FCC Consortium

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

for

EUROPEAN COMMISSION
Health and Consumers Directorate-General
SANCO/2008/E2/056

FINAL REPORT

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Abbreviations

BCR	Benefit cost ratio
BFASFC	Belgian Federal Agency for the Safety of the Food Chain
BPEX	British Pig Executive
CBA	Cost-benefit analysis
DALY	Disability-adjusted life year
DG SANCO	Health and Consumers Directorate-General
DIVA	Differentiation of Infected from Vaccinated Animals
EC	European Commission
EFSA	European Food Safety Authority
ELISA	Enzyme-linked Immunosorbent Assay
EU	European Union
FCC	Food Control Consultants Ltd
FSA	Food Standards Agency (UK)
GE	Gastroenteritis
GGP	Great Grand Parent
GHP	Good Hygiene Practice
GMP	Good Manufacturing Practice
GP	Grand Parent
GP	General Practitioner
HACCP	Hazard Analysis and Critical Control Points
IID	Infectious Intestinal Disease
IRR	Internal rate of return
MS	Member State
NPV	Net present value
SEK	Swedish Crown
SPF	Specific Pathogen Free
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
ZAP	Zoonoses Action Plan

Executive Summary

1) This analysis of the costs and benefits of setting a target in the EU for the reduction of *Salmonella* in breeding pigs follows a similar analysis in slaughter pigs, also undertaken by the FCC Consortium. Both analyses are part of a sequence of studies providing a part of the information to be used for the setting of targets for the reduction of *Salmonella* in live pigs.
2) Regulation (EC) No 2160/2003 on the control of *Salmonella* and other specified food-borne zoonotic agents states that the protection of human health against zoonotic diseases is of paramount importance. Zoonoses present at the level of primary production must be adequately controlled.
3) Although a considerable amount of information and analysis is available from reference studies, it is widely acknowledged that there remains a lack of sufficient accurate and comprehensive data and knowledge. This lack of data is partly due to the epidemiology of Salmonella spp. This has necessitated an analytical approach that takes account of the data shortcomings.
4) The cost of human salmonellosis caused by pork and pork products was assessed using a Cost of Illness approach, expressing the cost per case of illness in Euros for each EU-27 Member State.
5) The analysis presented in the report has covered in more detail the costs of interventions in the breeding pig population and has responded to comments made since the slaughter pig report was produced in the middle of 2010.
6) *Salmonella* in pigs at the breeding stage of the food chain does not generate a human health impact that is different or distinguishable from *Salmonella* in slaughter pigs. Logic suggests that control or reduction of *Salmonella* spp. would have greatest impact on human health near to the point of consumption in high prevalence countries, while in countries with low prevalence among pigs, eradication and prevention early in the production chain (e.g. in feed) will be more effective.
7) Human cases of Salmonellosis derived from pigs remain a significant cause of disease at EU level. The study has calculated that the cost of human Salmonellosis from pigs is € 86.1 million per annum across the EU. This corresponds to €600 per human case.
8) Data and information available on interventions at breeding population level show variable impacts on *Salmonella* in pigs in different contexts..
9) Interventions in terms of coordination, monitoring and feed were assumed to be the same as for the slaughter pig analysis.
10) The numbers of piglets produced per year by breeding farms was updated with an estimate of the total piglets produced per year rather than a standing population estimate used for the slaughter pig analysis.
11) The direct costs of interventions in the breeding stock farms are estimated to be €37 million with a discount rate of 4% over a ten year period. Whilst this may appear to be a significant sum, it only represents around 5% of the costs for scenario 3 and 2.5% of the costs for scenario 4.
12) An estimate was made of €17 million needed to improve the transportation of piglets from breeding to fattening facilities. Therefore a total discounted cost of actions relating to the breeding pigs is €54 million over a ten year period.

13) The cost-benefit analyses for the four scenarios described in the slaughter pig report were repeated. The only analysis that produced an economic profit (a positive NPV and a BCR greater than 1) was scenario 1 with benefits for *Salmonella* control included from rapid and fixed improvements in pig and human health. This scenario only includes costs for coordination and monitoring, and it is questioned whether the assumptions on the reductions in *Salmonella* in both pigs and humans are likely..
14) More detailed cost-benefit analyses of scenarios 3 and 4 produced negative returns to the investments, which is not surprising given that this analysis has slightly lower benefits from human health changes and slightly higher costs for breeding farm interventions. The analysis for scenario 4 did not produce a positive return even if it is assumed that all disease is removed from pigs and humans from day one of a programme.
15) On the basis of current scientific advice and the experience of Member States, it is not possible at this time to demonstrate cost-beneficial interventions to reduce *Salmonella* infections at EU level in either breeding pigs or slaughter pigs, or in combinations of both herds. Sensitivity analyses indicate that positive cost-benefits can be found only in extreme scenarios.
16) Literature review as well as communication and discussion with the European Commission, EFSA, scientists and industry representatives during the study has confirmed that the findings are consistent with other studies and can be considered robust.
17) Although the cost-benefit analysis does not provide quantitative evidence to support the setting of *Salmonella* reduction targets in pigs at this time, salmonellosis derived from pigs continues to be a significant cause of human disease in the European Union. Food chain operators in the EU have a responsibility to control zoonoses at the level of primary production. The report therefore includes expert comment and discussion that may be useful in indicating possible steps to develop cost-effective *Salmonella* control and monitoring along the pig production chain over a period of time.

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 (SANCO/2008/E2/056) by the European Commission Health and Consumers Directorate-General (DG SANCO) to provide the European Commission (EC) with an analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in breeding pigs. The study follows a similar cost-benefit analysis (CBA) in slaughter pigs (SANCO/2008/E2/036), also carried out by the FCC Consortium.

Both contracts were 18 months in length. The slaughter pigs contract ran from 23 December 2008 until 23 June 2010, and the breeding pigs contract from 9 July 2009 to 8 January 2011. The FCC Consortium developed synergies and links between the two projects and the breeding pigs analysis can be seen as an extension of the slaughter pigs analysis further back along the food chain. This synergy has enhanced the overall outputs of both projects and this report brings together the findings and conclusions of each study.

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 academics.

The project team comprised:

Expert	**Organisation**	**Role**
O. Oddgeirsson	Food Control Consultants Ltd.	Team Leader
J. Rushton	Royal Veterinary College*	Animal Health Economist
B. Otero Abad**	Royal Veterinary College*	Veterinary Epidemiology Support
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.

** Not a formal team member; part of the additional support contributed by the Royal Veterinary College.

*** Participated in final stages of project only.

1.2 Objectives

1.2.1 Wider objective

The wider objective of the project is consistent with the EU integrated approach to food safety, which aims to assure a high level of food safety, animal health, animal welfare and plant health within the European Union through coherent farm-to-table measures and adequate monitoring, whilst ensuring the effective functioning of the internal market.

As stated in Regulation (EC) No 2160/2003 on the control of *Salmonella* and other specified food-borne zoonotic agents, the protection of human health against zoonotic diseases is of paramount importance. Zoonoses present at the level of primary production must be adequately controlled. *Salmonella* spp. and Campylobacter spp. cause the majority of cases of zoonoses in humans. Although there seems to be a decreasing trend of human cases of salmonellosis, reflecting the success of control measures taken, it is nevertheless assumed that many cases remain unreported and therefore the data collected do not necessarily give the full picture of the situation. It is therefore necessary to improve the existing control systems.

1.2.2 Purpose of the contract

The purpose of the contract is to provide an analysis of the costs and benefits in the EU of setting a target for reduction of *Salmonella* infections in breeding pigs in accordance with Regulation (EC) No 2160/2003.

When defining a Community target for *Salmonella* in pigs, the Commission shall provide an analysis of its expected costs and benefits taking into account the criteria laid down in paragraph 6(c) of Article 4 to Regulation (EC) No 2160/2003, with regard to *Salmonella*, in particular:

- its frequency in animal and human populations, feed and food;
- the gravity of its affects for humans;
- its economic consequences for animal and human health care and for food and feed business;
- epidemiological trends in animal and human populations, feed and food;
- scientific advice;
- technological developments, particular relating to the practicality of the available control options; and
- requirements and trends concerning breeding and production systems.

1.2.3 Analysis to be carried out

The analysis carried out within this contract should:

1) Evaluate the correlation between the prevalence of *Salmonella* serotypes with public health significance[1] in breeding pigs and the prevalence of *Salmonella* in pigs at entry in the fattening unit.
2) Estimate the efficacy of the most important currently available control options in terms of reduction of prevalence in herds of breeding pigs.
3) Use the outcome of the baseline survey in breeding 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 faecal samples as in the baseline survey, over a period of 5 to 10 years.
4) Coordinate 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 the 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.
5) Coordinate intensively with the ongoing work as regards a cost/benefit analysis on *Salmonella* in slaughter pigs to guarantee that both studies are complementary.

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[1] As defined in Annex III of Regulation (EC) No 2160/2003

6) When carrying out the assessments under points 1 to 3, the different production systems (e.g. outdoor versus intensive, large scale versus small scale holdings,…) and prevalence levels in the Member States should be taken into account.

1.3 Context of the analysis

This analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in breeding pigs follows a similar analysis in slaughter pigs, also undertaken by the FCC Consortium. Both analyses are part of a sequence of studies leading up to the setting of targets for the reduction of *Salmonella* in live pigs.

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 aims to set targets for the reduction of *Salmonella* prevalence in the EU pig herd.

The legal base for the setting of targets in pigs is established in Regulation (EC) No 2160/2003 on the control of *Salmonella* and other specified food-borne zoonotic agents. The Regulation lays down provisions for the control of *Salmonella* and other specified food-borne agents in poultry and pig populations and at other stages of the food chain.

This study, sponsored by DG SANCO, is produced in parallel with a series of EFSA sponsored reports produced since 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 (QMRA):

Quantitative Microbiological Risk Assessment on Salmonella in Slaughter and Breeder pigs: Final Report, Revised 19 October 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.

Cost-benefit analysis in slaughter pigs (EU DG SANCO):

Analysis of the costs and benefits of setting a target for the reduction of Salmonella in slaughter pigs (http://ec.europa.eu/food/food/biosafety/*Salmonella*/impl_reg_en.htm)

1.4 Structure of the report

The report draws heavily on the report produced for the cost-benefit analysis of the control of *Salmonella* in slaughter pigs. It is recommended that readers refer to the methodology presented for that analysis as a similar approach is used for the breeding pig analysis. The current document has the following structure:

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

The document also responds to some of the comments and suggestions made by experts since the publication of the slaughter pig cost-benefit analysis. Particular thanks go to Ivar Vågsholm, Helene Walström, Martin Wierup, Jan Dahl, Thomas Blaha and Derek Armstrong who have all given significant time in reviewing our work, attending meetings and making written comments.

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 Breeding pig sector structure and *Salmonella*

2.1 Background

The EU integrated "farm-to-fork" approach to food safety establishes that the responsibility of producing safe food must be shared among operators in the pork chain. Breeding pig herds are the source of future slaughtered pigs and play a role in the maintenance and transmission of *Salmonella* in the pork food chain and therefore cannot be ignored in the cost-benefit analysis.

The *Salmonella* cost-benefit analysis in breeding pigs follows two major studies that to some extent pointed out the relevant role of the breeding herds as a source of *Salmonella* infection in slaughtering pigs. The EFSA baseline survey on the prevalence of *Salmonella* in holdings with breeding pigs in the EU (2008) established an average prevalence of *Salmonella*-positive holdings on EU Farms with breeding pigs of 31.8% (*S. Typhimurium* 7.8% and *S. Derby* 8.9%). In addition, the same study estimated a prevalence of EU *Salmonella*-positive production holdings (holdings housing breeding pigs and selling mainly pigs for fattening or slaughter) of 33.3% (*S. Typhimurium* 6.6% and *S. Derby* 9.0%). The outcome of this survey highlighted an elevated level of *Salmonella* isolation on the pool of faecal samples taken randomly from pens hosting maiden gilts, pregnant pigs, farrowing and lactating pigs, pigs in the service area, or mixed. The study reflects the apparent *Salmonella* prevalence of the sows or boars of at least six months of age kept for breeding purposes at breeding holdings and the pigs for fattening or slaughter at production holdings (The EFSA Journal (2008) 134, 1-91).

The baseline prevalence work was followed by a Quantitative Microbiological Risk Assessment on *Salmonella* in Slaughter and Breeder pigs (QMRA, 2009) which indicated that breeding pig herd prevalence might be a strong indicator of national pig prevalence, stating that:

"Breeding herd prevalence has already been established as a significant factor within the model via sensitivity analysis – broadly speaking, low breeding herd prevalence (low number of positive piglets) equals low slaughter pig prevalence and vice versa."

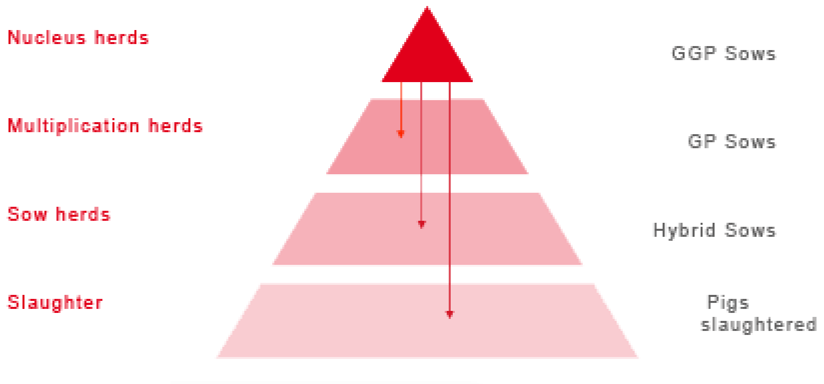
The QMRA predicted a theoretical reduction of 70-80% of the pig lymph node prevalence in Member States with high breeding pig herd prevalence if a reduction in *Salmonella* prevalence in the breeder pig herds could be achieved (QMRA, 2009).

The Consortium, following the Terms of Reference (ToR) has taken into account the EFSA survey on *Salmonella* prevalence level in holdings housing breeding animals and the QMRA predicted impact on lowering the risk of human illness attributable to pig meat consumption from the implementation of specific control strategies aimed to diminish the prevalence levels at the breeding herds.

2.2 Breeding sector structure

Most of the pigs slaughtered in the EU are hybrid animals. To maintain a steady production of hybrids it is necessary to maintain nucleus herds of pure line breeds. The breeding companies and nucleus or multiplier breeders supply males and females to commercial producers.

Figure : Schematic representation of the breeding pyramid in swine production



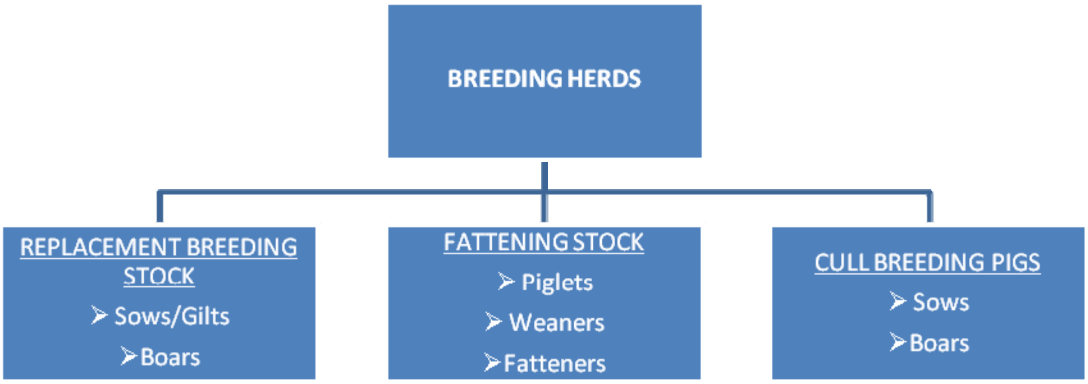
Source: Selección Batallé Group®

Depending on the type of animals produced and their position in the pork production chain, pig farms can be classified into:

1. Selection/nucleus herds: engaged in the selection and maintenance of pure-bred lines, which are the great grandparents (GGP) of the final slaughter pigs. The outputs of these herds are the grandparent (GP) breeding stock. Strict movement licensing requirements adopted by the pig industry have ensured the maintenance of excellent bio-security in the face of many disease challenges.
2. Multiplication herds: grandparent animals dedicated to the multiplication and cross-breeding of pure-bred lines to produce parent breeding stock.
3. Commercial breeding herds: hybrid parent stock dedicated to the breeding of fattening piglets.
4. Production holdings: in accordance with the EFSA baseline survey of *Salmonella* in breeding pigs, production holdings may include various combinations of commercial breeding, rearing and fattening operations, such as:
   - Farrow-to-finish production: where the entire process is performed on the same farm; birth, lactation, weaning, fattening and finishing of the pigs.
   - Farrow-to-weaner/grower production: breeding and rearing of weaner or grower pigs for transfer to finishing holdings.
   - Grower/finisher herds: dedicated to the growing and fattening of animals received from breeder herds and destined for slaughter.

The production types described show the variety of pig holdings that host breeding animals and supply gilts (young female usually not yet mated/or farrowed), sows (breeding female, could be sold pregnant), boars (male pig of breeding age) or piglets (usually weaners or young pigs).

Figure: Schematic representation of the breeding herds as sources of pigs for pork production



2.3 Correlation of *Salmonella*-positive breeding and slaughter herds

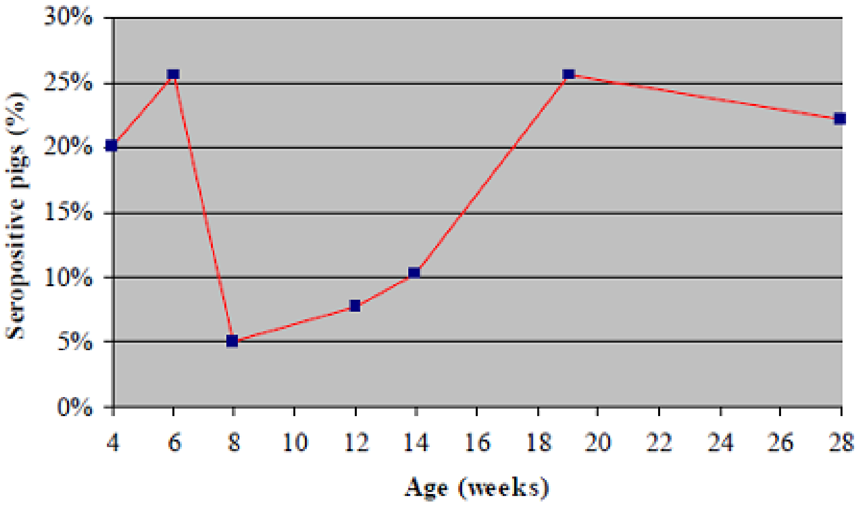
The relation between *Salmonella*-positive sows and slaughter pigs has been examined in several studies. However, there is a lack of consensus between researchers on whether the sows and boars represent a possible source of infection to suckling piglets. Several studies have agreed that that sows play an important role in maintaining *Salmonella* infection on farms (Ishiguro et al., 1979; Fedorka-Cray et al., 1997; Davies et al., 1998; Letellier et al., 1999; Funk et al., 2001). The importance placed on the breeding herds is based on concerns that incoming pigs from these herds are a potentially important source of infection for growing pig populations (Ghosh, 1972; van Schie, 1987a; Nollet et al., 2005; van der Heijden et al., 2005). Nevertheless, a considerable amount of published literature suggesting that breeder sows might not be a major or even important source of infection for finishing pigs (Berends, 1996; Davies et al., 1998; Mejia et al., 2006).

