 456,915	€ 484,304
Czech Republic	0.29	€ 192,882	1.00	60	€ 11,528,968	€ 192,882
Denmark	1.53	€ 1,036,975	1.00	20	€ 21,239,608	€ 1,036,975
Estonia	0.21	€ 142,544	1.00	4	€ 514,852	€ 142,544
Finland	1.09	€ 736,384	1.00	17	€ 12,850,613	€ 736,384
France	0.98	€ 665,577	1.00	40	€ 26,700,316	€ 665,577
Germany (including ex-	1.21	€ 816,646	1.00	240	€ 195,619,710	€ 816,646
Greece	0.74	€ 497,851	1.00	6	€ 2,887,654	€ 497,851
Hungary	0.28	€ 186,193	1.00	37	€ 6,898,672	€ 186,193
Ireland	1.39	€ 941,870	1.00	2	€ 2,350,332	€ 941,870
Italy	0.99	€ 668,084	1.00	18	€ 12,054,059	€ 668,084
Latvia	0.25	€ 167,556	1.00	7	€ 1,149,590	€ 167,556
Lithuania	0.22	€ 147,657	1.00	18	€ 2,726,786	€ 147,657
Luxembourg (Grand-Du	1.36	€ 921,900	1.00	1	€ 1,039,599	€ 921,900
Malta	0.47	€ 315,718	1.00	1	€ 283,763	€ 315,718
Netherlands	1.29	€ 873,248	1.00	9	€ 7,931,509	€ 873,248
Poland	0.25	€ 166,131	1.00	51	€ 8,485,055	€ 166,131
Portugal	0.48	€ 323,090	1.00	2	€ 598,815	€ 323,090
Romania	0.16	€ 109,168	1.00	3	€ 380,285	€ 109,168
Slovakia	0.24	€ 159,710	1.00	38	€ 6,106,470	€ 159,710
Slovenia	0.24	€ 162,668	1.00	6	€ 938,068	€ 162,668
Spain	0.68	€ 462,382	1.00	21	€ 9,893,965	€ 462,382
Sweden	1.10	€ 745,130	1.00	23	€ 17,408,359	€ 745,130
United Kingdom	1.45	€ 981,138	1.00	64	€ 63,048,332	€ 981,138

5.7.5 Module 5: Total costs

The total costs of *Salmonella* are derived from all the earlier assumptions, equivalent to nearly 600 million Euros and 1.5 million cases. Three quarters of the cost is associated with premature death (based on 20 years average earnings in each MS).

5.7.6 Module 6: Total costs attributed to pork

15% of salmonellosis is attributed to pork and pork products in our model. The consequence is that 230 000 *Salmonella* cases are associated with pork at a cost of 90 million Euros, three quarters of which is due to premature death. The model attributes 110 deaths across EU-27 to *Salmonella* through pork.

Table 27: Total costs of all *Salmonella* infection

TOTAL COSTS OF ALL SALMONELLA INFECTION

	Cases	Productivity: Total Productivity	Productivity: Cost per Case	GP Visit: Total Cost GP Visits	GP Visit: Cost per Case	Emergency Department: Total Cost ED Visits	Emergency Department: Cost per Visit	Outpatient: Total Cost OP Visits	Outpatient: Cost per OP Visit	Hospital Admission: Total Cost Hospital Admits	Hospital Admission: Cost per Hospital Admit	Premature Death: Cost of Premature Death	Premature Death: Cost per Case of Premature Death	Total Cost: Total Cost	Total Cost: Cost per Case
Min	1,852	€ 35,913	€ 4	€ 5,790	€ 2	€ 2,028	€ 9	€ 7,553	€ 14	€ 37,299	€ 228	€ 283,763	€ 61,573	€ 372,345	€ 40
Max	493,454	€ 30,863,752	€ 83	€ 3,991,686	€ 38	€ 1,397,717	€ 153	€ 5,206,735	€ 230	€ 25,713,166	€ 3,832	€ 195,619,710	€ 1,036,975	€ 262,792,765	€ 680
European Union (27 countries)	1,511,882	€ 68,070,915	€ 45	€ 8,999,955	€ 22.21	€ 3,151,397	€ 88.84	€ 11,739,498	€ 133.26	€ 57,974,840	€ 2,220.99	€ 441,058,928	€ 600,961	€ 590,995,533	€ 390.90
Austria	26,565	€ 1,591,520	€ 60	€ 205,750	€ 28.90	€ 72,045	€ 115.59	€ 268,380	€ 173.38	€ 1,325,377	€ 2,889.71	€ 10,083,159	€ 781,905	€ 13,546,231	€ 509.93
Belgium	44,057	€ 2,364,484	€ 54	€ 354,285	€ 30.00	€ 124,055	€ 120.01	€ 462,128	€ 180.02	€ 2,282,192	€ 3,000.31	€ 17,362,378	€ 811,833	€ 22,949,522	€ 520.91
Bulgaria	17,434	€ 74,094	€ 4	€ 10,633	€ 2.28	€ 3,723	€ 9.10	€ 13,870	€ 13.65	€ 68,495	€ 227.56	€ 521,096	€ 61,573	€ 691,912	€ 39.69
Cyprus	1,944	€ 73,008	€ 38	€ 9,324	€ 17.90	€ 3,265	€ 71.59	€ 12,162	€ 107.39	€ 60,059	€ 1,789.86	€ 456,915	€ 484,304	€ 614,731	€ 316.30
Czech Republic	123,131	€ 1,766,144	€ 14	€ 235,252	€ 7.13	€ 82,375	€ 28.51	€ 306,862	€ 42.77	€ 1,515,421	€ 712.84	€ 11,528,968	€ 192,882	€ 15,435,022	€ 125.35
Denmark	42,194	€ 3,488,708	€ 83	€ 433,401	€ 38.32	€ 151,758	€ 153.29	€ 565,327	€ 229.94	€ 2,791,833	€ 3,832.37	€ 21,239,608	€ 1,036,975	€ 28,670,635	€ 679.50
Estonia	7,441	€ 81,709	€ 11	€ 10,506	€ 5.27	€ 3,679	€ 21.07	€ 13,704	€ 31.61	€ 67,675	€ 526.80	€ 514,852	€ 142,544	€ 692,124	€ 93.02
Finland	35,949	€ 2,003,758	€ 56	€ 262,221	€ 27.21	€ 91,819	€ 108.86	€ 342,040	€ 163.29	€ 1,689,144	€ 2,721.47	€ 12,850,613	€ 736,384	€ 17,239,595	€ 479.56
France	82,639	€ 3,774,421	€ 46	€ 544,829	€ 24.60	€ 190,776	€ 98.39	€ 710,672	€ 147.59	€ 3,509,614	€ 2,459.79	€ 26,700,316	€ 665,577	€ 35,430,628	€ 428.74
Germany (including ex-	493,454	€ 30,863,752	€ 63	€ 3,991,686	€ 30.18	€ 1,397,717	€ 120.72	€ 5,206,735	€ 181.09	€ 25,713,166	€ 3,018.10	€ 195,619,710	€ 816,646	€ 262,792,765	€ 532.56
Greece	11,949	€ 403,547	€ 34	€ 58,924	€ 18.40	€ 20,632	€ 73.60	€ 76,860	€ 110.40	€ 379,567	€ 1,839.92	€ 2,887,654	€ 497,851	€ 3,827,183	€ 320.31
Hungary	76,326	€ 895,513	€ 12	€ 140,770	€ 6.88	€ 49,291	€ 27.52	€ 183,619	€ 41.29	€ 906,794	€ 688.12	€ 6,898,672	€ 186,193	€ 9,074,658	€ 118.89
Ireland	5,141	€ 361,177	€ 70	€ 47,959	€ 34.81	€ 16,793	€ 139.24	€ 62,558	€ 208.85	€ 308,939	€ 3,480.89	€ 2,350,332	€ 941,870	€ 3,147,759	€ 612.34
Italy	37,168	€ 1,555,503	€ 42	€ 245,967	€ 24.69	€ 86,127	€ 98.76	€ 320,838	€ 148.14	€ 1,584,442	€ 2,469.06	€ 12,054,059	€ 668,084	€ 15,846,936	€ 426.36
Latvia	14,134	€ 187,670	€ 13	€ 23,458	€ 6.19	€ 8,214	€ 24.77	€ 30,598	€ 37.15	€ 151,108	€ 619.24	€ 1,149,590	€ 167,556	€ 1,550,638	€ 109.71
Lithuania	38,042	€ 398,898	€ 10	€ 55,641	€ 5.46	€ 19,483	€ 21.83	€ 72,578	€ 32.74	€ 358,421	€ 545.70	€ 2,726,786	€ 147,657	€ 3,631,808	€ 95.47
Luxembourg (Grand-Du	2,323	€ 144,486	€ 62	€ 21,213	€ 34.07	€ 7,428	€ 136.28	€ 27,671	€ 204.43	€ 136,650	€ 3,407.09	€ 1,039,599	€ 921,900	€ 1,377,046	€ 592.79
Malta	1,852	€ 35,913	€ 19	€ 5,790	€ 11.67	€ 2,028	€ 46.67	€ 7,553	€ 70.01	€ 37,299	€ 1,166.81	€ 283,763	€ 315,718	€ 372,345	€ 201.10
Netherlands	18,711	€ 1,320,763	€ 71	€ 161,845	€ 32.27	€ 56,671	€ 129.09	€ 211,110	€ 193.64	€ 1,042,555	€ 3,227.29	€ 7,931,509	€ 873,248	€ 10,724,453	€ 573.18
Poland	105,214	€ 1,185,206	€ 11	€ 173,140	€ 6.14	€ 60,626	€ 24.56	€ 225,843	€ 36.84	€ 1,115,315	€ 613.97	€ 8,485,055	€ 166,131	€ 11,245,187	€ 106.88
Portugal	3,818	€ 96,752	€ 25	€ 12,219	€ 11.94	€ 4,279	€ 47.76	€ 15,938	€ 71.64	€ 78,711	€ 1,194.05	€ 598,815	€ 323,090	€ 806,714	€ 211.29
Romania	7,176	€ 53,629	€ 7	€ 7,760	€ 4.03	€ 2,717	€ 16.14	€ 10,122	€ 24.21	€ 49,986	€ 403.45	€ 380,285	€ 109,168	€ 504,500	€ 70.30
Slovakia	78,764	€ 928,708	€ 12	€ 124,605	€ 5.90	€ 43,631	€ 23.61	€ 162,534	€ 35.41	€ 802,663	€ 590.24	€ 6,106,470	€ 159,710	€ 8,168,610	€ 103.71
Slovenia	11,880	€ 146,696	€ 12	€ 19,142	€ 6.01	€ 6,703	€ 24.05	€ 24,968	€ 36.07	€ 123,304	€ 601.18	€ 938,068	€ 162,668	€ 1,258,880	€ 105.97
Spain	44,080	€ 1,521,690	€ 35	€ 201,890	€ 17.09	€ 70,693	€ 68.35	€ 263,344	€ 102.53	€ 1,300,509	€ 1,708.84	€ 9,893,965	€ 462,382	€ 13,252,090	€ 300.64
Sweden	48,128	€ 2,827,019	€ 59	€ 355,223	€ 27.54	€ 124,384	€ 110.15	€ 463,352	€ 165.23	€ 2,288,236	€ 2,753.79	€ 17,408,359	€ 745,130	€ 23,466,573	€ 487.59
United Kingdom	132,377	€ 9,926,147	€ 75	€ 1,286,522	€ 36.26	€ 450,485	€ 145.04	€ 1,678,133	€ 217.56	€ 8,287,366	€ 3,626.02	€ 63,048,332	€ 981,138	€ 84,676,985	€ 639.67

TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK

% Attribution Pork: 0.15

Min	278	€ 5,387	€ 4	€ 869	€ 2	€ 304	€ 9	€ 1,133	€ 14	€ 5,595	€ 228	€ 42,564	€ 61,573	€ 55,852	€ 40
Max	74,018	€ 4,629,563	€ 83	€ 598,753	€ 38	€ 209,657	€ 153	€ 781,010	€ 230	€ 3,856,975	€ 3,832	€ 29,342,956	€ 1,036,975	€ 39,418,915	€ 680

		Productivity		GP Visit		Emergency Department		Outpatient		Hospital Admission		Premature Death		Total Cost	
	Cases	Total Productivity	Cost per Case	Total Cost GP Visits	Cost per Case	Total Cost ED Visits	Cost per Visit	Total Cost OP Visits	Cost per OP Visit	Total Cost Hospital Admits	Cost per Hospital Admit	Cost of Premature Death	Cost per Case of Premature Death	Total Cost	Cost per Case
European Union (27 countries)	226,782	€ 10,210,637	€ 45	€ 1,349,993	€ 22	€ 472,710	€ 89	€ 1,760,925	€ 133	€ 8,696,226	€ 2,220.99	€ 66,158,839	€ 600,961	€ 88,649,330	€ 391
Austria	3,985	€ 238,728	€ 60	€ 30,863	€ 29	€ 10,807	€ 116	€ 40,257	€ 173	€ 198,807	€ 2,889.71	€ 1,512,474	€ 781,905	€ 2,031,935	€ 510
Belgium	6,608	€ 354,673	€ 54	€ 53,143	€ 30	€ 18,608	€ 120	€ 69,319	€ 180	€ 342,329	€ 3,000.31	€ 2,604,357	€ 811,833	€ 3,442,428	€ 521
Bulgaria	2,615	€ 11,114	€ 4	€ 1,595	€ 2	€ 558	€ 9	€ 2,080	€ 14	€ 10,274	€ 227.56	€ 78,164	€ 61,573	€ 103,787	€ 40
Cyprus	292	€ 10,951	€ 38	€ 1,399	€ 18	€ 490	€ 72	€ 1,824	€ 107	€ 9,009	€ 1,789.86	€ 68,537	€ 484,304	€ 92,210	€ 316
Czech Republic	18,470	€ 264,922	€ 14	€ 35,288	€ 7	€ 12,356	€ 29	€ 46,029	€ 43	€ 227,313	€ 712.84	€ 1,729,345	€ 192,882	€ 2,315,253	€ 125
Denmark	6,329	€ 523,306	€ 83	€ 65,010	€ 38	€ 22,764	€ 153	€ 84,799	€ 230	€ 418,775	€ 3,832.37	€ 3,185,941	€ 1,036,975	€ 4,300,595	€ 680
Estonia	1,116	€ 12,256	€ 11	€ 1,576	€ 5	€ 552	€ 21	€ 2,056	€ 32	€ 10,151	€ 526.80	€ 77,228	€ 142,544	€ 103,819	€ 93
Finland	5,392	€ 300,564	€ 56	€ 39,333	€ 27	€ 13,773	€ 109	€ 51,306	€ 163	€ 253,372	€ 2,721.47	€ 1,927,592	€ 736,384	€ 2,585,939	€ 480
France	12,396	€ 566,163	€ 46	€ 81,724	€ 25	€ 28,616	€ 98	€ 106,601	€ 148	€ 526,442	€ 2,459.79	€ 4,005,047	€ 665,577	€ 5,314,594	€ 429
Germany (including ex-	74,018	€ 4,629,563	€ 63	€ 598,753	€ 30	€ 209,657	€ 121	€ 781,010	€ 181	€ 3,856,975	€ 3,018.10	€ 29,342,956	€ 816,646	€ 39,418,915	€ 533
Greece	1,792	€ 60,532	€ 34	€ 8,839	€ 18	€ 3,095	€ 74	€ 11,529	€ 110	€ 56,935	€ 1,839.92	€ 433,148	€ 497,851	€ 574,077	€ 320
Hungary	11,449	€ 134,327	€ 12	€ 21,115	€ 7	€ 7,394	€ 28	€ 27,543	€ 41	€ 136,019	€ 688.12	€ 1,034,801	€ 186,193	€ 1,361,199	€ 119
Ireland	771	€ 54,177	€ 70	€ 7,194	€ 35	€ 2,519	€ 139	€ 9,384	€ 209	€ 46,341	€ 3,480.89	€ 352,550	€ 941,870	€ 472,164	€ 612
Italy	5,575	€ 233,325	€ 42	€ 36,895	€ 25	€ 12,919	€ 99	€ 48,126	€ 148	€ 237,666	€ 2,469.06	€ 1,808,109	€ 668,084	€ 2,377,040	€ 426
Latvia	2,120	€ 28,150	€ 13	€ 3,519	€ 6	€ 1,232	€ 25	€ 4,590	€ 37	€ 22,666	€ 619.24	€ 172,439	€ 167,556	€ 232,596	€ 110
Lithuania	5,706	€ 59,835	€ 10	€ 8,346	€ 5	€ 2,922	€ 22	€ 10,887	€ 33	€ 53,763	€ 545.70	€ 409,018	€ 147,657	€ 544,771	€ 95
Luxembourg (Grand-Du	348	€ 21,673	€ 62	€ 3,182	€ 34	€ 1,114	€ 136	€ 4,151	€ 204	€ 20,497	€ 3,407.09	€ 155,940	€ 921,900	€ 206,557	€ 593
Malta	278	€ 5,387	€ 19	€ 869	€ 12	€ 304	€ 47	€ 1,133	€ 70	€ 5,595	€ 1,166.81	€ 42,564	€ 315,718	€ 55,852	€ 201
Netherlands	2,807	€ 198,114	€ 71	€ 24,277	€ 32	€ 8,501	€ 129	€ 31,666	€ 194	€ 156,383	€ 3,227.29	€ 1,189,726	€ 873,248	€ 1,608,668	€ 573
Poland	15,782	€ 177,781	€ 11	€ 25,971	€ 6	€ 9,094	€ 25	€ 33,877	€ 37	€ 167,297	€ 613.97	€ 1,272,758	€ 166,131	€ 1,686,778	€ 107
Portugal	573	€ 14,513	€ 25	€ 1,833	€ 12	€ 642	€ 48	€ 2,391	€ 72	€ 11,807	€ 1,194.05	€ 89,822	€ 323,090	€ 121,007	€ 211
Romania	1,076	€ 8,044	€ 7	€ 1,164	€ 4	€ 408	€ 16	€ 1,518	€ 24	€ 7,498	€ 403.45	€ 57,043	€ 109,168	€ 75,675	€ 70
Slovakia	11,815	€ 139,306	€ 12	€ 18,691	€ 6	€ 6,545	€ 24	€ 24,380	€ 35	€ 120,399	€ 590.24	€ 915,971	€ 159,710	€ 1,225,292	€ 104
Slovenia	1,782	€ 22,004	€ 12	€ 2,871	€ 6	€ 1,005	€ 24	€ 3,745	€ 36	€ 18,496	€ 601.18	€ 140,710	€ 162,668	€ 188,832	€ 106
Spain	6,612	€ 228,253	€ 35	€ 30,283	€ 17	€ 10,604	€ 68	€ 39,502	€ 103	€ 195,076	€ 1,708.84	€ 1,484,095	€ 462,382	€ 1,987,814	€ 301
Sweden	7,219	€ 424,053	€ 59	€ 53,284	€ 28	€ 18,658	€ 110	€ 69,503	€ 165	€ 343,235	€ 2,753.79	€ 2,611,254	€ 745,130	€ 3,519,986	€ 488
United Kingdom	19,856	€ 1,488,922	€ 75	€ 192,978	€ 36	€ 67,573	€ 145	€ 251,720	€ 218	€ 1,243,105	€ 3,626.02	€ 9,457,250	€ 981,138	€ 12,701,548	€ 640

5.7.7 How to Interpret the Results

The unit cost per human case of illness is €391 and the total estimated cost of *Salmonella* in the human population in the table above is € 88,649,330. These figures obviously need to be treated with great caution. The model is transparent, exposing the strength and weakness of underlying assumptions. The assumptions are reasonable at the time of publishing but, in the next stage of modelling (Stage 2, to be reported December 2010), we hope to refine the model further. We have identified three key areas for development in Stage 2 (discussed further in Chapter 8):

- Value of premature death – there is a case for omitting this from the model;
- Community multiplier – at the moment we assume that only 1 in 11.5 cases of *Salmonella* are reported in every MS. This is a strong assumption;
- Cost of Service utilisation – work is underway to refine the costs of GP and hospital costs.

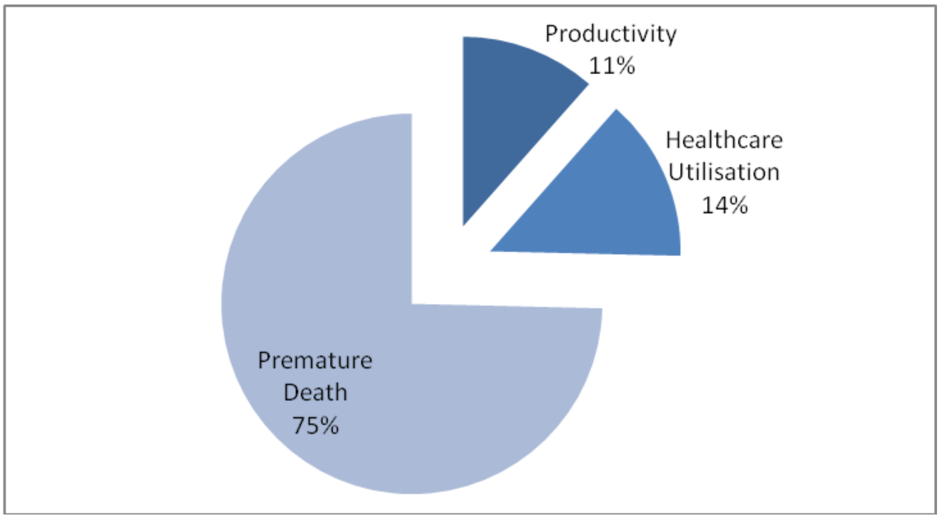
The estimated cost of human *salmonellosis* is conservative because it excludes the cost of chronic sequelae, out of pocket expenses, inconvenience and pain and suffering. On the other hand, it includes the cost of premature death (which is often omitted from cost estimates), so arguably there is a compensating variation between the two variables.

An earlier UK study (Roberts *et al*, 2003) produced an estimate of c £606 per case at 1994/5 prices excluding the cost of chronic sequelae, excluding the cost of loss of life, but including out of pocket expenses. Our estimate of € 640 per case in the UK is relatively low against this comparator, because it is at 2008 prices and includes the cost of loss of life. However, the severity mix is weaker, which would attract a lower unit cost. It includes a large number of non-severe cases (11.5 per 1 reported case compared to 3.2 per reported case in Roberts *et al*) which would not be hospitalised, would not require treatment, and would result in fewer days off work. This single comparison illustrates the caution needed in comparing cost estimates between studies.

5.7.8 Sensitivity of Model to Assumptions

Premature Death. In terms of costs, premature death is currently the most significant element, accounting for 75% of human health costs. The pie chart below shows the distribution of costs between productivity (days absent from work), healthcare utilisation and premature death. The total cost of salmonellosis in the EU-27, according to the model is approximately € 600 million. The pork attribution, at 15%, equates to c. € 90 million.

Figure 34: Distribution of Costs of *Salmonella* Attributed to Pork



The cost of premature death is conservative compared to Willingness to Pay (WTP) estimates: "Values based on the willingness-to-pay approach tend to be about twice as high as values not based on the willingness-to-pay approach". The assertion is confirmed by our model , since the UK value based on productivity (Stage 1) approaches € 1 million, compared to a transport estimate based in WTP uses € 2 million (see the figure below). The official figure used in the UK for food safety, on the other hand, is £1,065,504[16], which is in line with the Stage 1 model (at current exchange rates).

Cost of Chronic Sequelae. The exclusion of chronic sequelae costs means that human health costs are conservative.

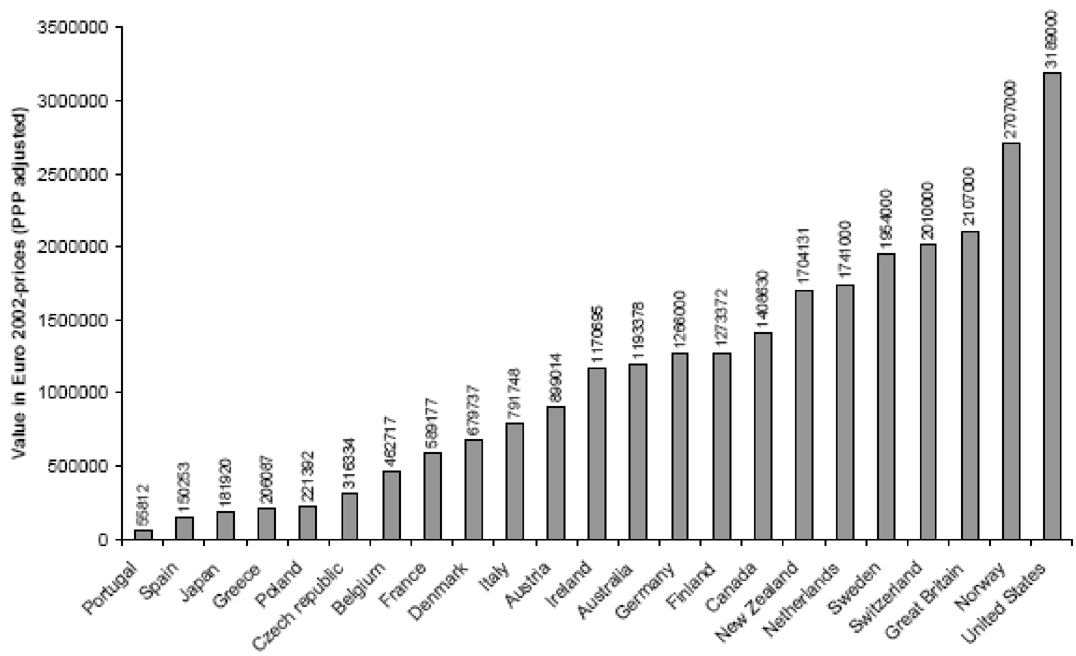
Severity and Incidence of *Salmonella*. The number of reported cases is multiplied by a factor of 11.5 in the model to gain an estimate of total *Salmonella* cases in the community. It is assumed that 0.05% of total cases result in a fatality. The model is sensitive to these assumptions. England, for example, quotes a lower multiplier of 3.2 (IID, 2000) but has a higher severity ratio of 0.3% of cases resulting in fatality (see end Tables response to consultation).

Attribution Between Pigs and Humans. We are using an estimate of 15% to attribute human salmonellosis to pigs and pork products. The model is clearly sensitive to this assumption. The Cost of Illness model does not address the complex attribution problem of the production chain, i.e. the extent to which reductions in *Salmonella* prevalence at slaughter as opposed to breeding translate into reductions in the human pool of pathogens. It is factored into the Cost Benefit Analysis (Chapter 7) model through a constant linear reduction year-on-year in human cases.

16 http://www.food.gov.uk/multimedia/pdfs/EURegulationsRIA.pdf

Figure 35: Cost of Premature Death and Statistical Value of Life

Official monetary valuation of a road accident fatality in selected countries. Euro in 2002- Prices (Source: page 9, Ref[17])



"The valuations vary substantially. An interesting pattern is that some of the countries that have a good safety record, such as Norway, Great Britain, Sweden and the Netherlands, assign a high monetary value to the prevention of a traffic fatality. Some countries with a rather bad road safety record, like Portugal, Spain and Greece, assign a low monetary value to the prevention of a fatality. The values are determined by two main factors: (1) The method used for estimating them. Values based on the willingness-to-pay approach tend to be about twice as high as values not based on the willingness-to-pay approach.(2) The level of real income in a country. Generally speaking, lower values are found in countries that have a relatively low gross domestic product per capita, higher values are found in the richer countries." See also Ref [18].

5.8 Summary

The chapter has presented an assessment of the economic impact of *Salmonella* in the Member States of the EU. A Cost of Illness model was developed for this purpose. Stage 1, reported here, uses uniform assumptions across all Member States. Stage 2, to be reported in December 2010 (SANCO/2008/E2/056) will refine the model based on individual MS assumptions. The model estimated the total number of cases using a pyramid of illness, an understanding of incidence and severity of disease. With this as a scale factor various costs were estimated in terms of: productivity costs (loss of labour); healthcare costs and premature death. The total annual costs for *Salmonella* as a whole are estimated to be approximately

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[17] SafetyNet (2009) Cost-benefit analysis, retrieved <15th June 2010> http://ec.europa.eu/transport/road_safety/specialist/knowledge/pdf/cost_benefit_analysis.pdf

[18] http://www.transportproblems.polsl.pl/pl/Archiwum/2008/zeszyt4/2008t3z4_07.pdf

€600 million, not all of which are attributable to *Salmonella* in pigs. Based on published sources, an attribution of 15% was used across all Member States. The total annual human health losses due to *Salmonella* in pigs were estimated to be approximately €90 million.