One of the arguments that support the disregard of implementing measures to decrease *Salmonella* prevalence on the breeding herds is the lack of correlation between the serovars isolated in the sows and the finishers. In the USA different serotypes were isolated in the breeding herds compared with the ones found at the finishing stages (McCracken et al., 1997; Davies et al., 1998). These results raise questions about the potential benefits obtained at the end of the pig chain by implementing control measures in the breeding stock (Blaha). In any case, some authors claimed that point estimates of *Salmonella* prevalence from *Salmonella* serotyping should not be considered as reliable since there are numerous factors that have an impact on these results, such as sampling and processing of samples (Beloeil et al., 2003; Funk et al., 2001).

Some researchers found that the proportion of seropositive animals seemed to be associated to the risk of introducing *Salmonella* in the herds by purchase of new pigs, whereas integrated herds were less likely to become infected (Cook and Miller, 2005). Similarly as in the fattening herds the probability of infection within the breeding holdings relies heavily on the indirect transmission from other factors like the type of housing and management practices applied on breeding units due to their impact on the level of environmental exposure (Kasemsuwan et al., 2008; Lurette et al., 2008 and 2009). Good farming practices that involve adequate hygiene and biosecurity protocols help to prevent the introduction of the pathogen into the breeding holdings and consequently reduce the environmental exposure of the pigs to the bacteria. Some studies revealed the possibility of preventing *Salmonella* infection in the grower-finisher stage by moving the weaning pigs to clean facilities (Nietfeld et al., 1998; Dahl et al. (1997). However, asymptomatic infected sows will occasionally excrete the bacteria in their faeces, contributing to the environmental exposure and maintaining *Salmonella* infection in the breeding herd.

In addition, some studies show the role of maternal immune protection in lowering *Salmonella* infection among piglets during the first month (Creus, 2007; Bode, 2008; Lurette et al., 2009). Bode (2008) concluded that infected sows transfer to their piglets a high level of maternal antibodies, explaining how negative piglets can be weaned from positive sows (K. Bode, 2008)

Figure : Evolution of serological *Salmonella* response in individual pigs at the nursery



Source: Creus (2007) Mesures d'intervenció per al control de *Salmonella* en la cadena de producció porcina.

Summarising, some researchers have been able to show an association between the *SSalmonella* status of sow herds and finishing herds (Dahl et al., 2000; Nollet et al., 2005). Nevertheless, a number of studies do not support the necessity of applying intensive control and monitoring in the breeding herds arguing that infection of piglets occurring prior to weaning is a relatively minor source of *Salmonella* infections found in finishing pigs (Berends, 1996; Creus, 2007). However, *Salmonella* infection of breeding stock has direct implications for food safety, because culled sows provide a substantial component of the pork products available to consumers (Davies et al., 2000)

The epidemiology of infection between sow and offspring deserves further attention with regard to reducing the burden of infected new stock entering the weaning/growing/finishing units. Some of the suggested measures to achieve it include some form of certification system for the production of *Salmonella*-free gilts and feeders based on monitoring of the *Salmonella* status of sow herds (Lo Fo Wong et al., 2000).

2.4 Summary

To conclude, there are different opinions within the scientific community concerning the role of the breeding herd in the *Salmonella* infection cycle. Berends et al (1997) only regard breeding herds as a minor source of infection for finishing herds, whereas Dahl et al. (2000) were able to demonstrate a direct association between the status of sow herds and finishing herds. Furthermore, the impact of the pre harvest control measures upon human case numbers remains unclear since there are differing sources of contamination or infection at each stage in the production chain (e.g. contaminated raw materials, cross-contamination, inappropriate storage, inadequate heat treatment, infected food handlers, etc.) Nevertheless, *Salmonella* interventions at pre harvest may have an additional benefit since they help to improve health and the welfare status of the herd, and may improve pig performance and avoid the spreading of other diseases within the holding.

The following chapter covers the reason why we are interested in the control of *Salmonella* in pigs – the impact of this on the human population.

3 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. It marks the second of a two stage approach:

Stage 1: The first stage was completed in June 2010 as part of the cost-benefit analysis relating to slaughter pigs[2]. A model was generated using common assumptions for all Member States based on literature and other published sources;

Stage 2: Following consultation with EU-27, assumptions and methodology are refined.

The chapter starts by examining the distinction between slaughter and breeding stages and their impact upon human health, i.e. the relationship between Stages 1 and 2. It then develops Stage 2 as a refinement of Stage 1 in response to the earlier consultation process.

3.1 Linking Stage 1 (slaughter pig) with Stage 2 (breeding pig)

The terms of reference for Stages 1 and 2, in relation to human health, do not vary. The TOR refer to *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

In comparing and contrasting Stages 1 and 2, the first question to be addressed is: "does *Salmonella* in pigs at the breeding stage of the food chain generate a human health impact which is different or distinguishable from *Salmonella* at the slaughter stage?" The answer is largely "no". The Stage 1 analysis segmented the disease chain between source (attribution to pigs) and outcome (disease in the human population). We attributed 15% of all human *Salmonellosis* to pork and pork products, linked mainly to food consumption, but with acknowledgement that cross-contamination can take place throughout the production cycle.

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, lairage and transport, abattoir/slaughter, cutting and processing, retail, household.

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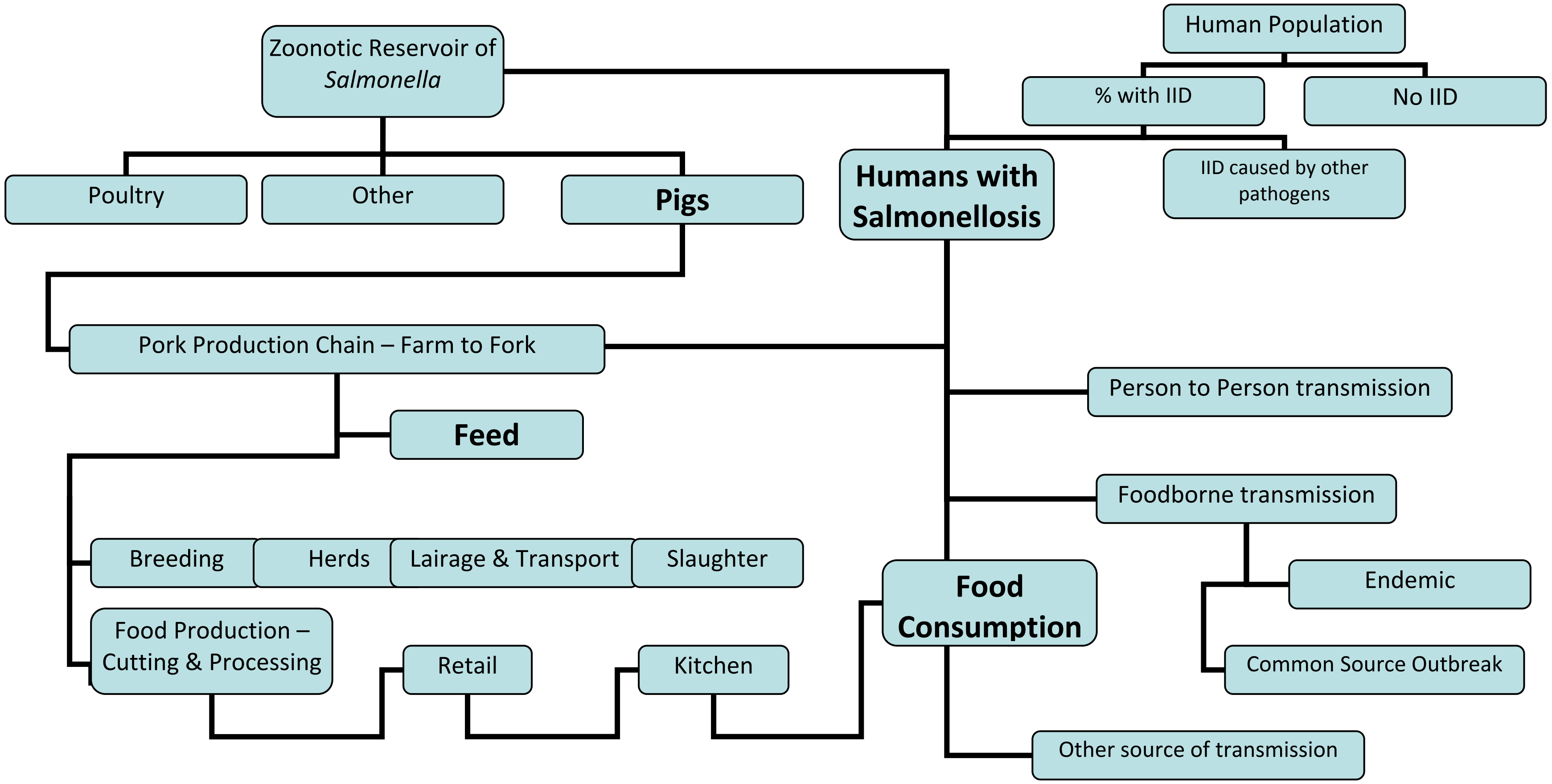
[2] (SANCO/2008/E2/036), *pigs*, http://ec.europa.eu/food/food/biosafety/*Salmonella*/impl_reg_en.htm

Figure 1: A schema showing transmission of salmonellosis relating to the human population



3.1.1 Attribution of human salmonellosis at breeding vs slaughter stage

Salmonellosis is a peroral infection, incurred through ingestion of material contaminated by *Salmonella* spp bacteria. Presence of the pathogen on meat occurs through events along the food chain pre and post harvest. It is convenient to conceptualise transmission routes of *Salmonella* spp as being vertical, horizontal, or circular:

- Vertical transmission follows the farm-to-fork chain: bacteria are transmitted from pig to pig throughout the chain from breeding, herd, transport, lairage, slaughter, cutting and processing, retail and household.
    - Although feed is an external agent, it is an integral element of the food chain (and an important potential contaminant) and so can be regarded as part of the vertical route of transmission;
- Horizontal transmission: bacteria are introduced through external agents in the environment, e.g. rodents, birds, people, trucks, pets, other foodstuff in the kitchen;
- Circular: permanent contamination – infection – contamination cycle on a farm. Positive pigs contaminate their environment through shedding; cross-contamination takes place as negative pigs become infected by bacteria carried on boots, equipment and surfaces. This is really a combination of vertical and horizontal transmission and illustrates the difficulty in isolating infection once it is introduced to a herd.

The vertical model effectively attributes disease in humans to the fork end of the farm-fork continuum. If 15% of all human salmonellosis is attributed to pork and pork products, and the primary route is through ingestion of food, then logic suggests that the source of most of that 15% for humans, in the farm to fork chain, can be located as near to fork as possible. By implication, control or reduction of *Salmonella* spp would have greatest impact near to the point of consumption. According to this vertical model of transmission, *Salmonella* in breeding pigs (which contribute to food consumption mainly through their offspring) would have less human health impact than *Salmonella* in slaughter pigs.

In practice, there are three things to consider:

- The vertical model implies that food hygiene and kitchen practices would eliminate *Salmonella* (since the bacteria can be killed through cooking, and likewise can be acquired in the kitchen). Note that this does not detract from the requirement of EU Food Law[3] that food and feed must not be placed on the market if it is unsafe.
- There is no observable correlation between prevalence of *Salmonella* in pigs and incidence in humans (as noted in Stage 1). Nevertheless we have competing assertions, e.g.
    - 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);

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[3] Regulation (EC) No 178/2002

  - "Prevalence of an agent alone is a highly inadequate measure of zoonotic or food borne risk." (Davies, 2010[4]).
- The connection between *Salmonella* in lymph nodes of pigs (identified at slaughter) and disease in humans is logically flawed and weaker than the connection between *Salmonella* on carcasses and in humans.

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. However, 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.

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 carcass swab test reflects the surface contamination of the carcass. 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. A contaminated carcass is a risk to public health as the carcass is part of the food chain.

The conclusion of this discussion is that there are significant gaps in the scientific knowledge base around biological and epidemiological determinants of risk between humans and animals. In terms of our cost-benefit analysis, however, in the absence of precise attribution between pigs and humans along the farm-fork continuum, there are several options:

a) load all attribution at the last vertical point being modelled, as we did in Stage 1 for slaughter pigs;

b) distribute the source of attribution by varying the risk weight along the farm-fork continuum. Risk of *Salmonella* acquisition in humans would be lower at the breeding phase and higher at the slaughter phase, reflecting proximity to point of consumption and reduced risk of re-contamination along the continuum. A working assumption of 5% breeding and 10% slaughter would be a reasonable starting point, linked to total attribution of 15% of the human disease burden. The implication is that reduction of 1% prevalence at slaughter stage would be twice as effective as a 1% prevalence reduction at breeding stage. It is a modelling assumption that can be varied through sensitivity analyses;

c) segment Member States and flex the attribution of human *Salmonellosis* (and therefore benefits of intervention) according to whether the prevalence of *Salmonella* in pigs is high or low. It has been argued during consultation with Member States that prevention (i.e. intervention at the feed point) is logically more cost-effective in low prevalence countries, whereas in high prevalence countries, greater benefit is to be gained by targeting abattoir practices.

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[4] Davies PR, "Pork Safety: Achievement and Challenges", editorial in *Zoonoses and Public Health*, 57 (Suppl 1) 2010 1-5

EU PIG INDUSTRY STRUCTURE

	Pig Census (population)	**% of EU Pig Population**	**Slaughtering in Tons**	**Production**	**Slaughtering in Heads**	**carcass weight (kg)**	**Heads Slaughtered Per Population**	**% Prevalence Salmonella**	**Extrapolation No. Heads Infected with Salmonella**	**% Burden of EU Salmonella**	**Slaughtered 000 tons**	**Kilo per capita slaughtered**	**Per capita consumption (kg)**	**Sufficiency (net production as % of consumption)**	**% +Import, (-) Export**	
Geo/Year	**2007**		**2008**	**2008**	**2008**						**2008**	**2008**				
Suomi	1,426,800	1%	206,334	0.9%	2,313,505	89.19	1.62	0.0	0	**0.0%**	206	39	39	99%	+1%	Finland
Sverige	1,727,500	1%	248,822	1.1%	2,803,894	88.74	1.62	1.3	36,451	**0.1%**	249	27	36	74%	+26%	Sweden
Lietuva	923,100	1%	75,425	0.3%	948,966	79.48	1.03	1.8	17,081	**0.0%**	75	22	42	54%	+46%	Lithuania
Österreich	3,286,300	2%	494,235	2.2%	5,208,277	94.89	1.58	2.0	104,166	**0.3%**	494	59	62	95%	+5%	Austria
Eesti	374,700	0%	42,360	0.2%	535,388	79.12	1.43	4.7	25,163	**0.1%**	42	32	32	97%	+3%	Estonia
Slovenia	542,600	0%	31,275	0.1%	370,625	84.38	0.68	4.8	17,790	**0.1%**	31	15	25	63%	+37%	Slovenia
Polska	17,621,200	12%	1,721,023	7.8%	20,287,703	84.83	1.15	5.1	1,034,673	**3.0%**	1721	45	54	83%	+17%	Poland
Latvia	414,400	0%	40,018	0.2%	512,352	78.11	1.24	5.6	28,692	**0.1%**	40	18	27	66%	+34%	Latvia
Czech Rep.	2,661,800	2%	288,356	1.3%	3,234,481	89.15	1.22	5.8	187,600	**0.5%**	288	28	41	68%	+32%	Czech Republic
Slovakia	951,900	1%	88,555	0.4%	954,439	92.78	1.00	6.2	59,175	**0.2%**	89	16	23	72%	+28%	Slovakia
Danmark	13,170,000	9%	1,699,967	7.7%	20,421,031	83.25	1.55	7.7	1,572,419	**4.5%**	1700	310	47	660%	-560%	Denmark
Nederland	11,710,000	8%	1,343,763	6.1%	14,739,809	91.17	1.26	8.5	1,252,884	**3.6%**	1344	82	59	138%	-38%	Netherlands
Magyarozag	3,860,000	3%	437,807	2.0%	4,717,205	92.81	1.22	9.3	438,700	**1.3%**	438	44	49	89%	+11%	Hungary
Deutschland	26,948,100	18%	4,943,986	22.4%	52,923,965	93.42	1.96	10.9	5,768,712	**16.4%**	4944	60	55	109%	-9%	Germany
Kypros	471,700	0%	58,198	0.3%	698,246	83.35	1.48	12.4	86,583	**0.2%**	58	75	67	112%	-12%	Cyprus
Belgie	6,200,300	4%	1,052,395	4.8%	11,150,849	94.38	1.80	13.9	1,549,968	**4.4%**	1052	99	49	202%	-102%	Belgium
Ireland	1,574,600	1%	210,944	1.0%	2,667,956	79.07	1.69	16.1	429,541	**1.2%**	211	49	45	109%	-9%	Ireland
Italia	9,273,000	6%	1,669,317	7.6%	14,080,587	118.55	1.52	16.5	2,323,297	**6.6%**	1669	28	41	68%	+32%	Italy
Bulgaria	865,300	1%	38,425	0.2%	572,117	67.16	0.66	16.7	95,543	**0.3%**	38	5	15	33%	+67%	Bulgaria
France	14,968,000	10%	2,212,568	10.0%	24,907,481	88.83	1.66	18.1	4,508,254	**12.9%**	2213	34	35	99%	+1%	France
U.K.	4,674,000	3%	756,152	3.4%	9,638,390	78.45	2.06	21.2	2,043,339	**5.8%**	756	12	26	48%	+52%	UK
Luxembourg	86,400	0%	7,764	0.0%	117,512	66.07	1.36	22.4	26,323	**0.1%**	8	16	0			Luxembourg
Portugal	2,345,000	2%	371,120	1.7%	5,631,759	65.90	2.40	23.4	1,317,832	**3.8%**	371	35	48	73%	+27%	Portugal
Ellas	1,038,000	1%	104,909	0.5%	1,681,098	62.40	1.62	24.8	416,912	**1.2%**	105	9	27	35%	+65%	Greece
Espana	25,616,500	17%	3,470,474	15.7%	40,440,302	85.82	1.58	29.0	11,727,688	**33.4%**	3470	75	64	118%	-18%	Spain
Malta	76,900	0%	10,344	0.0%	120,371	85.94	1.57		0	**0.0%**	10	25	50	51%	+49%	Malta
Roumania	6,644,700	4%	416,032	1.9%	5,183,571	80.26	0.78		0	**0.0%**	416	19	31	63%	+37%	Romania
Eur 27	152,731,200	100%	22,040,567	100.0%	241,557,937	89.28	1.58	10.3	24,880,468		22041	46	44	104%	-4%	Eur 27
								15%	**35,068,785**	**100%**						
							relates to sum total, not average									

If EU-27 were to be segmented into quintiles according to burden of disease shown in the previous table (prevalence of *Salmonella* in pigs weighted by number of heads slaughtered) then Member States would be grouped as shown below. This quintile ranking has potential application in discriminating where the human health benefits of intervention may be located along the transmission route, from farm (including feed) to fork.

Ranking weighted prevalence into quintiles

High Burden				**Low Burden**	
Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**	
France	Belgium	Austria	Bulgaria	Estonia	Malta
Germany	Denmark	Czech Republic	Cyprus	Finland	Romania
Italy	Netherlands	Greece	Latvia	Lithuania	
Spain	Poland	Hungary	Slovakia	Luxembourg	
UK	Portugal	Ireland	Sweden	Slovenia	

3.1.2 Distribution of human health benefits between breeding & slaughter

The relationship between the human health model and industry costs of intervention are affected by the slaughter/breeding distinction as follows:

- The total human health costs of *Salmonella* do not change. The Stage 1 assumption of 15% attribution (15% of human salmonellosis cases being attributable to pork) relates to the whole farm-fork chain;
- When we model individual links in the farm-fork chain, then each component could be mapped to 0-15% of human *Salmonella* cases, with the sum of components adding to the assumed 15%;
- The impact is to spread the human health costs (i.e. benefits or cost saving of intervention) across multiple interventions. The net effect is to reduce the attributable benefit of intervention at slaughter stage because some benefit needs to be attributed to the breeding stage.

3.2 Structure of the cost of illness (cost calculator) model for EU-27

The cost calculator adopts a modular structure. It starts by estimating the volume of human salmonellosis, then aggregates the total cost, before apportioning costs according to disease attribution. Stage 1 applied a common set of assumptions to EU-27. The model estimates the cost per case of human salmonellosis in a single year. Refinements are considered within each module in the sections which follow.

Module 1: Total Number of Cases	•Pyramid of Illness : Community – GP – Reported •Outcome Severity :Mild – Moderate – Severe – Dead •No treatment – GP – Hospital – Dead
Module 2: Productivity Costs	•Labour market cost and participation; labour market index •Days absent from work by Outcome Severity
Module 3: Healthcare utilisation costs	•GP Visit , Emergency Department, Outpatients, Hospital Admission
Module 4: Premature Death	•Include/Exclude •Willingness to Pay, Productivity, Flat Rate
Module 5: Total Costs	•Costs of Salmonellosis in Humans by MS •Cost per Case
Module 6: Attribution to Pork	•Cases and Costs Associated with Pork •15% attribution

We consulted EU-27 on the model and tested assumptions relating to Modules 1 (total number of cases), 3 (healthcare costs) and 4 (premature death). The results of consultation are discussed in the sections which follow.

- Total number of cases:
    - Estimating the incidence of disease, based on a pyramid of illness;
    - Categorising severity, distinguishing between mild and severe cases;
- Estimating chronic complications, i.e. chronic sequelae;
- Impact of premature death

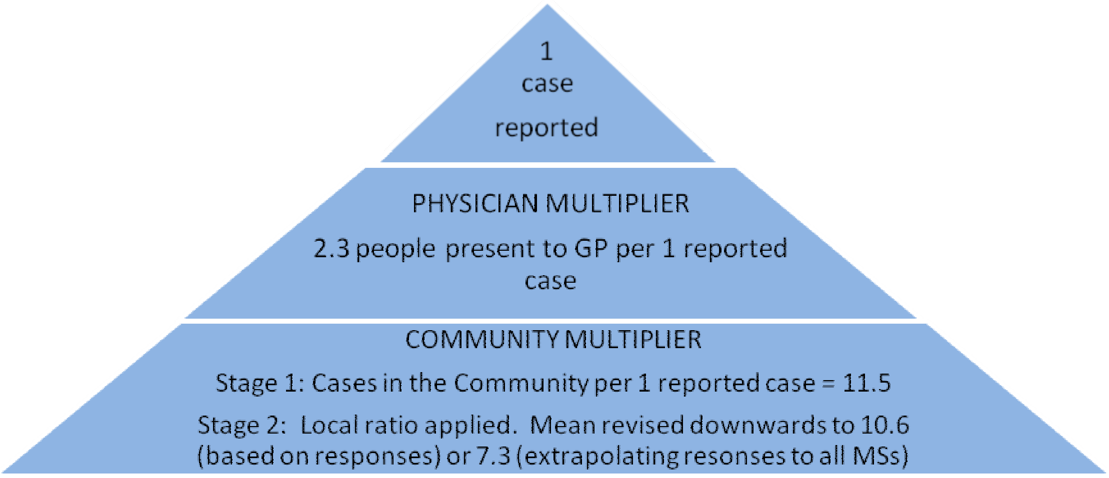
3.3 Total number of cases

3.3.1 Pyramid of illness

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).

- **Stage 1** assumed a relationship of 11.5 cases in the community per 1 reported case, derived as a mean between measured estimates in England, Netherlands and USA (see table below). We use the term "Community Multiplier" to describe this relationship;
- **Consultation Question.** EU-27 Member States were asked: "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?
- **Consultation Results (n=12):**
    - 1MS, England, supported (a) 3.2 as the most recent England figure;
    - 5 MSs supported the model's approach of (b) 11.5, based on an average of England, Netherlands, and USA
    - 1 MS supported (c) 13.9, cited by EFSA (2008a) as the Netherlands multiplier based on Sensor.
    - 5 MSs supported the use of (e) other based on local assumptions:
        - 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.
- **Implications of Consultation on Stage 2:**
    - The 12 MS responses alter the EU-27 average multiplier downwards to 10.6, which is only 8% lower than the original assumption of 11.5.
    - It is worth noting, however, that local estimates were invariably lower than the modelling assumption of 11.5. Local estimates had a mean of 7.4.
    - The impact upon total costs is small. If we reduced the community multiplier to 7.4 among all MSs that did not supply a local estimate (changing 11.5 to 7.4) then the EU-27 mean multiplier would change to 7.3, reducing incidence by 37%, reducing total costs by 3%, and increasing cost per case by 54% due to shift in severity away from mild cases.

Pyramid of Illness



1
case
reported

PHYSICIAN MULTIPLIER

2.3 people present to GP per 1 reported case

COMMUNITY MULTIPLIER

Stage 1: Cases in the Community per 1 reported case = 11.5

Stage 2: Local ratio applied. Mean revised downwards to 10.6 (based on responses) or 7.3 (extrapolating resonses to all MSs)

Other Observations on Incidence of Disease

	Salmonella reported cases 2008	Incidence Report Cases per 100,000 Population 2008	Community Multiplier based on 12 MS responses	Community Incidence per 100,000 Pop	Stage 2 Community Multiplier	Community Incidence per 100,000 Pop
European Union (27 countries)	131468	26.4	10.6	279	7.3	192
Austria	2310	27.8	11.5	319	7.4	205
Belgium	3831	35.9	11.5	413	7.4	266
Bulgaria	1516	19.8	11.5	228	7.4	147
Cyprus	169	21.4	11.5	246	7.4	158
Czech Republic	10707	103.1	11.5	1186	7.4	763
Denmark	3669	67.0	8.3	556	8.3	556
Estonia	647	48.2	2.5	121	2.5	121
Finland	3126	59.0	11.5	678	7.4	436
France	7186	11.2	11.5	129	7.4	83
Germany	42909	52.2	11.5	600	7.4	386
Greece	1039	9.3	11.5	107	7.4	69
Hungary	6637	66.1	11.5	760	7.4	489
Ireland	447	10.2	8.0	81	8.0	81
Italy	3232	5.4	11.5	62	7.4	40
Latvia	1229	54.1	11.5	622	7.4	400
Lithuania	3308	98.3	13.9	1366	13.9	1366
Luxembourg (Grand-Duché)	202	41.8	11.5	480	7.4	309
Malta	161	39.2	11.5	451	7.4	290
Netherlands	1627	15.5	16.5	164	16.5	164
Poland	9149	24.0	11.5	276	7.4	178
Portugal	332	3.1	11.5	36	7.4	23
Romania	624	2.9	11.5	33	7.4	21
Slovakia	6849	126.8	11.5	1458	7.4	938
Slovenia	1033	51.4	11.5	591	7.4	380
Spain	3833	8.5	11.5	97	7.4	63
Sweden	4185	45.6	6.1	278	6.1	278
United Kingdom	11511	18.8	3.2	60	3.2	60

During the consultation process (between Stages 1 and 2) it has been commented that:

- former Soviet bloc states (e.g. Slovakia, Czech Republic) tend to show higher incidence of reported cases than the rest of the EU, especially southern Europe (e.g. Spain and Greece) implying a difference in diagnostic and reporting disciplines and infrastructure;
- consumption patterns may have a bearing on incidence of disease, e.g. through consumption of raw pork in Germany;
- levels of immunity in the population may vary, especially when considering Spain and Greece, that have low reported rates, compared to Sweden and Finland that have high reported rates that are largely imported through tourism and travel (EFSA Journal 2010, p25).

In practice we have no means of establishing whether variation in reported incidence of *Salmonella* is due to (a) different levels of morbidity or (b) different methods of detection, or a combination of the two. We continue, therefore, to use published reported cases as the basis for modelling the human health impact of *Salmonella* .

The model remains stable at the higher level of severity, since the assumption of 2.3 people visiting their GP for every 1 notified case of salmonellosis is fixed (consistent with England and US findings and used by RIVM Netherlands). All variation in volumes therefore occur at the lower (and least costly) level of severity.

3.3.2 Categorising severity

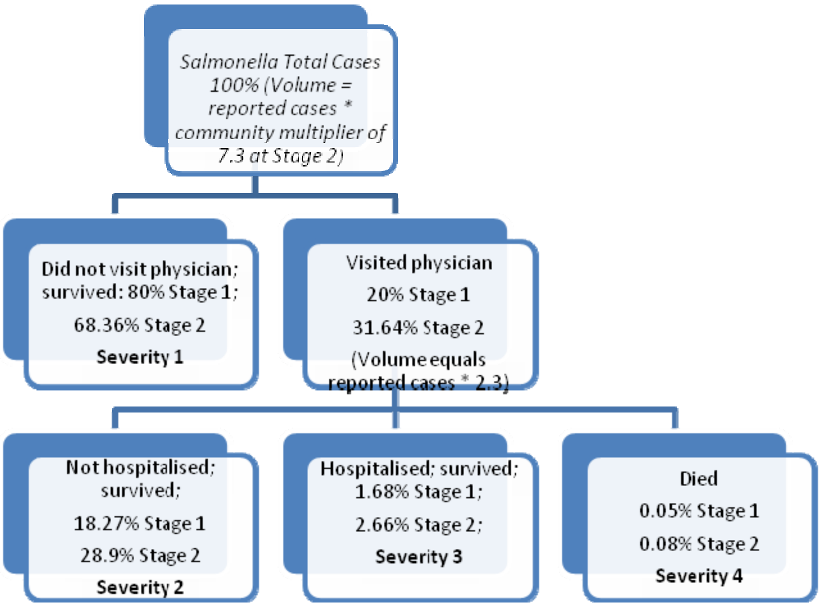
Severity of disease is quantified according to outcome, linked to healthcare utilisation. Total cases comprise:

- 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 model is driven by volumes of reported cases, multiplied in accordance with the pyramid of illness assumptions. Severities 2+3+4 aggregate to the volume of patients who visit a GP (using “physician multiplier”). The percentage distribution between Severities 2, 3 and 4 is informed by the ERS/USDA model (www.ers.usda.gov). It follows that the lower the Community Multiplier (which determines total cases), the higher the percentage in Severity Categories 2 to 4.

The model is sensitive to low volume/high cost estimates, such as the number of fatalities. The volumes of cases in Severities 2 to 4 has not been varied between Stages 1 and 2. This is an area that would benefit from further refinement within Member States.

Figure: Severity outcome distribution linked to multipliers in burden of illness pyramid, showing Stage 1 and Stage 2 mean



3.4 Premature death

In Stage 1 we incorporated a wage-weighted assumption (20 years average earnings for the Member State based on a labour cost index) to account for fatalities, producing an average cost per fatality of €600,000 ranging from €60,000 to €1,000,000 unit value. These costs are conservative compared to Willingness to Pay (WTP) estimates (which tend to be twice as high) but in line with other comparators (e.g. the UK unit value emerged as €1 million compared to £1 million[5] used in the UK for food safety). The US cost calculator uses $5 million as the value per statistical life, based on WTP estimates[6].

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[5] http://www.food.gov.uk/multimedia/pdfs/EURegulationsRIA.pdf

[6] A 2006 US Institute of Medicine report on valuing health (Institute of Medicine. 2006. *Valuing Health for Regulatory Cost-Effectiveness Analysis*. (Washington DC: National Academies Press) recommends that regulatory analyses should not assign monetary values to estimates of health-adjusted life years (IOM 2006). Nevertheless there is a precedent for assigning monetary values to health adjusted life years (a generic term covering Disability Adjusted Life Years and the mirror opposite Quality Adjusted Life Years. See: discussion of cost-effectiveness threshold for end of life drugs at £30,000 per QALY in Raftery J, 2009, "Should NICE's threshold range for cost per QALY be raised? No", BMJ 2009; 338:b185). The Economic Research Service of the US Department of Agriculture assigns a value to disutility based on compensating wage estimates and describes the FDA approach: "For their disutility calculations, FDA [Food and Drug Administration] researchers assigned a value of $5 million to premature death and a proportion of this amount to all other outcomes, depending on the outcome's disutility weight. Assuming that the average illness strikes a 40 year old with an average remaining lifespan of 36 years, FDA researchers discounted future health benefits to estimate the value of a "discounted life year" at $230,000 and the value of a "discounted day" at $630. FDA used the discounted value of a healthy day (along with information on duration) to calculate a dollar measure of utility loss per case.

In Stage 1 we asked Member States: "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?"

Responses

- There was broad support (6 out of 13 responses) for the model's approach of (c) productivity using 20 years average earnings because it is transparent and consistent;
- 4 MSs suggested that a financial value of premature death should be excluded;
- England proposed the use of QALYs as an alternative to the Cost of Illness approach;
- Netherlands suggested a methodology based on friction cost, as described below (http://www.rivm.nl/bibliotheek/rapporten/330080001.html) ; this would have an effect similar to (a) excluding a financial value.

Friction Cost

Kemmeren et al[7] apply a friction cost to estimate the indirect non-health care costs, defined as the value of production lost to society due to a) temporary absence from work; b) permanent or long-term disability; and c) premature mortality. "In this method, production losses are only considered for the period needed to replace a sick, invalid or dead worker, the so-called 'friction period'. The friction cost method takes into account the economic processes a sick, invalid or dead person can and will be replaced after a period of adaptation. The length of the friction period depends on the situation on the labour market. A high unemployment rate generally allows fast replacement of a sick, invalid or dead person, whereas in the case of a low unemployment rate, on average more time is needed to find someone on the labour market that could fill in the position. We assumed for the year 2004 a friction period of 154 days." (p31). The impact of the friction cost approach was to assign €0.1 million to fatalities, which is approximately 1% of the cost assigned in the Stage 1 model which uses a value per statistical life.

3.5 Chronic complications – chronic sequelae

Salmonella infections may cause acute gastroenteritis. In most cases this will be self-limiting within a few days to weeks, but the disease may be fatal for a few patients or may result in complications, of which reactive arthritis (ReA) and inflammatory bowel disease (IBD) are the most significant (van Lier and Havelaar, 2007). Salmonellosis has also been identified as a focal infection in large vessels including heart and aorta, increasing risk of aorta aneurysm, a severe complication that requires costly preventive actions[8].

The Stage 1 analysis acknowledged that nearly 5% of people who suffer acute foodborne disease may experience chronic sequelae in the form of prolonged reactive arthritis (Raybourne et al, 2003; in Buzby et al, 2009; based on 8% of people experiencing sequelae, 3.2% of whom make a full recovery). However, the Stage 1 model did not include an estimate

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[7] J.M. Kemmeren, M.-J.J. Mangen, Y.T.H.P. van Duynhoven, A.H. Havelaar , 2006, "Disease burden and costs of selected enteric Pathogens" RIVM report 330080001/2006 **Priority setting of foodborne pathogens**

[8] 1)Egeblad H, Wierup P, Laursen AL. *Salmonella*-infected left ventricular thrombus. Eur Heart J. 2005 Dec; 26(23):2549; and or 2) Mutlu H, Babar J, Maggiore PR. Extensive *Salmonella* enteritidis endocarditis involving mitral, tricuspid valves, aortic root and right ventricular wall. J Am Soc Echocardiogr. 2009 Feb;22(2):210.e1-3. Epub 2009 Jan 10.

of the impact of chronic sequelae. This has been identified as a deficit and so is addressed here in Stage 2. We draw on the work of RIVM.

3.5.1 Methodology for measuring chronic sequelae

The Centre for Infectious Disease Control Netherlands, Rijksinstituut voor Volksgezondheid en Milieu (National Institute of Public Health and the Environment, RIVM) has undertaken detailed work in this area[9]. Methodologically, RIVM has advanced the use of Disability Adjusted Life Years (DALYs) as a composite measure that takes into account duration and severity of sequelae, as well as reported mortality and incidence. The DALY methodology uses years of life lost due to mortality (YLL) and years of living with a disability (YLD), weighted with a factor between 0 and 1 for the severity of the disability: DALY=YLL + YLD. DALY is the converse of a Quality Adjusted Life Year (QALY) which is often used to reflect years gained through an intervention[10]. RIVM has also derived financial estimates of the impact of *Salmonellosis* in humans in the Netherlands.