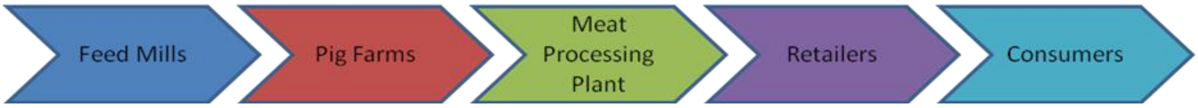
Given the scale of these losses it is important to ask how to minimize the risks that humans acquire *Salmonella* infections from the pig zoonotic reservoir, and in the process reduce the economic impact of this disease in society. The following Chapter examines the possible pre-harvest methods to reduce *Salmonella* in pigs and present a model to estimate the costs of a range of pre-harvest interventions within Member States and across the EU.

6 Pre-harvest interventions and their costs

6.1 Introduction

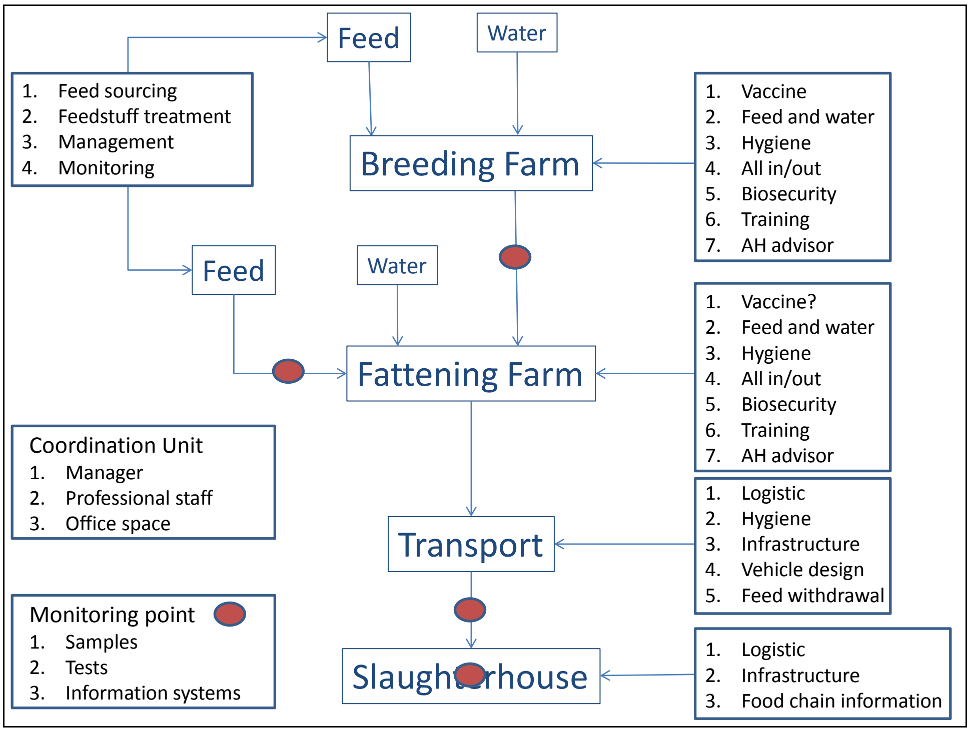
The recent concept of food production "farm-to-fork" establishes that the responsibility of producing safe food must be shared among the pork chain. Conceptually, the pig meat supply process can be represented as a flow diagram (see Figure 36) where a linear series of sectors are engaged in production, harvest, distribution, and consumption of pork (Sauli et al., 2005)

Figure 36: Schematic representation of the pork chain's steps included in a basic example



The components of the input industry and pig sector have been broken down into a conceptual model. The pig farms were separated into breeding and fattening pig units, the transport industry was identified and also the slaughterhouses. In addition the Consortium team realised the need for monitoring points in a *Salmonella* control campaign and also a coordination unit of all the activities. Potential interventions were identified in each point and then clustered according to the centre of attention. The model developed from this exercises is presented in Figure 37.

Figure 37: The pig sector and the clusters of *Salmonella* control points (developed by the Consortium)



6.2 Feed

One of the critical aspects of maintaining *Salmonella* control in pig units is the supply and handling of feed. A range of questions on the structure of the feed industry were defined to identify current location, capacity and management practices in each Member State. Very few Member States responded to this request for data. Procedures applied by feed and breeding stock industries pose risks in terms of *Salmonella* threats to the finishing pig units that produce slaughter pigs. An example of such a threat is the recent *Salmonella tenessee* outbreak in Finland.

The source of raw materials, management actions and general attitudes towards animal disease control and *Salmonella* in particular applied by the people involved in these industries has an impact on the ability of the pig finishing units to manage *Salmonella* in pigs under their control. There are two issues to be considered when elaborating on the relation between the feed factor and *Salmonella* infections in pig herds: commercial feed and home-mixed feed as a potential source of introduction of *Salmonella* and the role of feed in establishing infection in the animal. The latter is discussed at the "on-farm interventions- feed strategies" chapter.

6.2.1 Role of animal feed in *Salmonella* contamination

Animal feeds frequently contain *Salmonella* and the possibility that pigs fed contaminated feed may become infected should be considered.

Members of genus *Salmonellae* are characterized by their capacity to resist environmental stress and to grow on a wide range of feeds and feed ingredients due to their undemanding survival requirements. Large quantities of feed are produced, transported and stored daily for use in the pork production industry and ven minor *Salmonella* contamination at this level represents a potential hazard that can infect many pigs, and consequently expose consumers of food of animal origin to a food borne hazard (Davies et al., 2004). Despite the fact that most frequent *Salmonella* serotypes isolated from feed are rarely the most prevalent in animals, the potential for infection exists, and the consequences can be serious. Furthermore, four of the serotypes ranked in the top ten feed isolates (*infantis, typhimurium, agona* and *enteritidis*) are also in the top ten public health serotypes (EFSA, 2007) Therefore, it is sensible to include *Salmonella* animal feed production strategies when designing a national control programme to reduce herd prevalence, and ultimately human cases (Wierup et at., 1994)

6.2.1.1 Raw materials source

Some authors have found evidence to show that the main source of *Salmonella* contamination in feed mills is the feed ingredients that enter the mill (Coma, 2003;Davies et al., 2004) such as bone, meat, and fish meal, which have been associated with high rates, of *Salmonella* contamination (Appendix 2). As well as ingredients of animal origin, it should be emphasized that ingredients of vegetable origin can also be a source of *Salmonella*-contaminated feed (Jones et al., 2004).

In most instances contamination is however likely to occur at low prevalence and be highly clustered (i.e., not homogeneously distributed within infected batches) (Jones et al., 2004). In conjunction with the imperfect sensitivity of available laboratory testing methods (Maciorowski, 2000), these attributes make testing of ingredients both inefficient (many samples must be taken to identify contamination) and unreliable. Pragmatically, all feed inputs must be viewed as potentially contaminated since complete exclusion of contaminated feed ingredients is not currently feasible.

6.2.1.2 Feed mills environment source

Feed trucks have also been implicated as a source for feed and feeding stuffs contamination (Fedorka-Cray et al., 1997a). Davies and Wray (1997) carried out detailed sampling of spillage and dust from milling equipment in 9 animal feed mills. The *Salmonella* isolation rate ranged from 1.1%-41.7% of the samples and the most contaminated mills were from those where the inside of the cooling systems for pellet or mash had been colonised by *Salmonella*. A wide range of *Salmonella* serovars were found and included *S. Typhimurium* and *S. Enteritidis*.

6.2.1.3 Commercial animal feed control interventions

The Swedish *Salmonella* program has focused on animal feed, providing for extensive sampling and analysing of feed and raw material used in the production of compound feedingstuffs. The feed mills take the majority of the samples, around, 8-9 500 per year. From 1995 to 2005 between 0.2-1% of the samples were positive (Vagsholm, I, 2007). It is considered to be a fundamental pre-condition for a food chain free of *Salmonella* to provide feedingstuffs free of bacteria (here *Salmonella*). It has therefore been obligatory to heat treat all poultry feed since 1986 and today the same requirement is applicable to pig and cattle feed. The feed concerned is destroyed if *Salmonella* is found in compound feedingstuff (Wierup 2006). This is emphasised in the EFSA report in feed (EFSA 2008), in particular that moist heat can effectively decontaminate feed materials, as well as compound feed as long as sufficiently high temperatures and treatment times are used.

A similar approach has been also been used in Finland and Norway, which together with Sweden have the lowest *Salmonella* prevalence in Europe.

6.2.2 Feed Interventions and their costs

The following interventions have been identified at the level of sourcing and producing feed:

- <u>Feed Sourcing Interventions</u>
    - SUPPLIER ASSESSMENT: Extra costs for the choice of a more expensive supplier.
    - SEPARATE STORAGE (Quarantine): Extra costs concerning storage facilities.
    - RISK BASED SAMPLING & TESTING (for *soybean meal, rape seed meal, palm kernel meal and maize/corn*) Feed ingredients' surveillance is based on a sampling procedure which takes into consideration an uneven distribution of *Salmonella* contamination and is designed to detect a contamination in 5% of the batch with 95% probability. The size of the analytical sample is 25 gram and usually 8 samples are analyzed; each consisting of 10 pooled subsamples of 2.5 gram (see Appendix 3).
    - ACTION TAKEN WHEN POSITIVE (such as *heat treatment, chemical treatment, back to supplier, etc.)* Contaminated material if possible, be removed from the mill and treated elsewhere (thermal-*pelleting*- or chemical-organic acids)

- <u>Feed Stuff Treatment</u>
    - HEAT TREATMENT (*PELLETING*): ground feed is treated with hot water steam in a conditioner and then pressed to pellets
    - CHEMICAL TREATMENT *(organic acids, formaldehyde, pro-biotic, antimicrobials, sodium chlorate, etc.)*
- <u>Feed Safety Management System</u>
    - PEST CONTROL (rodent, insects, birds…)
    - GOOD HYGIENE PRACTICES TO AVOID CROSS CONTAMINATION
        - Storage Facilities: Regularly Cleaning and Disinfection and Maintenance
        - Delivery trucks: Cleaning & Disinfection and between trips
        - Cleaning & Disinfection: *Salmonella* positive findings will result in a dry cleaning, vacuum cleaning systems, of the unloading pit followed by chemical disinfection.
        - Good Manufacturing Practices: *Salmonella* Tailored Programme
        - Feed Mills: Modifications
        - Measures when Positive findings
- Monitoring
    - FINAL PRODUCT
    - ENVIRONMENT: two samples a week (from the silo and the elevator for feed material)
    - WATER QUALITY
    - EXTERNAL MONITORING (Official Feed Inspectors)

Table 28 presents an estimate of the costs of feed sourcing interventions:

Table 28: Costs associated with feed sourcing interventions to eliminate the risks of *Salmonella*

Country	FEED SOURCING (€/tonne)				**Reference**
	Sourcing	Separate Storage	Risk Based Testing	Treatment	
Spain			0.25	2.00	Personal communication with Spanish Private Industry February 2010
Sweden	3.20	0.63	1.00	0.40	*Enheten för foder och djurprodukter*

Table 29 presents an estimate of the costs of feedstuff treatment, management and monitoring at feed mills:

Table 29: Costs associated with feedstuff treatment, management and monitoring

Country	FEEDSTUFF TREATMENT (£/tonne)		FEED SAFETY MANAGEMENT (£/tonne)			MONITORING (£/tonne)	Reference
	T°	Acids	Pest Control	C&D	C&D trucks	Total costs	
Spain	3.00	3.50	0.10			1.15	Personal communication with Spanish Private Industry, February 2010
Sweden	0.90			0.09	0.05	1.15	*Enheten för foder och djurprodukter*

Table 30 presents the predicted impact of preventing contaminated feed into the pig holding:

Table 30: Decrease in *Salmonella* prevalence in pigs by preventing introduction of contaminated feed (%)

Country	FEED INTERVENTIONS (*Salmonella*-free feed)	Reference
	10-20% in high prevalence Member States 60-70% in low prevalence Member States	QMRA (2009)
Netherlands	Reduction of 15-30% of infections during the finishing period	Berends et al. (1996)

6.3 Replacement stock – breeding herd

There is consensus among some authors that the purchase of new infected stock and the subsequent transmission within the herd is a risk factor for introduction of *Salmonella*. Lo Fo Wong et al. (2004) reported that pigs in herds recruiting from more than three supplier herds had three-times higher odds to test seropositive than pigs in herds which bred their own replacement stock or recruited from a maximum of three supplier herds. van der Heijden et al. (2005) found that purchase of *Salmonella*-positive piglets increased the *Salmonella* prevalence at slaughter. Fedorka-Cray et al. (1997) showed that *Salmonella* might be introduced through infected pigs added to the herd. Cook and Miller (2005) found evidences that the proportion of seropositive animals in the herds seemed mostly associated with the risk of introducing *Salmonella* in the herds by purchase and transport of growing pigs, while integrated herds were less likely to become infected.

To guard against introduction of *Salmonella* through purchased animals, *Salmonella*-free breeding herds should be identified or established through a certification system (Oosterom, 1991) or through weaning in a clean environment (Fedorka). In addition, the number of supplier herds should be kept to a minimum (Quessy and Lo).

The breeding pigs project will carry out a thorough investigation of interventions relevant to breeding pigs, including vaccines, feed and water, hygiene, all in/all out, biosecurity, training, and animal health advisers.

6.3.1 Breeding pig interventions and costs

Infected replacement has been suggested as being a risk factor of *Salmonella* introduction (Lo Fong Wong, 2001; Fedorka-Cray et al. 1997). However; other researchers have not found a clear link between infected sows and their weaned pigs (Creus, 2007)

The current study has focused on slaughter pigs. Greater emphasis on breeding pigs will be included in a subsequent breeding pigs project. The slaughter pig model uses an estimate of the costs of producing and supplying replacement stock to fattening units that are *Salmonella* free. Literature reviews indicate that ensuring *Salmonella* free replacements is difficult and cannot be done with certainty. Attempts to produce *Salmonella* free replacement stock are also costly, but there are data that suggest that an overall reduced bacterial load in the breeding and sow areas can have an overall positive impact on costs. The results from the *Salmonella* tests in breeding stock indicate that this is an area that needs to be considered.

The analysis has used a estimate that a low-risk *Salmonella* replacement piglet for fattening will cost an extra €0.10 and that there will be associated additional costs in monitoring (see Table 31 and Table 32 below).

Table 31: Monitoring costs associated with low risk *Salmonella* replacements.

Country	***SALMONELLA*-LOW RISK REPLACEMENT** MONITORING (€/sample)					Reference
	Bacteriology ISO 6579	Serology (IDEXX ELISA)	Serotype	Sampling materials	Delivery	
Spain	32.3	2.5				CECAV Consultation February 2010
Spain	9.14	3.5	3	1	3	UAB-ASSAPORC Project November 2007

Table 32: Costs of veterinary checks of sows in the production of low risk *Salmonella* replacements

Country	***SALMONELLA*-LOW RISK REPLACEMENT**	**Reference**
Spain	102.31 €/sow/year	Sabata (2004)

6.4 On-farm interventions

Modification of farm practices can reduce the risk of *Salmonella* related foodborne illnesses but this reduced risk has to be continuous after harvest to the point of consumption.

Cook and Miller (2005) reported that farms feeding home-mixed rations had a lower seroprevalence of *Salmonella* and that feed might constitute a risk of introducing *Salmonella* in the herd. It has been seen that although *Salmonella*-free feed may help to prevent the introduction of *Salmonella* to a negative herd it does not have a controlling effect in herds where *Salmonella* is already present. In the situation where *Salmonella* is present in the herd, some form of acidification of feed or drinking water could be achieved through the addition of organic acids or other additives (Creus et al., 2007). The protective effect of offering pigs feeding materials with a low pH, in the form of added organic acids, whey or fermented by-products, against *Salmonella* infections has been proved in various studies. Apart from feed there are numerous possible routes of infection and transmission, some proven, some hypothesised and difficult to assess. A number of prevention and control options are available at farm level which are based on these potential risk factors and sources for *Salmonella*.

6.4.1 On-farm feed strategies

6.4.1.1 Feed sources: commercial versus home mixed

A substantial proportion of feed produced for animals is home produced although pigs normally grow and breed better when fed purchased pelleted rations (Walker, 1987) and that there is a lack of information about the risk of *Salmonella* introduction to the pig herd as a result of home-mixing of contaminated ingredients. As this type of feeding does not normally follow a heat treatment procedure that may help to destroy *Salmonella*, the risk can be mitigated by using antibacterial supplement such as organic acids, which may also have a beneficial effect on general *Salmonella* levels in animals receiving the feed (Creus et al., 2007). Both et al. (1982) found *Salmonella* in only 7% of faeces samples from sows on farms using own feeding stuffs compared with in one third of the sows on farms using commercial feed. Further studies in Denmark (Wingstrand et al. 1997, Dahl 1997, Stege et al. 1997) provide similar results indicating that *Salmonella* prevalence is higher in farms using commercial feed alone compared with own mixed feed.

Table 33 presents an estimate of the costs of using home-mixed feed to slaughter pigs (Goldbach et al., 2007):

Table 33: Costs associated with shifting from commercial feed to home-mixed feed

Country	**FEED SOURCING (Switch to home-mixed feed)**		**Reference**
	Feed Mixer (€)	Production costs associated with shifting to home-mixed(€/pig)	
Denmark	€89 000	€0.30	Goldbach et al., 2007

Table 34 presents the predicted impact of this strategy on *Salmonella* prevalence calculated by a Danish published research study (Goldbach et al., 2007):

Table 34: Decrease in *Salmonella* prevalence in pigs on farms switching to home-mixed feed

Country	**FEED SOURCING (Decreased *Salmonella* prevalence after switch to home-mixed feed)**	**Reference**

Denmark	63% (43%-83%)	Goldbach et al., 2007

6.4.1.2 Feed structure: meal versus pellets

It has been repeatedly reported that there is a marked effect of feed physical properties on microbial ecology and survival of *Salmonella typhimurium* in the pig gastrointestinal tract.

Pelleting was introduced primarily to provide all feed with a nutritionally better structure but pelleting prevents separation of different feed materials during handling ensuring a homogenous final feed. Changing from pelleted feed to meal results in a microbiological ecosystem in the gut that provides *Salmonella* with poorer growing conditions than pelleted feed (Jørgensen et al., 1999).

A significant number of authors have found lower *Salmonella* prevalence in pigs fed meal (Hansen et al., 2001; O'Connor et al., 2005; Lettelier et al., 2003; Kjeldsen & Dahl, 1999; Rajic et al, 2007; Garcia-Feliz et al., 2007). However, the purchasing of meal feed is commonly cheaper compared to pelleted feed because it is associated with worse conversion indexes.

Table 35 and Table 36 present an estimate of the costs of giving meal feed instead of pelleted feed and its predicted impact on *Salmonella* prevalence.

Table 35: Costs associated with shifting from pelleted feed to meal feed (€/tonne)

Country	FEED STRUCTURE (Meal feed instead of pelleted feed)	Reference
USA	4.1 (less when purchasing meal)	Harper (1998)
Spain (€/tonne)	2.5 (less when purchasing meal)	Personal communication with Spanish Private Industry June (2010)

Table 36: Impact on *Salmonella* prevalence in pigs on farms shifting from pelleted feed to meal feed (%)

Country	FEED STRUCTURE (Meal feed instead of pelleted feed)	Reference
Denmark	2- and 2.5-times lower odds of seropositivity	Lo Fo Wong et al. (2004)
Spain	Pelleted feed associated with increased risk of culture-positive faecal samples (OR = 2.28)	Garcia-Feliz et al. (2007)

6.4.1.3 Feed moisture: wet feed vs. dry feed

The association of liquid feed with lower *Salmonella* prevalence has been reported in several studies. Wet food favours fermentation leading to a rise of organic acids facilitating friendly bacteria growth that diminishes *Salmonella* (Stege et al. 1997, Dahl 1997, Van der Wolf et al. 2001a). For instance, Dubroca et al. (2006) studying 20 fattening farms in France found that sero-prevalence for *Salmonella* as well as *Salmonella* prevalence in the caecum was different depending on type of feeding, with sero-prevalence being 21.5% for dry feed and 10.3% for wet feed and prevalence in ceacum 28.5% and 12.7% respectively. Nevertheless, some authors have not found this relation (Rajic et al. 2007)

Table 37 and **Fehler! Verweisquelle konnte nicht gefunden werden.**present an estimate of the costs of giving liquid feed instead of dry feed and its predicted impact on *Salmonella* prevalence.

Table 37: Costs associated with shifting from dry feed to wet feed

Country	**FEED STRUCTURE (Wet feed instead of dry feed)**	**Reference**
USA (€/kg pig meat produced)	0.20€ more if giving wet feed	Dunn (2005)
Netherlands (€/pig)	1.48€ (wet feed)	van der Gaag (2004)

6.4.1.4 Feed particle size: coarse vs. fine-ground feed

Some studies reported that pigs that are fed with coarsely ground meal tend to have lower *Salmonella* prevalence than those fed the finely ground diet, since coarse feed is retained in the pigs' stomach for longer periods where the acidic conditions help destroy *Salmonella*. However, pigs consuming the coarsely ground diet exhibited significantly poorer feed conversion rates when compared to those receiving the finely ground feed (Farzan et al., 2006; Kranker et al., 2001; van der Wolf et al., 2001b; Beloeil et al., 2004).

Wingstrand et al. (1997) carried out some research on feeding where grinding intensity was used to investigate the impact on seroprevalence of *Salmonella*. The results show the proportion of seropositive animals in the group receiving coarse feed between 13% and 26%, compared with the animals receiving fine feed having considerably higher prevalence of between 34-57%. Kjeldsen and Dahl (1999) emphasised the importance of feed in their study on the impact of grinding intensity (particle size max 2 mm or 4.5 mm) and conditioning of feed (whole grain / pellet). The difference was significant only on farms with low prevalence of *Salmonella*.

Coma (2003) pointed out several times the increased feed conversion ratio (FCR) associated with feeding whole grain compared with pelleted feed. The FCR in the above mentioned studies by Kjeldsen and /Dahl (1999) was 2.62 kg feed per kg increase in body weight in case of mixed pelleted feed (particle size max 2 mm or 4.5 mm), while the FCR was 2.89 using the same base feed as whole grain. This resulted in an increased feed cost of about 5-7% due to not pelleting.

Visscher (2006) used four fattening farms in North Germany to study the impact on *Salmonella* prevalence based on different grinding intensity (course / conventional) and several types of acid additives. The results indicated clearly that the number of animals which tested positive (in meat juice) could be reduced considerably.

It is interesting to observe that the locations where *Salmonella* was most frequently found were the tonsils and the caecum content, indicating the caecum to represent a reservoir for *Salmonella*, something Visscher (2001) verified on finished fattening pigs at slaughter which had been monitored since the beginning of the fatterning period. The increased starch content in the caecum / colon already observed by Papenbrock et al. (2005) and Brüning (2005) after feeding with coarser grain was also observed and verified here under field conditions. This increased starch in the caecum / colon changes the substrate and therefore also its flora and fermentation capabilities, expressing it in increased production of free fatty acids, lower pH and increased butyric acid.

Offenberg (2007) used piglets in the flatdeck phase (8-27 kg) in four large farms in Northern Germany showing high prevalence of *Salmonella*. The home-mixed feed was specific for the farms concerned. The results clearly indicated that coarser feed in combination with the use of acids was beneficial for *Salmonella* reduction.

Sloth et al. (1998) found that the use of mixed whole grain during fattening had a positive impact on *Salmonella* prevalence on a farm. The same results were achieved by Kjærgaard et al. (2002), who observed that fattening pigs receiving whole grain had less *Salmonella*, however, Kjærgaard et al. did not detect the same effect by sows fed whole grain.

Rajic et al. (2007) studied the risk parameters having impact on *Salmonella* prevalence in slaughter pigs in Alberta, Canada. Their results support others that found pelleted mixed feed carries a higher risk for *Salmonella* than whole grain type (coarse) feed. They found *Salmonella* in 31.9% of pooled faecal samples overall, with 60% of the samples from farms using pelleted feed showing positive and 16% of samples from farms using whole grain type (coarse) of feed.

6.4.1.5 Addition of additives: organic acids and other additives

At a farm level, some feeding strategies have been shown effective to prevent colonization of the gastrointestinal tract by *Salmonella*e. A low pH of feed or water is has been shown to have a protective effect against *Salmonella* infection. The mechanism behind this effect is probably not that pigs presented with acidified feed or water have a different colonisation resistance but that *Salmonella* are killed in the feed (van Winsen et al., 1997) or in the stomach by the low pH and the acids and therefore cannot infect the animal (Rubin, 1978; Rubin et al., 1982). The protective effect of offering pigs feeding materials with a low pH, in the form of added organic acids, whey or fermented by-products against (subclinical) *Salmonella* infections has been discussed in a number of papers (van Schie, 1987; van Winsen et al.,1997; Dahl, 1997a). These findings support the hypothesis that a decrease in exposure and an increase in pig resistance may be obtained through a change in feeding strategy.

The anti-bacterial impact of organic acids (natural fermentation) has been known for a long time and they have therefore been used in feedingstuffs to conserve the feed but also to assist the digestion process (e.g. by improve the acidification of the intestinal tract. The use of organic acids (e.g. formic- and propionic acids) can contribute to the decontamination of with *Salmonella* contaminated feed and also prevent the recontamination of such feed through transport, storage and use on the farm (Strauss 2001).

These organic acids have furthermore been used for decades to influence the gastro-intestinal flora including that of pathogens such as *E. Coli* and or zoonotic pathogens such as *Salmonella* and Campylobacter in poultry (Van Immerseel et al. 2006).

Feeding regimes aiming at reducing *Salmonella* in pigs recommend the use of acid (as additive to dry feed / or wet feed / or drinking water). Van der Wolf et al. (2001b) came to the conclusion that increase of *Salmonella* in faecal samples can be expected if acids are left out of the feed.

Creus et al. (2007) found also that adding acids to commercial pelleted mixed feed had a positive impact on *Salmonella* prevalence. The positive effect could be verified in two separate test phases using mesenteric lymph nodes for testing, first by adding 0.6% of lactic acid in combination with 0.6% of formic acid during the last 14 months of the fattening and in the second phase – due to the high price of the acids used in the first phase – using 0.8% of formic acid or 0.4% of lactic acid in combination with 0.4% of formic acid, but only for eight or nine last weeks of the fattening period. A positive effect was also found in this second phase, both in sero-prevalence in the group receiving combination of formic and lactic acid as well reduction in excretion of *Salmonella* through faeces and bacteriological test of mesenteric lymph nodes. Recommendations in Denmark for pig farmers also include the use of organic acids (e.g. Jørgensen 2005).

Nevertheless, some studies couldn't find any significant benefit of using these acids. For example Nollet et al (2004) and Lo Fo Wong et al. (2004), carried out epidemiological investigation on the use of organic acids and found no significant effect on *Salmonella* prevalence in pigs. The reason for this might be that other parameters overshadow the effect of organic acids, such as the amount used, time and duration of use as well as other condition of the wet feed, e.g. the different components of the feed which could include organic acid or not. The grain size of the feed could be another overshadowing parameter possibly having a considerable impact.

It can be concluded that the use of organic acids, such as formic, acetic, propionic and butyric acid, can inhibit *Salmonella* by reducing the pH of the gut, creating an unfavourable environment for the organism (8–40 kg can help reduce infection in finishers). However, it has implications for the equipment on the unit such as metal pipe work and fittings as well as concrete under drinkers may be corroded by the acid and will need replacing.