3.5.2 Comparing RIVM findings with consortium Stage 1 model

We have compared the output of our Stage 1 model with the findings of RIVM to gain some insight into how much adjustment to make to take account of chronic sequelae. We have mapped the RIVM's cost-of-illness estimates to the DALY distribution and uprated 2004 figures to 2009 (see table below). Our conclusion is that the Stage 1 model underestimates burden of disease but does not underestimate cost:

- Consortium Stage 1 model under-estimates the impact of *Salmonella* by excluding chronic sequelae (ReA and IBD) by up to 20% in terms of burden of disease;
- The RIVM application of a friction cost approach to mortality produces a low cost per fatality;
- The Consortium Stage 1 model produces a relatively high cost per fatality, based on value per statistical life;
- If we distribute RIVM costs according to the DALY weighting, the DALY-weighted costs show a better match between the RIVM model and Consortium Stage 1 model[11], but costs of fatalities are still higher in the Consortium model;
- It is possible to argue that the high cost imputed to premature death offsets the omission of chronic sequelae from the model;
- RIVM data is extremely useful in giving an indication of the sensitivity of costs to chronic sequelae.

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[9] Sources: (i) J.M. Kemmeren, M.-J.J. Mangen, Y.T.H.P. van Duynhoven, A.H. Havelaar , 2006, "Disease burden and costs of selected enteric Pathogens" RIVM report 330080001/2006 **Priority setting of foodborne pathogens**
(ii) van Lier EA, Havelaar AH, 2007b, **"Disease burden of infectious diseases in Europe: a pilot study".** RIVM report 215011001/2007, available online: http://rivm.nl/bibliotheek/rapporten/215011001.html
(iii) van Lier EA, Havelaar AH, Nanda A, 2007, "The burden of infectious diseases in Europe: a pilot study." Euro Surveill. ;12(12):pii=751. http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=751

[10] For example, cost effectiveness analyses conducted by the National Institute for Clinical Excellence (NICE) in the UK uses QALY as the currency used to measure benefits of pharmaceuticals, with a threshold generally understood to be £30,000 per QALY gained.

[11] The Stage 1 Consortium model is based on a smaller number of reported cases due to the time difference (1627 in 2008 rather than 2500 in 2004) so that the underlying unit costs are very different

Extract from Kemmeren et al, RIVM, 2006

	RIVM Report 330080001, pp59 and 61					
	Cases	**Disability weight per case/ year**	**YLD**	**YLL**	**DALY**	**Cost 2004 €m**
Lab Cases (Reported)	2500					
Gastroenteritis	35000		100	440	550	7.0
No GP	30000	0.001	30		30	2.3
GP	5400	0.011	60		60	1.7
Hospital	640	0.017	11		11	2.7
Fatal	39	1		440	440	0.1
ReA	460		40		40	0.04
IBD	7	0.26	80		80	1.7
Sum			220	440	670	8.8

Linking DALYs (Kemmeren et al, RIVM, 2006) to Stage 1

	RIVM Report	**DALY- weighted Cost using RIVM data**		**Consortium Stage 1 Model for Netherlands (p97)**
	Cost 2004 €m	**2004 €m**	**2008 €m**	**2008 €m**
Gastroenteritis	7.0	7.2	8.3	10.7
No GP	2.3	0.4	0.5	2.8
GP	1.7	0.8	0.9	
Hospital	2.7	0.1	0.2	
Fatal	0.1	5.8	6.6	7.9
ReA	0.04	0.5	0.6	
IBD	1.7	1.1	1.2	
Sum	8.8	8.8	10.1	10.7

Comparison of RIVM and Consortium Stage 1 Models (referring to Netherlands)

Problem	**RIVM (2004 data) Approach to Resolving Problem**	**Consortium Model (Stage 1) Approach to Resolving Problem**	**Comparison**
Under-reporting of cases	Multiply laboratory cases by 14, i.e. 2500 lab cases was converted to incidence of 35000	Derive Community Multiplier as discussed in earlier section. Initially used 13.9 for Netherlands.	Consistent
Under-reporting of mortality	Estimated that 0.11% of cases would die	Estimated that 0.05% of cases would die in Stage 1. (Revised this to 0.08% in Stage 2 because the Community Multiplier was reduced). Mortality can be described as 0.25% of cases that visit a GP.	Consistent approach, which produces higher mortality rates than published
Cost of Mortality	A friction approach is applied, reflecting the duration before which the sick person is replaced in the labour force; Fatalities account for €0.1m out of a total of €8.8m in 2004	A value of statistical life is imputed, based on 20 years earnings (based on labour cost index reflecting difference in participation and wage rates between Member States); In Netherlands accounts for €7.9 m out of €10.7m in 2008	Completely different approach, producing higher costs associated with fatalities in the Consortium Model
Impact of Mortality on Resources	RIVM estimated that 80% of the impact of gastroenteritis (440/550 DALY) was accounted for by fatalities; Fatalities account for €0.1m out of a total of €8.8m.	Estimated that 75% of cost of Salmonella was associated with premature death	Consortium Model cost apportionment is consistent with the DALY burden of disease apportionment (but exceeds the RIVM cost estimate)
Impact of Chronic Sequelae	Included impact of ReA and IBD, adding 22% to the DALY caused by GE (120/550); chronic sequelae account for 18% (120/670) of total DALY	Excluded	Major difference
Total Cost of Salmonella in € million in Netherlands	€ 8.8 million at 2004 including € 1.8 million linked to chronic sequelae (20% of cost); Uprated to € 10.1 million in 2008. Equivalent to €4k per lab (reported) case or	€ 10.7 million in 2008; Based on 1,627 reported cases and 18,711 total cases in the community; Equivalent to € 6,600 per reported case or €570 per community case.	• Consistent total figure but different composition; • death is biggest cost factor in Consortium model;

	€290 per community case; Total 670 DALYs, so 1 DALY equivalent to €15,000 in 2008; therefore € 6.8 m relates to the 440 DALY associated with fatalities	€ 7.9m associated with fatalities	- death is biggest DALY factor in RIVM model.

3.6 Sensitivity of estimates to other comparators

Studies of disease costs make different methodological choices[12] which makes cross-comparison difficult, but a useful sensitivity check nevertheless. Santos et al (2010)[13] found that mean costs per case were in England were £1282 (Typhymurium) and £993 S. Enteritidis. It includes direct costs incurred by parents, families and carers of cases and the direct costs for the use of the NHS by the patients but excludes costs of death.

Our model (Stage 2) excludes out of pocket expenses to patients. It shows an average cost of € 2,173 (£1,940) for England (which has the highest unit cost in the EU-27 model, mainly due to the low community multiplier and consequent high severity) including cost of premature death, but only € 461 per case excluding cost of death. The average cost across the whole community (Stage 2) is estimated to be € 600 per case.

Cost per Case in £ Sterling, Santos et al (2010)

	S. Typhymurium		S. Enteritidis
Cases and families direct costs	£54.93	(4%)	£57.52 (6%)
Indirect costs	£409.41	32%)	£228.29 (23%)
NHS direct costs	£817.62	(64%)	£707.27 (71%)
Mean societal costs (per case)	£1281.96	(100%)	£993.08 (100%)

The variability of study findings is explored by Santos et al:

"Comparing our findings with the international estimates, we can find some similarities. In a 2009 study in Spain, the cost of a non-specific *Salmonella* infection was estimated to be E2411 (£2150; 2009 mean exchange rate). However, this investigation included patients with human immunodeficiency virus – acquired immune deficiency syndrome (HIV-AIDS), neoplasias or immunological cases. No specific cost was estimated for ST or SE[14]. Another study in Spain estimated an overall health system cost of E710 (£633; 2009 mean exchange rate) for gastrointestinal diseases, including *Salmonella*. This estimated cost included hospital

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[12] Havelaar A, 2007, " Methodological choices for calculating the disease burden and cost-of-illness of foodborne zoonoses in European countries" Med-Vet-Net Workpackage 23

[13] SANTOS AC, ROBERTS JA, COOK AJC, SIMONS R, SHEEHAN R, LANE C, ADAK GK, CLIFTON-HADLEY FA, RODRIGUES LC, 2010, "*Salmonella* Typhimurium and *Salmonella* Enteritidis in England: costs to patients, their families, and primary and community health services of the NHS", Epidemiol. Infect.,

[14] Gil Prieto R, et al. Epidemiology of hospital-treated *Salmonella* infection ; data from a national cohort over a ten-year period. Journal of Infection 2009; 58: 175–181.

admission, visits to A&E, visits to the GP, and laboratory investigations but no costs to patients[15]. The estimated overall direct out-of-pocket expenses of *Salmonella* cases were relatively stable. For the IID study, an overall mean cost of £32 was estimated. The IID study was about 26% higher than our estimates. Nappies, bleach and washing powder represented a large element of costs for cases in 1994. In 2007/2008 respondents expended more on transport, nappies and other items. The estimated costs in our study are likely to be underestimated, as we have not included the costs of cases that were treated at home, investigation costs and laboratory costs. We did not estimate the cost for the time lost from education or leisure or the extended time suffering from *Salmonella* , in spite of the high estimated number (and proportion) of days when activities of daily living were affected."

We are cautious about the values obtained in our model. Comparisons with England suggest that our direct costs of health care utilisation may be underestimated. We also exclude out of pocket expenses to cases and families. Further, we exclude the cost of chronic sequelae (but acknowledge its potential impact). The cost of death, however, is excluded by comparator studies. Inclusion in our model (following the methodology of the US Department of Agriculture) more than compensates for under-estimation of costs.

It is reassuring to find that studies of total burden of disease in Netherlands by RIVM produce comparable findings, linking DALY and euro estimates, although our model produces slightly higher overall costs.

In general, therefore, our model tends to produce higher total costs and higher unit costs than comparator studies. We know the reason for this: inclusion of statistical value of life to account for premature death. We also know that if we were to exclude it then our costs would be low relative to other studies. It would then be necessary to add 20% for chronic sequelae and possibly expand healthcare utilisation costs. The main adjustment to the model relates to severity through lowering the estimate of mild cases (reducing the Community Multiplier). Even with this reduction in incidence, the human health impact of *Salmonella* through pigs and pork are likely to be overstated rather than understated due to (a) attribution of 15% to pigs and pork as a source of *Salmonella* and (b) assumption of linear relationship between changes in *Salmonella* prevalence in pigs and *Salmonella* incidence in humans (see Stage 1 report and link to QMRA study).

3.7 Overall changes from Stages 1 and 2

The model has changed in response to consultation with EU-27 Member States at Stage 1. A detailed comparison is given in the table below. The main changes are as follows:

- 37% reduction in number of cases as average Community Multiplier drops from 11.5 to 7.3;
- Increase in severity as case reduction takes place in Severity 1 category (mild cases of people who do not visit a physician);
- 3% reduction in total costs of *Salmonella* changing from € 88.7 million to € 86.1 million associated with *Salmonella* in pork;
- 53% increase in unit costs from € 391 (min € 40 and max € 680) in Stage 1 to € 600 per case (min € 60 and max € 2,173) in Stage 2

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[15] Parada Ricart E, Inoriza Belurze JM, Plaja Roman P. Severe gastroenteritis : costs of a potentially evitable cause. Anales de Pediatrı´a 2007; 67: 368–373.

- 15% attribution has been retained in the model, but Member States are encouraged to estimate their local attribution of *Salmonella* to pigs and pork.

Examining Sensitivity of Variables by Comparing Stage 1 Model and Stage 2

Variable	**Stage 1**	**Stage 2**	**Impact**
Community multiplier	11.5	7.3 if we extrapolate local estimates that (apart from Netherlands) were lower than 11.5	• 37% reduction community incidence; • Reduction affects mild cases.
Cost of premature death	• 20 years earnings based on labour cost index; • 75% of costs; • Low volume/high cost	• No change; • Application of friction cost method would reduce to 1% of current estimate; would have similar impact to exclusion of the cost; • Application of Willingness to Pay method would potentially double cost; • Application of flat rate was not favoured by any MS.	• No change; • If we were to exclude it the risk of underestimating overall costs of *Salmonella* would increase; • It serves to compensate for exclusion of impact of chronic sequelae in the costs.
Severity of illness	• Applied outcome measures around multiplier of 2.3 people visiting the GP per 1 reported case (called the "GP Multiplier")	• The GP Multiplier is regarded as more robust than the Community Multiplier; • The volumes of cases in Severity categories 2-4 has remained stable (i.e. visited physician, hospitalised, died); • The volume of cases in Severity category 1 has reduced (did not visit physician);	• Severity increased; • Total costs reduced by 3% (so remained virtually stable); • Unit costs increased by 53%
Mortality Rate	• Applied assumption of 0.25% of GP cases and 0.05% of all cases; • This is higher than reported mortality rates, but consistent with findings of RIVM that mortality is under-reported	• Volume of fatalities remained unchanged; • Ratios became 0.25% of GP cases (unchanged) and 0.08% of total cases (because estimate of total cases reduced in line with Community Multiplier)	• No change in volumes or costs
Chronic sequelae	• Excluded • This proved to be the main criticism of the model	• DALYs should be increased by 22% (120/550) to include ReA and IBD according to RIVM, reflecting the fact that 8% of people with S. will suffer from ReA or IBD	• The currency of the Consortium model is Euros, not DALYs; • We consider the sensitivity of the Benefit Cost Ratio to 22% increase in

Variable	**Stage 1**	**Stage 2**	**Impact**
			a later chapter
Include cost of pain and suffering	• Excluded •	• Excluded	• No change
Hospital utilisation costs	• Common (notional) unit cost assumptions •	• Found to be reasonably stable when we consulted although lower than comparator studies	• No change
Attribution	• 15% of Salmonella attributed to pork	• 15% remains a bold assumption (discussed in detail in Stage 1); • There is a case to vary attribution between Member States, but we have not done this due to lack of evidence; • Attribution takes account of the whole farm-fork chain so does not distinguish between breeding and slaughter stage; • For modelling purposes it is reasonable to apportion the 15% between different stages of production, e.g. 5% breeding, 10% slaughter.	• No change • 15% probably errs on the high side; • Reduction in attribution % would reduce health impact benefits of intervention

Number of Cases

Min	161		1	2.3	2.5	0.08	0.1394	12.73%	1.17%	0.03%		370	1,191	129	338	31	0.9	6.7	21	0.016	
Max	42909		1	2.3	16.5	0.86061	0.92	84.04%	7.74%	0.22%		98,691	317,527	218,836	90,147	8304	239.5	291.7	1366	0.708	

					7.4																
			Assumptic	2.3	11.5							Muliple	Multiple	Severity 1	Severity 2	Severity	Severity 4				
			Reporting Pyramid						0.921739												
	Salmonella reported cases 2008	Incidence Report Cases per 100,000 Population	Reported cases	Presenting to GP	Community Cases	% of Cases that do not see GP	% 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	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	Fatality as % of reported c cases
European Union (27 countries)	131468	26.4			7.3	68.36%	31.64%	28.90%	2.66%	0.08%		302,376	955,784	653,408	276,200	25,443	734	60.8	192	0.147	0.56%
Austria	2310	27.8	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		5,313	17,094	11,781	4,853	447.0	12.9	63.9	205	0.155	0.56%
Belgium	3831	35.9	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		8,811	28,349	19,538	8,049	741.4	21.4	82.6	266	0.200	0.56%
Bulgaria	1516	19.8	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		3,487	11,218	7,732	3,185	293.4	8.5	45.6	147	0.111	0.56%
Cyprus	169	21.4	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		389	1,251	862	355	32.7	0.9	49.2	158	0.120	0.56%
Czech Republic	10707	103.1	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		24,626	79,232	54,606	22,494	2072.1	59.8	237.2	763	0.576	0.56%
Denmark	3669	67.0	1.0	2.3	8.3	72.29%	27.71%	25.31%	2.33%	0.07%		8,439	30,453	22,014	7,708	710.1	20.5	154.1	556	0.374	0.56%
Estonia	647	48.2	1.0	2.3	2.5	8.00%	92.00%	84.04%	7.74%	0.22%		1,488	1,618	129	1,359	125.2	3.6	111.0	121	0.269	0.56%
Finland	3126	59.0	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		7,190	23,132	15,943	6,567	605.0	17.5	135.6	436	0.329	0.56%
France	7186	11.2	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		16,528	53,176	36,649	15,097	1390.7	40.1	25.8	83	0.063	0.56%
Germany (including ex-GDR from 1991)	42909	52.2	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		98,691	317,527	218,836	90,147	8304.1	239.5	120.0	386	0.291	0.56%
Greece	1039	9.3	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		2,390	7,689	5,299	2,183	201.1	5.8	21.3	69	0.052	0.56%
Hungary	6637	66.1	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		15,265	49,114	33,849	13,944	1284.4	37.1	152.0	489	0.369	0.56%
Ireland	447	10.2	1.0	2.3	8.0	71.25%	28.75%	26.26%	2.42%	0.07%		1,028	3,576	2,548	939	86.5	2.5	23.4	81	0.057	0.56%
Italy	3232	5.4	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		7,434	23,917	16,483	6,790	625.5	18.0	12.5	40	0.030	0.56%
Latvia	1229	54.1	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		2,827	9,095	6,268	2,582	237.8	6.9	124.5	400	0.302	0.56%
Lithuania	3308	98.3	1.0	2.3	13.9	83.45%	16.55%	15.11%	1.39%	0.04%		7,608	45,981	38,373	6,950	640.2	18.5	226.0	1366	0.549	0.56%
Luxembourg (Grand-Duché)	202	41.8	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		465	1,495	1,030	424	39.1	1.1	96.0	309	0.233	0.56%
Malta	161	39.2	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		370	1,191	821	338	31.2	0.9	90.3	290	0.219	0.56%
Netherlands	1627	15.5	1.0	2.3	16.5	86.06%	13.94%	12.73%	1.17%	0.03%		3,742	26,846	23,103	3,418	314.9	9.1	22.8	164	0.055	0.56%
Poland	9149	24.0	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		21,043	67,703	46,660	19,221	1770.6	51.1	55.2	178	0.134	0.56%
Portugal	332	3.1	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		764	2,457	1,693	697	64.3	1.9	7.2	23	0.017	0.56%
Romania	624	2.9	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		1,435	4,618	3,182	1,311	120.8	3.5	6.7	21	0.016	0.56%
Slovakia	6849	126.8	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		15,753	50,683	34,930	14,389	1325.5	38.2	291.7	938	0.708	0.56%
Slovenia	1033	51.4	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		2,376	7,644	5,268	2,170	199.9	5.8	118.2	380	0.287	0.56%
Spain	3833	8.5	1.0	2.3	7.4	68.92%	31.08%	28.39%	2.62%	0.08%		8,816	28,364	19,548	8,053	741.8	21.4	19.5	63	0.047	0.56%
Sweden	4185	45.6	1.0	2.3	6.1	62.30%	37.70%	34.44%	3.17%	0.09%		9,626	25,529	15,903	8,792	809.9	23.4	104.8	278	0.254	0.56%
United Kingdom	11511	18.8	1.0	2.3	3.2	28.13%	71.88%	65.65%	6.05%	0.17%		26,475	36,835	10,360	24,183	2227.7	64.3	43.3	60	0.105	0.56%