Table 38 presents an estimate of the costs of different type of feed options

Table 38: On-farm costs associated with the addition of additives to the diet

Country	Adding Acids		Pro biotics	Pre biotics	Reference
	to Feed	to Water			
Netherlands (€/pig)	1.78	1.73			van der Gaag, (2004)
Netherlands (€/pig)	2.49				van der Wolf (2001)
Spain (€/tonne)	6				Spanish Private Industry consultancy March 2010
Spain (€/tonne)	3.5 (extra cost)		2.8 (extra	3.5 (extra	Spanish Private Industry consultancy June 2010

			cost)	costs)	
Denmark (€/pig)	0.4				Goldbach et al, (2006)

Table 39 presents the estimated reduction on *Salmonella* shedding of adding additives to feed or water:

Table 39: Reduction of *Salmonella* prevalence after addition of organic acids to pigs' diet (%)

Country	ADDITION OF ADDITIVES	Reference
Denmark	Reduced pen faecal prevalence after addition of 2.8% lactic acid to pigs' diet: 43%	Jorgensen et al. (2001)
Denmark	Decrease in *Salmonella* prevalence in pigs: 50%	Goldbach et al, (2006)

6.4.2 Water Sanitation (chlorine/peroxides)

Jensen et al. (2004) detected *Salmonella* in water samples from water bowls. Feder et al. (2001) also reported that *Salmonella* were detected in 63% (15 of 24) of the water samples, collected from water bowls or mud holes. Water bowls or drinking troughs might pose a higher risk for being contaminated by faeces compared to water nipples and thereby be a risk factor for *Salmonella*.

The water supply should be from a mains or other chlorinated source. If the water supply is from a private source, it should be tested regularly and treated with chlorine (2-3 mg/l) or peroxides (10-30ml/ 1,000 l)

Table 40 presents an estimate of adding chlorine or peroxides to treat drinkable water.

Table 40: Costs of farm water treatment in a herd of 100 pigs

Country	Water treatment		Reference
	Product	Equipment	
UK (€/pig)	0.06	0.008	Gadd (2001)

Table 41 presents an estimate of adding chlorine or peroxides to treat drinkable water.

Table 41: Association between use of non chlorinated water from private wells and *Salmonella* seropositivity

Country	Water treatment	Reference
Spain	OR = 3.64	Mejia (2003)

6.5 On-Farm health status, hygiene and biosecurity

Prevention of pathogen introduction into the farm will involve implementing pest controls, applying bio-security measures, ensuring good herd health status and following efficient cleaning and disinfection procedures. *Salmonella* control actions may contribute to increased production through reduced veterinary costs, incremental growth and reduced mortality figures.

6.5.1 Health status interventions

- ***Regular veterinary checks***

Concurrent infections of gastrointestinal pathogens may cause intestinal damage increasing risk of *Salmonella* shedding (Dahl et al., 1997; Beloeil et al., 1999; Bush et al., 1999; Funk et al., 2001). van der Wolf et al., (1999) described an association between good health herd status and lower *Salmonella* prevalence. Keeping a good general pig herd health status will prevent concurrent diseases that may increase susceptibility to *Salmonella*.

- ***Vaccination***

The vaccination of fattening pigs in Europe is rare and is more common in breeding pigs. Vaccination has an impact on the diagnostic tests used for the classification of farms (sero-diagnostis) (Selke et al. 2007) since the reaction of the field infection cannot be differentiated from the vaccination, except perhaps on the basis of the titre of the antibodies. A new marker vaccine which has been developed recently, might overcome this problem (Selke 2007). Springer et al. (2005) demonstrated a significant lower infection rate of the intestinal tract and the relevant lymph nodes in vaccinated pigs (an indication of a reduced infection pressure).

- ***Sanitary slaughter (depopulation when positive)***

Total depopulation is a potential way to break the cycle of infection but it has not always been successful (Wahlstrom et al., 1997; Davies et al., 2001a).

Table 42 presents estimated costs for measures that improve the general herd health status of the pig holding and, at the same time, improve control for *Salmonella*.

Table 42: Costs of farm-level health status measures (€/pig).

Country	HEALTH STATUS			Reference
	Vet Regular checks	Inactivated Vaccine	Sanitary Slaughter when positive	
USA		0.70		Miller (2005)
SPAIN		0.20		Veterinary College Leon (2010)
USA	0.70			Miller (2005)
SWEDEN			10.5	Engvall et al. (1994)

Table 43 presents estimated reduction in prevalence as a consequence of implementing measures that improve the general health status of the pig holding:

Table 43:Reduction of *Salmonella* prevalence after addition of organic acids to pig feed (%)

Country	ADDITION OF ADDITIVES	Reference
Denmark	Depopulation and repopulation after thorough cleaning & disinfection yielded a 45.6% success rate	(Dahl, 1999)
Denmark	Decrease in *Salmonella* prevalence in pork: 7%	Goldbach et al, (2006)

- **Cleaning and disinfection practices**

Animal housing facilities can quickly become contaminated and animals held in such pens are also rapidly infected. It is recommended that pig producers keep units clean but routine cleaning procedures are often insufficient to remove significant pathogens from the environment. A consistently high standard of cleaning and disinfection is considered to be one of the most important ways to break the on-farm cycle of re infection with *Salmonella*.

Inadequate cleaning is a risk factor for *Salmonella*. *Salmonella* is a very resistant pathogen, which can survive for long periods in the environment and resist chemical disinfection when surrounded by organic matter (Davies et al., 2003, cited by Creus, 2009). The presence of residual contamination after cleaning is a risk factor (Beloeil et al. 2004). The use of pressure washing on farms has been shown to produce aerosol containing *Salmonella* organisms, and may contribute to the spread of infection in animal housing (Hinton et al., 1983). Mannion et al. (2005) found lower *Salmonella* prevalence in herds that always washed and disinfected compared to herds that only washed, and Roesler et al. (2005) showed that efficient disinfection procedures were effective in decreasing the contamination with *Salmonella*. Berends et al. (1996) concluded that farm hygiene was a crucial risk factor for *Salmonella*. Blaha et al. (2009) presented very similar results from farms in Western Germany.

The efficacy of cleaning treatments has been ranked as follows: pressure washing followed immediately by steam application was the best method of cleaning a holding pen floor, followed by use of a sanitising agent at the greatest concentration recommended by the manufacturer, and then by pressure washing alone. Pressure washing followed by a delayed steam application appeared to give a poor final result on the surface (Small et al., 2007). This however contradicts however the results of Hinton et al. (1983).

- **Pig management**

Pig holding management and pig flow practices are an important tool to decrease the microbiological burden on a holding. All in/All out systems are particularly effective (Beloil et al., 2004; Lo Fo Wong et al., 2004). All in/All out systems prevent contamination between batches and break the cycle of infection within the farm (Lo Fo Wong Et Al., 2004). Continuous production compared to all-in/all-out increases the risk of individual *Salmonella* prevalence (OR = 2.3) (Farzan et al. 2006; Creus et al., 2005).

- Pig management:
  - Change to all in-all out production
  - *Salmonella*-negative replacements
- Improved Hygiene
  - Additional cleaning and disinfection

Table 44: Cost of farm-level hygienic measures (€/pig).

Country	CLEANING AND DISINFECTION		MANAGEMENT	Reference
	Hygienic daily protocol	Extra Hygiene	Move to AIAO	
Netherlands	0	0.08	0.42	van der Gaag (2004*)*

- **Bio-security**

Animal farms with intensive human traffic have been associated with high faecal *Salmonella* shedding (Funk et al., 2001). All vertebrates are susceptible to *Salmonella* infection and pests, insects and other livestock species share the same serotypes as pigs. Barber et al. (2002) found positive samples in cats (12%), bird faeces (8%), flies (6%), and mice intestine (5%). Wild and domestic fauna can potentially introduce *Salmonella* through direct contact with pigs, or by faecal contamination of feed or farm equipment. More than 2 people present on the site each day might increase *Salmonella* risk (Funk et al., 2001). Oosterom et al. (1983) proved that *Salmonella* serotypes occurring at the fattening farm did not find their way into the test piggery when hygienic barriers were used. Holdings with showers and changing room facilities at pig unit entrances were associated with reduced *Salmonella* seroprevalence (Lo Fo Wong et al., 2004).

The following have been identified as potential interventions for on-farm biosecurity measures:

- Biosecurity barriers
    - Pest Control (bird-proved nets in windows, rodent baits, electric fly killer): Baiting and trapping policy with frequent baiting for rodents and steps to exclude birds from buildings using netting and cover feeders.
    - Quarantine/Pens for Sick Pigs: To isolate and observe incoming stock. Preferably last for a minimum of five weeks, with no cross contact between quarantine and the main unit
    - Closed fences between pens: Construction of pen separations to avoid snout contact

- Biosecurity Procedures in place between pens:
    - Changing Clothes and Boots Facilities: Waterproof boots and protective overalls to be regularly disinfected and/or laundered on the farm.
    - Footbath: Boots cleaned and then dipped in suitable fresh disinfectant solution on entering and leaving separate buildings within the unit

Table 45 presents estimated costs for bio-security barriers.

Table 45: Costs of farm-level bio-security barriers

Country	BIOSECURITY BARRIERS			Reference
	Quarantine pen	Pest Control	Closed fences between pens	
Netherlands (€/pig).		0.07	0.01	van der Gaag (2004*)*
Spain (€/unit/year)		0.8		Spanish Private Industry consultancy March 2010
USA (€/pig)	0.20			Neumann and Kniffen, (1999)

Table 46 presents estimated costs for biosecurity procedures.

Table 46: Costs of farm bio-security procedures.

Country	BIOSECURITY PROCEDURES		Reference
	Special clothing	Footbath	
Netherlands (€/pig).	0.40		van der Gaag (2004*)*
Spain (€/holding)	0	125	Spanish Private Industry consultancy March 2010

Table 47: Reduction in slaughter pig lymph node prevalence by preventing infection from external sources of *Salmonella* (i.e. rodents and birds)

Country	ADDITION OF ADDITIVES	Reference
	10-20% in both high and low prevalence countries;	QMRA

6.6 Transport and handling facilities

During transportation, pigs are subjected to several stress factors, e.g. noise, smells, mixing with unfamiliar pigs from other rearing pens or farms, high stocking densities, long duration of transport, changes in environmental temperature and a general change of environment (Warriss et al., 1992). Stress can induce carriers to shed *Salmonella* at a higher rate and increase the susceptibility of *Salmonella*-free pigs to infection (Mulder, 1995; van Winsen et al., 2001). Davies et al. (2000) reported that the prevalence of *Salmonella* was higher in faecal samples from gilts after arrival at the breeding farm than before transport; with serotype profiles indicative of both increased *Salmonella* shedding after transport and occurrence of new infections after introduction in the breeding herd.

Transport and handling of pigs can cause stress and provoke carrier pigs to excrete *Salmonella* again. Most acute infections in pigs are sub-clinical ie pigs show limited or no disease symptoms. However, after initial infection pigs enter a carrier state of varying length in which they do not excrete *Salmonella* but in which a small focus of infection remains that can later be triggered to re-activate the infection and excretion.

In addition the condition and management of both transport and handling facilities can lead to environmental contamination, creating a source of risk through the infection of pigs in transit and the possibility of people involved in the transport carrying *Salmonella* onto farms and slaughterhouse facilities.

6.6.1 Transport Interventions

Intervention against *Salmonella* at transport can be summarized as follows:

- Reduce faecal shedding
    - Feed withdrawal 12 to 24 hours before transport reduces transport stress on carriers (Isaacson et al., 1999)
- Avoid stress: Stress increases both the animals' susceptibility to infection and the numbers of bacteria shed by carrier pig. Reduction of physical and psychological stress, by careful handling and transport. Drivers must have animal welfare training measured by a constant inspection on transport loss and carcass damage..
- Logistic Transportation
    - Limited number of herds per truck
    - Logistic Delivery: Lorries can carry only pigs from one herd at the time to another herd or slaughterhouse to avoid contact between different herds.
    - Herd status separation
- Truck design
    - Smooth sided trucks:
    - Adjusted loading platform
- Cleaning and disinfection of the vehicle
    - Clean and disinfect trucks prior to introduction of new pigs: Vehicles must have been cleaned and disinfected as soon as possible after animals have been transported in order to decrease the high level of contamination usually found in the trucks (Purvis G.M., et al. 2005)
    - Changing the clothes of drivers between batchesto minimise cross contamination

6.6.2 Transport Intervention costs

The costs of the transport interventions are summarized in Table 48 and Table 56.

Table 48: Costs of transport interventions that relate to stress avoidance and logistic delivery (€/pg).

Country	REDUCTION FAECAL SHEDDING		LOGISTIC TRANSPORTATION			References
	Feed withdrawal	Quiet loading/ driving	Logistic delivery	Limited addresses/truck	Herd status separation	
Netherlands	0.00	0.17	1.92	0.63	0.05	van der Gaag (2004)

Table 49: Costs of transport interventions that relate to maintenance and cleaning and disinfection (€/pig).

Country	TRUCK DESIGN		C&D		References
	Smooth sides truck	Adjust loading platform	vehicle after delivery	Changing drivers' clothes	
Spain	0	0	Included within transport costs	0	Spanish Private Industry consultancy March 2010
Netherlands	0.16	0.09	0.23	0.09	van der Gaag, (2004)

6.7 Lairage in slaughterhouses

After transport to the abattoir, pigs are usually kept in a lairage for a period before killing. This time period can vary considerably in length, but usually most pigs are slaughtered on the day of arrival (Warriss and Bevis, 1986). Besides functioning as a holding area for pigs waiting to be slaughtered, the lairage also allows the pigs to recover from the stressful effects of transport and the associated handling. Many of the same stress factors present during transport are also in force during the waiting time in the lairage, and the proportion of pigs shedding *Salmonella* has been shown to increase with the length of time spent there(Morgan et al., 1987b). Furthermore, the lairage is generally only cleaned at the end of the day and is therefore a potential source of contamination of *Salmonella*-negative or low-infected pigs that can easily pick up *Salmonella* from other pigs or the environment either by the oral or nasal route, or by soiling of the skin (Craven and Fedorka, in Lo Fo Wong et al 2002). The longer the time the pigs spend in the lairage the greater is the possibility of contamination and thus the probability of ending up as a positive carcass (Morgan and Simonsen, in Lo Fo Wong et al 2002).

It has been shown that infected pigs in slaughterhouses can be a source of contamination of slaughterhouse surfaces and clean carcasses. Facilities and systems of management in the slaughterhouses are therefore a critical aspect of *Salmonella* control and an important link between *Salmonella* in animals and humans.

The operation of slaughtering pigs in a modern slaughterhouse is a complex one and the possibilities of contamination are almost too numerous to count. The baseline survey carried out recently indicated a poor relationship between the prevalence of *Salmonella* in live pigs (lymph nodes) and surface contamination. This appears to support the view that a contamination on a pig surface does not necessarily originate from that same animal, but is rather an indication of the general contamination of the slaughter environment.

Contamination could possibly occur through e.g. cross-contamination between animals in the lairage, during scalding, polishing and evisceration or through handling or direct carcass-carcass contact on the production line. Slaughtering does also require considerable manual input and the operators themselves and their operations, such as cleaning and disinfection of utensils and hands, could also contribute to the contamination load of the environment.

While this CBA is not to take into account the exact impact of the operations carried out on the slaughter floor, it must be taken into account when attempting to assess the impact of intervention in the farming and feed industry on human health. The results of an recent QMRA[19] study has been used for this purpose.

6.7.1 Lairage Interventions

The potential lairage interventions can be summarized as follows:

- Logistic Slaughter: Minimising the mixing of pigs from different batches or sources to reduce stress and limit the possibility of spreading *Salmonella* between groups. In particular:
    - One group per compartment:
    - Closed compartments at the lairage
    - Herd Status Separation
- Cleaning and Disinfection
    - Clean and disinfection of lairage: To decrease the high level of contamination usually found in abattoir paddocks (Purvis G.M., et al. 2005)

6.7.2 Lairage Interventions costs

Table 50 summarizes the intervention costs for lairage improvement in the slaughterhouse.

Table 50: The costs of interventions in the slaughterhouse (€/pig slaughtered)

Country	**C&D**	**LOGISTIC SLAUGHTER**			**References**
	Extra Hygiene	1 group/ pen	Closed pens	Herd Status Separation	
Netherlands	0.16	0.09	0.01	0.05	van der Gaag, (2004)

6.8 *Salmonella* monitoring tools

Once the reduction in pig *Salmonella* prevalence is defined, a control strategy must be chosen to achieve the targeted prevalence. A prevalence reduction strategy means implementation of control measures in one or multiple stages in the pork chain. The duration of carrying out *Salmonella* control measures depends on the period of time needed to reach the threshold prevalence previously established.

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The implementation of control measures to achieve a reduction of *Salmonella* in swine incurs in increased costs. The costs for control measures could vary, since infection measurements are carried out continuously and depend on the current *Salmonella* prevalence., It is therefore paramount to be aware of the efficacy and limitations of the existing diagnostic procedures in order to improve accuracy when establishing and monitoring *Salmonella* pig prevalence. Decision-makers should use the right testing procedure to be able to evaluate the ongoing impact of the control interventions implemented and then minimize the control program expenditure.

The costs for testing depend on the characteristics of the test, the frequency of testing and the percentage of animals tested. Although samples to measure the prevalence can be taken at any stage of the pork chain, there are some practicalities to be taken into account. For instance, sampling of pigs during transportation to the abattoir or at the lairage is inconvenient and labour demanding and regular serological sampling cannot be executed in these stages. The final stages at primary production (finishing units) and at the end of the slaughtering process are more suitable for testing.

Serological sampling at the finishing stage can be use to determine farms' prevalence since the serological status does not change after pigs leave the holding. *Salmonella* prevalence can also be determined by bacteriological testing of faecal samples at this stage.

Faecal samples in the slaughterhouse are less useful since pigs may also become infected and start shedding during transportation or in the lairage. However, bacteriological culture of the lymph nodes represents a sensible and trouble-free way to determine the holding's *Salmonella* prevalence.

Hence, an essential part of having a successful control programme and achieving its goals is to choose appropriate testing procedures and sample sizes. Nowadays, there is a wide range of diagnostic procedures for *Salmonella* in the market. Through the evaluation of test characteristics (sensitivity and specificity) and their costs, the best diagnostic method can be selected. The calculation of a proper sample size is critical in order to rely on the prevalence established.

6.8.1 Quality of *Salmonella* detection

When monitoring *Salmonella* prevalence in pigs, the diagnostic tool to be used should be able to identify asymptomatic carriers since the subclinical infection plays a significant role in the spreading of this bacterium.

The complexity of *Salmonella* epidemiology has to be considered in order to choose the most suitable diagnostic test and to be able to interpret correctly its results.

Salmonella involves different infection-related types of pigs:

- Passive carriers with active faecal shedding but not producing antibodies
- Pigs infected with antibodies but shedding intermittently

Lymph nodes samples can be found positive in case of very invasive serotypes before antibodies are produced.

Some studies suggested that seroconversion generally occurs during the last third of the fattening phase (from 140 days of age to slaughter), while shedding was observed during the first half of the fattening period (Beloeil et al., 2003) The decline in serologic response in very young pigs is assumed to be due to decay of passively acquired maternal antibody from the sow (Creus, 2007)

There are several diagnostic options available depending on what kind of measure is intended. The two most widely used for the implementation of monitoring schemes aimed at detecting/evaluating *Salmonella* prevalence and/or previous exposure of pigs to *Salmonella* in pig production are based on bacteriological methods (examination of faeces, or lymph nodes) and immunological methods (examination of blood samples or meat juices) (Lo Fo Wong and Hald, 2000, Sorensen *et al.*, 2000).

The bacteriological cultures can be used to determined the current infection level in a pig herd. A positive isolation of *Salmonella* will leave little doubt of the presence of the bacteria in the animal or in the samples, however immuno-serological tests have been developed to achieve a more rapidly and cheap diagnose. These can be roughly classified into those based on enzyme-labelled antibodies (ELISA), fluorescent antibody staining, radio immunoassay and other methods. The most widely applied test for routine use is ELISA (Enzyme-Linked Immunosorbent Assay) technology. This technique takes only about 2 hours to perform but it cannot be determined if the infection is still present at the farm at the moment of positive testing and it will fFurthermore, not detect infections that occurred shortly (1-2 weeks) before sampling (van der Wolf *et al.*, 2001).

6.8.2 Microbiological culture: bacteriology

Cultural isolation under controlled laboratory conditions is the reference method by which all other methods are measured (“gold standard”) due to its high specificity (Lo Fo Wong and Hald, 2000). Nevertheless, the sensitivity of the culture method may also be affected by the phase of the infection. A large number of *Salmonella* are shed in the faeces of acute infection, while a low number of *Salmonella* are intermittently excreted in chronically infected pig or a carrier.

When performing bacteriology there are some factors that can influence results. Intermittent shedding and clustering have been acknowledged to reduce the diagnostic sensitivity of faecal culture methods (Hurd et al., 1999) underestimating the true prevalence. However, it has also been demonstrated that using at least 10g of faecal material will increase the diagnostic sensitivity of the faecal culture test (Funk et al., 2000)

The microbiological examination of the samples allows:

- Isolation and identification of the pathogen in faeces or mesenteric lymph nodes.
- Allows determination of serotype, phage type and resistance profile to antimicrobial agents.
- Almost 100% specificity (few false positives).

But this method is:

- Time consuming (3-5 days)
- Expensive (even if using pool of samples)
- Laborious (requiring pre-enrichment, selective enrichment, indicative plating and bio/serotyping)

6.8.3 Type of material sampled

A wide range of samples can be taken when carrying out the microbiological examination; from faecal material to environmental samples. However, sampling faeces and lymph nodes represent the best options if *Salmonella* prevalence is to be determined.

6.8.3.1 Faecal samples

The EU breeding pigs' prevalence was established using faecal samples from the farms which has the following advantages

- Information in the percentage of active excretory arriving at the slaughterhouse.
- Estimation of prevalence of a pig herd with minimal invasion (preferred type of sampling in breeders)

It also has the following disadvantages:

- Low sensitivity (excretion of *Salmonella* in faeces is intermittent and very low number. A smaller amount of sample analyzed, decreased sensitivity).
- Option not valid at the slaughterhouse (cross contamination during transport and slaughter pending) since the time required for initial infection *Salmonella* in the tonsils can be isolated in faeces is about 2 hours.

6.8.3.2 Mesenteric lymph nodes sampling

The EU slaughter pigs' prevalence was established using the mesenteric lymphnodes sampled at the slaughterhouse. The advantages of this method are:

- Information in the percentage of infected animals at the time.
- -Less likely to be affected by contamination during transportation and waiting at the slaughterhouse (unless the times are very long, such as more than 24 hours).
- Sampling more practical and easier at the abattoir. Reduced risk of contamination by faecal material.
- Improvement in sensitivity.

This sampling method has the following disadvantage:

- Differences between the serotypes in their ability to transfer to the lymph system (overestimation of the prevalence of invasive serotypes as *Salmonella typhimurium*).

6.8.4 Serology

Serological surveys have been frequently used by epidemiologists to determine the prevalence of *Salmonella* infection in pig populations. Performing serology refers to the diagnostic identification of antibodies in the serum. Such antibodies are typically formed in response to *Salmonella* infection.

There are several serology techniques that can be used depending on the antibodies being studied. The enzyme-linked immunosorbent assay, ELISA, has been adopted by some countries such as Denmark to determine *Salmonella* prevalence at pig farms. Some other serology techniques include; agglutination, precipitation, complement-fixation, and fluorescent antibodies.

ELISA results are reported as a number bringing the most controversial aspect of this test; laying down the "cut-off" point between a positive and negative result. A cut-off point may be determined by comparing it with a known standard. Samples that generate a signal that is stronger than the known sample are "positive". Those that generate weaker signal are "negative”.

Performing an ELISA involves at least one antibody with specificity for a particular antigen. Hence, it is critical to be aware of which *Salmonella* serotypes play the main role in the infection in order to implement an useful monitoring system.

Serological tests permit:

- ELISA detection of antibodies in serum or meat juice.
- Best cost-effective ratio (about 3.5 € / sample versus 35 € bacteriology).
- Faster (useful in large scale studies).
- High sensitivity.
- Ease of standardization between laboratories.

However there are some disadvantages:

- Does not necessarily indicate that the animals are infected at the time.
- Cannot detect very recent infections (seroconversion is between 7-30 days post-infection)
- May get a negative result in pigs that were infected for more than 3 months (antibodies can be present until 3-4 months after the onset of infection).
- Not useful to assess the prevalence at the individual level (high variability in each animal’s response).
- Low specificity.
- Prevalence values depend on the cut-off point chosen since test sensitivity is reduced with increasing cut-off. Reported cut-off values lower than 40% would result in higher prevalence estimates
- The currently available tests only detect antibodies against certain sero-groups.

6.8.5 Type of material sampled

6.8.5.1 Bood serum

Blood serum can be taken at either the farm or the slaughterhouse. The former requires trips to the farms and handling of the pigs, whereas the latter could be done at slaughter. This type of material provides a highly sensitive test for sero-positivity, but a low specificity and high labour costs.

6.8.5.2 Meat juice

Meat juice samples can only be taken at the slaughterhouse where a piece of meat tissue is taken and then the juice is later extracted. This allows for a high level of sensitivity but low specificity. It is an ideal method for large scale surveillance programmes, which is what this type of sampling and testing was designed for. It also allows for accurate identification of the serologic sample with the carcass. However, there tends to be variation between laboratories, and in some cases some serovars might not be detected. There appears be a poor correlation with culture if the herd is not heavily infected

6.8.6 Enzyme Linked Immunoabsorbent Assay (ELISA)

ELISA can be used to detect either the organism or a humeral immune response to the organism. ELISA can detect the organism in one day or less.

The Danish mix-ELISA (DME) has been used to examine serum samples collected from live animals on the farm or from meat juice (collected when a meat sample from the carcass is frozen and thawed). This ELISA uses mixed purified lipopolysaccharide (LPS) from *both S.Choleraesuis* and *S.Typhimurium* and has been applied for routine screening in breeding, multiplying and slaughtering herds in Denmark since 1993 (Nielsen et al., 1998). The meat juice is obtained by freezing a 10g sample of muscle tissue at -20°C overnight and then allowing it to thaw, thereby releasing antibody containing tissue fluid. For screening purposes, serological testing provides a good indication of exposure to *Salmonella* (Alban al., 2006).

Several commercial companies offer *Salmonella* ELISA testing on swine sera or meat juice or have produced test kits or components for laboratory use in various countries. In order to make results comparable, an international reference serum samples could be made available to standardize tests conducted by different laboratories (Van der Heijden, 2001)

6.8.7 Polymerase Chain Reaction (PCR)

The polymerase chain reaction (PCR) is a technique in molecular biology to exponentially replicate a target DNA sequence. The method relies on thermal cycling, consisting of cycles of repeated heating and cooling of the reaction for DNA melting and enzymatic replication of the DNA. Primers (short DNA fragments) containing sequences complementary to the target region along with a DNA polymerase (after which the method is named) are key components to enable selective and repeated amplification. As PCR progresses, the DNA generated is itself used as a template for replication, setting in motion a chain reaction in which the DNA template is exponentially amplified.

Mainar et al. (2008b) concluded the PCR method could be considered a cost-effective alternative to culture in *Salmonella* monitoring programmes. However, given the moderate specificity of this molecular technique, PCR-positive samples should be further confirmed through bacteriology.

Sensitivity was estimated to be 56% for culture and 91% for PCR. The specificity of the PCR was 88% while the specificity of the culture is considered 100%. PCR sensitivity was not affected by the *Salmonella* serotypes present in the samples analysed (Mainar et al., 2008b)

6.8.8 Carcass swabs

One of the most convenient methods to determine the burden of bacteria on the surface of pig carcasses is by swabbing. Carcass' swabbing has been described by Lasta et al. in 1992. The sampling technique involves rubbing of the carcass with a polyurethane sponge. Carcass swabs followed by microbiology culture to isolate *Salmonella* is an objectively technique when assessing the hygienic performance of the dressing process (Gill et al., 2000) Moreover, recent studies found that regardless of the level of training/experience of staff in charge of taking the swabs the numbers of bacteria recovered from carcasses by swabbing with sponges are unlikely to differ substantially when using the same procedure (Gill et al., 2010)

6.9 Test correlation

The correlation between serologic testing and the culture techniques is important, since culture has long been considered the gold standard for detection of *Salmonella*. There are many reasons for the discrepancy observed between both techniques.

Diagnostic test results should be interpreted taken into account the complexity of the *Salmonella* infection process. *Salmonella* organisms can e.g. enter into a host without reaching the lymph nodes and consequently without triggering the humeral immunity response whereas very invasive serotypes, like *S.typhimurium,* might reach the lymph nodes in a few hours without showing an immune response and animals with antibodies against *Salmonella* might have cleared the infection (Sanchez et al., 2007). However, the majority of *Salmonella* infections do not show clinical symptoms but their hosts undergo an infectious process resulting in an immune response. Some studies have attempted to show the correlation between conventional culture methods and serology in individual pigs, but the results of these two methods have a generally poor correlation (Davies *et al.*, 2003).

Funk et al. (2005) compared a traditional faecal culture test (BPW pre-enrichment followed by enrichment in Rappaport-Vaissilia-dis broth) with the Danish Mix-ELISA. They found that the prevalence estimates from both tests followed the same kinetics and that cut-point values of OD% 40 showed similar values as those obtained from the culture test. On the other hand, lower cut-off points (OD% 10) showed much higher prevalence estimates.

Sorensen *et al.* (2004) found that there was a strong association between herd serology and the prevalence of *Salmonella* bacteria measured at three sampling sites: faecal-content, pharynx and carcass surface. For these sites, the odds for being culture-positive for *Salmonella* varied from 1.3 to 1.5 for each increase of 10% in herd serology.

Lo Fo Wong et al. (2003) found a correlation coefficient of 0.62 between culture positive and seropositive samples in a herd at cut-off OD %> 10 and of 0.58 at cut-off OD% > 40. Serology is a measure of historical exposure, which may or may not correlate closely to the microbiological burden at the time of sampling. Due to the low sensitivity of culture methods, apparent 'false-positive' serological results may well represent real infections not detected by bacteriological testing. For screening purposes, serological testing provides an indication of exposure to *Salmonella*, which forms the basis for targeted sampling, intervention and logistic slaughter procedures.

German study results reveal that all tested ELISA systems are able to detect *S. typhimurium* infection in pigs in both, blood serum and meat juice samples. The sensitivity to detect *Salmonella* antibodies varied between tests according to the used cut-off (test specific cut-off vs. recommended surveillance cut-off) resulting in a change of seroprevalence and hence may influence the *Salmonella* status of the farm (Szabo et al., 2008)

6.9.1 Comments on surveillance design

Microbiological culture is considered as the ‘‘gold standard’’ test for the diagnosis of *Salmonella* infection in pigs and enables further research on an epidemiological point of view by allowing further characterization of isolated strains like sero-typing, phage typing, Pulse Field Gel Electrophoresis, or when assessing antimicrobial resistance. However, this method is expensive, time-consuming, and has low sensitivity meaning that considerable amount of infected animals could be classified as false negative (Rostagno et al., 2005; Hurd et el., 2004). This poor sensitivity is due to intermittent shedding of low numbers of *Salmonella* excreted from carriers.

It can be concluded that bacteriology on faeecal content is a poor diagnostic method to carry out large studies on *Salmonella* prevalence or to set up monitoring programmes in slaughter pigs (Mainar et al., 2008b). Test sensitivity may vary depending upon the type of material cultured, sample size, and enrichment procedure (Baggesen et al., 1996). Culture of pooled pen faeces has been shown to be useful on a herd basis (Funk et al., 2000) and is probably the method of choice for identifying the serovars present on a farm.

In other hand, diagnostic tests based on the detection of antibodies against *Salmonella* (ELISA) are more suitable for being used in national-based monitoring programs. Serology gives a good indication of herd status and is less costly and labour-intensive than bacteriologic isolation (Mainar et al. 2008a). However, there are some disadvantages involved such as the diversity of antibodies responses between each animal (Korsak et al., 2006). A North American study showed permanent overestimations of apparent prevalence using serology compared with that obtained from bacteriological analysis (Hurd et al., 2004). Major discrepancies have also been found when different commercial ELISAs were compared using the same field samples (Mejia et al., 2005; Farzan et al., 2007; Mainar et al., 2008a). The reasons for these discrepancies might include the condition under which tests are performed, the nature of the antigens used (whole lipopolysaccharide: LPS, vs. only the Opolysaccharide moiety of this antigen), the isotypes of immunoglobulins involved, the *Salmonella* serotypes targeted by the test, and even other unknown factors (Mainar et al. 2008a; Mejia et al., 2005)

Several studies agreed with the fact that while serological tests are related to old infections, faecal tests are related to recent infections such as infections acquired during transport. Therefore, faecal samples might not reflect the on-farm *Salmonella* prevalence (Sanchez et al., 2007) andit is therefore generally accepted that the serological status is not a good indicator of shedding or current infection at individual level (Funk et al., 2005) but can be used to follow the improvement based on the implementation of an integrated pig production system (Korsak et al., 2006).

The observed variations between *Salmonella* bacteriology and serology show that none of these methods on their own were reliable for point estimates of pre-harvest prevalence in subclinical infected herds. Repeated sampling was required in order to correctly assess the infection dynamics in the particular herd under study or surveillance (Kranker et al., 2003)

The results of a Danish study implicated that a surveillance programme based on herd sero-prevalence can identify a large part of the *Salmonella* burden, but miss the part that is due to individual and recent variations in a herd (Alban et al., 2006).

Based on the studies carried out by Funk in 2005, a higher OD% cut-off would be recommended if more approximate estimation of faecal prevalence is desired and longitudinal sampling would be suggested for evaluating the impact of on-farm interventions for *Salmonella* reduction whether utilizing faecal culture (Funk et al., 2005).

Farm-level prevalence obtained from the culture of pooled faecal samples was higher than those estimates using individual sampling. Factors such as true underlying prevalence, pool size and number of pools tested can affect the performance of a diagnostic procedure based on pooled samples (Sanchez et al., 2007).

In a study of Asai *et al.* (2002), *Salmonella* was isolated from 26 (28.9%) of 90 antibody-positive pigs and 21 (11.9%) of 117 antibody-negative pigs. The authors found that sero-conversion generally occurred during the last third of the fattening phase from 140 days of age to slaughter (Asai *et al.*, 2002a, Beloeil *et al.*, 2003, Creus, 2007), while shedding was considerable in the first half of the fattening period (Beloeil *et al.*, 2003), particularly in pigs between 4 to 5 months of age (Asai *et al.*, 2002).

If the intention is to monitor *Salmonella* pre-harvest, measures of herd serology or faecal content are appropriate (Sorensen *et al.* 2004) but for more precise results, the prevalence in fattening pigs should be investigated in the late stage of the fattening period or before slaughtering. If the transmissions within the herd are to be studied, it it is recommended during the first half of fattening period.

Sensitivity regarding bacteriological detection will be relatively high when samples come from animals experiencing an acute infection and it will be low if only a small number of microorganisms remain in the pig. Regarding serological diagnosis, there may be differences in sensitivity depending on the intensity of the infection process among the herd and the time lag between infection and examination. The specificity of serological detection of *Salmonella* may become reduced by microorganisms not belonging to *Salmonella*, induced by antibodies which react with the *Salmonella* antigen (Steinbach *et al*., 2002). Malorny, *et al.* (2003), found that the inter-laboratory diagnostic accuracy, (i.e. diagnostic specificity and sensitivity) was shown to be 97.5% using the PCR based method.

Tthe choice of method for detection of *Salmonella* depends e.g. on the purpose of the measure, where the combination of both techniques might be preferable. Initially, serology is the best option establishing the starting position of the infection status of the holdings but from this point, if additional sampling for bacteriological analysis is required in a herd, the temporal variability in *Salmonella* levels should be taken into consideration by making the necessary adjustments in the sampling strategy.

6.9.2 Tests and test procedures currently implemented

Some North European countries have been implementing *Salmonella* strategies for many years.

Control programmes have been implemented for food of animal origin targeting all *Salmonella* serotypes. The decision of targeting not only *Salmonella Enteritidis* and *Salmonella Typhimurium*, is based on the existence of a wide range of *Salmonella* serovars. Evidence support that control programmes have been useful in protecting public health is provided by the national surveillance reports. In addition, this continuous monitoring allows for continuous evaluation of the impact and possible changes of the programme during its implementation. However, the success of these programmes should be interpreted by taking into account other associated factors, such as the prevalence situation, weather conditions that could possibly constrain *Salmonella* survival, pig census, country-specific production practices and pig meat production.

Table 51 and Table 52 summarise diagnostic methods used in surveillance programmes in some European countries.

Table 51: Diagnostic methods

	Belgium	Netherlands	Germany	Ireland	UK
Blood Serology	X	X	X		
Meat juice Serology		X	X	X	X
Faecal Bacteriology	X	X			

Table 52: Diagnostic methods

	Denmark	Finland	Sweden	Estonia	Norway
Blood Serology	X				
Meat juice Serology	X				
Faecal Bacteriology	X	X	X		X
Meat samples Bacteriology		X	X	X	X
Lymph node Bacteriology		X	X		X
Carcass swab	X	X	x	X	x

6.9.3 Costs of monitoring *Salmonella* in pigs

Table 53 summarises the data on the costs of bacteriology for *Salmonella*.

Table 53: Estimates of costs for bacteriology sampling and testing for *Salmonella*.

Country	BACTERIOLOGY (€)					Reference
	Vet/visit	Sampling equip./visit	Delivery	Culture/ sample	Serotyping	
Belgium	30.00			15.00	30.00	Veterinary and Agrochemical Research Centre (VAR)
Spain		15.00		22.00	40.00	Spanish Private Industry consultancy (2010)
USA			3	18.3		Federal Register (1996)
Sweden			2.6	35	68	National Veterinary Institute website (2010)
Netherlands	0.12€/pig					van der Gaag, (2004)

Table 54 summarises the costs of antibody detection testing for *Salmonella*.

Table 54: Estimates of costs for serology sampling and testing for *Salmonella* in pigs.

Country	SEROLOGY (€)				Reference
	Vet/visit	Sampling equip./visit	Test/sample	Meat Juice	
Belgium	20.00	15.00	2.5	5.00	Veterinary and Agrochemical Research Centre (VAR)
Germany				5.00	German QS laboratory
Spain	40.00	15.00	2.50		Spanish Private Industry consultancy (2010)
Netherlands	0.11€/pig			0.25	van der Gaag, (2004)

Table 55 summarises costs of other diagnostic methods.

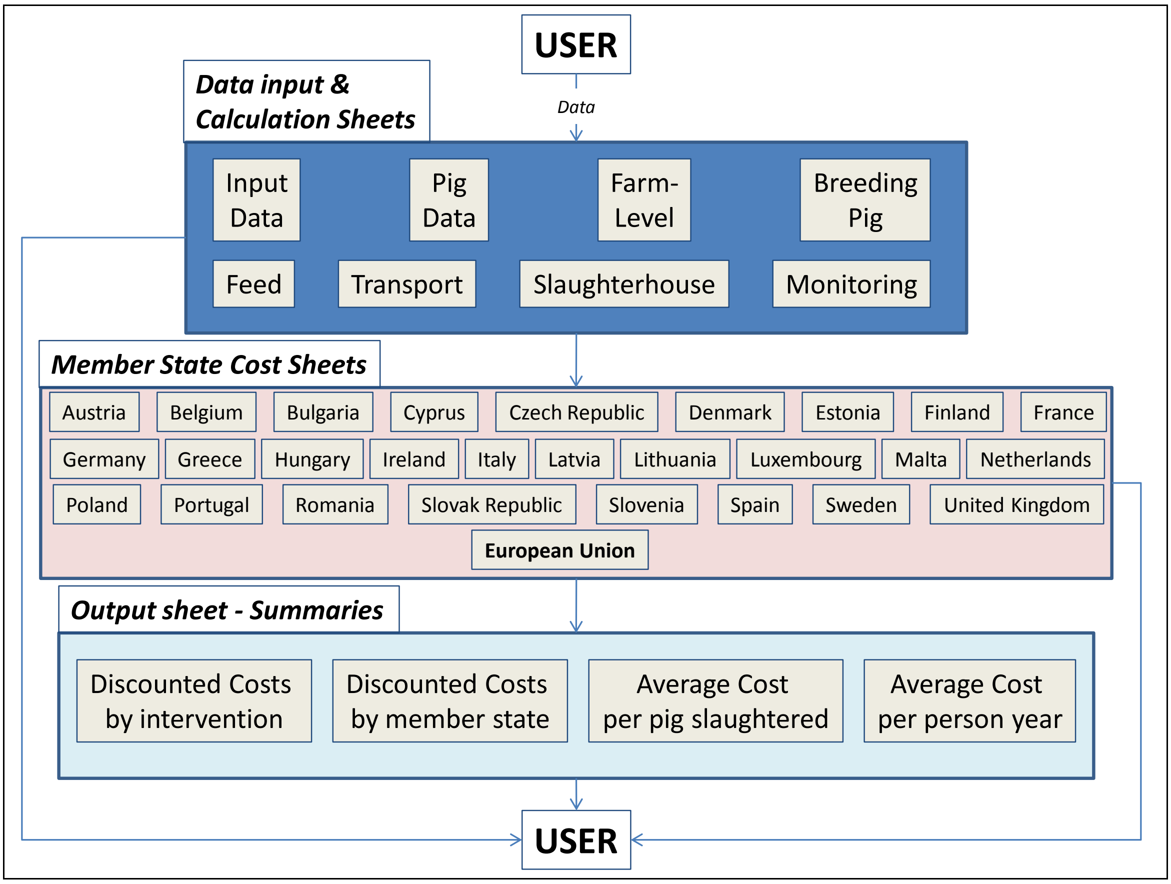
Table 55: Estimates of costs of PCR and carcass swabbing.

Country	CARCASS SWAB	Delivery	PCR	Reference
Netherlands	0.22 €/pig			van der Gaag, (2004)
Sweden		2.6€	626.5€	National Veterinary Institute website (2010)

6.10 Intervention cost model

To capture and quantify the costs of interventions by Member States and also across the EU the consortium developed an Excel spreadsheet model. The calculations are deterministic[20] and the calculations are relatively straightforward to understand and use. This has been done intentionally as the scoping study of the interventions and their costs indicate that data quality and technical understanding is insufficient to make a more complicated model. It also recognizes that the more complicated the model is the harder it is for the user to comprehend how to use it and interpret the output. In short the model is a cost calculator. The general structure of the model is shown in Figure 38

Figure 38: Structure of the intervention cost model.



[20] The data input are set by the user and are assumed to be constant, as opposed to a stochastic model that takes data input and the potential ranges of the data to estimate the data used for each model run.

After various potential options have been identified, each option must be appraised according to its effectiveness, feasibility, costs and anticipated benefits. There are several key questions that will routinely be addressed when stakeholders consider each possible option:

- What are the option's expected benefits and costs?
- Who benefits and who bears the cost? What are the equity and environmental justice considerations?
- How feasible is the option, given the available time and resources for its implementation? What are its legal, political, economic and technological limitations?
- Does the option increase certain risks while reducing others?

The expected costs and benefits of each control option will usually be estimated by quantitative economic analysis. However, the technological and social feasibility of a particular option is more difficult to determine by formal quantitative measures.(Bouder et al., 2003)

As mentioned before we are using a "direct measurement of compliance costs" estimating measures costs from published literature, scientific and industry consultation. The latter may be biased since companies have an incentive to over-state costs. Hence, it may be difficult to identify all of the inputs required to comply with a regulation and their levels of use; the method does not allow for the dynamics of competition that might drive some firms out of business, especially small firms if the fixed costs represent a large component of the total , and permit other firms to expand, meaning overall industry costs would be overstated; and finally, firms adapt to regulations by innovating and modifying their production processes, whereas the compliance cost approach assumes an unchanged process plus add-ons for improved safety, which is likely to overestimate costs in the long run.

It is important that only those costs necessary to comply with a proposed regulation are included. In practice it is highly probable that some firms already meet the requirements of the regulation, either to satisfy existing requirements of buyers (for example retailer private standards) or with a view to enhancing or maintaining their brand reputation. Only additional costs should be included in the calculation, which in some cases may only be borne by small firms or firms supplying non-traditional supply chains.

6.10.1 Data entry and cost calculation sheets

The data entry and cost calculation worksheets are detailed in the following sections.

6.10.1.1 Input data sheet

The Input Data sheet allows data to be entered by a Member State for the majority of the parameters. Over the entire analysis this sheet allows the user to **set** the **discount rate** for the cost calculations. This sheet is also requests data on the **control programme support unit** and calculates the number and costs of the **staff** required by Member State for their control programmes.

The sheet assumes that each Member State will require **a full time manager** for the programme. Additional **professional staff** can be added either manually or will be calculated base on a unit of professional time being used per number of pigs. The latter figure is set across the EU. The model allows the professional time to be split into indivisible unit recognizing that professional time can be bought through consultancies. **Administration staff** are set according to the average number of administration staff required per manager and professional staff. **Office space** is calculated based on the average office space required per staff member. Costs for staff is based on a labour cost index and an average salary per person in the EU. The cost of office space can be entered. Total numbers of staff and costs are calculated automatically per Member State.

The cost data generated are annual figures and are used in the Member State and EU cost sheets across all years, assuming that these costs will remain fixed.

6.10.1.2 Pig data sheet

The pig data sheet summarises much of the data collected from the pig sector analysis. It does not use strong distinctions between different pig systems as intended in the initial stages of the work, but this reflects the lack of data in this area and poor agreement on pig system classification. The following data have been entered and can be modified by Member State:

- Pig population by type – sows and slaughter pigs
- Production parameters (based on BPEX, 2009 data for the main Member States with additional information from country study searches
    - Litters per sow
    - Mortality rates
- Weights at different points of the pig cycle
- The number of days in different stages of the pig cycle (weaning, rearing, fattening)
- Feed conversion ratios (number of kilogrammes of feed need per kilogramme of live-weight pig produced)
- Number of pig spaces required for weaners, rearers and fatteners. This reflects the length of time in each stage and also the number of animals in the population.

The pig population figures used at the Eurostat 2008 estimates by Member State. The other data have come from the BPEX (2009) for many of the Member States. Where data were not available from BPEX, country study search information was used and where this was not available an average figure across the data from of Member States was calculated and used as a baseline.

The sheet makes estimates of the

- The population of each category of pig
    - Weaners = (No. sows x litter size x No. litters per sow) less (piglets born x pig mortality rate)
    - Rearers = Weaners less (weaners x mortality rate of weaners)
    - Slaughter numbers are based on the slaughter data from Eurostat
- The feed consumed by rearer and fattener pigs based on
    - The number of pigs in each category per year
    - The feed consumed per pig based on the weight at the beginning and end of that period multiplied by the feed conversion ratio for that period.

6.10.1.3 Feed sheet

As discussed in the previous section of this Chapter feed is an important entry point for *Salmonella* to a pig population and therefore the processing of feed is an important aspect of a control campaign. The model recognizes that not all aspects of feed manufacture need to be controlled to the same degree and it focuses only on the control of oilseed cakes. The following data have been entered and can be modified by Member State:

- Proportion of feed that is oilseed cake – based on data gathered on the use of oilseed cakes in pig feed formulation
- Proportion of Member States with good practices for sourcing, treatment, management and monitoring of oilseed cakes – currently based on information collected by Member State and from expert opinion
- The rate of increase in the amount of oilseed oilseed cakes that have good practices for sourcing, treatment, management and monitoring of oilseed cakes. The model allows this to be done on a constant rate or a variable rate across 10 years
- Costs per tonne of good practices for sourcing, treatment, management and monitoring of oilseed cakes

The model calculates the increase in amount of feed that has good sourcing, treatment, management and monitoring per year based on the rate of change in the systems. The model will not allow this amount to go above the amount of feed that was not in this category at the beginning. The costs per year per Member State of the changes in feed practices are calculated in each Member State intervention cost sheet using the quantity per year and the costs of the change per tonne of feed.

6.10.1.4 Breeding pig sheet

The breeding pig interventions have been reduced to the simplest level as this will be expanded in the contract relating to the cost-benefit analysis of *Salmonella* control in breeding pigs. The following data have been entered and can be modified by Member State:

- Proportion of pig replacements with *Salmonella* – the proxy used for this parameter is the *Salmonella* herd level prevalence calculated from the EFSA breeding pig survey.
- Costs of producing a clean pig replacement – currently set to a low figure as the data on this subject suggested that this may be a cost neutral or positive farm-level gain[21].
- Rate of increase in the numbers of clean pigs produced per year. The model allows this to be done on a constant rate or a variable rate across 10 years

6.10.1.5 Farm-level sheet

For simplicity the model has grouped the fattening farm-level changes into two categories: hygiene and feed. This is in recognition of the conclusions from the QMRA study that have these two very unspecific categories. The following data have been entered and can be modified by Member State:

- Proportion of pig spaces that have good hygiene practices – a proxy of the herd prevalence from the EFSA study for breeding pigs has been used for the initial data.

[21] Data suggest that more hygienic management practices that lead to *Salmonella* free piglets give a cost saving on the production of replacement piglets. These cost savings cannot be attributed to *Salmonella* as other influences contribute to such changes. It is also questionable if such cost savings occur as it would probably have been adopted by farmers in the past if the measures were understandable and implemented in the current management practices. Changes in management systems and knowledge may not have been costed in these estimates of economic impact of such changes.

- The rate of increase in the number of pig spaces with good hygiene practices. The model allows this to be done on a constant rate or a variable rate across 10 years
- The costs per pig place of good farm management practices
- Proportion of feed that has on farm practices that would control *Salmonella* – based on country level data collection and expert opinion.
- The rate of increase in feed with farm practices that would control *Salmonella*. The model allows this to be done on a constant rate or a variable rate across 10 years
- The costs per tonne of feed for farm practices that control *Salmonella*

The farm-level sheet calculates the incremental increase in

- pig spaces with good hygiene practices per year
- feed used that has *Salmonella* control measures applied to it

The total costs per year of these interventions are calculated in each Member State cost sheets by multiplying the incremental quantity estimates for pig spaces and feed by the costs per unit of implementing these measures.

6.10.1.6 Transport sheet

The transport worksheet separates the pigs into three groups: piglets; rearers and fatteners. For each group the following data have been entered and can be modified by Member State:

- Proportion transported
- Proportion transported in poor conditions
- The rate of increase in good transport. The model allows this to be done on a constant rate or a variable rate across 10 years
- The cost of good transport per animal

The transport sheet calculates the incremental increase per year in:

- Piglets with good transport
- Rearers with good transport
- Fatteners with good transport spaces

The total costs per year of these interventions are calculated in each Member State cost sheets by multiplying the incremental quantity estimates for each category of pig with the increased costs per animal of that transport.

6.10.1.7 Slaughterhouse sheet

For the slaughterhouse sheet the following data have been entered and can be modified by Member State:

- Proportion of pigs slaughtered in poor conditions
- The rate of increase in the number of pigs slaughtered in clean conditions. The model allows this to be done on a constant rate or a variable rate across 10 years
- The costs per pig of slaughtering in clean conditions

The sheet calculates the incremental increase per year in:

- Pigs slaughtered with good slaughterhouse systems

The total costs per year of this intervention is calculated in each Member State cost sheets by multiplying the incremental quantity estimates with the increased costs per animal for improved slaughter.

6.10.1.8 Monitoring sheet

For the monitoring sheet the following data have been entered and can be modified by Member State:

- Proportion of pigs currently being monitored – based on country data collection and expert opinion.
- Target population to be sampled with a control campaign – this will vary according to the control interventions selected. For example if replacement pigs are targeted as the main intervention there will be a need to increase the monitoring of the movement of piglets from breeding to fattening units.
- The rate of increase in the number of pigs sampled and tested. The model allows this to be done on a constant rate or a variable rate across 10 years.
- The costs of sampling and testing per pig – based on the type of test used and the data collected on the sample required and the costs of sample taking and diagnostic test.

The sheet calculates the incremental increase per year in:

- The number of pigs sampled and tested

The total costs per year of this intervention is calculated in each Member State cost sheets by multiplying the incremental quantity estimates with the increased costs per animal tested.

6.10.2 Member State cost sheets

The data entered in the above listed data input and calculation sheets are used to calculate the costs of interventions for each Member State per year over a 10 year period. Each Member State and the EU as a whole has a worksheet to calculate the undiscounted and discounted costs of the interventions. The discount rate is standard across all Member States and can be modified in the Input Data worksheet.

Each Member State and the EU as a whole has a cost sheet that calculates the costs of the seven different categories of intervention:

1. Feed
2. Breeding Farm
3. Fattening Farm
4. Transport
5. Slaughterhouse
6. Monitoring
7. Support Unit

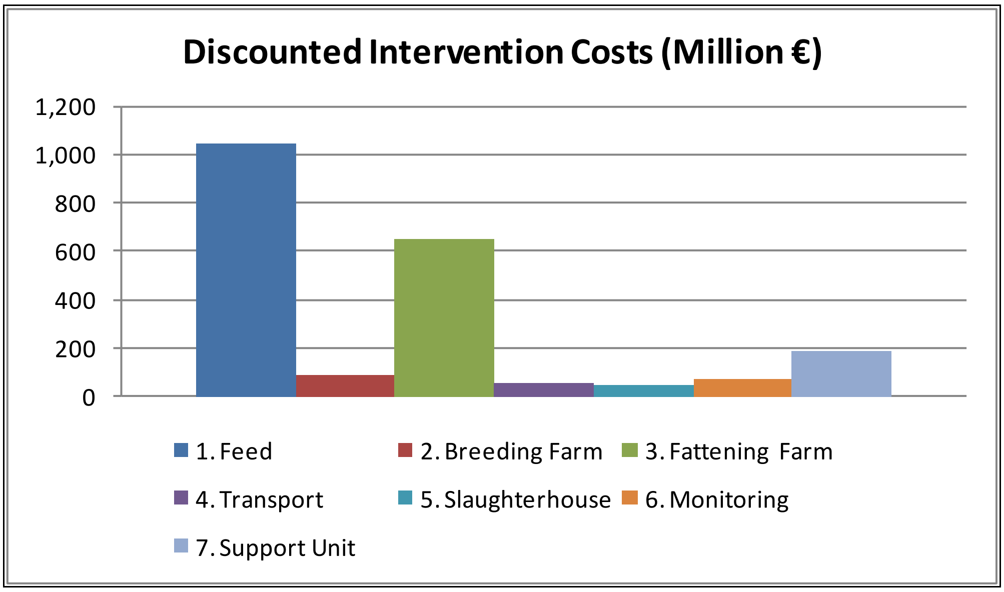
The undiscounted costs are calculated by intervention category and an overall total per year. These figures are then used with the discount rate set in the Input Data sheet to calculate the discounted costs (present value) as a yearly total and an overall sum of discounted costs.

6.10.3 Model output

The model output is summaries in the **Costs Summary** sheet with the following outputs:

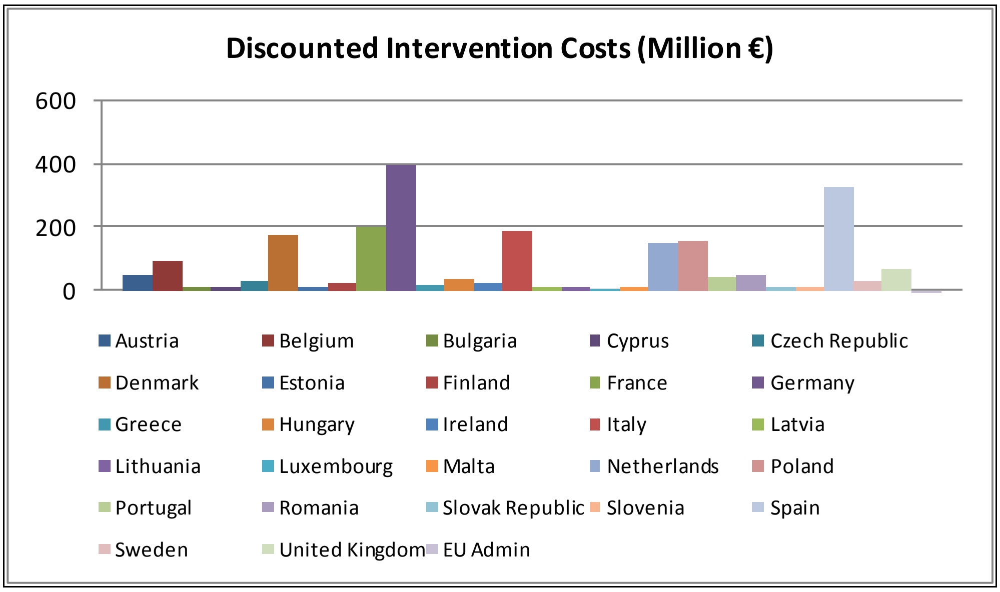
- **Discounted costs by intervention** with the interventions broken down into: Feed; Breeding Farm; Fattening Farm; Transport; Slaughterhouse; Monitoring and Support Unit. An example of the graphic produced is shown in Figure 39.