TOTAL COSTS OF ALL SALMONELLA INFECTION

Min	1,191	€ 27,601	€ 5	€ 5,790	€ 2	€ 2,028	€ 9	€ 7,553	€ 14	€ 37,299	€ 228	€ 283,763	€ 61,573	€ 364,033	€ 60
Max	317,527	€ 23,720,510	€ 143	€ 3,991,686	€ 38	€ 1,397,717	€ 153	€ 5,206,735	€ 230	€ 25,713,166	€ 3,832	€ 195,619,710	€ 1,036,975	€ 255,649,523	€ 2,173

		Productivity		**GP Visit**		**Emergency Departmen**		**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)	955,784	€ 50,747,147	€ 53	€ 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	€ 573,671,765	€ 600
Austria	17,094	€ 1,223,171	€ 72	€ 205,750	€ 28.90	€ 72,045	€ 115.59	€ 268,380	€ 173.38	€ 1,325,377	€ 2,889.71	€ 10,083,159	€ 781,905	€ 13,177,882	€ 771
Belgium	28,349	€ 1,817,238	€ 64	€ 354,285	€ 30.00	€ 124,055	€ 120.01	€ 462,128	€ 180.02	€ 2,282,192	€ 3,000.31	€ 17,362,378	€ 811,833	€ 22,402,276	€ 790
Bulgaria	11,218	€ 56,946	€ 5	€ 10,633	€ 2.28	€ 3,723	€ 9.10	€ 13,870	€ 13.65	€ 68,495	€ 227.56	€ 521,096	€ 61,573	€ 674,763	€ 60
Cyprus	1,251	€ 56,110	€ 45	€ 9,324	€ 17.90	€ 3,265	€ 71.59	€ 12,162	€ 107.39	€ 60,059	€ 1,789.86	€ 456,915	€ 484,304	€ 597,834	€ 478
Czech Republic	79,232	€ 1,357,380	€ 17	€ 235,252	€ 7.13	€ 82,375	€ 28.51	€ 306,862	€ 42.77	€ 1,515,421	€ 712.84	€ 11,528,968	€ 192,882	€ 15,026,258	€ 190
Denmark	30,453	€ 2,858,510	€ 94	€ 433,401	€ 38.32	€ 151,758	€ 153.29	€ 565,327	€ 229.94	€ 2,791,833	€ 3,832.37	€ 21,239,608	€ 1,036,975	€ 28,040,437	€ 921
Estonia	1,618	€ 40,197	€ 25	€ 10,506	€ 5.27	€ 3,679	€ 21.07	€ 13,704	€ 31.61	€ 67,675	€ 526.80	€ 514,852	€ 142,544	€ 650,612	€ 402
Finland	23,132	€ 1,539,999	€ 67	€ 262,221	€ 27.21	€ 91,819	€ 108.86	€ 342,040	€ 163.29	€ 1,689,144	€ 2,721.47	€ 12,850,613	€ 736,384	€ 16,775,836	€ 725
France	53,176	€ 2,900,853	€ 55	€ 544,829	€ 24.60	€ 190,776	€ 98.39	€ 710,672	€ 147.59	€ 3,509,614	€ 2,459.79	€ 26,700,316	€ 665,577	€ 34,557,059	€ 650
Germany (including ex	317,527	€ 23,720,510	€ 75	€ 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	€ 255,649,523	€ 805
Greece	7,689	€ 310,148	€ 40	€ 58,924	€ 18.40	€ 20,632	€ 73.60	€ 76,860	€ 110.40	€ 379,567	€ 1,839.92	€ 2,887,654	€ 497,851	€ 3,733,784	€ 486
Hungary	49,114	€ 688,251	€ 14	€ 140,770	€ 6.88	€ 49,291	€ 27.52	€ 183,619	€ 41.29	€ 906,794	€ 688.12	€ 6,898,672	€ 186,193	€ 8,867,397	€ 181
Ireland	3,576	€ 289,818	€ 81	€ 47,959	€ 34.81	€ 16,793	€ 139.24	€ 62,558	€ 208.85	€ 308,939	€ 3,480.89	€ 2,350,332	€ 941,870	€ 3,076,399	€ 860
Italy	23,917	€ 1,195,490	€ 50	€ 245,967	€ 24.69	€ 86,127	€ 98.76	€ 320,838	€ 148.14	€ 1,584,442	€ 2,469.06	€ 12,054,059	€ 668,084	€ 15,486,924	€ 648
Latvia	9,095	€ 144,235	€ 16	€ 23,458	€ 6.19	€ 8,214	€ 24.77	€ 30,598	€ 37.15	€ 151,108	€ 619.24	€ 1,149,590	€ 167,556	€ 1,507,203	€ 166
Lithuania	45,981	€ 452,941	€ 10	€ 55,641	€ 5.46	€ 19,483	€ 21.83	€ 72,578	€ 32.74	€ 358,421	€ 545.70	€ 2,726,786	€ 147,657	€ 3,685,850	€ 80
Luxembourg (Grand-Du	1,495	€ 111,046	€ 74	€ 21,213	€ 34.07	€ 7,428	€ 136.28	€ 27,671	€ 204.43	€ 136,650	€ 3,407.09	€ 1,039,599	€ 921,900	€ 1,343,606	€ 899
Malta	1,191	€ 27,601	€ 23	€ 5,790	€ 11.67	€ 2,028	€ 46.67	€ 7,553	€ 70.01	€ 37,299	€ 1,166.81	€ 283,763	€ 315,718	€ 364,033	€ 306
Netherlands	26,846	€ 1,693,548	€ 63	€ 161,845	€ 32.27	€ 56,671	€ 129.09	€ 211,110	€ 193.64	€ 1,042,555	€ 3,227.29	€ 7,931,509	€ 873,248	€ 11,097,238	€ 413
Poland	67,703	€ 910,897	€ 13	€ 173,140	€ 6.14	€ 60,626	€ 24.56	€ 225,843	€ 36.84	€ 1,115,315	€ 613.97	€ 8,485,055	€ 166,131	€ 10,970,877	€ 162
Portugal	2,457	€ 74,360	€ 30	€ 12,219	€ 11.94	€ 4,279	€ 47.76	€ 15,938	€ 71.64	€ 78,711	€ 1,194.05	€ 598,815	€ 323,090	€ 784,322	€ 319
Romania	4,618	€ 41,217	€ 9	€ 7,760	€ 4.03	€ 2,717	€ 16.14	€ 10,122	€ 24.21	€ 49,986	€ 403.45	€ 380,285	€ 109,168	€ 492,088	€ 107
Slovakia	50,683	€ 713,764	€ 14	€ 124,605	€ 5.90	€ 43,631	€ 23.61	€ 162,534	€ 35.41	€ 802,663	€ 590.24	€ 6,106,470	€ 159,710	€ 7,953,666	€ 157
Slovenia	7,644	€ 112,744	€ 15	€ 19,142	€ 6.01	€ 6,703	€ 24.05	€ 24,968	€ 36.07	€ 123,304	€ 601.18	€ 938,068	€ 162,668	€ 1,224,928	€ 160
Spain	28,364	€ 1,169,503	€ 41	€ 201,890	€ 17.09	€ 70,693	€ 68.35	€ 263,344	€ 102.53	€ 1,300,509	€ 1,708.84	€ 9,893,965	€ 462,382	€ 12,899,904	€ 455
Sweden	25,529	€ 1,965,261	€ 77	€ 355,223	€ 27.54	€ 124,384	€ 110.15	€ 463,352	€ 165.23	€ 2,288,236	€ 2,753.79	€ 17,408,359	€ 745,130	€ 22,604,815	€ 885
United Kingdom	36,835	€ 5,275,412	€ 143	€ 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	€ 80,026,250	€ 2,173

Unit Cost per Reported Case

TOTAL COSTS OF ALL SALMONELLA INFECTION

Min	161	€ 27,601	€ 38	€ 5,790	€ 7	€ 2,028	€ 2	€ 7,553	€ 9	€ 37,299	€ 45	€ 283,763	€ 344	€ 364,033	€ 445	€ 80,271	€ 101
Max	42,909	€ 23,720,510	€ 1,041	€ 3,991,686	€ 118	€ 1,397,717	€ 41	€ 5,206,735	€ 154	€ 25,713,166	€ 761	€ 195,619,710	€ 5,789	€ 255,649,523	€ 7,643	€ 60,029,813	€ 1,946
		Productivity		GP Visit		Emergency Departmen		Outpatient		Hospital Admission		Premature Death		Total Cost		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	Cost Exc Death	Cost per Case
European Union (27 countries)	131,468	€ 50,747,147	€ 386	€ 8,999,955	€ 68	€ 3,151,397	€ 24	€ 11,739,498	€ 89	€ 57,974,840	€ 441	€ 441,058,928	€ 3,355	€ 573,671,765	€ 4,364	€ 132,612,837	€ 1,009
Austria	2,310	€ 1,223,171	€ 530	€ 205,750	€ 89	€ 72,045	€ 31	€ 268,380	€ 116	€ 1,325,377	€ 574	€ 10,083,159	€ 4,365	€ 13,177,882	€ 5,705	€ 3,094,724	€ 1,340
Belgium	3,831	€ 1,817,238	€ 474	€ 354,285	€ 92	€ 124,055	€ 32	€ 462,128	€ 121	€ 2,282,192	€ 596	€ 17,362,378	€ 4,532	€ 22,402,276	€ 5,848	€ 5,039,898	€ 1,316
Bulgaria	1,516	€ 56,946	€ 38	€ 10,633	€ 7	€ 3,723	€ 2	€ 13,870	€ 9	€ 68,495	€ 45	€ 521,096	€ 344	€ 674,763	€ 445	€ 153,667	€ 101
Cyprus	169	€ 56,110	€ 332	€ 9,324	€ 55	€ 3,265	€ 19	€ 12,162	€ 72	€ 60,059	€ 355	€ 456,915	€ 2,704	€ 597,834	€ 3,537	€ 140,919	€ 834
Czech Republic	10,707	€ 1,357,380	€ 127	€ 235,252	€ 22	€ 82,375	€ 8	€ 306,862	€ 29	€ 1,515,421	€ 142	€ 11,528,968	€ 1,077	€ 15,026,258	€ 1,403	€ 3,497,291	€ 327
Denmark	3,669	€ 2,858,510	€ 779	€ 433,401	€ 118	€ 151,758	€ 41	€ 565,327	€ 154	€ 2,791,833	€ 761	€ 21,239,608	€ 5,789	€ 28,040,437	€ 7,643	€ 6,800,829	€ 1,854
Estonia	647	€ 40,197	€ 62	€ 10,506	€ 16	€ 3,679	€ 6	€ 13,704	€ 21	€ 67,675	€ 105	€ 514,852	€ 796	€ 650,612	€ 1,006	€ 135,759	€ 210
Finland	3,126	€ 1,539,999	€ 493	€ 262,221	€ 84	€ 91,819	€ 29	€ 342,040	€ 109	€ 1,689,144	€ 540	€ 12,850,613	€ 4,111	€ 16,775,836	€ 5,367	€ 3,925,223	€ 1,256
France	7,186	€ 2,900,853	€ 404	€ 544,829	€ 76	€ 190,776	€ 27	€ 710,672	€ 99	€ 3,509,614	€ 488	€ 26,700,316	€ 3,716	€ 34,557,059	€ 4,809	€ 7,856,743	€ 1,093
Germany (including ex	42,909	€ 23,720,510	€ 553	€ 3,991,686	€ 93	€ 1,397,717	€ 33	€ 5,206,735	€ 121	€ 25,713,166	€ 599	€ 195,619,710	€ 4,559	€ 255,649,523	€ 5,958	€ 60,029,813	€ 1,399
Greece	1,039	€ 310,148	€ 299	€ 58,924	€ 57	€ 20,632	€ 20	€ 76,860	€ 74	€ 379,567	€ 365	€ 2,887,654	€ 2,779	€ 3,733,784	€ 3,594	€ 846,130	€ 814
Hungary	6,637	€ 688,251	€ 104	€ 140,770	€ 21	€ 49,291	€ 7	€ 183,619	€ 28	€ 906,794	€ 137	€ 6,898,672	€ 1,039	€ 8,867,397	€ 1,336	€ 1,968,725	€ 297
Ireland	447	€ 289,818	€ 648	€ 47,959	€ 107	€ 16,793	€ 38	€ 62,558	€ 140	€ 308,939	€ 691	€ 2,350,332	€ 5,258	€ 3,076,399	€ 6,882	€ 726,067	€ 1,624
Italy	3,232	€ 1,195,490	€ 370	€ 245,967	€ 76	€ 86,127	€ 27	€ 320,838	€ 99	€ 1,584,442	€ 490	€ 12,054,059	€ 3,730	€ 15,486,924	€ 4,792	€ 3,432,865	€ 1,062
Latvia	1,229	€ 144,235	€ 117	€ 23,458	€ 19	€ 8,214	€ 7	€ 30,598	€ 25	€ 151,108	€ 123	€ 1,149,590	€ 935	€ 1,507,203	€ 1,226	€ 357,612	€ 291
Lithuania	3,308	€ 452,941	€ 137	€ 55,641	€ 17	€ 19,483	€ 6	€ 72,578	€ 22	€ 358,421	€ 108	€ 2,726,786	€ 824	€ 3,685,850	€ 1,114	€ 959,064	€ 290
Luxembourg (Grand-Du	202	€ 111,046	€ 550	€ 21,213	€ 105	€ 7,428	€ 37	€ 27,671	€ 137	€ 136,650	€ 676	€ 1,039,599	€ 5,147	€ 1,343,606	€ 6,652	€ 304,007	€ 1,505
Malta	161	€ 27,601	€ 171	€ 5,790	€ 36	€ 2,028	€ 13	€ 7,553	€ 47	€ 37,299	€ 232	€ 283,763	€ 1,763	€ 364,033	€ 2,261	€ 80,271	€ 499
Netherlands	1,627	€ 1,693,548	€ 1,041	€ 161,845	€ 99	€ 56,671	€ 35	€ 211,110	€ 130	€ 1,042,555	€ 641	€ 7,931,509	€ 4,875	€ 11,097,238	€ 6,821	€ 3,165,728	€ 1,946
Poland	9,149	€ 910,897	€ 100	€ 173,140	€ 19	€ 60,626	€ 7	€ 225,843	€ 25	€ 1,115,315	€ 122	€ 8,485,055	€ 927	€ 10,970,877	€ 1,199	€ 2,485,822	€ 272
Portugal	332	€ 74,360	€ 224	€ 12,219	€ 37	€ 4,279	€ 13	€ 15,938	€ 48	€ 78,711	€ 237	€ 598,815	€ 1,804	€ 784,322	€ 2,362	€ 185,507	€ 559
Romania	624	€ 41,217	€ 66	€ 7,760	€ 12	€ 2,717	€ 4	€ 10,122	€ 16	€ 49,986	€ 80	€ 380,285	€ 609	€ 492,088	€ 789	€ 111,802	€ 179
Slovakia	6,849	€ 713,764	€ 104	€ 124,605	€ 18	€ 43,631	€ 6	€ 162,534	€ 24	€ 802,663	€ 117	€ 6,106,470	€ 892	€ 7,953,666	€ 1,161	€ 1,847,196	€ 270
Slovenia	1,033	€ 112,744	€ 109	€ 19,142	€ 19	€ 6,703	€ 6	€ 24,968	€ 24	€ 123,304	€ 119	€ 938,068	€ 908	€ 1,224,928	€ 1,186	€ 286,860	€ 278
Spain	3,833	€ 1,169,503	€ 305	€ 201,890	€ 53	€ 70,693	€ 18	€ 263,344	€ 69	€ 1,300,509	€ 339	€ 9,893,965	€ 2,581	€ 12,899,904	€ 3,365	€ 3,005,939	€ 784
Sweden	4,185	€ 1,965,261	€ 470	€ 355,223	€ 85	€ 124,384	€ 30	€ 463,352	€ 111	€ 2,288,236	€ 547	€ 17,408,359	€ 4,160	€ 22,604,815	€ 5,401	€ 5,196,456	€ 1,242
United Kingdom	11,511	€ 5,275,412	€ 458	€ 1,286,522	€ 112	€ 450,485	€ 39	€ 1,678,133	€ 146	€ 8,287,366	€ 720	€ 63,048,332	€ 5,477	€ 80,026,250	€ 6,952	€ 16,977,919	€ 1,475

TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK

% Attribution Pork: 0.15

		Productivity		GP Visit		Emergency Departmen		Outpatient		Hospital Admission		Premature Death		Total Cost		Original Stage 1 Model 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**	**Stage 2**	**Cost per Case**	**Stage 1**	**Cost per Case**
Min	179	€ 4,140	€ 5	€ 869	€ 2	€ 304	€ 9	€ 1,133	€ 14	€ 5,595	€ 228	€ 42,564	€ 61,573	€ 54,605	€ 60	€ 55,852	€ 40
Max	47,629	€ 3,558,076	€ 143	€ 598,753	€ 38	€ 209,657	€ 153	€ 781,010	€ 230	€ 3,856,975	€ 3,832	€ 29,342,956	€ 1,036,975	€ 38,347,428	€ 2,173	€ 39,418,915	€ 680
European Union (27 countries)	143,368	€ 7,612,072	€ 53	€ 1,349,993	€ 22	€ 472,710	€ 89	€ 1,760,925	€ 133	€ 8,696,226	€ 2,220.99	€ 66,158,839	€ 600,961	€ 86,050,765	€ 600	€ 88,649,330	€ 391
Austria	2,564	€ 183,476	€ 72	€ 30,863	€ 29	€ 10,807	€ 116	€ 40,257	€ 173	€ 198,807	€ 2,889.71	€ 1,512,474	€ 781,905	€ 1,976,682	€ 771	€ 2,031,935	€ 510
Belgium	4,252	€ 272,586	€ 64	€ 53,143	€ 30	€ 18,608	€ 120	€ 69,319	€ 180	€ 342,329	€ 3,000.31	€ 2,604,357	€ 811,833	€ 3,360,341	€ 790	€ 3,442,428	€ 521
Bulgaria	1,683	€ 8,542	€ 5	€ 1,595	€ 2	€ 558	€ 9	€ 2,080	€ 14	€ 10,274	€ 227.56	€ 78,164	€ 61,573	€ 101,214	€ 60	€ 103,787	€ 40
Cyprus	188	€ 8,417	€ 45	€ 1,399	€ 18	€ 490	€ 72	€ 1,824	€ 107	€ 9,009	€ 1,789.86	€ 68,537	€ 484,304	€ 89,675	€ 478	€ 92,210	€ 316
Czech Republic	11,885	€ 203,607	€ 17	€ 35,288	€ 7	€ 12,356	€ 29	€ 46,029	€ 43	€ 227,313	€ 712.84	€ 1,729,345	€ 192,882	€ 2,253,939	€ 190	€ 2,315,253	€ 125
Denmark	4,568	€ 428,776	€ 94	€ 65,010	€ 38	€ 22,764	€ 153	€ 84,799	€ 230	€ 418,775	€ 3,832.37	€ 3,185,941	€ 1,036,975	€ 4,206,065	€ 921	€ 4,300,595	€ 680
Estonia	243	€ 6,030	€ 25	€ 1,576	€ 5	€ 552	€ 21	€ 2,056	€ 32	€ 10,151	€ 526.80	€ 77,228	€ 142,544	€ 97,592	€ 402	€ 103,819	€ 93
Finland	3,470	€ 231,000	€ 67	€ 39,333	€ 27	€ 13,773	€ 109	€ 51,306	€ 163	€ 253,372	€ 2,721.47	€ 1,927,592	€ 736,384	€ 2,516,375	€ 725	€ 2,585,939	€ 480
France	7,976	€ 435,128	€ 55	€ 81,724	€ 25	€ 28,616	€ 98	€ 106,601	€ 148	€ 526,442	€ 2,459.79	€ 4,005,047	€ 665,577	€ 5,183,559	€ 650	€ 5,314,594	€ 429
Germany (including ex	47,629	€ 3,558,076	€ 75	€ 598,753	€ 30	€ 209,657	€ 121	€ 781,010	€ 181	€ 3,856,975	€ 3,018.10	€ 29,342,956	€ 816,646	€ 38,347,428	€ 805	€ 39,418,915	€ 533
Greece	1,153	€ 46,522	€ 40	€ 8,839	€ 18	€ 3,095	€ 74	€ 11,529	€ 110	€ 56,935	€ 1,839.92	€ 433,148	€ 497,851	€ 560,068	€ 486	€ 574,077	€ 320
Hungary	7,367	€ 103,238	€ 14	€ 21,115	€ 7	€ 7,394	€ 28	€ 27,543	€ 41	€ 136,019	€ 688.12	€ 1,034,801	€ 186,193	€ 1,330,110	€ 181	€ 1,361,199	€ 119
Ireland	536	€ 43,473	€ 81	€ 7,194	€ 35	€ 2,519	€ 139	€ 9,384	€ 209	€ 46,341	€ 3,480.89	€ 352,550	€ 941,870	€ 461,460	€ 860	€ 472,164	€ 612
Italy	3,588	€ 179,324	€ 50	€ 36,895	€ 25	€ 12,919	€ 99	€ 48,126	€ 148	€ 237,666	€ 2,469.06	€ 1,808,109	€ 668,084	€ 2,323,039	€ 648	€ 2,377,040	€ 426
Latvia	1,364	€ 21,635	€ 16	€ 3,519	€ 6	€ 1,232	€ 25	€ 4,590	€ 37	€ 22,666	€ 619.24	€ 172,439	€ 167,556	€ 226,080	€ 166	€ 232,596	€ 110
Lithuania	6,897	€ 67,941	€ 10	€ 8,346	€ 5	€ 2,922	€ 22	€ 10,887	€ 33	€ 53,763	€ 545.70	€ 409,018	€ 147,657	€ 552,878	€ 80	€ 544,771	€ 95
Luxembourg (Grand-Du	224	€ 16,657	€ 74	€ 3,182	€ 34	€ 1,114	€ 136	€ 4,151	€ 204	€ 20,497	€ 3,407.09	€ 155,940	€ 921,900	€ 201,541	€ 899	€ 206,557	€ 593
Malta	179	€ 4,140	€ 23	€ 869	€ 12	€ 304	€ 47	€ 1,133	€ 70	€ 5,595	€ 1,166.81	€ 42,564	€ 315,718	€ 54,605	€ 306	€ 55,852	€ 201
Netherlands	4,027	€ 254,032	€ 63	€ 24,277	€ 32	€ 8,501	€ 129	€ 31,666	€ 194	€ 156,383	€ 3,227.29	€ 1,189,726	€ 873,248	€ 1,664,586	€ 413	€ 1,608,668	€ 573
Poland	10,155	€ 136,635	€ 13	€ 25,971	€ 6	€ 9,094	€ 25	€ 33,877	€ 37	€ 167,297	€ 613.97	€ 1,272,758	€ 166,131	€ 1,645,632	€ 162	€ 1,686,778	€ 107
Portugal	369	€ 11,154	€ 30	€ 1,833	€ 12	€ 642	€ 48	€ 2,391	€ 72	€ 11,807	€ 1,194.05	€ 89,822	€ 323,090	€ 117,648	€ 319	€ 121,007	€ 211
Romania	693	€ 6,183	€ 9	€ 1,164	€ 4	€ 408	€ 16	€ 1,518	€ 24	€ 7,498	€ 403.45	€ 57,043	€ 109,168	€ 73,813	€ 107	€ 75,675	€ 70
Slovakia	7,602	€ 107,065	€ 14	€ 18,691	€ 6	€ 6,545	€ 24	€ 24,380	€ 35	€ 120,399	€ 590.24	€ 915,971	€ 159,710	€ 1,193,050	€ 157	€ 1,225,292	€ 104
Slovenia	1,147	€ 16,912	€ 15	€ 2,871	€ 6	€ 1,005	€ 24	€ 3,745	€ 36	€ 18,496	€ 601.18	€ 140,710	€ 162,668	€ 183,739	€ 160	€ 188,832	€ 106
Spain	4,255	€ 175,425	€ 41	€ 30,283	€ 17	€ 10,604	€ 68	€ 39,502	€ 103	€ 195,076	€ 1,708.84	€ 1,484,095	€ 462,382	€ 1,934,986	€ 455	€ 1,987,814	€ 301
Sweden	3,829	€ 294,789	€ 77	€ 53,284	€ 28	€ 18,658	€ 110	€ 69,503	€ 165	€ 343,235	€ 2,753.79	€ 2,611,254	€ 745,130	€ 3,390,722	€ 885	€ 3,519,986	€ 488
United Kingdom	5,525	€ 791,312	€ 143	€ 192,978	€ 36	€ 67,573	€ 145	€ 251,720	€ 218	€ 1,243,105	€ 3,626.02	€ 9,457,250	€ 981,138	€ 12,003,938	€ 2,173	€ 12,701,548	€ 640

Addendum to Sensitivity Analysis – See Annex

We have been asked to test the model against assumptions from two new sources that are contained in a draft opinion by EFSA on the public health impact of control measures in broilers: (a) annex showing under-reporting of salmonellosis among humans based on Swedish tourism data and (b) attribution based on serovar distribution:

- Under-reporting factor (described in our study as the Community Multiplier), representing incidence in the community that is not diagnosed or reported: it increases nearly sevenfold from 7.3 to 47.5[16];
- Attribution: increases from 15% to 35.1%. This is a very bold assumption and exceeds any of the literature sources explored in our study[17].

The impact of under-reporting is not very important to total costs in our model because it assumes that under-reporting is linked to cases with mild severity. The very high cost element, i.e. premature death, is not affected by the volume of under-reporting. Total costs are increased by 6% which, in modelling terms, is within a +-10% tolerance limit of impact. Much more significant is the change in attribution from 15% to 35.1%. This more than doubles the pork-related cost of salmonellosis among humans from circa €90 million euros to €200 million.

	Current Model (based on 2008 data)	**Summary of Annex**
Reported Cases	131468	No change (using 2008 data)
Total Cases	955784	6,240,270
Community Multiplier	7.3	47.5
Cost of Total Salmonellosis	€574 million	€608 million
Unit Cost per Case	€600	€97
Attribution of S. to pork	15%	35.1%
Cost of Salmonellosis attributed to pork	€90 million	€200 million

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[16] Derived by taking total cases and linking them to 2008 reported S. cases and 2008 population in our model. If 2009 reported S. cases and 2009 population are used then the under-reporting factor is 51.3 which is more than a seven-fold increase against 7.3;

[17] The Stage 1 Slaughter Pig Report Summarised the Literature: *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%, so15% 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, 2008

4 Pre-harvest interventions and their costs

The QMRA mentioned that *Salmonella* control in breeder pig farms should focus on the proper implementation of *Salmonella* biosecurity programs, the control of *Salmonella* in incoming pigs and the provision of clean feed to the animals (QMRA, 2009). Therefore, when aiming to decrease pig herd prevalence at the breeding holdings, similar strategies as the ones suggested on the finisher units, should be applied in a long term perspective.

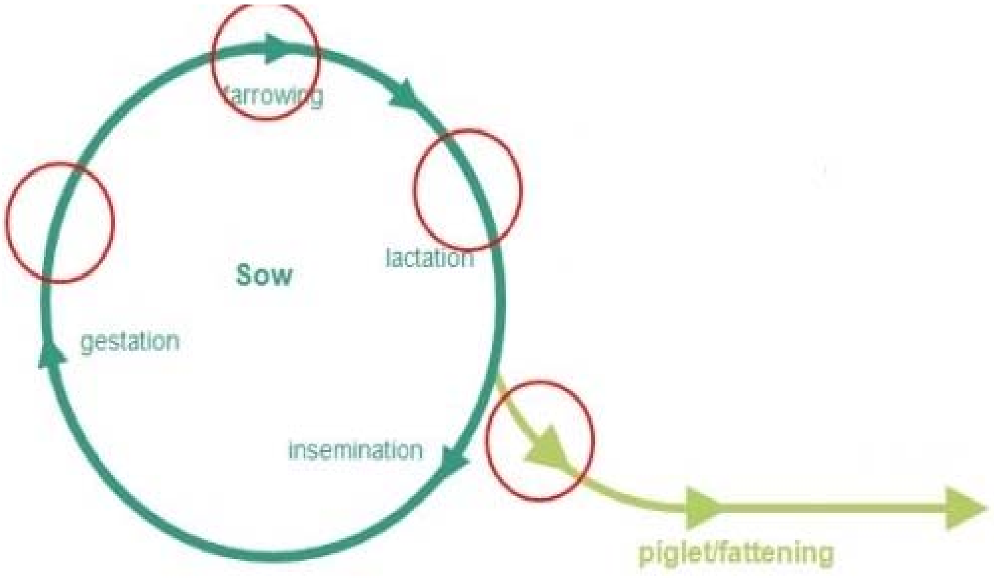
The 5 main groups of pre harvest measures identified at the pre harvest stage have been already described in the slaughter pig study (SANCO/2008/E2/036):

a. Provide feed not contaminated with *Salmonella*.
b. Purchase of *Salmonella* free replacements.
c. On farm strategies aiming to prevent infection from external sources. Strategies being classified into:
    i. Hygiene and Biosecurity measures
    ii. Feed strategies
d. Transport interventions
e. Abattoir (lairage) interventions

Most of these measures can be extrapolated to the breeding holdings with some minor changes to adapt them to the breeding framework, resulting in:

a. Provide feed free of *Salmonella* contamination.
b. Purchase of *Salmonella* free new stock replacement.
    ⇒ Is it feasible to issue some type of "*Salmonella*-free" certification?
c. On farm strategies aiming to prevent infection from external sources. Strategies being classified into:
    i. Hygiene and Biosecurity measures
    ii. Feed strategies

Figure: Schematic representation of the sow cycle in swine production



Source: Dr Steinbeck at the "Sow nutrition technical meeting" (Denmark, 2009)

Some of these interventions have already been described in detail and their implementation costs estimated in the previous cost-benefit analysis of the slaughter pigs. For this reason, some of the control activities will not be explained in detail to avoid duplication of the information already presented.

The QMRA report does not specify exactly how *Salmonella* prevalence reductions in breeding pigs can be achieved and the Consortium has undertaken a wide ranging literature review, consultation with experts and - where time and resources allowed - data collection as close to source as possible. The present chapter summarises this information and uses it as a basis for making cost estimates at the end of this chapter.

4.1 Provide clean feed to the breeding holdings

Animal and plant origin feed ingredients are frequently contaminated with *Salmonella spp.* Consequently, animal feed may be a crucial source of infection for farm animals, which could lead to human illness on consumption of foods of animal origin (Linton et al., 1970). A high number of serovars isolated from feed are pathogenic to humans. In 2007, four of these serovars commonly isolated in the livestock feeding were found within the top ten strains detected in human salmonellosis cases (Wierup et al, 2010). Control of *Salmonella* in animal production cannot be successful if we continue to introduce *Salmonella* to our farms through contaminated feed.

Providing clean feed involves a group of measures that take place at feed mills and that we have listed as:

- **Feed sourcing:** Avoid the introduction of contaminated feed ingredients by obtaining from trusted sources, following quarantine procedures at reception, sampling and testing of high risk materials and taking corrective actions when positive.
- **Feedstuff treatment:** Achieve reduction of the bacteria through heat or chemical treatments.
- **Good feed manufacturing practices**: Avoid recontamination of the product through the application of adequate protocols with regard to pest control, availability of facilities for delivery trucks to perform their cleaning, disinfection, ongoing maintenance of the production systems, implementation of corrective actions when appropriate, etc.
- **Monitoring:** Ensure that there are no breaches that could hamper the production of *Salmonella* free feed.

As previously done on the Slaughter Pigs report, each strategy has been broken down into more specific interventions for which implementation costs can be estimated (SANCO/2008/E2/036).

4.1.1 Feed sourcing interventions

- Supplier assessment: Extra costs entailed for choosing a more expensive supplier.
- Separate storage for the new incoming materials (quarantine procedures): Extra costs concerning the availability and use of additional storage facilities out of the feed mills.
- Risk based sampling and testing of high risk materials: soybean meal, rape seed meal, palm kernel meal, fish meal, sunflower meal, cotton seed meal, etc.
- Action taken when positive results found: feed ingredients could either go through a decontamination treatment or be sent back to the supplier.

Table: Costs associated with feed sourcing interventions

Country	**FEED SOURCING (€/tonne)**				**Reference**
	Sourcing	Separate Storage	Risk Based Testing	Treatment	
Spain			0.25€/tonne	2.00€/tonne	*Vall Companys Group consultancy (2010)*
Spain			0.05€/tonne	2.00€/tonne	*Nutreco Group consultancy (2010)*
Sweden	30 SEK/ton	4-8 SEK/ton	9,8 SEK/ton (rapeseed)	10-15 SEK/ton (soy & rapeseed)	*Enheten för foder och djurprodukter*
Sweden	30 SEK/ton		4-8 SEK/ton	100-200 SEK/ton	*Swedish Board of Agriculture (2010-04-15)*

4.1.2 Feedstuff treatment interventions

The treatment of feedingstuffs aims at the reduction of existing microbiological contamination.

- Heat treatment: A method widely used to ensure the microbiological quality of animal feed by putting the feedstuffs through a terminal heater whereby the materials in meal form are heated to a temperature of 99°C with a retention time of 2.5-3.0 minutes at that temperature, and with a moisture content of at least 10% in the materials entering the heater (Wilder, 1968)
- Irradiation: considered a potentially control measure for certain microbial agents in the feed of food-producing animals (WHO Consultation, 2001)
- Chemical treatments: including the use of organic acids, formaldehyde, pro-biotic, antimicrobials, sodium chlorate, etc.

Table : Costs associated with feedstuff treatment

	FEEDSTUFF TREATMENT		**Reference**
Country	T°	Acids	
Spain	3.00€/tonne	3.50€/tonne	*Vall Companys Group* consultancy *(2010)*
Spain		3.50€/tonne	*Nutreco Group* consultancy *(2010)*
Sweden	5 cc/kg		*Engvall et al. (1994)*
Sweden	7-10 SEK/ton		*Swedish Board of Agriculture (2010-04-15)*

4.1.3 Feed safety management system in place

For the industrial production of animal feeding stuffs, the producer or manufacturer should establish quality assurance systems based on the principles of Good Manufacturing Practice (GMP) and the application of Hazard Analysis and Critical Control Point (HACCP) principles. *Salmonella spp.* contamination in rendered products and finished feed is most likely due to recontamination from rodents and fomites in the environment at the processing plants (McChesney et al., 1995). Control measures include:

- Implementation of effective pest control plans for rodents, birds and insects.
- Completion of hygiene protocols that include the regular cleaning and disinfection of the feed mill layout including the storage facilities and delivery trucks between trips.
- Adaptation of the feed mill building structure when needed and the compliance with a continuous maintenance record.
- Execution of a *Salmonella* tailored control programme including corrective measures when *Salmonella* positive results are obtained.

In countries with longer experience of producing animal feed with zero tolerance towards *Salmonella* (e.g. Sweden) there is an increasing use of insurance companies that covers a set percentage of the production loss and hygienic measures costs that arise when *Salmonella*-positive results are diagnosed.

Table: Costs associated with good manufacturing practices; pest control and cleaning and disinfection protocols

Country	**FEED SAFETY MANAGEMENT**				**Reference**
	Pest Control	Cleaning and disinfection			
		Feed Mills	Warehouse	Trucks	
Spain	0.10 €/tonne				*Vall Companys Group* consultancy *(2010)*
Spain	Bird control 120 €/month		6,000 €/year	9 €/vehicle/trip	*Nutreco consultancy(2010)*
Sweden		0.9 SEK/tonne		< 0.5 SEK/ ton	*Enheten för foder och djurprodukter*

Table: Costs associated with good manufacturing practices

Country	**FEED SAFETY MANAGEMENT**				**Reference**
	Feed Mills Modifications		*Salmonella* Programme		
	Unclean/ clean section	Regular maintenance	GMP	Corrective actions	
Denmark			400-5,000 €		*The Danish Grain and Feed Trade Association (DAKOFO)*
Sweden	1-2 SEK/ton		3.3 SEK/ton	0.7-1.0 SEK/ton	*Enheten för foder och djurprodukter*
Spain		1 €/tonne			*Vall Companys Group* consultancy *(2010)*

4.1.4 Feed monitoring

Ongoing sampling of:

- Raw materials; particularly soy beans which constitutes an essential ingredient that has been proved to present a *Salmonella* contamination rate of about 30 % (Wierup & Häggblom, 2010).
- Compound feedingstuffs; which should be destroyed if a positive result is reported.
- Water; in order to assess its quality and ensure freedom of microbiological contamination.
- Feed mills environment; some of the hot points commonly suggested to be sampled include the intake pit for trucks, the pneumatic intake, the intake pit for bags, elevators, storage bins, scales, mixers, coolers, storage bins for finished feed, etc.