Figure 39: Output from the intervention costs model with costs split by intervention type



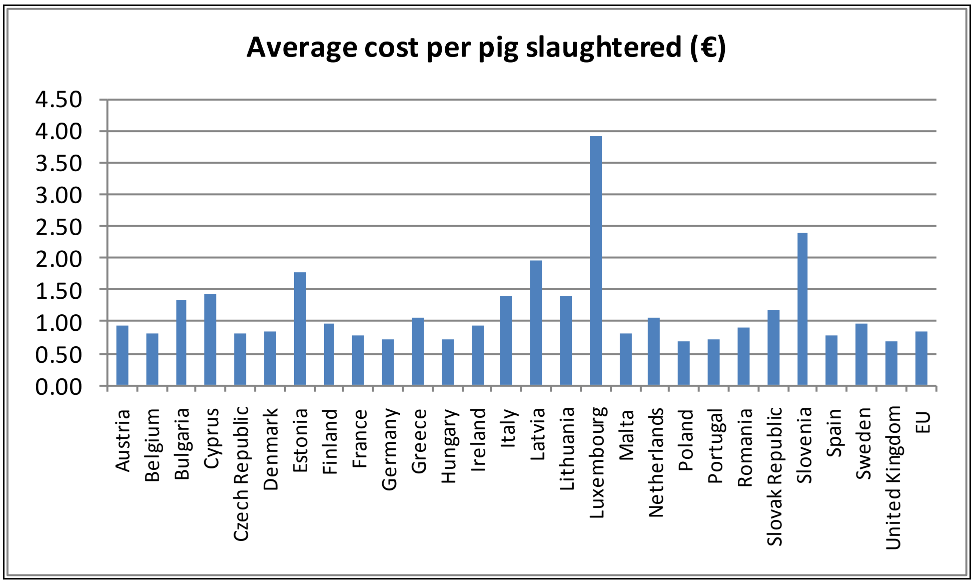
- **Discounted costs by Member State**

Figure 40: Output from the intervention costs model with discounted costs by Member State



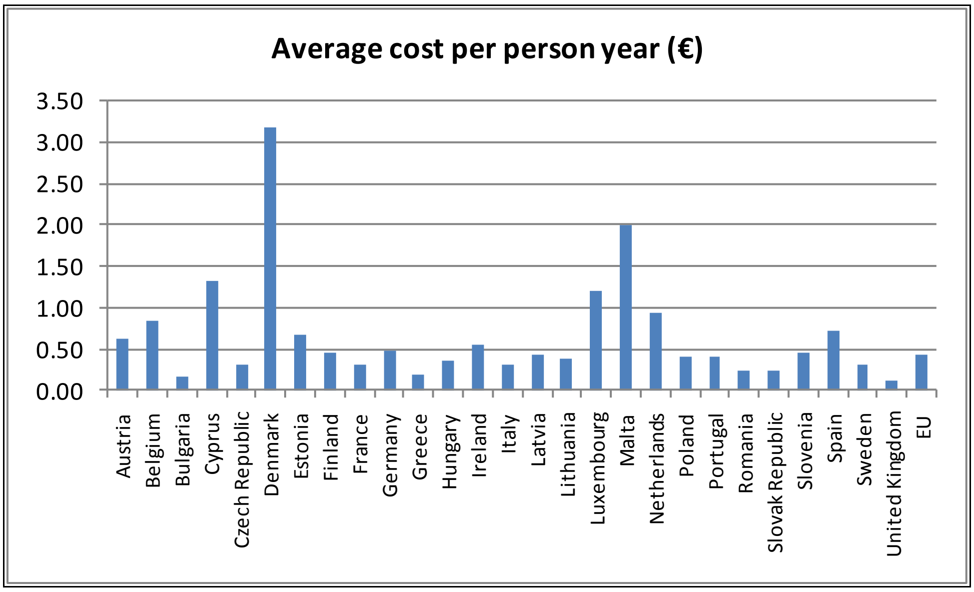
- The average cost per pig slaughtered. This takes the total discounted costs and divided them by an estimate of the number of pigs slaughtered over a ten year period.

Figure 41: Output from the intervention costs model with the average cost per pig slaughtered



- The average cost per person year across the EU and for each Member State. This takes the total discounted costs and divides them by an estimate of the number of people years over a ten year period[22].

Figure 42: Output from the intervention costs model with the average cost per person year



Further outputs to the model were developed for the cost-benefit analysis calculation that draw together the intervention costs with the benefits from the reductions in human health impacts. These will be described in the following Chapter.

An electronic version of the cost intervention model is available with the report.

[22] Calculated by multiplying the 2008 human population by 10

6.11 Estimated costs of selected interventions

QMRA (2010) identified a number of potential sources of infection for fattening pigs pre-harvest which can be broken down into: feed, on-farm circulation of *Salmonella* and potential infection during transport and lairage. Measures should be applied within any sector to reduce the risk of foodborne illnesses by keeping the burden of bacteria at their possible lowest level at minimal cost. However this study also suggested that transport and lairage are not such important issues. However after consultations with other experts in the *Salmonella* pigs field (personal communication with Thomas Blaha and Jan Dahl) it was decided that this was also a contentious issue. Therefore a number of different scenarios have been tested with the model and these are the following:

1. An establishment of a support unit and some increased sampling
2. Scenario 1 plus improvement of:
    a. feed practices at feed mill and farm-level
    b. farm-level biosecurity
3. Scenario 1 plus targeted interventions according to country *Salmonella* levels
    a. High prevalence – countries with slaughter pig prevalence's above the EU average.
        i. Clean replacement pigs
    b. Low prevalence – countries with slaughter pig prevalence's below the EU average
        i. Feed control measures
4. Scenario 3 plus all transport and slaughterhouse measures.

6.11.1 Costs of Scenario 1

Cost of scenario 1 is fundamental to any control programme, it requires mechanisms to coordinate activities and means to test if technical outcomes are being achieved. It could be argued that some programmes require only greater coordination of private actions to achieve success and given that *Salmonella* programmes are ongoing in a number of countries this may well be all that is needed. The most important input data for the baseline and monitoring scenario are as follows:

- The analysis period is 10 years
- Discount rate of 4% has been applied
- Support Unit
    - It is assumed that each country has a control programme manager.
    - The manager is supported by professional staff for every 6 million heads of pigs.
    - The manager and professional staff are supported by two administrative staff per person.
    - The average annual wage for the EU is €33,823 per year.
    - The labour cost index for each Member State is used to calculate the average salary per Member State.

- The cost of the manager, professional staff and administrators are three, two and one times the average salaried income for each Member State respectively.
- Each member of staff is provided with 20 metres square of office space and the cost of the office space is €1,000 per year.
- The EU also has to establish a core coordination unit consisting of one manager, one professional and two administrators.

- Monitoring
    - The target pig population monitored is 10% of the slaughter pigs per year
    - There is annual increase in the number of pigs slaughter per year of 10% until the target is reached
    - The cost of each additional sample and diagnostic testing is on average €2.61[23]
- All other interventions are set to zero

The model estimates that a total of €287 million of discounted costs will be incurred with Scenario 1, and of those costs 57% will be due to monitoring (see Table 56).

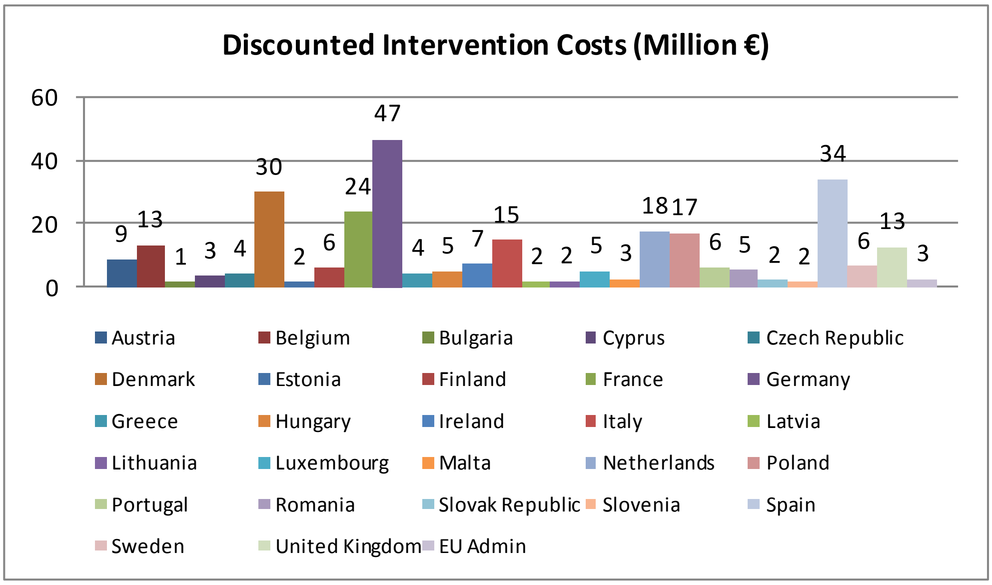
Table 56: Estimated undiscounted and discounted costs for scenario 1

Intervention	Costs (million €)	
	Undiscounted	Discounted
Monitoring	220	163 (57%)
Support Unit	152	124 (43%)
Total	**371**	**287 (100%)**

A major proportion of the costs are borne by the countries with the largest pig populations and levels of production, Germany, Spain, Denmark and France (see Figure 43).

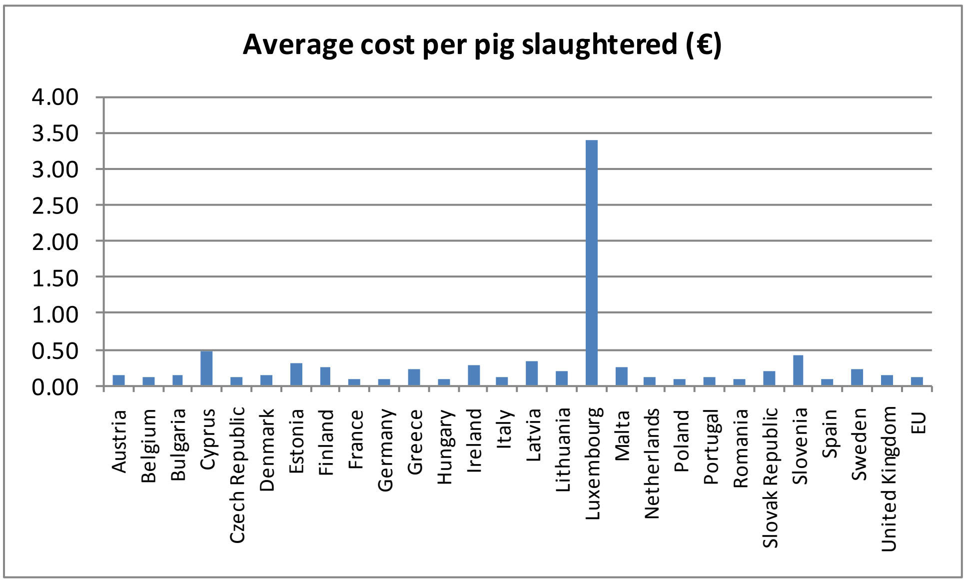
[23] This assumes the lowest cost for taking samples of €0.11 per pig and for diagnostic test per sample of €2.50

Figure 43: Intervention costs by Member State for scenario 1



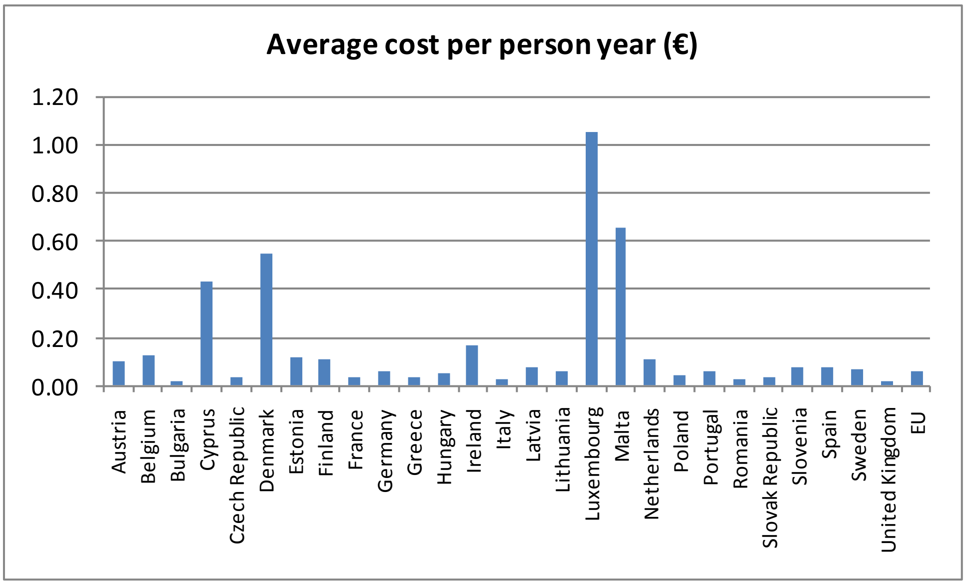
The average cost per pig slaughtered for scenario 1 is €0.11 with a high of €3.40 in Luxembourg and a low of €0.08 in Spain. It tends to be the smaller countries that incur the greatest cost per pig slaughtered (see Figure 44) reflecting that the support unit would be more efficiently utilized in a control programme in a large country.

Figure 44: Intervention costs per pig slaughtered for scenario 1



The average cost per person per year for scenario 1 is €0.06 with the lowest being for the UK at €0.02 and the highest in Luxembourg at €1.05. The cost per person is most favourable in countries that import a significant proportion of their pork meat (see Figure 45).

Figure 45: Intervention costs per person year for scenario 1



Scenario 1 cost estimates will be combined with estimates of the benefits of *Salmonella* control interventions in the following Chapter.

6.11.2 Costs of Scenario 2

Cost of scenario 2 looks at the most direct methods of feed and farm-level interventions to control *Salmonella*, supported by a coordination unit and monitoring.. The most important input data for the baseline and monitoring scenario are as follows:

- The same set of activities as for scenario 1
- Feed mills
    - It is assumed that all countries except Sweden and Finland introduce good practices for 36% feed manufactured. Sweden and Finland are assumed to have all feed under good practice.
    - Improvement in standards of feed manufacture increase at a constant 10% rate per year
    - The cost per tonne of these increases in feed manufacture are €10.82 per tonne
- Farm-level
    - Feed and hygiene
        - The good management and farm-level feed practices are assumed to correspond to the survey of breeding farms for *Salmonella* prevalence, i.e. if 25% of *Salmonella* was the reported prevalence then 75% of farms have good practices.
        - There is a 10% constant increase in good farm level practices per year across the Member States
        - Good hygiene practices cost €0.78 per pig
        - Good farm-level feed practices cost €1.78 per tonne
- All other interventions are set to zero

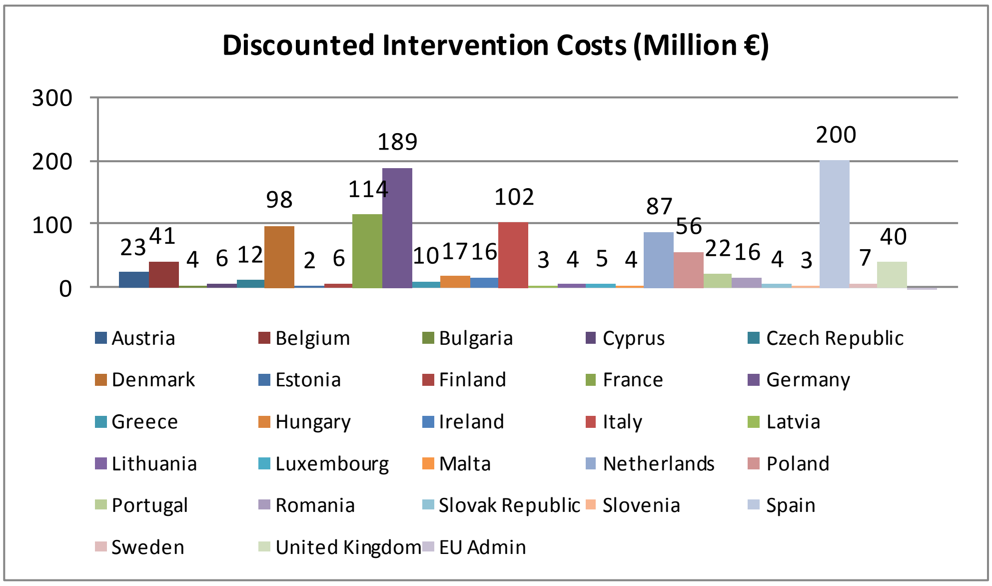
The model estimates that a total of €1,089 million of discounted costs will be incurred with Scenario 2, and of those costs 45% are due to feed interventions (see Table 57).

Table 57: Estimated undiscounted and discounted costs for scenario 2.

Intervention	Costs (million €)	
	Undiscounted	Discounted
1. Feed	631	487(45%)
3. Fattening Farm	408	316 (29%)
6. Monitoring	220	163 (15%)
7. Support Unit	152	124 (11%)
Total	**1,410**	**1,089**

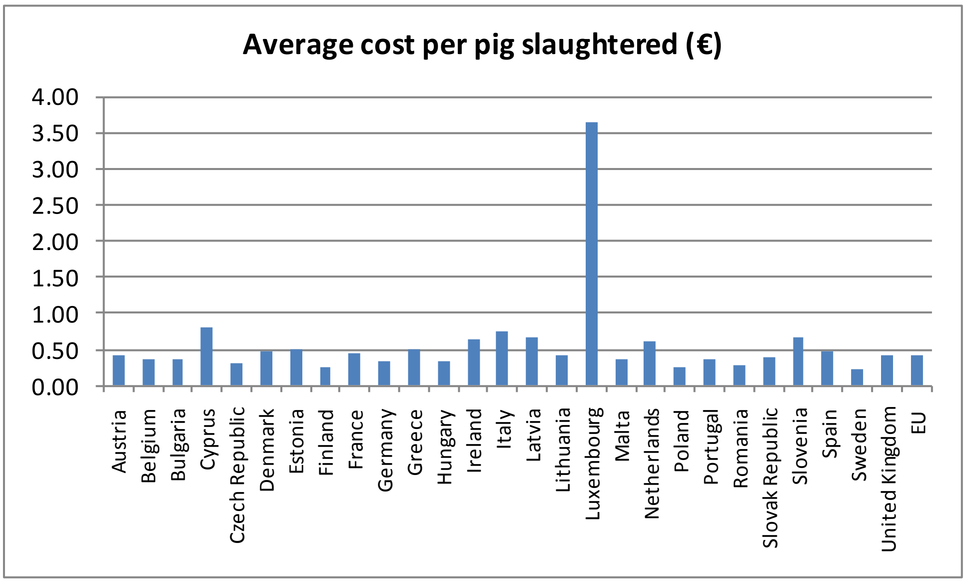
A major proportion of the costs are borne by the countries with the largest pig populations and levels of production, Germany, Spain, Denmark and France (see Figure 46).

Figure 46: Intervention costs by Member State for scenario 2



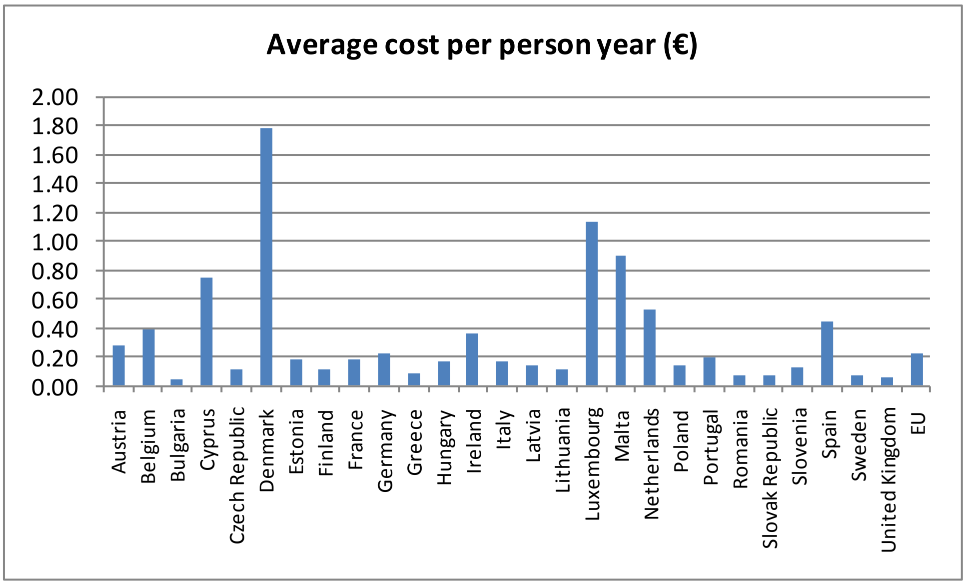
The average cost per pig slaughtered for scenario 2 is €0.43 with a high of €3.64 in Luxembourg and a low of €0.22 in Sweden (see Figure 47).

Figure 47: Intervention costs per pig slaughtered for scenario 2



The average cost per person year for scenario is €0.22 with the lowest being for Bulgaria at €0.05 and the highest in Denmark at €1.79. The cost per person is most favourable in countries that import a significant proportion of their pork meat (see Figure 48).

Figure 48: Intervention costs per person year for scenario 2



Scenario 2 cost estimates will be combined with estimates of the benefits of *Salmonella* control interventions in the following Chapter.

6.11.3 Costs of Scenario 3

Cost scenario 3 looks at targeting interventions according to disease prevalence levels and based on the recommendations of the QMRA study. These interventions are supported by a coordination unit and monitoring. The most important input data for the baseline and monitoring scenario are as follows:

- The same set of activities for scenario 1
- Feed mill interventions

  - Set to zero for high prevalence pigs
  - Set to the parameters for scenario 2 for low prevalence countries
- Farm hygiene and farm feed same as scenario 2
- Clean replacement pigs
  - Breeding pig prevalence was assumed to be equivalent to the breeding pig herd prevalence from the EFSA study[24]
  - Additional clean pigs for rearing would cost €0.10 per pig
  - There would be a constant 10% increase in the additional number of clean pigs reared per year in the high prevalence countries
- All other interventions are set to zero

The model estimates that a total of €752 million of discounted costs will be incurred with Scenario 3, and of those costs 42% are incurred at the fattening farm level (see Table 58).

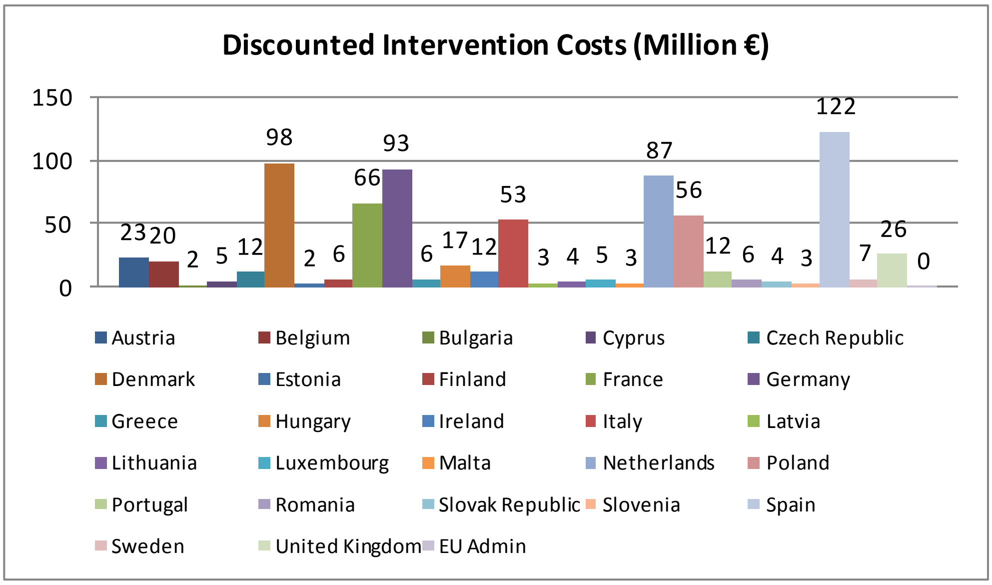
Table 58: Estimated undiscounted and discounted costs for scenario 3.

Intervention	Costs (million €)	
	Undiscounted	Discounted
Feed	189	146 (19%)
Breeding Farm	6	4 (1%)
Fattening Farm	408	316 (42%)
Monitoring	220	163 (22%)
Support Unit	152	124 (16%)
Total	**974**	**752**

Like the other scenarios a major proportion of the costs are borne by the countries with the largest pig populations and levels of production, Germany, Spain, Denmark and France (see Figure 49).

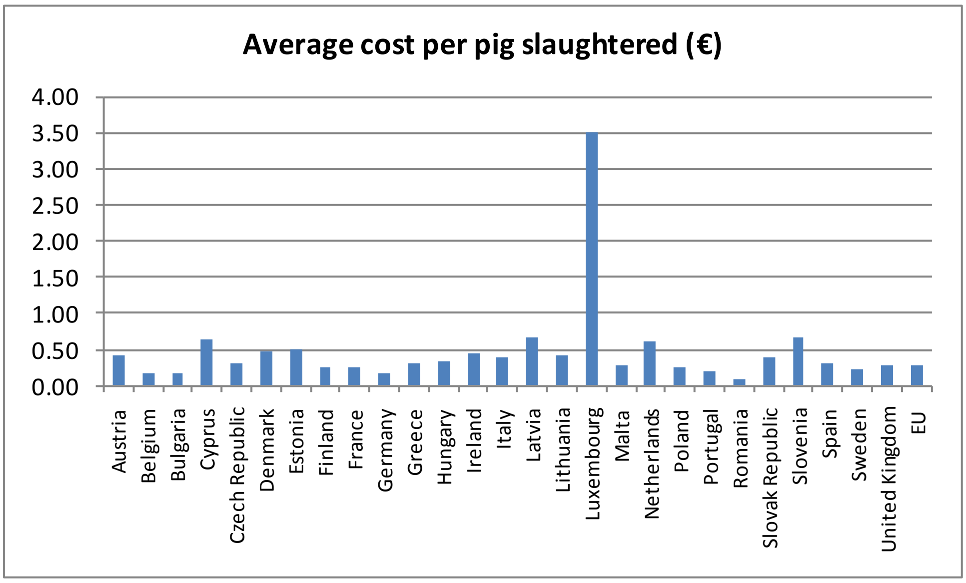
[24] The authors know that herd and animal prevalence are different, but this was the only proxy available for the analysis

Figure 49: Intervention costs by Member State for scenario 3



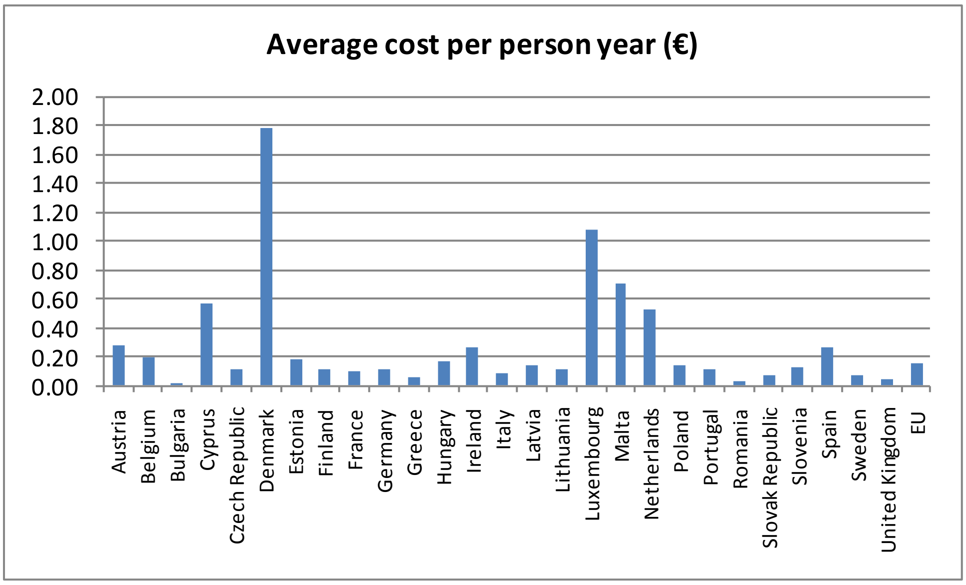
The average cost per pig slaughtered for scenario 3 is €0.29 with a high of €3.49 in Luxembourg and a low of €0.10 in Romania (see Figure 50).

Figure 50: Intervention costs per pig slaughtered for scenario 3



The average cost per person year for scenario 3 is €0.15 with the lowest being for the Bulgaria at €0.02 and the highest in Denmark at €1.79 (see Figure 51).

Figure 51: Intervention costs per person year for scenario 3



Scenario 3 cost estimates will be combined with estimates of the benefits of *Salmonella* control interventions in the following Chapter.

6.11.4 Costs of Scenario 4

Cost of scenario 4 implements all potential pre-harvest interventions identified in the study. These interventions are supported by a coordination unit and monitoring. The most important input data for the baseline and monitoring scenario are as follows:

- The same set of activities for scenario 3
- Transport assumes that:
    - 10% of weaners and rearers are transported
    - 100% of fatteners are transported
    - 80% of the transport is of good quality
    - There is a constant 10% increase in the number of pigs well transported for all categories
    - The extra costs for transporting a pig well (versus badly) are €0.79, €0.79 and €3.34 for weaners, rearers and fatteners respectively
- Slaughterhouse assumes that
    - 50% of pigs are slaughtered in inadequate systems to reduce *Salmonella* infection
    - There is a constant 10% increase in the number of pigs slaughtered in adequate facilities
    - The extra costs of slaughter a pig in low risk facilities is €0.31 per pig
- All other interventions are set to zero

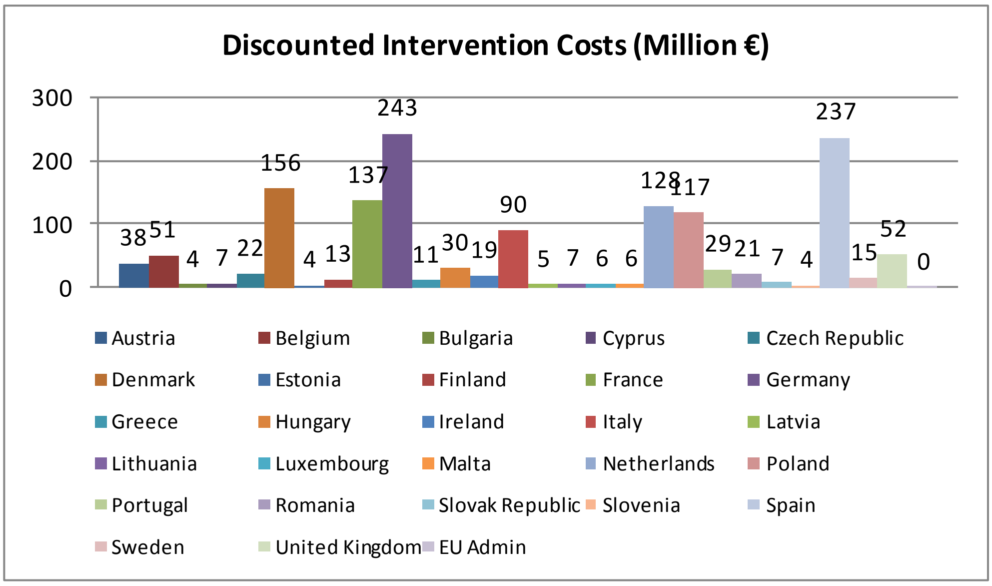
The model estimates that a total of €1,458 million of discounted costs will be incurred with Scenario 4, and of those costs 40% are due to transport (see Table 59). This indicates that the transport costs may be too high, particularly for finished pigs.

Table 59: Estimated undiscounted and discounted costs for scenario 4.

Intervention	Costs (million €)	
	Undiscounted	Discounted
Feed	189	146(10%)
Breeding Farm	6	4(0.3%)
Fattening Farm	408	316(22%)
Transport	750	579 (40%)
Slaughterhouse	164	127 (9%)
Monitoring	220	163 (11%)
Support Unit	152	124 (8%)
Total	**1,888**	**1,458**

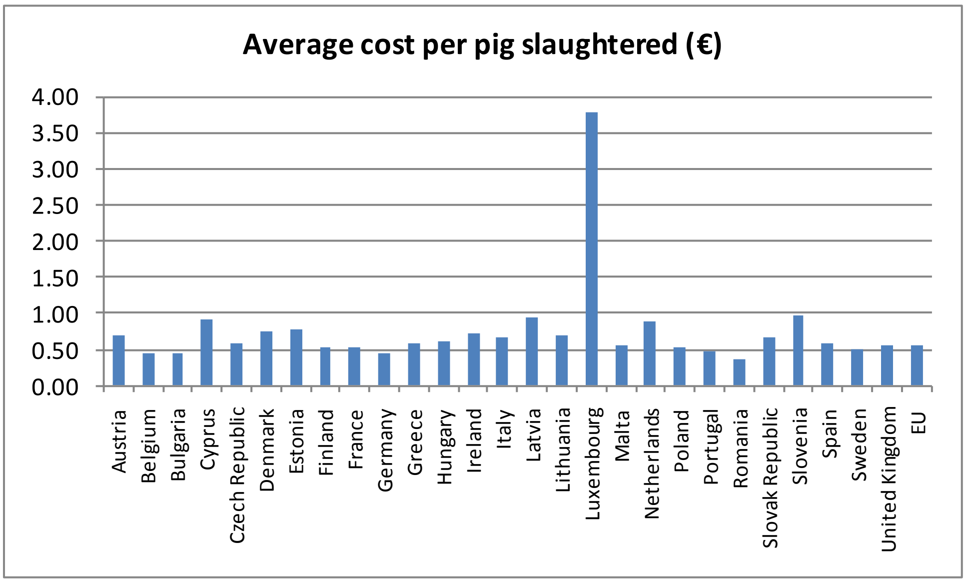
Again the major proportion of the costs are borne by the countries with the largest pig populations and levels of production so Germany, Spain, Denmark and France (see Figure 52).

Figure 52: Intervention costs by Member State for scenario 4



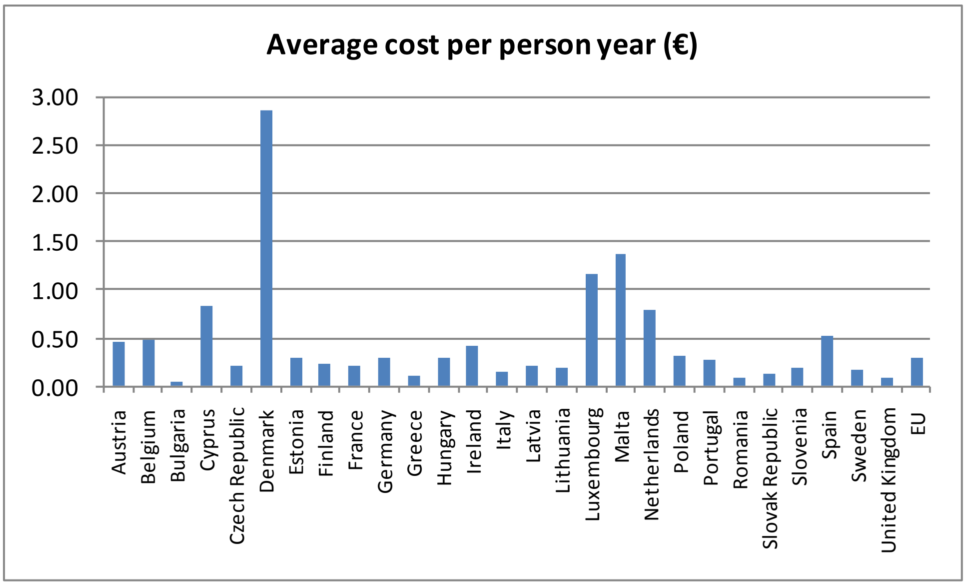
The average cost per pig slaughtered for scenario 4 is €0.57 with a high of €3.77 in Luxembourg and a low of €0.38 in Romania(see Figure 53).

Figure 53: Intervention costs per pig slaughtered for scenario 4



The average cost per person year for scenario is €0.29 with the lowest being for the Bulgaria at €0.06 and the highest in Denmark at €2.85(see Figure 54).

Figure 54: Intervention costs per person year for scenario 4



Scenario 4 cost estimates will be combined with estimates of the benefits of *Salmonella* control interventions in the following Chapter.

6.12 Summary

The Chapter has presented information on the possible pre-harvest interventions to control and manage *Salmonella* in pigs. It has identified seven different categories of costs associated with the control of *Salmonella* in pigs: feed; breeding pig and replacement stock; farm-level measures; transport; slaughterhouse; monitoring and a support unit. The consortium has carried out thorough review of the literature, both peer reviewed and gray, on these different categories and presents summaries of what the practical interventions are and what they would cost if implemented. A cost intervention model was developed to determine the costs of the interventions across individual Member States and also across the EU. The model is deterministic, but allows user to modify input parameters by intervention and also by Member State, and therefore can be used to carry our sensitivity analysis. The model output presents an overall sum of the costs of interventions and theses costs by intervention category and by Member State. In addition some cost-effectiveness measures are also presented in terms of cost per pig slaughtered and cost per person year.

Based on what is known about the potential impacts of the interventions reviewed on *Salmonella* prevalence at slaughter point in pigs four scenarios were developed and placed into the model to determine their costs. All the scenarios described are plausible as either small scale interventions of a support unit and monitoring relying on the existing structures of the pig industry and public sector to implement change to a targeted selection of interventions prioritized on the basis of the QMRA and finally a whole sale level of interventions. The costs vary from €287 million for the smallest set of interventions through to €1,458 million for most comprehensive programme. Estimations of costs alone is an inadequate measure to make decisions on targets for the reduction of *Salmonella* in pigs. Therefore the next Chapter will combine the cost estimates with the potential benefits from reducing *Salmonella* in pigs.

7 Cost-benefit analysis

7.1 Introduction

In recent years, the food supply chain has lengthened bringing additional sources of risk to the safety of food. The food production process that ensures the delivery of 100% safe products is not available but a practical tool measuring marginal social costs and benefits could establish whether a higher level of safety proposed in the legislation is justified or not. This is the basis for carrying out an economic cost–benefit analysis as part of the overall assessment and evaluation of regulatory options available to risk managers. (Traill et al., 2009).

The conventional form of benefit-cost analysis is to calculate the present discounted value of benefits and costs associated with the regulatory intervention. It is essential to differentiate between private benefits which come directly to the individual consuming the food product (decrease risk of suffering from ill-health and premature death), and public benefits, public sector savings from reduced visits to doctors and hospitals, reduced medication and costs associated with missed days of work. The costs are based on the changes in pig production's expenditure as well as costs associated with enforcement duties (Antle, 1998).

When investigating the potential intervention options at the pre-harvest farm level to achieve a targeted reduction of *Salmonella* in slaughter pigs, the foreseen results of applying those options must be combined with the feasibility of implementing such interventions. This feasibility is dependent on e.g. the practicality, sustainability, pig producer compliancy and the cost of the intervention, which could also be summarised as the *efficiency* (Lo Fo Wong et al., 2006).

This consideration is especially relevant in this particular case where the *Salmonella* infection may not cause clinical symptoms in pig herds and *equity* is therefore not achieved since the pig producer bears the cost of the public health benefits. The costs are therefore quantified to be used by policy-makers. In spite of the possible indirect benefit to the farmer when controlling *Salmonella* through improving the health status of the herd, producer's costs may not be recovered from the consumers due to unwillingness to pay an extra premium for safer food, especially if cheaper alternative products from third countries are available on the market (Lo Fo Wong et al., 2006). The previous Chapter has reviewed the potential interventions in depth and selected only the interventions that were considered feasible.

The Chapter presents how the cost-benefit analysis model has been developed and how it links the human health impact model with the intervention cost model. This model is then used to present the cost-benefit analysis of the four scenarios of interventions described in the previous Chapter. This is followed by a discussion of how these scenarios relate to the targets of 50% and 90% in *Salmonella* in pigs over the analysis period.

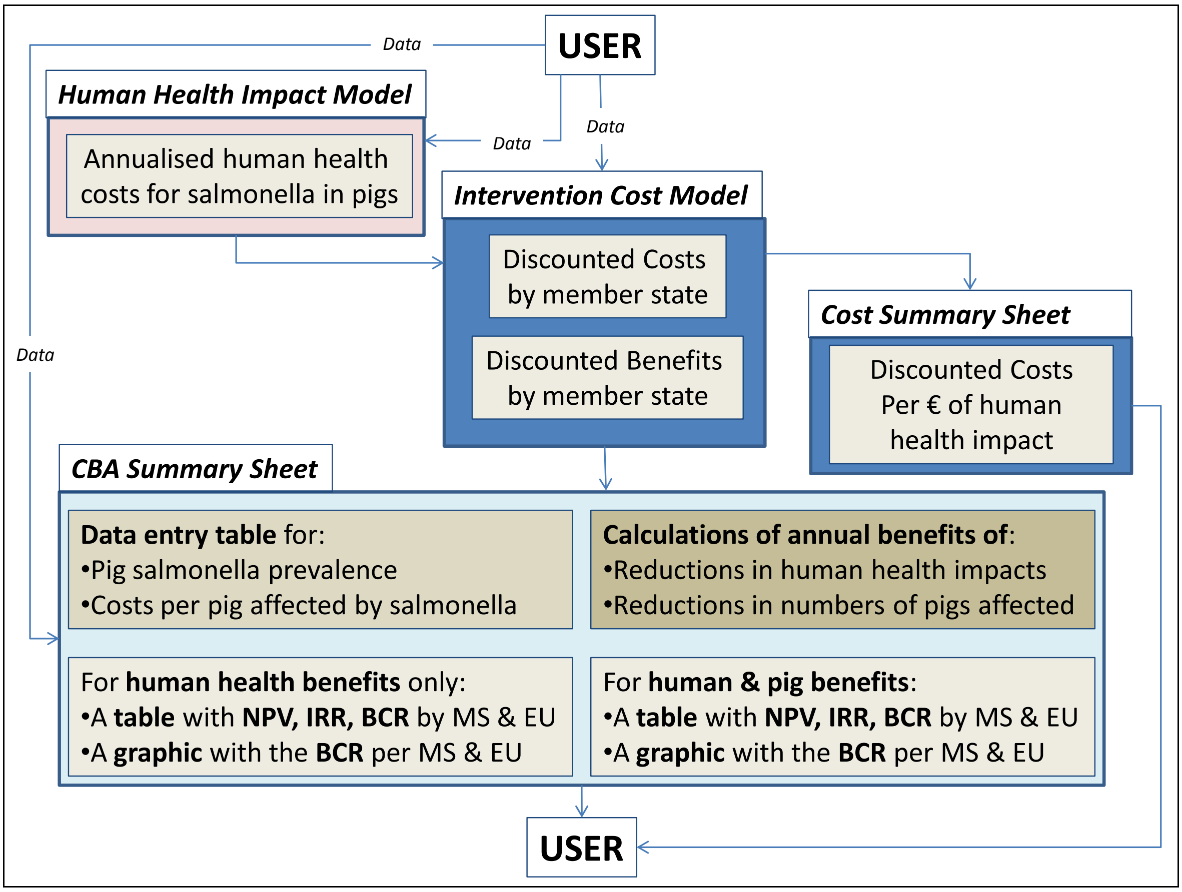
7.2 Description of model structure

The cost-benefit analysis model uses three different elements:

1. The estimates of the impact of *Salmonella* in pigs on human health
2. The costs saved by reducing the prevalence of *Salmonella* in the pig herd
3. The costs of the pre-harvest interventions

Points 1 and 2 are used to make estimates of the benefits from the control of *Salmonella* in pigs, so the reduction in *Salmonella* in pigs is assumed to generate benefits in terms of costs saved in pig production and losses avoided in the terms of human health. These are combined with the costs of interventions to calculate to perform a cost-benefit analysis. The model structure is presented in Figure 55.

Figure 55: The cost-benefit analysis model and its relationship to the models to estimate human health impact and intervention costs



The analysis period is ten years, which given the time required to make changes significant enough to have an impact on pig *Salmonella* seem reasonable[25]. The discount rate used for the analysis is 4%. The model is flexible enough to allow a change in discount rate, but would require major modification to make the analysis period either shorter or longer.

7.2.1 Benefit calculations –

The benefit calculations are carried out in a CBA Summary Sheet, which is part of the cost interventions model work book. The next two sections describe how data has been entered and the calculations are carried out to estimate the benefits.

[25] Note the Swedish programme has been running for many years and so has the Danish system, both took time to realise reductions in *Salmonella* in pigs.

7.2.1.1 Human health impacts avoided

Data have been entered and can be modified on the annualized health losses due to *Salmonella* in pigs by Member State. Data used for the model runs are based on the human health impacts estimated in Chapter 5. The model allows the user to set the rate at which these losses can be reduced each year either as a standard annual percentage or as a differing percentage over the 10 year analysis period. The calculation is as follow:

Human health impacts avoided in Year 1 $= I \times r$

Human health impacts avoided in Years 2 to 10 $= a + ((I-a) \times r)$

Where *I = estimated annualized losses*

r = rate of reduction (either constant or variable)

a = previous year's avoided impacts

Overall the benefits from avoiding human health losses caused by *Salmonella* in pigs are the most important and of greatest societal concern.

7.2.1.2 Herd-level productivity benefits from the control of Salmonella in pigs

In addition to the benefits generated in human health, the removal of *Salmonella* from pigs can also have an impact on pig production. Production losses have been reported due to salmonellosis in livestock in various countries derived from increased mortality, veterinary and drugs expenditure, lack of weight uniformity on the lot and production parameters' impact (Lo Fo Wong et al., 2000 and Krug (1985) stated that in some countries livestock production losses due to salmonellosis may exceed the costs of *Salmonella* infection in humans.

In Netherlands a cost-benefit analysis showed that the costs associated with adding acids to water was completely compensated by the pigs' improved technical and economic results (van der Heijden, 2006) Lo Fo Wong et al. (2000) showed that average productivity losses associated with *Salmonella* infection were significantly greater than the costs of control measures to avoid the infection. The study reports that the with the addition of organic acid to feed or drinking water, the daily weight gain was 22 grams (2.82%) higher and feed conversion rate 0.075 feed units (2.61%) lower than without these control measures. Where margins are tight this can affect producer profits and may result in increased food costs to consumers (Lo Fo Wong et al., 2000).

Given the above information the consortium decided to include the benefits from losses avoided by the reduction of *Salmonella* in pigs in the cost-benefit analysis. Within the CBA Summary sheet data were entered, and can be modified, on the prevalence of *Salmonella* in slaughter pigs. The data used were the results from the EFSA study on lymph node prevalence in slaughter pigs by Member State, which does not include data from Malta or Romania. These prevalences are used to calculate the number of slaughter pigs per year that are affected by *Salmonella* by multiplying the total number of slaughter pigs by the average prevalence. Data were also added in terms of the costs of a pig having *Salmonella* in its lifetime. In the current model this was set to €1.55 per pig, which is the sum of daily weight impacts, antibiotic therapy and impact on the quality of the pig.

The model has entered data, which can be modified, on the rate of reduction in the numbers of pigs affected by *Salmonella*. The rate can either be constant for each year of the analysis period or varied for each year. It is used to calculate the additional pigs produced that are free from *Salmonella* in the following way:

Additional clean pigs in Year 1 = I x r

Additional clean pigs in Years 2 to 10 = a + ((I-a)xr)

Where I = initial number of pigs with Salmonella

r = rate of reduction (either constant or variable)

a = previous years additional clean pigs produced

It is recognized that large changes in the supply management of slaughter pigs will have an impact on pigmeat markets. If these changes are large and significant there is a need to estimate price changes and calculate producer and consumer surpluses from the changes. The changes recorded for *Salmonella* control appear relatively small and therefore it was decided not to include an estimate of the impact on markets in the cost-benefit analysis.

7.2.1.3 Additional considerations in the benefit streams - market shocks

Over the last thirty years information that livestock products have food borne diseases has created significant market shocks. Of greatest significance have been the

- *Salmonella* in eggs shock in the 1980s in the UK
- BSE in cattle shocks in the 1990s in Europe and globally
- HPAI in poultry in the 2000s both nationally and globally.

These shocks are difficult, if not impossible, to predict, and can only be adequately quantified after the event. They are of much concern to the livestock industry and of particular importance where there is:

- High infrastructure and genetic investments – high fixed costs
- Inflexibility in the range of finishing times
- Small capacity for storage of excess pork meat during dips in demand

The model has not included a component to estimate the impact of a market shock because of the random nature of these events and that across society they create winners and losers. The winners are the people involved in the sector that produce livestock products that are perceived as being safer which are purchased in greater quantities. The losers are those involved in the livestock products identified as high risk. The impact of these perceptions has been shown to be short lived for poultry products, but has accelerated downward trends in red meats.

It is recognized that if a market shock were to occur with regards the presence of *Salmonella* in pigs it would have a major impact on this component of the livestock sector.

7.2.2 Cost calculations

The cost calculations for the cost-benefit analysis use the intervention cost model described in the previous chapter.

7.2.2.1 Additional considerations on the cost streams

Pig sectors are not static, they are constantly adapting the production levels to the market usually through the variation of prices. The sector is known for the “pig cycle” typified by oscillating fluctuations in prices and supply. In addition to these general characteristics of the pig sector, the sector in the EU is dynamic for other reasons. Labour costs and differences in enforcement of legislations have created differentials across the Member States. Some Member States have been able to take advantage of these differentials to rapidly expand their pig production. The most notable is Spain where lower labour costs and different adoption rates of environmental and welfare legislation plus the existence of a significant entrepreneurial spirit has created a very large pig production cluster in the south-eastern part of the country. The original establishment of these units involved the movement of pigs from northern Europe in large numbers. It is possible that these pigs brought *Salmonella* with them and that the journey of many kilometres created an environment where infection rates were high. This may be one of the explanatory factors for the relatively high levels of *Salmonella* detected in pigs in Spain.

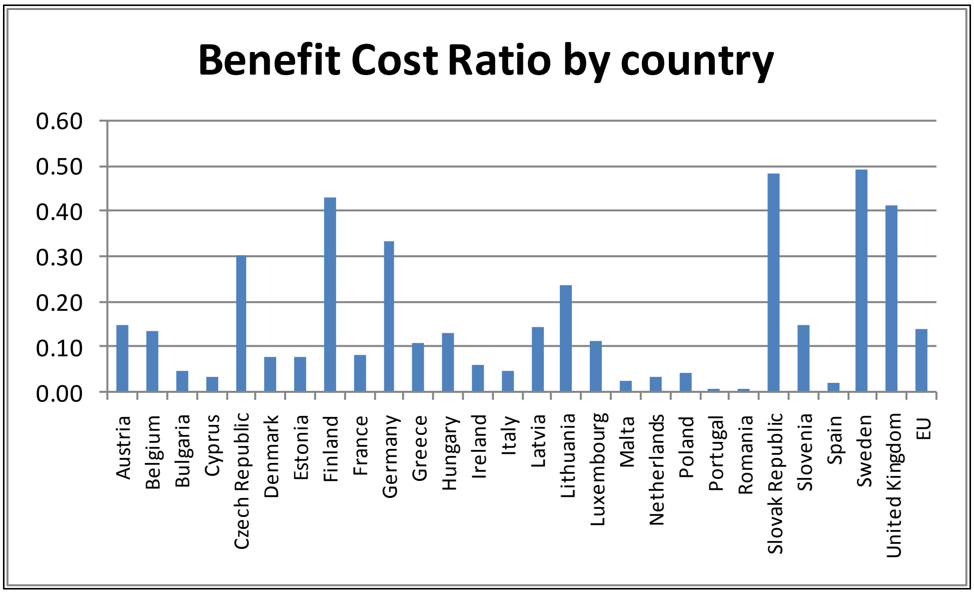
7.2.3 Cost-benefit analysis output

The CBA Summary sheet calculates the discounted benefits using the discount rate set in the Input Data sheet. The estimated undiscounted and discounted benefits are used for each Member State and EU sheets to calculate the NPV, IRR and BCR by Member State and for the EU. Two different cost-benefit analyses are presented which:

1. Only includes the benefits from the human health impacts
2. Includes the benefits from human health impacts and pig production.

For each a summarized table for the project worth criteria is presented and also a graphic is produced showing the BCR by country (see Figure 56).

Figure 56: Output graphic showing the BCR by Member State and EU as a whole



These criteria give a good indication of the social economic profitability of a change in *Salmonella* control interventions in pigs. There are two points of caution:

- The criteria do not provide a complete understanding of the drivers for change in terms of individual and private company incentives to modify actions and make investments.
- The benefits from avoidance of human health impacts need to be tempered with the realization that they may lead to a change in the occurrence of *Salmonella* from other causes. The most likely of these are travel which has been the experience in the Scandanavian countries and appears to be the trend in the Netherlands.

7.3 Results of the CBA for agreed scenarios to reduce human infection

7.3.1 General considerations

In regards to the predicted impact of the potential measures to control *Salmonella* in pigs, results from the Quantitative Microbiological Risk Assessment (QMRA) of *Salmonella* in slaughter and breeder pigs was meant to be used as referred to in the contract specifications. The QMRA model was based on input data from the EFSA's baseline studies of *Salmonella* in breeder and slaughter pigs, and other relevant data (EFSA Journal 2010; 8(4):1547). However, this model has not given clear indications of which set of control interventions would lead to a 50% and 90% reduction in *Salmonella* prevalence in pigs. The study made the following observations:

- Purchase of *Salmonella* negative pigs is of particular importance in herds with low *Salmonella* infection level or no *Salmonella* infection.
- Batch (all in/all out) production enables the farmer to break infection chains between batches by cleaning and disinfecting the production sites prior to introducing new pigs.
- Feed can be formulated and treated (e.g. acid supplements, grain size, no pelleting, pro- or pre biotics) to reduce survival and multiplication of *Salmonella*, once ingested, by lowering pH in the gastrointestinal tract and increasing the concentration of short-chain organic acids (Hansen, 2004).
- To reduce infection risk, codes for good farming practice must be followed: ensure daily routines starting in lower risk areas towards high risk areas i.a. from sections with young animal to older animals where the likelihood of an animals having been exposed to infection is higher.
- Wash and disinfect hands continuously between infected and non-infected areas and clean/disinfect or change boots and change clothes on entry to barns
- Avoid in-farm spread by rearing pigs in smaller groups and avoiding physical contact between groups through sectioning and closed pen separations.
- Prevent *Salmonella* entering the feed and subsequently the herd, by transporting and storing the feed and feedstuff in clean environments,
- Ensure high biosecurity by controlling the entrance of rodents, birds, insects, etc. and restrict traffic by personnel and pets.

The efforts to control *Salmonella* infection in pigs should in general be a combination of minimising or preventing exposure to *Salmonella* and maximising pig resistance. Most single interventions and control measures are not effective enough to reduce or remove a *Salmonella* infection or contamination from a herd. It is therefore recommended that a herd-specific intervention and control strategy is formulated, based on a combination of measures which are the most practical and economically feasible in a herd. A multi-factorial infection such as *Salmonella* requires a multi-level approach of intervention and control, i.e. between and within herds, as well as between and within pigs.

7.3.2 Predicted impact of pre-harvest interventions (QMRA)

The *Salmonella* transmission has been modelled "form-farm-to-fork" by the QMRA Consortium in order to estimate the relative impact on predicted *Salmonella* prevalence of some potential control interventions on the incidence of human cases, suggesting that around 10-20% of human *Salmonella* infections in EU may be attributable to the pig reservoir as a whole.