Table: Costs associated with feedstuff treatment, management and monitoring

Country	MONITORING			Reference
	Culture	Serotyping	Water Analysis	
Spain	22 €/sample	50 €/sample	20 €/sample	*Vall Companys* consultancy (2010)
Spain	58€	35 €/sample	30 €	*Nutreco* consultancy *(2010)*
Sweden	US$ 330 (ex. VAT)	US$ 645 (ex.VAT)		National Vet Institute SVA

Table: Total monitoring costs

Country	TOTAL MONITORING COSTS	Reference
Spain	0.8 - 1.5 €/ton	*Nutreco* consultancy *(2010)*
Sweden	7 SEK/tonne of feed	*Engvall et al. (1994)*

The Swedish Board of Agriculture has estimated the actual cost for the feed industry to fulfil current demands from legislation and producers as about 18-20 SEK/ton based on compound feed; equivalent to 1.8 - 2 € /ton (2010).

4.2 Purchase of *Salmonella* free replacement stock

The QMRA predicted a significant reduction in pig lymph nodes prevalence by switching breeding pig herd prevalence to zero in Member States that show higher breeding pig herd prevalence. Introduction of infection to herds through purchase of carrier breeding animals or symptomless excretors has been identified as a potential *Salmonella* risk factor (Ishiguro et al.,1979; van Schie, 1987a). Ideally stock should be sourced from a *Salmonella*-free unit and producers should be aware of the status of their supplier unit (i.e. by requesting laboratory testing of faecal samples for the incoming stock).

The Consortium summarises the main actions to ensure the providing of clean replacement as:

- Find a trustworthy supplier.
- Get *Salmonella*-free certified replacement.
- Follow quarantine procedures for new arrival livestock.

4.2.1 Trustworthy supplier

Within the breeding herds, replacement stock is commonly represented by gilts and boars. Ideally, all gilts and boars for breeding should be sourced from breeding herds (including nucleus, multiplier, and integrated herds) that implements a *Salmonella* Control plan or complies with high standards of farm-management practises that enhance control measures for *Salmonella* serovars of public health significance. Hence, finding a trustable supplier would imply to obtain your replacement from a holding that also applies the same good farming practices recommended in a fattening holding. Such as:

- Supply of clean feed.
- Purchase of incoming stock from trustable suppliers or use own replacement.
- Compliance with adequate Hygiene and Biosecurity protocols.
- Potential implementation of feeding strategies.
- Ensure a high level of pig herd health status through ongoing veterinary visits and checks.

In addition, the number of suppliers used appears to be a risk factor for *Salmonella* introduction into a clean herd. Pigs in herds recruiting from more than 3 supplier herds were more likely to test seropositive than pigs in herds breeding their own replacement stock or recruiting from a maximum of 3 supplier herds. More sources of stock increase the probability of introduction of infection through one of these contacts (Lo Fo Wong, 2004; Quessy et al., 2005) Thus, limiting the number of sources for replacement stock may help along with finding a trusted supplier when controlling *Salmonella* introduction.

Table : Costs associated with some of the practises expected from a trusted supplier

Country	**CLEAN FEED**	**REPLACEMENT**		**ON-FARM**		**Reference**
		Clean	External vs. Own	Pest Control	Addition of Feed	
UK		€0.10 (plus monitoring costs)				CBA in Slaughter Pigs (2009) *SANCO/2008/E2/036*
Sweden	1.8 - 2 € /ton					*Swedish Board of Agriculture (2010-04-15)*
Spain					3 - 9 €/tonne	*Nutreco* consultancy (2010)
Spain			100-200€ extra			*Vall Companys* consultancy *(2010)*
Netherlands				0.07€/pig		*van der Gaag (2004)*

4.2.2 *Salmonella*-free certified replacement pigs

Newly introduced pigs can act as potential sources of *Salmonella* infection. Hence, it seems important to assess whether or not there is evidence of *Salmonella* in herds delivering pigs to other herds (Lo Fo Wong, 2000). The idea of issue some kind of "*Salmonella* free certification" led us to discuss current diagnostic tools and performance. This is usually done by taking samples from animals (e.g. blood or faecal samples) or the stable environment, representing the animals present (e.g. pen faecal samples). Broadly speaking there are two major ways to diagnose *Salmonella* by following bacteriology and serology methods.

In the slaughter pigs report there is an extensive chapter focused on currently available *Salmonella* monitoring tools (SANCO/2008/E2/036, p.122). Some of the main points that summarise this chapter are presented in the following tables.

Table : Brief summary of bacteriology test features.

ADVANTAGES	**DISADVANTAGES**	**SENSITIVITY**	**SPECIFICITY**
Isolation/identification of the pathogen in faeces or mesenteric lymph nodes.	Time consuming (3-5 days)	Low sensitivity (a negative result may not be meaningful)	Almost 100% specificity (few false positives)
Allows know serotype, phage type and resistance profile to antimicrobial agents.	Expensive (even if using pool of samples)		
Still considered as the "gold standard"			

Table : Brief summary of serology test features.

ADVANTAGES	DISADVANTAGES	SENSITIVITY	SPECIFICITY
Best cost-effective ratio (about 3.5 €/ sample vs. 35€ bacteriology)	Positive results indicate that the pigs were exposed to *Salmonella* infection at some stage during their lifetime (not necessarily indicate that the animals are infected at the time)	High sensitivity (however test sensitivity is reduced with increasing cut-off)	Low specificity.
Fast (useful in large scale studies)	It cannot detect very recent infections (seroconversion is between 7-30 days post-infection)		
Ease of standardization between laboratories	May get a negative result in pigs that were infected more than 3 months (antibodies reach maximum levels within 2-3 weeks, persisting for about 5 weeks and then slowly declining)		
	Not useful to assess the prevalence at the individual level (high variability in each animal's response)		
	Prevalence values depend on the cut-point chosen. Reported cut-off values lower than 40%, would result in higher prevalence estimates.		
	Currently available tests only detect antibodies against certain serogroups.		

Some European Member States that have been implementing *Salmonella* control programmes in pig production have also included some sort of surveillance of the breeding herds that may be used as an example of different monitoring strategies.

The aim of the Swedish *Salmonella* control program is the elimination of *Salmonella* infection in the primary production with the ultimate objective of protecting public health (Vågsholm, 2007) Samples taken on:

- Breeding farms (Nucleus and multiplier herds) depending on herd size 10-55 faeces samples annually (95% confidence at 5% prevalence; collecting at least 10g faeces per animal, pooling from five.
- All sows are sampled twice a year in herds with 50 sows or less (faecal pool). In larger herds a sufficient number to detect a prevalence of 5% *Salmonella* with 95% confidence are sampled twice a year.
- In case of new pigs from farms outside of the program: 2 times at a week interval.

The Danish *Salmonella* Surveillance and Control Programme for pigs also involves the sampling of breeding and multiplying herds. Pigs from breeding and multiplying herds are tested monthly by serologic testing of blood samples. If a specific cut off level is reached, bacteriologic confirmatory testing is carried out. Furthermore, if the serologic reactions exceed a specific high level, all movement of animals is restricted.

- Each month, all herds are tested for *Salmonella* antibodies in serum samples and based on the results a *Salmonella* index is calculated. If the index exceeds 5, faeces from pens are collected and cultured for *Salmonella*. If the index exceeds 15 a sales ban is imposed on breeding pigs, which is not lifted until the index is below 15.

- If a sow herd sells weaners to a *Salmonella* level 2 or 3 finishing herd, pen samples must be examined for *Salmonella*.

In Ireland the National Pig *Salmonella* Control Programme is focused on the entire food chain and therefore will comprise the breeding herds by:

- Establishing a sero-prevalence of 10% or less based on serology:
    - For integrated herds under the same identifier, the sero-prevalence can be based on results from fatteners tested at slaughter.
    - For nucleus herds, not sending fatteners to slaughter, the sero-prevalence can be established by testing of sera collected from 24 pigs on three occasions at 4 monthly intervals per annum.
    - In both cases, the herd sero-prevalence will be established by calculating a weighted average of the three most recent test results available.
- In addition, all breeding herds (nucleus, multiplier, and integrated) must carry out on-farm bacteriological sampling annually (as undertaken for the EU baseline study in breeding pigs) to establish the *Salmonella* serovars present on-farm.

(From the National Pig *Salmonella* Control Programme in Ireland)

There are various factors that can have a big effect on the diagnostic results:

- Test characteristics (specifity and sensitivity)
- Test costs (depend on the type of test, the frequency of testing and the percentage of animals tested)
- Appropriate sample size.
- Frequency of sampling (i.e. if using a bacteriological method shedding of bacteria is a critical factor to be taken into account)

Most of the pig suppliers approached by this Consortium did not rely on any of the diagnostic tools available at present to certified 100% that their replacements are free from *Salmonella*.

Previous attempts of producing Specific Pathogen Free (SPF) herds can be found at experimental level (e.g. Denmark and the Netherlands). Conventional herds had a higher risk of *Salmonella* than SPF herds (Dahl, 1997; Kranker et al. (2001). Nevertheless, Lo Fo Wong et al. (2004) did not find any associations between health declaration and *Salmonella* seroprevalence in more than 350 finishing-pig herds.

To conclude, at the moment there are no available tools to certify without some level of uncertainty *Salmonella* freedom status of a pig herd. Nevertheless, there is an added benefit for monitoring the breeding herds as part of the *Salmonella* surveillance programme since it provides some guidance when purchasing replacements by classifying these holdings. Although it cannot be guaranteed whether an incoming pig comes from *Salmonella*-free sources, it should be ensured that replacement breeding stock is obtained from reputable breeding sources with a *Salmonella* monitoring system in place or an equivalent programme that delivers the same results. This can be achieved by demanding some proof of information on the health status of the herd, the herd’s routine vaccination and other treatments and disease prevention measures applied by the suppliers. For instance by sourcing their breeding stock from farm assured units, which are identified and recorded.

4.2.3 Follow quarantine procedures for new arrival livestock

Newly purchased stock, from different sources and health background, are frequently highly sensitive to stress and more susceptible to infections when arriving at the pig holding. The isolation of the new purchased animals before introducing them into herd is often ignored (Stanković et al., 2010). The presence of separate quarantine facilities for the incoming pigs is a must that prevents potential introduction of the bacteria from the newly arrived breeding stock. Carrier animals are more likely to excrete *Salmonella* when they are stressed (e.g. after transport or mixing). Replacement stock should therefore be held and assessed in isolation pens for 4-5 weeks after purchase with no cross contact between quarantine animals and the main unit. Disinfectant footbaths and different clothing should be used before entering and after leaving isolation pens. Furthermore, it is recommended that, where possible, quarantined animals should be looked after by non-farm personnel. In addition, veterinary advice should be sought to provide additional information on the health of the stock purchased or to provide veterinary treatment when needed (MAFF, 2000; FSA, 2007).

Table : Cost associated with the use of a quarantine facility.

Country	Quarantine pen cost	Reference
USA	0.20€/pig	Neumann and Kniffen, (1999)

4.3 On-farm interventions

The efforts to control *Salmonella* infection in pigs through on-farm strategies may involve a combination of minimising or preventing exposure to *Salmonella* from external sources (Hygiene and Biosecurity measures) and maximising pig resistance (Feed strategies)

4.3.1 On-Farm health status, hygiene and biosecurity

At herd level, similar interventions to the ones already described in the Slaughter pigs' report (SANCO/2008/E2/036) can be implemented to ensure an adequate standard of hygiene and to minimise the introduction of *Salmonella*. The implementation of these measures should also deliver a potential indirect benefit to the farmer by controlling other pathogens in the farm and ultimately improving productivity (Lo Fo Wong et al., 2006)

4.3.2 Health status interventions

- Regular veterinary checks

Preservation of the required level of swine herd health status is one of the most important aspects of farm production and animal welfare (Stanković et al. 2010). It is broadly accepted that there is an association between good health herd status and lower *Salmonella* prevalence (van der Wolf et al., 1999). It seems plausible that implementing good managing practices, such as keeping a high level of swine herd health status through regularly veterinary visits to the holding, will have a collateral benefit by reducing the burden of *Salmonella*. It is also strongly recommended to consult the pig farm veterinarian in order to get advice when designing a control plan based on the particular circumstances of each particular farm.

- Vaccination

Vaccination constitutes a promising approach to reduce colonization and shedding. However, it has not been widely used as it interferes with current monitoring programs relying on serology as a means for herd classification. Nowadays, there is some research evidence of the successful developing of a negative marker vaccine which allows the differentiation of infected from vaccinated animals for some *Salmonella* strains; i.e. DIVA concept (Selke et al., 2007). In contrast, a trial study on a farrow-to-finish swine production unit in Canada found that vaccinating pigs against *Salmonella* did not produce the desired effects. Pigs vaccinated with *S. typhimurium* bacterin had no effect on *Salmonella* reduction and pigs vaccinated with an oral live *S. choleraesuis* vaccine failed to produce cross-protection immunity against *S. typhimurium* and other *Salmonella* strains (Wayne Du et al., 2010). Some experts claim that most studies on immunity have been badly designed and data used is of questionable value (Denagamage et al., 2007) It seems that little is known about whether vaccines (live or inactivated) really work, how the host responds to infection and vaccination and whether we know anything about how best to vaccinate (Barrow, 2010).

Table 1: Costs of farm-level health status measures (€/pig).

Country	**Health Status**		**Reference**
	Vet Regular checks	Inactivated Vaccine	
USA	0.70/pig	0.70	Miller (2005)
Spain		0.20	Veterinary College Leon (2010)
Spain	102.31/sow/year		Sabata (2004)

4.3.3 Improve farm hygiene through cleaning and disinfection practices

Poor hygiene has been shown as a determinant risk factor for maintaining *Salmonella* endemic cycles on pig farms (Berends et al., 1996; Barber et al., 1999). A constantly high standard of cleaning and disinfection is one of the most important ways to break the on-farm cycle of reinfection with *Salmonella* ("on-farm perpetuation") at the pig holding (Blaha, 2010). Furthermore, it may coincidentally also reduce the prevalence of other diseases in pigs such as Aujeszkys disease (Lo Fo Wong et al., 2000) Some authors have found evidence which shows that *Salmonella*-free pigs usually remain clean when being kept in a non-contaminated environment (Heard et al., 1966; Fedorka-Cray et al., 1994). Mannion et al. (2002) carried out a national level study finding that residual contamination remained on the surfaces of the feeders and drinkers on all the farms monitored. Better hygiene practices on pig farms should involve; ensure the frequent removal of manure, perform cleaning between batches, guarantee disinfection after cleaning, use an adequate type of disinfectant and recommended dose, empty pens after cleaning and the presence of hygienic-lock facilities.

However, less literature is available to demonstrate significant benefits from keeping high hygiene standards on a continuous production site such as a breeding herd. (Stege et al., 2001) compared to batch production of pigs according to the all-in/all-out principle (Lo Fo Wong et al., 2004))

Table 2: Costs of improving cleaning and disinfection practices at farm

Country	**Extra daily cleaning and disinfecting C&D**	**Reference**
Netherlands	0.08€/pig	van der Gaag (2004)
UK	Cleaning: 1,07-1,3p/m2 (product). Disinfection: 0,79p-1,7p/m2	Gadd (2001)

4.3.4 Bio-security measures

Biosecurity barriers and procedures should be part of the good manufacturing practice at farm. An effective vermin control procedure must be maintained at all times to prevent the introduction of *Salmonella* from the environment. Records of baits used to be kept along with safety data sheets. Adequate facilities must be provided for visitors and farm staff, including provision of clean, protective clothing, footwear dipping and hand washing or provision of other precautions to prevent the spread of disease. A record of all visitors to the unit needs to be kept. The development of efficient on-farm strategies to control *Salmonella* should be based on the knowledge of the specific epidemiology present in those production units. Since the dissemination of *Salmonella* between and within farms is related to multiple factors, these differences must be taken into account with regards to the feasibility and the cost/efficacy of any given measure in a particular situation (Creus, 2007). Since all pig farms have their own weak points with respect to the introduction and spread of bacteria a tailored plan should be implemented. Each farm requires its own measures of disease prevention and control and bio-security protocols (Stanković et al., 2010). This approach has been embraced by some countries in the form of issuing a code of "Good Farming Practices" for pig producers with an attached checklist (e.g. FSA, 2007).

Table: Example of the breeding check points listed in the FSA guide for pig producers

Always provide a foot dip containing a disinfectant at the correct strength at entrances to the farrowing house.	Remove visible muck with a boot brush before dipping boots in the disinfectant foot dip.
Thoroughly clean under slats where possible.	Keep sows off wet or dirty crates.
Use powder disinfectants in crates.	Use clean overalls daily.
Pay particular attention to fly control.	Wash hands regularly with soap and water.

Source: Serious about *Salmonella* A guide for pig producers (2007). Published by the Food Standards Agency.

Similar type of check points are commonly presented in the compulsory implementation of a HACCP (Hazard Analysis of Critical Control Points) system in slaughterhouses and meat plants. For the primary stages an approach like HACCP with determined limits is probably most cost-effective and expected to reach a higher level of food safety (van der Gaag, 2004). The HACCP concept is well suited for quality control at farm level, involving risk identification and risk management. The on-farm monitoring and surveillance system of critical control points in the animal production process is the most important tool in this procedure. Principles for HACCP application as well as certification fitness of HACCP are elaborated upon (Noordhuizen, 1999).

Table: Costs of bio-security measures at farm

Country	**BIOSECURITY MEASURES**			**Reference**
	Special clothing per compartment	Closed fences between pens	Rodent Control	
Netherlands	0.40€/pig	0.01€/pig	0.07€/pig	van der Gaag (2004)
Spain			0.8€/unit/year	Vall Companys consultancy (2010)

4.3.5 On-farm feed strategies

At farm level, some feeding strategies have been shown effective to prevent colonisation of the gastro-intestinal tract of the pigs by *Salmonella* (van der Wolf et al., 2001; Jorgensen et al., 2001; Creus et al., 2007). Most of these strategies aim to enhance the natural resistance of the pigs by granting a hostile environment to *Salmonella* colonisation. Some scientific studies have proven to show feeding interventions that deliver a positive effect against *Salmonella*, such as:

- Using meal instead of pelleted feed
- Using coarse feed instead of fine-ground feed
- Using liquid feed instead of dry feed

The acidification of feed or water has also tended to demonstrate positive outcomes. More inconsistent findings were reported with the addition of probiotics and competitive exclusion products.