Taken into account the data gaps of the model, the QMRA has found an almost direct relation between the reduction in pig lymph node prevalence and the reduction in the number of human cases attributable to pig meat products

The QMRA has also identified the main sources of *Salmonella* infection at the pre-harvest stage of the pork production. Implementing control interventions may lead to a significant reduction in *Salmonella* pig prevalence, and consequently, in the number of food borne human cases linked with pig meat consumption. Theoretically, according to the QMRA following scenarios appear possible:

(a) by ensuring that breeder pigs are *Salmonella*-free a reduction of 70-80% in high prevalence MSs and 10-20% in low prevalence MSs can be foreseen;

(b) by feeding only *Salmonella*-free feeding stuffs, a reduction of 10-20% in high prevalence MSs and 60-70% in low prevalence MSs can be foreseen; and

(c) by preventing infection from external sources of *Salmonella* (i.e. rodents and birds) a reduction of 10-20% in slaughter pig lymph node prevalence can be foreseen in both high and low prevalence MSs.

7.3.2.1 Breeding

Breeding pig herd prevalence is a strong indicator for slaughter pig prevalence (validated in some part by the results of the EU-wide baseline surveys in breeding and slaughter pig surveys), which in turn is a strong indicator of human risk. Hence, by reducing breeding pig herd prevalence major reductions in the number of human cases could be achieved. Greater reductions could be achieved when breeding pig herd prevalence is high. As the sensitivity analysis for the farm suggested that the most important factor within the model was the amount of *Salmonella* the pigs (either sows or slaughter pigs) were shedding. Therefore to reduce slaughter pig prevalence the number of infected piglets entering the weaning stage must be reduced.

Feed and external sources of contamination (e.g. rodents) become more important once the number of infected pigs entering the weaning stage is reduced, suggesting those parameters as the **first step**, but if breeding pig herd prevalence is high that should be controlled as a first measure. Feed and external contamination of finishing pigs can also have a positive effect once breeding pig herd infection is reduced to low levels (perhaps below 5-10%).

7.3.2.2 Feed

Reducing feed contamination can have a measurable effect in reducing slaughter pig prevalence, and hence human illness, even where breeding pig herd prevalence is high. A greater relative effect can be seen for Member States where breeding pig herd prevalence is lower.

7.3.2.3 On-farm

In contrast, evidence that specific farm and transport interventions work consistently is sparse, if non-existent, presumably due to the more complex environment in which these interventions will have to be applied, and the difficulty in standardizing experiments to trial interventions. Hence, while the evidence for consistent effects is lacking, some farm interventions may well be effective. This was the conclusion of Denagamage *et al.* 2007 for vaccination, but no quantitative effect was shown. This lack of evidence for a consistent and/or quantitative effect meant that specific farm interventions could not be modelled. In order to provide some assessment of farm interventions, only the effect has been modelled of the varying mechanisms applied to farm interventions (e.g. modifying the dose-response for vaccination, lowering the contamination of pens for cleaning).

7.3.2.4 Increased cleaning/downtime

While the mechanisms for removing *Salmonella* are different for downtime and cleaning, the effect is similar – a reduction in the *Salmonella* levels present in a pen at the point where a new batch of pigs enters the pen. There is a marked effect of reducing contamination levels before pen re-population, especially if levels up to 2 logs can be achieved. However, at present it is unlikely that average cleaning efficiency can be improved to achieve this 2 log reduction. The effect of downtime is very similar (if achieved by different means), because the number of days chosen 3 and 6, correspond to a 1.2 and 2.4 log reduction in contamination levels. Therefore downtime could also have a positive effect if pens are left empty for 3+ days

7.3.2.5 Increasing resistance of the pig (vaccination, organic acids)

Within the model, the resistance of the pig to infection is governed by the probability of infection given ingestion of a particular dose. Modifying the dose-response relationship for ALL pigs at ALL stages of production across a MS will produce a similar trend in results for each MS. It is clear that a modest 1-log increase in the dose needed to cause the average probability of infection will have a significant effect (~ 90% for all product types) in reducing slaughter pig prevalence and subsequently the human risk of illness. It must be remembered that this is the effect of consistently modifying the dose response relationship for *all* pigs at *all* stages of production – something which has yet to be shown to be practical for such interventions as vaccination or organic acids.

There is stronger evidence that feed type (coarser feed) might have an effect, but still whether a significant increase in the dose needed to cause infection can be achieved is still being investigated.

A further log increase in dose needed to produce the same baseline probability of illness doesn't have the same magnitude of effect, and the published literature suggests this may well be unobtainable with current interventions.

7.3.2.6 Varying probability of feed contamination

The effects of reducing feed contamination are shown for two countries investigated by the QMRA (MS4 and MS1). One country (MS1) was also investigated for this analysis due to the identified importance of feed. There is a relatively linear relationship between slaughter prevalence of feed contamination and slaughter pig prevalence (and the human risk of illness) for both MS1 and MS4, although there is a steeper gradient for MS1 (meaning, as suspected, that feed is relatively more important in MS1 than MS4).

7.3.2.7 Transport

Transport interventions (logistic transport, increased cleaning), even assuming 100% uptake and 100% compliance/effectiveness, were assessed to have an insignificant effect in reducing the probability of human illness

7.3.2.7.1 Logistic transport

Transporting more than one batch of pigs in one transport vehicle had minimal effect on slaughter pig prevalence, and hence risk of human illness, for any MS.

7.3.2.7.2 Logistic slaughter

The effect of slaughtering high-risk batches at the end of the slaughter day was negligible on slaughter pig prevalence, and hence risk of human illness, for any MS. This is because the vast majority of cross-contamination during transport occurs within the same batch, rather than between batches of pigs.

7.3.2.7.3 Increased cleaning at transport

Increased cleaning techniques producing a 0.5, 1 or 2 log reduction in transport contamination before loading of pigs) had minimal effect on slaughter pig prevalence, and hence risk of human illness, for any MS.

7.3.3 Scenario 1 – Cost-benefit analysis

7.3.3.1 Key input data

The analysis is performed over a ten year period with a 4% discount rate.

The costs of scenario 1 are the described and presented in Chapter 6.11.1

The following data have been entered to calculate the benefits:

- Human health benefits
    - The losses from human health are those presented in Chapter 5.7.
    - The rate of reduction in human health impacts has been varied over the ten year period starting at 1% in year one and increasing by a 1% a year across all Member States.
    - A sensitivity analysis was performed with a constant rate of reduction and taken to be 6%[26] a year across all Member States.
- Pig production benefits
    - The number of pigs affected by *Salmonella* is taken to be the proportion reported to have *Salmonella* during the EFSA slaughter pig prevalence study (the only animal prevalence study available).
    - The benefit from a clean pig produced is taken to be €1.55 per pig
    - The rate of reduction in human health impacts has been varied over the ten year period starting at 1% in year one and increasing by a 1% a year across all Member States.
    - A sensitivity analysis was performed with a constant rate of reduction and taken to be 6% a year across all Member States.

[26] A constant 6% rate of reduction would achieve 50% reduction in *Salmonella* impact over 10 years.

7.3.3.2 Results

Only two Member States had a positive cost-benefit analysis, Germany and the United Kingdom. The BCR results for both benefit scenarios are shown in Figure 57 and Figure 58 and the general results for the EU are shown in Table 60

Figure 57: Benefit cost ratios by Member State and the EU for scenario 1 with a varying rate of reduction and only the human health benefits

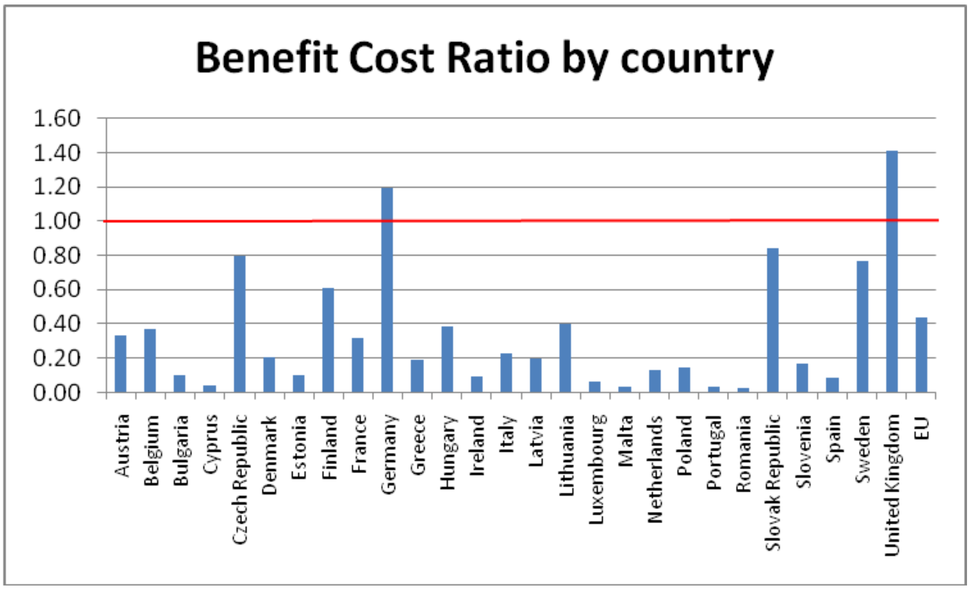


Figure 58: Benefit cost ratios by Member State and the EU for scenario 1 with a varying rate of reduction and human health and pig benefits

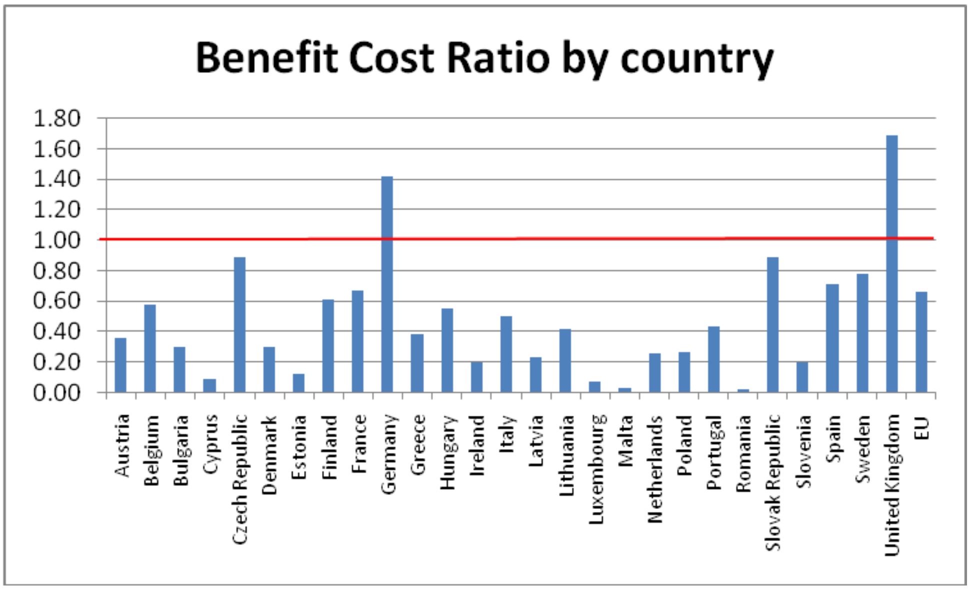


Table 60: Net present value, internal rate of return and benefit cost ratio for the EU for scenario 1 and a varying rate of reduction.

Benefits included	NPV	IRR	BCR
Human health	-161,538,589	Could not be Calculated	0.44
Human health and pig production	-97,705,579	Could not be Calculated	0.66

Countries with low levels of *Salmonella* and/or high levels of imports of pig meat products would appear to create the highest BCR. The former group may have too much being attributed to reductions in *Salmonella* in pigs to human health and the latter are receiving benefits from the costs of implementation in countries they receive pig meat products from.

A sensitivity analysis with a constant rate of reduction in human losses and increase in pig productivity generated a more positive scenario, but still only just broke even when pig benefits were included (see Table 61).

Table 61: Net present value, internal rate of return and benefit cost ratio for the EU for scenario 1 and a constant rate of reduction in human health losses and increase in pig productivity of 6%

Benefits included	NPV	IRR	BCR
Human health	-97,794,102	Could not be Calculated	0.66
Human health and pig production	20,929,862	Could not be Calculated	1.07

The scenario only adds a small coordination unit to each country and some extra monitoring, a realistic assumption given that a control programme needs a group doing the coordination and has to be monitored. The effect of these minimal changes to the pig sector may encourage private sector changes that are cost neutral such as replacement of equipment and upgrading of management systems. However, the impact is unlikely to be rapid and the analysis performed assumed first that a slow rate of reduction in human health cases would accrue, plus a similar change in pig productivity. This does not produce an investment that generates an economic profitability in direct monetary terms.

Sensitivity analysis with a more optimistic constant rate of reduction of 6% in health losses alone also does not give a positive NPV or a BCR greater than 1. However, if a similar constant rate of reduction in pigs affected by *Salmonella* is included the investment gives a small NPV of €21 million and a BCR 1.07.

7.3.4 Scenario 2 – Cost-benefit analysis

7.3.4.1 Key input data

The analysis is performed over a ten year period with a 4% discount rate.

The costs of scenario 2 are the described and presented in Chapter 6.11.2

The following data have been entered to calculate the benefits:

- Human health benefits

  - The losses from human health are those presented in Chapter 5.7.
  - The rate of reduction in human health impacts is constant and taken to be 6% a year across all Member States.
- Pig production benefits
  - The number of pigs affected by *Salmonella* is taken to be the proportion reported to have *Salmonella* during the EFSA slaughter pig prevalence study (this is the only animal prevalence study available).
  - The benefit from a clean pig produced is taken to be €1.55 per pig
  - The rate of reduction in the numbers of pigs is constant across years and taken to be 6% across all Member States.

7.3.4.2 Results

Only Sweden had a BCR greater than one, and the overall EU BCR was 0.17 when only the human health benefits were considered. The BCR results for both benefit scenarios are shown in

Figure 59 and Figure 60 and the general results for the EU are shown in Table 62.

Figure 59: Benefit cost ratios by Member State and the EU for scenario 2 with only the human health benefits

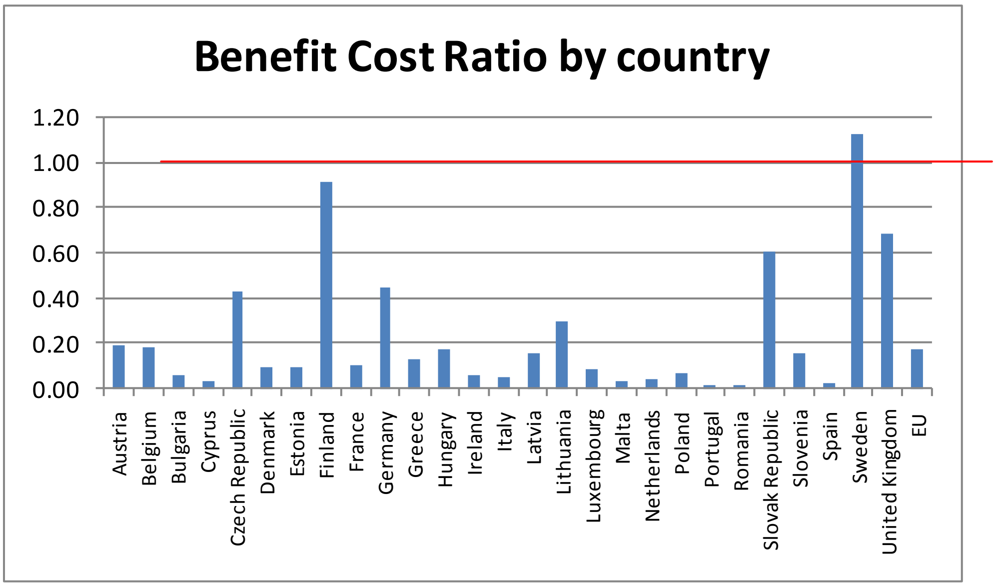


Figure 60: Benefit cost ratios by Member State and the EU for scenario 2 with human health and pig benefits

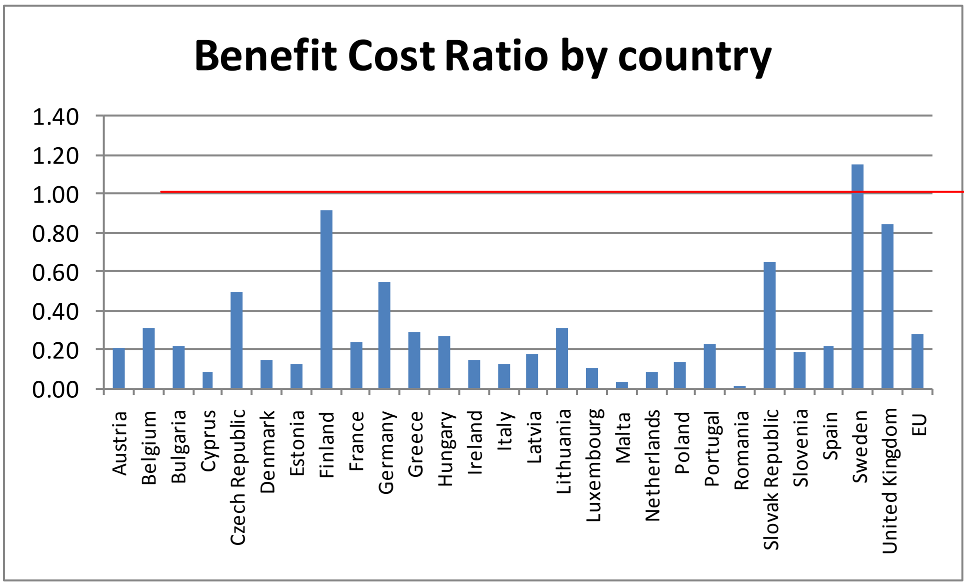


Table 62: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 2

Benefits included	NPV	IRR	BCR
Human health	-900,397,401	Could not be Calculated	0.17
Human health and pig production	-781,673,436	Could not be calculated	0.28

Countries with larger pig sectors and high levels of *Salmonella* in their herd gain show a more marked improvement in the cost-benefit analysis results with the inclusion of pig benefits. However, only Sweden returns a positive result and overall the EU had a low BCR at 0.28 for this change.

A sensitivity analysis was carried out that assumes all the human health losses would be eliminated in the first year and in every subsequent years and that all pigs were free of *Salmonella* returned a BCR of 1.07. This would however be impossible to achieve. The result does indicate that the investment would only be worthwhile with the immediate elimination of *Salmonella* in both humans and pigs.

7.3.5 Scenario 3 – Cost-benefit analysis

7.3.5.1 Key input data

The analysis is performed over a ten year period with a 4% discount rate.

The costs of scenario 3 are the described and presented in Chapter 6.11.3.

The following data have been entered to calculate the benefits:

- Human health benefits
    - The losses from human health are those presented in Chapter 5.7

- The rate of reduction in human health impacts is constant and taken to be 10% a year across all Member States.
- Pig production benefits
    - The number of pigs affected by *Salmonella* is taken to be the proportion reported to have *Salmonella* during the EFSA slaughter pig prevalence study (the only animal prevalence study available).
    - The benefit from a clean pig produced is taken to be €1.55 per pig
    - The rate of reduction in the numbers of pigs is constant across years and taken to be 10% across all Member States.

7.3.5.2 Results

Overall the cost-benefit analysis generates a negative NPV and a BCR less than one. For the benefit scenario that includes only the losses saved with human losses Finland, Germany, Sweden and the UK have a positive CBA.

The BCR results for both benefit scenarios are shown in Figure 61 and Figure 62 and the general results for the EU are shown in Table 63.

Figure 61: Benefit cost ratios by Member State and the EU for scenario 3 with only the human health benefits

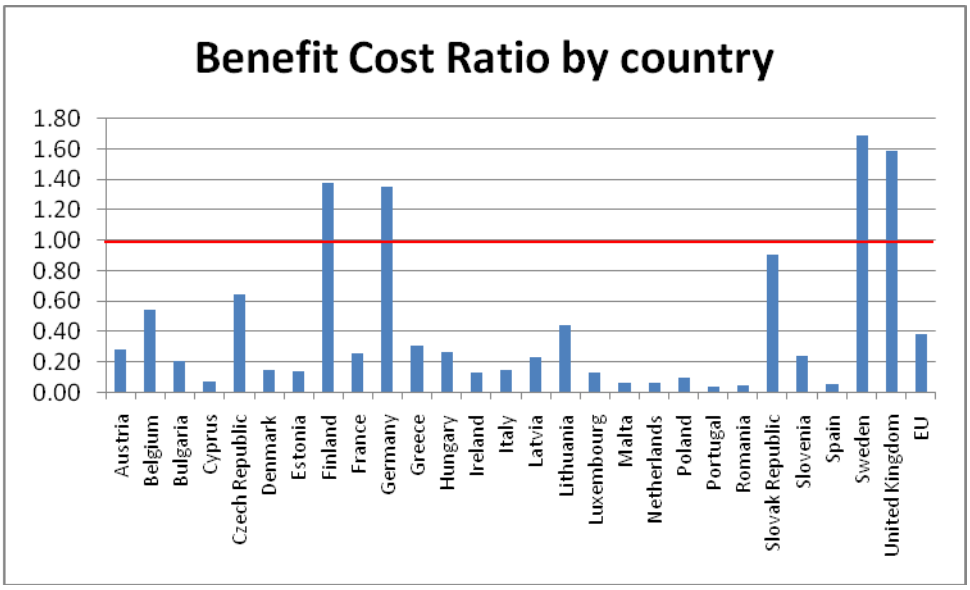


Figure 62: Benefit cost ratios by Member State and the EU for scenario 3 with human health and pig benefits

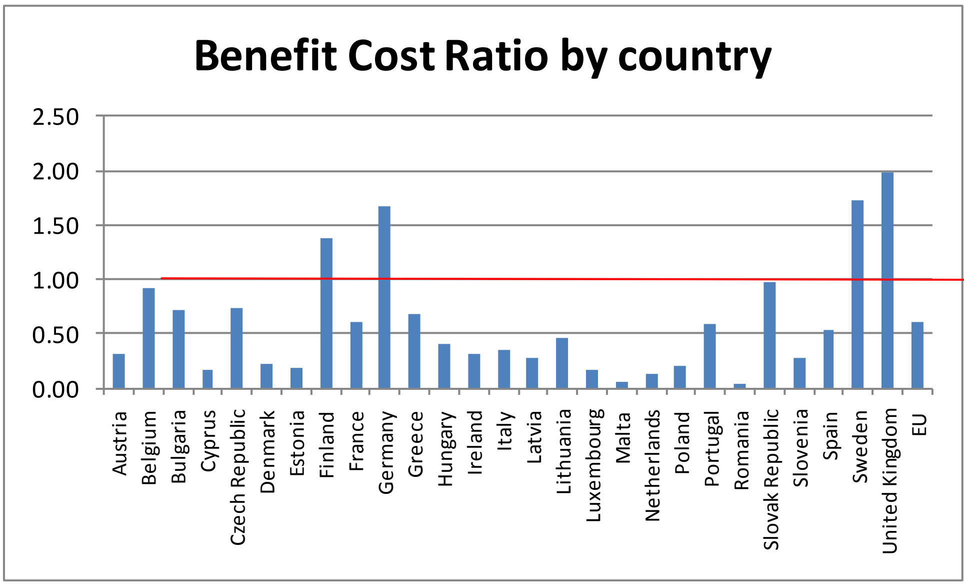


Table 63: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 3

Benefits included	NPV	IRR	BCR
Human health	-469,093,526	Could not be Calculated	0.38
Human health and pig production	-291,023,937	Could not be calculated	0.61

By adding the benefits from having fewer pigs affected by *Salmonella* there was an improvement in the CBA measures of project worth but still no overall positive outcome and no additional countries that returned an economically positive investment.

A sensitivity analysis was performed assuming that all *Salmonella* in the human population was eliminated immediately and for every year of the analysis. This returned close to a break-even, i.e. NPV close to zero and BCR close to 1. As stated for scenario 2 this is an impossible outcome and demonstrates the difficulties of achieving a positive return.

7.3.6 Scenario 4 – Cost-benefit analysis

7.3.6.1 Key input data

The analysis is performed over a ten year period with a 4% discount rate.

The costs of scenario 4 are the described and presented in Chapter 6.11.4.

The following data have been entered to calculate the benefits:

- Human health benefits
    - The losses from human health are those presented in Chapter 5.7
    - The rate of reduction in human health impacts is constant and taken to be 20% a year across all Member States.
- Pig production benefits

- The number of pigs affected by *Salmonella* is taken to be the proportion reported to have *Salmonella* during the EFSA slaughter pig prevalence study as this is the only animal prevalence study available.
- The benefit from a clean pig produced is taken to be €1.55 per pig
- The rate of reduction in the numbers of pigs is constant across years and taken to be 20% across all Member States.

7.3.6.2 Results

Finland, Sweden and the United Kingdom show a BCR greater than 1. The former two countries have relatively small numbers of additional interventions and potentially the human health benefits are too high for these countries given their already very low levels of *Salmonella* in pigs. The UK imports around a half of its pig meat and therefore benefits from investments in control from other countries. Overall the EU cost-benefit analysis for a change in interventions and control of *Salmonella* in pigs was negative.

The BCR results for both benefit scenarios are shown in Figure 63 and Figure 64 and the general results for the EU are shown in Table 64.

Figure 63: Benefit cost ratios by Member State and the EU for scenario 4 with only the human health benefits

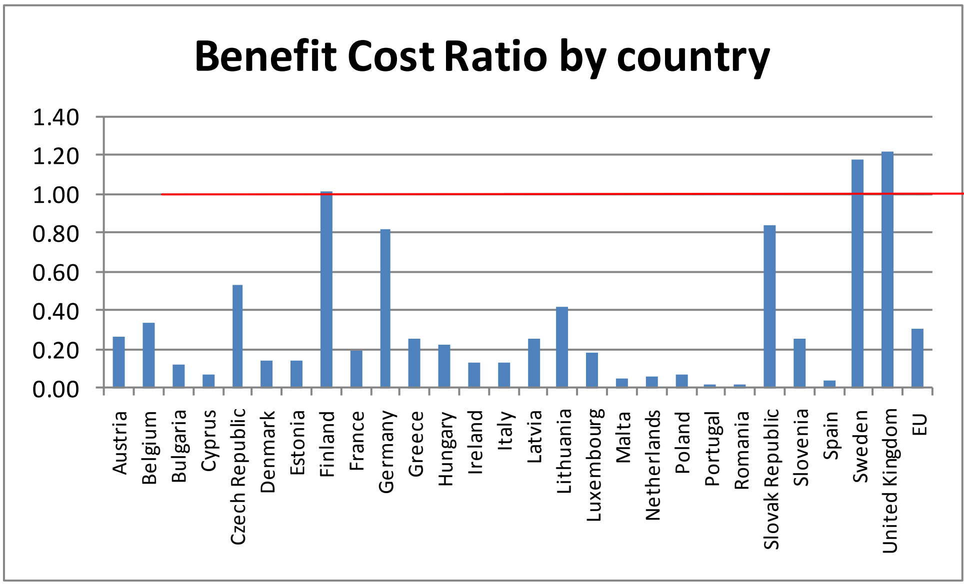


Figure 64: Benefit cost ratios by Member State and the EU for scenario 4 with human health and pig benefits

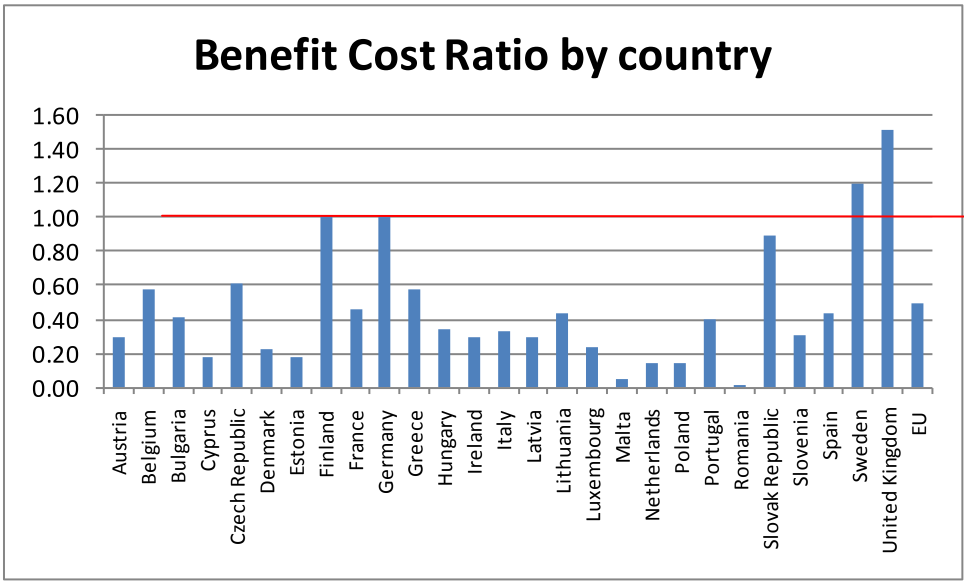


Table 64: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 4

Benefits included	NPV	IRR	BCR
Human health	-1,013,309,251	Could not be Calculated	0.31
Human health and pig production	-733,701,721	Could not be calculated	0.50

The addition of benefits from the pig sector make a difference to Germany and the Slovak Republic, but overall the EU analysis is still negative.

Even assuming that *Salmonella* can be immediately and constantly removed from both human and pig populations, the EU cost-benefit analysis is not positive.

7.4 Summary

The Chapter has presented the cost-benefit analysis model developed to test the economic profitability of the *Salmonella* control interventions in slaughter pigs. In addition to the human health benefits from the control of this disease there was also the inclusion of a benefits associated with improved pig productivity. The model was used to perform a cost-benefit analysis on the four intervention scenarios described in Chapter 6.11. The results of the analysis demonstrate that scenario 1 is superior to all others, but that no scenario was economically profitable. It is recognized that the analysis lacks the ability to examine the impact on the markets of *Salmonella* control interventions, in particular a market shock if people perceive pig products to be more risky than alternatives sources of protein and modify their consumption behaviour accordingly.

The main task outlined by the terms of reference was to make an assessment of a 50% and 90% reduction of *Salmonella* in slaughter pigs. This task has been made difficult, if not impossible, with the clear lack of attribution on how much a particular intervention or group of interventions has on *Salmonella* lymph node prevalence. However the analysis performed would equate that a 50% reduction in *Salmonella* would be scenario 2 and a 90% reduction scenario 4. Neither of these scenarios was positive even if it is assumed that the interventions they represent could eliminate immediately and maintain free the pig population from *Salmonella* and that all *Salmonella* in humans that has its origin in pigs could also be removed immediately.

The following Chapter will discuss this in more details and make recommendations on how to interpret the analysis in this Chapter and the preceding ones.

8 Discussion and conclusions

8.1 Background

The project has undertaken a study based on a cost-benefit analysis model structured to capture the costs of pre-harvest *Salmonella* control interventions and the benefits in terms of the reductions of human health costs. The model also includes the possibility to include benefits to pig health and productivity. The study is based to a large extent on the findings of preceding EFSA reports supplemented with information gathered in literature reviews and from consultations with DG SANCO, EFSA, the industry and academic institutions.

The purpose of the study was to undertake an analysis of the costs and benefits in the EU of setting a target for the reduction of *Salmonella* infections in slaughter pigs. The identification and costing of interventions at the pre-harvest stage (defined as up to the point of slaughter) of the food chain was undertaken in recognition that controls should be applied throughout the entire food chain in accordance with the “farm to fork” principle and EU policy. The project purpose did not therefore involve a comparison between pre- and post-slaughter interventions. The contract specifications required that only interventions up to the point of slaughter were taken into account and the specified measure of *Salmonella* infection was the bacteriology of ileo-caecal lymph nodes. A linear relationship was assumed between pig prevalence and human *Salmonella* incidence, in keeping with the QMRA (2009).

A recent critical review of on-farm intervention strategies against *Salmonella* in pigs sponsored by BPEX (Friendship et al., 2009) carried out an extensive screening of the literature. The review found “a general lack of data on the costs and benefits associated with the implementation of the interventions against *Salmonella* in swine at the farm level.” It also found that “All economic models that evaluate interventions that prevent *Salmonella* shedding but have no impact on pig growth performance are unlikely to show an economic benefit unless the cost is shared by other sectors of the industry in addition to the pork producers.” Furthermore “There is no guarantee of success with the application of any particular intervention on an individual farm and the impact of wide scale adoption of an interventions strategy is also unpredictable in that no single approach or combination of interventions can be expected to result in 100% success.” Although this review did not provide the basis for the study, it does summarise the context in terms of the variability of farm production systems and the lack of precise and consistent data (understandable considering the variations in productions systems and conditions), both of which make it difficult to make an attribution of interventions and the cost/benefit assessment of a 50% and 90% reduction in *Salmonella* prevalence.

8.2 Development of the intervention cost model

To capture and quantify the costs of interventions by Member States and also across the EU, the Consortium developed a cost calculator approach. The model is deterministic[27] and relatively straightforward to understand and use, constructed as a spreadsheet tool.

[27] The data input are set by the user and are assumed to be constant, as opposed to a stochastic model that takes data input and the potential ranges of the data to estimate the data used for each model run.

The model has been used to test four intervention cost scenarios with different combinations of seven categories of intervention. The costs vary from €287 million for the smallest set of interventions through to €1 458 million for most comprehensive programme. Whilst the four scenarios are plausible, the model has the flexibility to run any number of different scenarios to investigate different situations and conduct sensitivity analysis. The strength of the model depends entirely on the quality of data available and the accuracy of the assumptions.

One consideration that is difficult to model is the dynamic and cyclical nature of the pig sector in the EU. Feed costs also fluctuate according to supply and demand. The cost of interventions (as well as benefits in pig productivity) may vary significantly over time and the model is likely to generate different intervention cost scenarios according to the stage in the pig cycle when the costs were estimated. Differential changes in pig production may be seen across Member States with a consequent effect on intervention costs at EU level.

The model will be extended during the complementary breeding pigs project, also being implemented by the FCC Consortium, and it will be possible to refine further the intervention cost scenarios as better data becomes available and more accurate assumptions can be made. An electronic version of the cost intervention model is available with the report.

8.3 Development of the Human Health Model

The human health model is similarly deterministic, building a cost calculator through six modules based on (1) number of *Salmonella* cases estimated through a pyramid of illness severity linked to reported cases; (2) productivity costs associated with days lost through absenteeism from work; (3) healthcare utilisation costs in terms of hospital and general practitioner visits; (4) the cost of premature death using an economic or statistical value of life; (5) total costs of *Salmonella* among humans; (6) the element attributed to pork (as opposed to poultry and other zoonotic reservoirs), estimated to be 15%.

The model is designed to be interactive, allowing Member States to vary local assumptions and input to the model. The structure and intelligence is informed by the US Department of Agriculture cost calculator developed by their Economic Research Service.

The interactive stage is to be implemented in Stage 2 of the model (to be reported in SANCO 2008/E2/056) as part of the Breeding Pig study. Stage 1, developed and documented here, assigns common assumptions to every Member State.

8.4 Limitations of the Human Health Model and Next Steps

The human health model is limited by the quality of its assumptions, reprised here. We also report on the consultation process with Member States that will be used to refine the model in Stage 2 and consider its potential impact on the Cost Benefit Analysis.

8.4.1 Assumptions and Limitations

We are aware that the following areas need to be refined through improved data:

- Estimate of *Salmonella* in the human population – the role of the Community Multiplier:
    - We have used 11.5 as the mean between three published figures (relating to England, Netherlands and US). The consultation stage indicates that the actual figure is probably lower in some Member States;
- Attribution between *Salmonella* in the pork production chain and *Salmonella* in the human population:

  - When *Salmonella* is reduced in slaughter houses, what effect does this have on humans?
  - What role does immunity play, e.g. contrasting the experience of Finland (high reported incidence among humans and low prevalence among pigs) and Spain (low reported incidence among humans and high prevalence among pigs)?
  - We have assumed a linear relationship between pig prevalence and human *Salmonella* incidence, in keeping with the QMRA (2009) report, but the evidence-base on this may change in the future;
- The statistical value of life and cost of premature death:
  - Willingness to Pay is the technique frequently used to give a statistical value to life. In practice it tends to produce relatively high estimates;
  - We have used a productivity measure based on 20 years average earnings for the MS. It has the advantage of reflecting economic purchasing power parity (PPP) between MSs and providing a pragmatic measure, but we recognise the scope for refining this assumption. The current assumption equates to € 600k per fatality, ranging from € 62k (Bulgaria) to € 1 million (Denmark).
- Cost of healthcare utilisation:
  - We have used indicative costs, combining notional averages with a labour market index for MSs. It may be possible to improve on these estimates through use of local actual costs.
- The cost of chronic sequelae:
  - This is absent from the model due to lack of firm assumptions;
- The cost of pain (physical and emotional) and inconvenience:
  - This is absent from the model;
- Probability assumptions, e.g. number of days per case absent from work due to salmonellosis, number of fatalities as a percentage of *Salmonella* cases:
  - We have drawn on assumptions used by the US Department of Agriculture Economic Research Service;
  - The model is capable of being modified if different assumptions are selected.
- The role of consumer behaviour and market shocks due to confidence and perceptions about *Salmonella* in the food chain:
  - We have not incorporated this into the model.

8.4.2 Development: Stage 1 and Stage 2 Design

We have addressed the limitations of the model by introducing a staged approach that includes consultation with Member States. Stage 1 is presented in this Slaughter Pig report, based on uniform assumptions for EU-27. Stage 2, to be concluded in the Breeding Pigs stage of analysis (SANCO/2008/E2/056), gives us an opportunity to modify assumptions based on a questionnaire consultation exercise.

Consultation

- **Consultation Questions.** A consultation process took place in April-May 2010. We invited Member States to answer three questions:
  - What Community Multiplier would you recommend for application to your MS? Is it (a) 3.2 (England, IID, 2000); (b) 11.5 (used in the Stage 1 Model); (c) 13.9 (Netherlands, Sensor, as quoted in EFSA, 2008a); (d) 18 (USA); (e) other?

- How should we deal with the cost of premature death? Should the model (a) exclude a financial value; (b) use a flat rate, e.g. €1 million, for every MS; (c) use the current modelling assumption of 20 years average earnings for each MS (because it is transparent and consistent); (d) other?
- Is it possible to improve the modelling assumptions by giving local estimates of (a) GP visit, (b) outpatient attendance, (c) emergency department attendance, (d) hospital admission for salmonellosis (see Module 3 of Stage 1 model)?

Results of Consultation

- **Participation.** 16 out of 27 MSs have responded to the consultation exercise (including 3 who declined to express an opinion based on lack of data), and 1 has asked for more time to respond. 10 MSs have not responded.
  - **Proposal:** We invite the 10 remaining MSs to respond to the questions, to be reflected in the Stage 2 Model.

- **Question 1 – Community Multiplier:**
  - 5 MSs supported the model's approach of (b) 11.5, based on an average of England, Netherlands, and USA
  - 5 MSs supported the use of (e) other:
    - Mainly lower values, ranging from 2-3 to 8.3 across 4 MSs;
    - Netherlands has proposed 16.5, as an alternative to (c) 13.9 which was cited as the Dutch figure in the model;
  - England supports (a) 3.2 as the most recent England figure;
  - 1 MS supports (c) 13.9, cited by EFSA (2008a) as the Netherlands multiplier based on Sensor.

- **Question 2 – Cost of Premature Death (and Methodology):**
  - There is broad support (6 out of 13 responses) for the model's approach of (c) productivity using 20 years average earnings;
  - 4 MSs suggest that a financial value of premature death should be excluded;
  - Netherlands suggests a methodology based on friction cost, that includes the cost of chronic sequelae; England suggests the use of QALYs (non financial currencies) to take into account chronic sequelae. Finland indicates that it is disappointed that the cost of chronic sequelae has been excluded from the model, but understands the reason why.

- **Question 3 – Cost of Hospital Utilisation:**
  - 5 MSs provided alternative references as guides to healthcare utilisation costs
  - 1 MS indicated that the model's costs were correct locally and should be adopted;
  - For the majority of MSs, no local estimates were available;

8.4.3 Proposed Refinement in Stage 2

Stage 2 (the breeding pigs project) presents an opportunity to refine the model as more information becomes available. We will factor in the following refinements, based on consultation responses and recent developments in the literature:

- Change community multiplier for individual Member States
- Introduce alternative scenarios for cost of premature death
- Consider impact of chronic sequelae
- Consider impact of pain and suffering
- Examine effect of different hospital utilisation costs
- Vary the assumptions underpinning attribution between *Salmonella* in pigs at slaughter, breeding and transmission to humans
- Quantify market shock scenarios: where public health confidence affects consumer behaviour

8.4.4 Potential Impact on Cost Benefit Analysis

The CBA brings together intervention costs in the industry against benefits gained through reduction in human health losses. The Benefit Cost Ratio (BCR) is greater than 1 when benefits exceed costs. The analysis undertaken in Chapter 7 produced a BCR that was predominantly lower than 1. In looking to Stage 2 we ask: "How would changes to the human health model affect the BCR?" At this point the answer is: "There are a range of compensating variations. We cannot predict the net impact on the BCR"

Potential compensating variations are as follows:

Model Variation	Probable Direction of Change	Impact on Benefits of Intervention	BCR Change
Community multiplier	↓	↓	↓
Exclude cost of premature death	↓	↓	↓
Include cost of premature death using Willingness to Pay	↑	↑	↑
Severity of illness - % deaths	↑	↑	↑
Include cost of chronic sequelae	↑	↑	↑
Include cost of pain and suffering	↑	↑	↑
Hospital utilisation costs	~	~	~
Vary assumptions on attribution and transmission	?	?	?
Quantify market shock scenarios	↑	↑	↑

8.5 Cost-benefit analysis

On the basis of the available data and the assumptions made, the cost-benefit analysis did not show an economic benefit from any of the intervention scenarios. The EU-wide BCR was less than 1 (so that the economic benefits were lower than the costs) in all scenarios. Sensitivity analyses did not markedly change the results, although benefits would accrue to individual Member States under certain conditions and to the EU in one instance.

Scenario 2 corresponds to a 50% reduction in *Salmonella* prevalence at EU level and shows a negative return with a BCR of 0.28 (Table 65). Scenario 4 corresponds to a 90% reduction in *Salmonella* prevalence and shows a slightly better, but still negative, return with a BCR of 0.50.

Scenario 1 produced the most favourable outcome, albeit still with a negative benefit cost ratio. However, a sensitivity analysis (Scenario 1+ in Table 65) based on optimistic assumptions of a constant rate of reduction of 6% in human health losses plus a 6% constant rate of reduction in pigs affected by *Salmonella*, did show a small positive BCR of 1.07 and an NPV of €21 million. Whilst this is a very modest return under rather optimistic assumptions, it may indicate a possible way forward for *Salmonella* control in slaughter pigs.

Scenario 1 involves the establishment of a coordination unit and increased surveillance, which in any case would be a prerequisite for a comprehensive *Salmonella* control programme. If desired, at least some of the costs could be borne by the authorities or industry organisations, rather than the burden falling entirely on producers. A successful surveillance programme would identify areas of infection, which would enable more focused targeting of control measures and thereby improve the rate of return on subsequent interventions.

Thus, the most economically preferable approach would be a gradual introduction of *Salmonella* control measures, starting with the establishment of surveillance measures. Further interventions would be targeted according to the surveillance results.

Table 65: Summary of cost-benefit analysis of four scenarios

Scenario	Description	Discounted Costs (million €)	BCR Human health + pig production	BCR Human health and pig production	Cost per Slaughter Pig (€)
1	Establish support unit and increased sampling (varying rate of reduction of human health losses)	287	0.44	0.66	0.11
1+	Scenario 1 (but constant rate of reduction in human health costs and increase in pig productivity of 6%)	287	0.66	1.07	0.11
2	Scenario 1 plus feed practices and farm-level biosecurity	1 089	0.17	0.28	0.43
3	Scenario 1 plus targeted	752	0.38	0.61	0.29

	MS interventions, based on high and low prevalence				
4	Scenario 3 plus transport and slaughterhouse measures	1 458	0.31	0.50	0.57

The results have to be qualified by the lack of precise data and information to make accurate assumptions. The lack of available data may be partly due to the nature of *Salmonella* infection in both pigs and humans. This may explain why many studies have failed to come up with more than very broad findings and general conclusions.

In this light, the most appropriate interpretation of the results is that they failed to demonstrate a positive economic benefit from setting targets to reduce *Salmonella* in slaughter pigs. However, it would be premature to conclude that the cost-benefit will be negative under all circumstances and it is worthwhile continuing the investigations to explore possible ways forward

Issues to be considered with respect to the animal model include:

- **The epidemiology of pig-human salmonellosis is complex** *Salmonella* species and serotypes can manifest themselves in different ways in pigs and humans, and the links between live pigs and human infection are not straightforward. The EFSA studies have shown that countries with high prevalence of *Salmonella* in slaughter pigs can have low incidence of human salmonellosis due to pigs, and vice versa. High prevalence breeding herds can produce low prevalence weaners, and vice versa. Post-slaughter procedures can increase or decrease the level of carcass contamination at the point of slaughter. These effects can be due to a number of factors, such as immunity in the pig and hygiene and bio-security procedures. Eliminating *Salmonella* from a herd and developing immunity would appear to be counterproductive objectives, yet some control programmes may not be sufficiently specific about their objectives. It might even be considered if the present focus on immune response parameters in some of the Member States' control programs might be counterproductive.
- **Conditions between individual pig farms can vary widely** It is widely accepted that specific *Salmonella* control measures are not equally effective across all pig farms and need to be tailored to individual circumstances. No universal control measure has been identified and most advice involves a combination of measures aimed at preventing transmission.
- **Herd health status is often not known** Testing can be relatively expensive and time consuming, and different types of tests are not strictly comparable. Many countries do not have universal surveillance testing programmes and individual herd prevalence is often not known. The intervention cost model approximates the level of clean herds to allow targeting of infected herds, but more accurate data would allow the assumptions to be refined and, perhaps, intervention costs reduced.
- **Pig and feed producers have little incentive to improve** The nature of the pork production chain is that pig and feed producers bear many of the costs of *Salmonella* control, but the benefits are reaped by the pork consumers. Lack of testing programmes and of clear attribution of human cases to infected pigs means that

producers have little incentive to invest in *Salmonella* control. Although some benefits to pig health have been identified, they are not sufficient to justify the control measures. The availability of more cost-effective post-slaughter control measures means that these measures may be implemented in preference to on-farm measures. One major incentive to producers would be the fear of market shocks, for example from outbreaks of human *Salmonella*, as has been seen with other zoonoses and food safety incidents (BSE, Dioxin, *Salmonella* in eggs). However, due to their unpredictability, it has not been possible to include the impact of market shocks in the cost-benefit model.

The FCC Consortium will continue to implement a complementary study to analyse the costs and benefits of setting a target for the reduction of *Salmonella* infection in breeding pigs. This contract runs until December 2010. The study will extend the same cost-benefit model to include breeding pigs, which will enable refinement of the current findings as more information becomes available. In this regard, we propose further close consultation with EFSA, DG SANCO, the industry and institutions to review the current findings and facilitate further analysis.

End Tables

Table 66: Results of Stage 1 Consultation

	Response Sum:	**1**	**5**	**1**		**5**		**4**	**1**	**6**	**2**
	Order of Return	(a) 3.2 (England, IID, 2000)	(b) 11.5 (used in Stage 1 Model)	c) 13.9 (Netherlands, Sensor)	d) 18 (USA)	e) Other		(a) Exclude	(b) flat rate	(c) Current assumption of 20 years average earnings	(d) other
Denmark	1					✓	8.3			✓	
Luxembourg	2		✓				11.5	✓			
Netherlands	3					✓	16.5[28]				✓
Italy	4		✓				11.5			✓	
Czech Republic	5										
Estonia	6					✓	2-3				
Belgium	7										
Portugal	8		✓					✓			
Lithuania	9			✓						✓	
Sweden	10					✓	6.11		✓		✓
Finland	11		✓				11.5			✓	
Slovenia	12		✓				11.5			✓	
Ireland	13					✓	8			✓	
Hungary	14										
United Kingdom	15	✓						✓			
Germany	16							✓			
France	extension request										
Bulgaria	no response										
Greece	no response										
Spain	no response										
Cyprus	no response										
Latvia	no response										
Malta	no response										
Austria	no response										
Poland	no response										
Romania	no response										
Slovakia	no response										

[28] Note: there is a mismatch between Netherlands response and the value quoted in EFSA (2008A)

Table 67: Reason Supporting Answer to Question 1

Country	No.	Reason Supporting Answer to Question 1
Denmark	1	Most recent published model estimate a mean of 10.8% (SD=2.8%), based on probabilistic modelling. Korsgaard et al. Epidemiol. Infect. (2009) 137, 828-836.
Luxembourg	2	11,5 is near to the average of the different multipliers
Netherlands	3	The estimated incidence of salmonellosis for the Netherlands in 2006 is 43,000 cases (see http://www.rivm.nl/bibliotheek/rapporten/330331001.html). The reported incidence was 1667 (EFSA Zoonoses Report 2006), for a coverage of 64%, hence 2604 for the country. Multiplier is 16.5
Italy	4	In Italy for human salmonellosis we consider this as reasonable community multiplier, since it represents the average between England, Netherlands and US multipliers. However, as a general comment, we suggest to consider the possibility to implement different multipliers in the community for different age-groups. Unfortunately no reference has been found this is why we have considered option b and not e.
Czech Republic	5	With respect to the epidemiological situation in human salmonellosis, this project seems to be very interesting. However, there is no harmonized surveillance system of human salmonellosis in EU and there are also differences in the reporting system itself, hence the problem of comparatibility of data between EU Member States. And this is very dangerous for interpretation of any mathematical model which compare EU Member State. And we would like if the situation would be taken in to account for analysis of the cost and benefits. Answering questions requires sufficient time to prepare the data that we have to consult and cooperate in their treatment with other organizations (eg insurance). In view of these facts we don't have at this time of strong opinion and cannot answer individual questions, and we are not able to choose the appropriate model for the Czech Republic
Estonia	6	In Estionia there haven´t been any studies carried out to estimate the true prevalence of salmonellosis in the community. But on the basis of epidemiological situation the proposed estimate- 11, 5 cases for every reported case- seems to be an overestimation. The Health Board would propose that the number for Estonia would be 2-3 cases for every reported case.
Belgium	7	Belgium has no available data on the costs of human Salmonellosis.
Portugal	8	
Lithuania	9	
Sweden	10	Result from simulations; forthcoming in Djursmittsutredningen in October 2010, Bilaga 8, "Samhällskostnader för salmonellos, campylobacterios och EHEC" by Kristian Sundström
Finland	11	We do not have any national estimate on the "true number" of human salmonellosis cases. We think that it is better to use the mean of different countries than a figure of a single country.
Slovenia	12	
Ireland	13	Professional opinion
Hungary	14	no data available so prefer not to make estimations
United Kingdom	15	• This is the best evidence available for UK. Unreported cases may be predicted to be less severe. • It is unlikely in reality that a single value can be applied to all MS given the diversity in reporting, testing & underlying risk. • A new Infectious Intestinal Disease (IID) study is due to report in Autumn 2010, so a more up-to-date multiplier may be available then
Germany	16	no data

Table 68: Reasons supporting answer to question 2 on cost of premature death

Denmark	1	Use the current modelling assumption of 20 years average earnings for each MS. This is our favorite option. Our second choise is a) exclude a financial value. In our view a flat rate, that doesn't really fit any country, would not be very useful.
Luxembourg (Grand-Duché)	2	Exclude: It is very difficult to fix the value of a person
Netherlands	3	The Netherlands uses a friction cost method (see http://www.rivm.nl/bibliotheek/rapporten/330080001.html). Our estimate for the case-fatality ratio is in the order of 0.1% (same reference) but we also include reactive arthritis and inflammatory bowel disease in our cost estimates. A recent paper highlights the importance of irritable bowel syndrome as a sequel to salmonellosis (Haagsma JA, Siersema PD, De Wit NJ, Havelaar AH. Disease burden of post-infectious irritable bowel syndrome in the Netherlands. Epidemiol Inf early view; doi:10.1017/S0950268810000531).
Italy	4	*Use current modelling assumption: We believe this is the most suitable and reasonable solution in order to define YLL due to Salmonella infections.*
Czech Republic	5	
Estonia	6	As there haven´t been any studies carried out to estimate the cost of premature death of salmonellosis in Estonia, it is difficult to say, which financial value to use in the model. We don´t have a strong opinion in this question.
Belgium	7	
Portugal	8	Taking into account the difficulties in estimating the cost of premature death. We consider a) exclude a financial value.
Lithuania	9	Use the current modelling assumption of 20 years average earnings for each MS (because it is transparent and consistent)
Sweden	10	We would prefer either b (flat rate) or d (other). Flat rate based on calculations on VSL (value of a statistical life) could be a solution or calculations of production losses according to a method of human capitals or frictions. Our experts would definitely not recommend ad hoc values.
Finland	11	We do not have any better solution. But we think it is very important to include some estimate to the model. This option is transparent and consistent as mentioned. **General Comment:** we are a bit disappointed that it was not possible to include the cost of chronic sequelae to the model but we can understand the reasons behind this. Although the estimates might be rough and uncertainty high, we think it is very important that the Consortium will continue the work with the model.
Slovenia	12	
Ireland	13	Use the current modelling assumption because it is transparent and consistent
Hungary	14	
United Kingdom	15	• *The use of QUAYLs (Quality-Adjusted Life Years) or DALYs (Disability-Adjusted Life Years) would avoid the issue of different cross MS costs and provides a standardised, well-established method of incorporating the impact of an illness. These measures include an estimate for chronic sequelae – e.g. reactive arthritis, irritable bowel syndrome, vascular disease.* • *Any inclusion of a premature death would need to be weighted by age. Depending upon the objective of the measure the weighting will vary. For instance an infant or child death may be weighted higher for the loss of time to life than an elderly person who is much closer to the natural end of their life but may be weighted lower if the estimate of cost to society is focussed on short-medium term productivity.* • *It is recognised that for any individual MS the cost to it would be important in budgeting and any model should include values for days of sickness and those lost to labour. So, module 2 would be relevant for individual MSs.* • *Based on 2000 IID study, the number of Salmonella cases resulting in deaths is 0.3%.*
Germany	16	

Table 69: Reasons supporting question of cost of health service utilisation

Denmark	1	Korsgaard et al. (Epidemiol. Infect. (2009) 137, 828-836) also present estimated proportion of cases to GP and hospital, and estimated DK costs in 2001 prices
Luxembourg (Grand-Duché)	2	
Netherlands	3	
Italy	4	*We cannot provide any information about this question. Please, for further comments, ask to the competent body of Italian MOH: Directorate General of Health Planning.*
Czech Republic	5	
Estonia	6	
Belgium	7	
Portugal	8	the Portuguese estimate of the health cost assumed in module 3, pages 43 – 47 of the report" analysis of the cost and benefits of setting a target for the reduction of *Salmonella* in slaughter pigs" are correct. So they should be adopted.
Lithuania	9	
Sweden	10	(a) SEK 1672, (b) no info, (c) no info, (d) SEK 26692
Finland	11	(a) 64,7 euro, (b) 174,2 euro, (c) 289,9 euro, (d) 2818,0 euro based on 2006 data. These figures are from the year 2006. Reference: T. Hujanen, S. Kapiainen, U. Tuominen, M. Pekurinen: Terveydenhuollon yksikkökustannukset Suomessa vuonna 2006. Stakesin työpapereita 3/2008. Stakes, Helsinki 2008. (unofficial translation of the title: The unit cost of healthcare in Finland in the year 2006)
Slovenia	12	
Ireland	13	No studies have been conducted to calculate these costs in Ireland for *Salmonella*
Hungary	14	
United Kingdom	15	Specific costs may vary over time so, the UK calculate this cost based on an established methodology which, among other things takes in to account all the factors listed in the questionnaire including days lost at work and cost of death. An FSA paper presenting this methodology is attached. This is based upon the Regulatory Impact Assessment on the Consolidation of EU Food Hygiene Legislation (Annex D), which can be accessed via the FSA website: http://www.food.gov.uk/multimedia/pdfs/EURegulationsRIA.pdf . This sets out in fair detail the methodology and calculations used in estimating the economic costs of foodborne related illnesses inclusive of *Salmonella*.
Germany	16	Some data supplied

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