Special attention should be focus on carrying out proper water sanitation. There are several studies that isolated *Salmonella* in water from the pig water bowls or mud holes (Jensen et al. (2004) Water bowls or drinking troughs might pose a higher risk for contaminatoin by faeces and thereby be a risk factor for *Salmonella* (Zheng et al., 2007). Anderson et al. (2004) found that pigs drinking water with experimental chlorate preparations effectively reduced caecal *Salmonella* concentrations.

Table: Costs associated with on farm feeding strategies

Country	**Feed strategies**			**Water**	**Reference**
	Meal vs. Pellets	Wet vs. Dry	Acids	Chlorinated water	
Spain			3 - 9 €/tonne		*Nutreco* consultancy (2010)
Netherlands		1.48€ (wet feed)	1.78-1.73 €/pig		van der Gaag (2004)
UK				5,43p/pig in a herd of 100 pigs	Gadd (2001)
USA	US $3 – 7/ton (extra cost of using pellets)				(Harper, 1998)

4.4 Previous Experiences

4.4.1 Belgium

Since 2005, the Belgian Federal Agency for the Safety of the Food Chain (FASFC) installed a National *Salmonella* surveillance and control program in pigs (SAP) which became compulsory by means of a Royal act in July 2007. The *Salmonella* infection status of the fattening herds is determined by on-farm serological testing of pigs by indirect ELISA on blood samples which are collected by the herd veterinarians within the frame of the monitoring programme for Aujeszky's disease. Once the herds are identified as risk herds they will subsequently be invited to participate in a *Salmonella* support and control programme to reduce the risk for *Salmonella* infections (van der Stede et al., 2009).

4.4.2 Denmark

In Denmark, the Danish *Salmonella* Surveillance and Control Programme for pigs operates at all stages of the production chain and has been applied nationally since 1995. An ELISA technique based on meat juice samples taken at slaughter which can detect 90-95% of the *Salmonella* serogroups in pigs is used for monitoring and in any one year 800,000 are analyzed and results are available monthly.

Based on the results of the previous 3 months the herds are classified into 3 categories:

Level 1. Herd with no or very low *Salmonella* prevalence (95% of herds).

Level 2. Herds with a higher *Salmonella* prevalence (3.1% of herds).

Level 3. A higher proportion of reactors (1.3% of herds).

Furthermore, the Danish Meat Association slaughterhouses employ a financial penalty-system to encourage implementation of *Salmonella*-controlling measures in level-2 and level-3 herds (Nielsen et al., 2001). The surveillance Danish programme covers almost the whole pork chain (feedstuffs, breeding and multiplying herds, fattening herds, abattoirs, cutting plants). Since its start in 1993 the number of human salmonellosis cases caused by pork has declined from 1,100 in 1993 to around 100-200 since 2002. Caution needs to be taken interpreting these data as there were also *Salmonella* control campaigns for poultry during the same period. Based on data published by Wegener et al. (2003) a recent BPEX publication estimated that the control costs of a comprehensive integrated farm-to-abattoir control program in Denmark amount to approximately $0.075 (U.S)./kg of pork (Friendship et al., 2009) or between €4.22 to 5.64[18] per pig depending on the finish weight. The Danish programme could be used as an example to follow of how implementing a well-functioning and comprehensive control programme among the pre-harvest pork chain step. However, several Danish studies support the fact that surveillance of *Salmonella* in the primary production alone does not secure food safety, but can act as a valuable support. To ensure food safety, slaughter hygiene is of equal importance and more cost-effective (Jensen et al., 2000; Alban et al., 2006; Goldbach et al., 2006)

4.4.3 USA

In the United States an assessment was made on the impact of *Salmonella* across the pig sector in terms of human health costs and risks from consuming pork. This work found that abattoir level measures are less costly ($0.20/carcass) than those implemented at the farm level, for example vaccination at $0.85/pig. For this reason the Americans have adopted an approach of interventions post-harvest.

4.4.4 Netherlands

The costs of an integrated farm-to-abattoir control program in the Netherlands to reduce the prevalence of *Salmonella* below 2% were estimated to be at least €4.5 /pig (van der Gaag, 2004).

4.4.5 Sweden

Sweden is a country on which strict requirements and comprehensive monitoring on animal feed stuffs and feed products have been applied since 1961. The positive effect on public health of keeping down the number of pig herds infected have been quantified as there is a very low level of human salmonellosis cases from Swedish pigs. In fact, it has been estimated that at least 75% of all notified episodes of salmonellosis in Sweden come from people travelling overseas (de Jonges et al., 2006). Sweden has a long history of controlling *Salmonella* in feedingstuffs, as well as the entire food chain from “farm to fork”. Any finding of *Salmonella*, irrespective of serotype, in animals, humans, feed and food of animal origin is notifiable independent of the reason for sampling. If cattle or pigs are found infected, restrictions are put on the farm and are not lifted until the infection has been eliminated, as shown by consecutive sampling of faeces. All primary isolates are sero and phage typed, and primary isolates of animal origin are tested for antibiotic resistance. This has given the result that virtually all domestic red and white meat and table eggs are free from *Salmonella* prevalence is below 0.1%. Engvall et al., found that the costs for control was much lower than the cost related with human salmonellosis cases based on data back in 1992.

4.4.6 Finland

Finland joined the European Union in 1995, the prevalence of *Salmonella* infections in poultry, beef and pork production was low. When joining the EU, Finland was granted a permission to run its own food safety policy concerning *Salmonella*. The policy, called Finnish *Salmonella* Control Program (FSCP), aims to maintain the national annual prevalence of *Salmonella* in

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[18] Assuming finished carcass weight of between 75 to 100 kilos and an exchange of €1 = US$1.33

meat and egg production below 1% and the prevalence of *Salmonella* positive samples at individual abattoirs or cutting plants below 5% (beef, pork and poultry meat) (Maijala et al., 2005). Maijala et al. (1998 and 2006) found that health benefits produced by FSCP are larger than the expenditure. Maijala (1998) and Maijala et.al (1998) found the direct cost of the program to be about €0.5 per household annually. This author has used the consumers' willingness-to-pay as one of the factors to be taken into account when assessing a control programme economically. Finnish citizens concluded that they will be ready to spend an additional €3.30-8.30 (on average roughly €5.80) per month to finance the current level *Salmonella* control in Finland if it was otherwise to be ceased. Annually, this would be about €70, which is similar to the one obtained in previous surveys (Maijala & Peltola, 2000)..

4.4.7 Norway

Even though the Norwegian *Salmonella* surveillance programme in live pig and pork did not have any significant consumer protection effect (Sandberg et al., 2002), Norway have managed to keep their livestock free from the burden of salmonellosis with a given prevalence of 0.3% (The EFSA Journal (2008) 135, 1-111)

4.4.8 United Kingdom

In June 2002 the British Pig Executive (BPEX), in partnership with the FSA and Defra, launched the Zoonoses Action Plan (ZAP) *Salmonella* Monitoring Program which aims to monitor trends in the levels of *Salmonella* on pig farms so that action can be taken to reduce the prevalence in pigs at slaughter. Since then £4 million has been spent with little change in the prevalence of *Salmonella* in pigs (The Pig Veterinary Society, Communication Press 2008). An increase in prevalence of meat-juice ELISA positives in England (2.7%), Northern Ireland (3.2%) and Scotland (3.5%) was reflected in increases in within-herd prevalence..

4.4.9 Summary

A number of European countries have implemented programmes for the control of *Salmonella* in pigs. Some have been successful in either maintaining a low base or reducing further the prevalence from what was already a minor problem. The conclusion from this brief review is that there are no generic measures that can be applied in all contexts. The following section will briefly describe what interventions have been included and how the costs have been estimated.

4.5 Costs of the scenarios

QMRA (2010) identified a number of potential sources of infection for fattening and breeding pigs pre-harvest which can be broken down into: feed, on-farm circulation of *Salmonella* and potential infection during transport and lairage. The slaughter pig study used these along with expert opinion to examine different scenarios to reduce the risk of foodborne illnesses. The following scenarios were assessed:

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 prevalences above the EU average.

            i. Clean replacement pigs
    b. Low prevalence – countries with slaughter pig prevalences below the EU average
            i. Feed control measures

4. Scenario 3 plus all transport and slaughterhouse measures.

Full details of the analysis can be found in the slaughter pig report. For the analysis of the breeding pigs only scenario 3 and 4 will be reworked as these involve breeding pig interventions and the costs of these interventions will be modified accordingly. Reasons for this selection are presented in the following sections.

4.5.1 Critical data for the analysis

The structure of the pig sector was detailed in Chapter 2 with a description of the pyramid shape of the population. However, this population structure is much flatter than a pyramid with only between 6 to 13 percent of the standing population in the breeding herd and cull stock being between 0.2 to 4% of the total pigs slaughtered per year (see Table below).

Table: Pig population in Europe and the number of pigs slaughtered (Eurostat 2008 pig sow slaughter data based on replacement rates).

Country	Pig population ('000 head)			Slaughtered pigs ('000 head)		
	Total	Sows		Total	Sows	
		Number	%		Number	%
Austria	3,064	291	9.5	5,553	55	1.0
Belgium	6,208	543	8.7	11,157	135	1.2
Bulgaria	784	77	9.8	993	15	1.5
Cyprus	465	48	10.3	725	10	1.4
Czech Republic	2,135	212	9.9	3,804	63	1.6
Denmark	12,195	1,289	10.6	20,790	440	2.1
Estonia	364	34	9.3	496	6	1.2
Finland	1,400	167	11.9	2,459	48	2.0
France	14,796	1,201	8.1	25,735	271	1.1
Germany	26,719	2,296	8.6	54,848	519	0.9
Greece	1,061	142	13.4	1,913	37	1.9
Hungary	3,383	314	9.3	4,994	84	1.7
Ireland	1,605	155	9.7	2,578	37	1.4
Italy	9,252	756	8.2	13,616	165	1.2
Latvia	384	48	12.5	486	20	4.0
Lithuania	897	78	8.7	937	19	2.0
Luxembourg	78	7	9.0	150	2	1.4
Malta	66	7	10.6	1,012	2	0.2
Netherlands	11,735	1,025	8.7	14,505	236	1.6
Poland	14,242	1,279	9.0	22,321	184	0.8
Portugal	2,340	303	12.9	5,976	73	1.2
Romania	6,174	376	6.1	5,660	141	2.5
Slovak Republic	749	64	8.5	1,084	19	1.8
Slovenia	432	42	9.7	381	10	2.7
Spain	26,290	2,542	9.7	41,306	440	1.1
Sweden	1,703	168	9.9	3,034	62	2.0
United Kingdom	4,550	487	10.7	9,427	115	1.2
EU	153,067	13,952	9.1	255,940	3,223	1.3
Minimum			6.1			0.2
Maximum			13.4			4.0

These figures indicate the importance of the fattening pig component in terms of feed and infrastructure. Therefore, whilst the sows are a critical component of the overall system their use of fixed resources and feed is far less than the fattening pigs. For this reason it was decided not to rework the evaluation, monitoring or feed cost analysis used in the slaughter pig work as it was felt that this adequately captured the investments required to upgrade these components of the pig sector to have a workable *Salmonella* control programme. This assessment also recognises some of the criticisms made of the slaughter pig report that stated the management systems should already be in place and therefore did not merit additional costs.

The following table presents analysis to estimate the number of pigs moving in and out of the different development stages in a pig life cycle. These are numbers per year and are compared against Eurostat estimates for piglets which presumably is a standing population estimate.

Table: Estimates of the numbers of piglets, rearers and finishers in any year with a comparison of the Eurostat standing population for piglets.

Country	Pig born	Piglets			Rearers		Finishers	
		Mortality	Final population	Eurostat	Mortality	Final population	Mortality	Final population
Austria	7,331	872	6,458	743	226	6,232	237	5,995
Belgium	14,478	1,955	12,523	1,609	413	12,110	436	11,674
Bulgaria	1,861	242	1,619	147	49	1,570	55	1,516
Cyprus	1,169	152	1,017	160	31	986	35	952
Czech Republic	5,130	667	4,463	561	134	4,330	152	4,178
Denmark	40,604	5,603	35,000	4,071	945	34,055	1,192	32,863
Estonia	823	107	716	117	21	694	24	670
Finland	4,044	526	3,518	383	106	3,413	119	3,293
France	35,324	4,839	30,484	3,542	640	29,844	1,104	28,740
Germany	62,306	9,284	53,022	6,551	1,591	51,432	1,749	49,683
Greece	3,436	447	2,990	299	90	2,900	101	2,798
Hungary	6,287	679	5,608	743	205	5,403	197	5,206
Ireland	4,245	420	3,825	426	111	3,714	104	3,610
Italy	18,420	1,879	16,542	1,691	612	15,930	112	15,818
Latvia	1,152	150	1,002	81	30	972	34	938
Lithuania	1,890	246	1,644	239	49	1,595	56	1,539
Luxembourg	177	23	154	10	5	149	5	144
Malta	177	23	154	18	5	149	5	144
Netherlands	31,447	4,057	27,390	4,555	520	26,870	672	26,198
Poland	27,120	2,658	24,462	3,778	514	23,948	671	23,278
Portugal	7,337	954	6,384	705	192	6,192	217	5,975
Romania	9,109	1,184	7,925	816	238	7,687	269	7,418
Slovak Republic	1,537	200	1,337	190	40	1,297	45	1,251
Slovenia	1,014	132	882	122	26	856	30	826
Spain	68,102	7,764	60,339	7,149	2,293	58,046	3,541	54,505
Sweden	4,657	764	3,893	500	97	3,796	95	3,701
United Kingdom	12,305	1,550	10,755	1,126	258	10,497	346	10,150
EU	371,481	0	324,107	40,330	9,439	314,667	0	303,065

These data are critical as they are the scale factors in the cost analysis. The estimates of cost are based on per-piglet-produced from the breeding units multiplied by the number of piglets.

4.5.2 Scenario 3 with reworked figures on the breeding pigs

4.5.2.1 A reasonable cost to produce a piglet free of *Salmonella*

It was stated above that the conclusion from the interventions available for the control of *Salmonella* in breeding pigs and their application in a number of countries is that there is no generic set of measures and there is significant divergence on costs. Some have also argued since the publication of the slaughter pig report that many measures have multiple disease impacts therefore the costs of any one intervention should be split across diseases. Finally others have said that their countries are already implementing measures and therefore no additional costs need to be included, the following section will return to this point.

Given the lack of certainty described, the analysis assumes that to produce a *Salmonella* free piglet would require on average €0.10 per animal. The cost would cover the changes in management and infrastructure. This is recognised as an arbitrary figure, but the data available does not justify any complicated analysis to reach an alternative. The model is structured so that the analysis can be rerun with different estimates and can be made available for people who are concerned of the impact of this figure.

4.5.2.2 Which countries would have additional costs for breeding pigs

Not all countries were included in the estimate for additional costs as many countries have control measures in place, and in some cases even without a formal programme the prevalences reported in the breeding farms were low. The selection of countries included in the analysis is shown in the following table:

Country	Piglets	Prevalence	Additional cost for clean piglet (€/head)	Reason for not including*
Austria	6,458	6.3%	0	LP
Belgium	12,523	18.8%	0.1	
Bulgaria	1,619	2.1%	0.1	
Cyprus	1,017	50.0%	0.1	
Czech Republic	4,463	10.4%	0	LP
Denmark	35,000	41.1%	0	CP
Estonia	716	0.0%	0	LP
Finland	3,518	0.0%	0	LP
France	30,484	50.3%	0.1	
Germany	53,022	28.3%	0.1	
Greece	2,990	28.7%	0.1	
Hungary	5,608	30.0%	0	CP
Ireland	3,825	52.5%	0.1	
Italy	16,542	51.2%	0.1	
Latvia	1,002	20.0%	0	CP
Lithuania	1,644	0.0%	0	LP
Luxembourg	154	33.3%	0.1	
Malta	154	28.7%	0.1	
Netherlands	27,390	57.8%	0	CP
Poland	24,462	6.9%	0	LP
Portugal	6,384	45.5%	0.1	
Romania	7,925		0.1	
Slovak Republic	1,337	11.5%	0	LP
Slovenia	882	0.0%	0	LP
Spain	60,339	64.0%	0.1	
Sweden	3,893	1.8%	0	LP and CP
United Kingdom	10,755	52.2%	0.1	
EU	324,107	28.7%		

* LP = Low Prevalence; CP = Control Programme

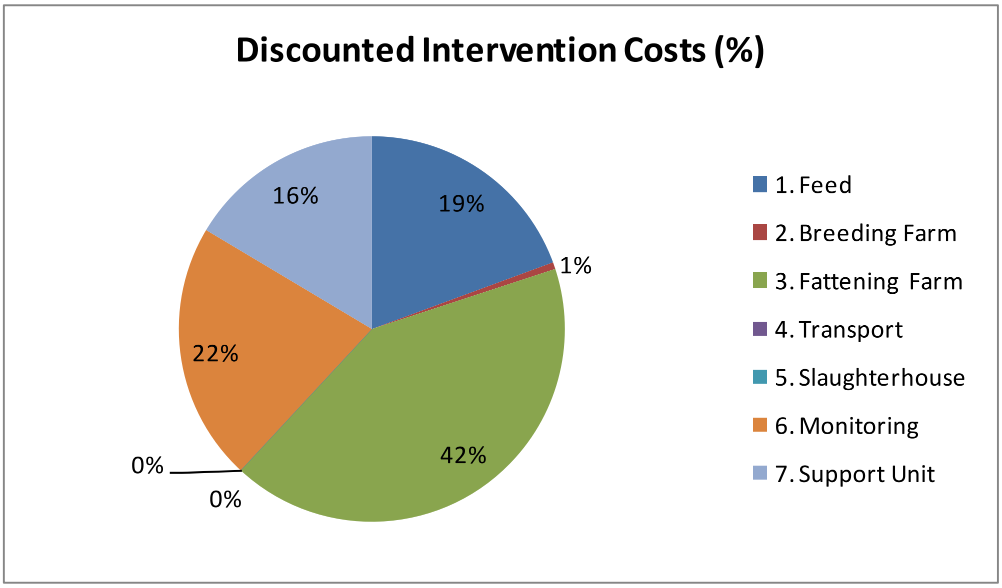
4.5.2.3 The scale factor – which population of pigs to use

The original analysis used the Eurostat data on the number of piglets, which is a standing population that does not take into account that a pig is a piglet for only 21 days and then becomes a weaner (see Table above). The proportion of the costs from the breeding pigs was therefore relatively small as can be seen in the following Table and Figure.

Table: Costs for the different interventions for scenario 3 from the slaughter pig analysis.

Intervention	Costs (million €)	
	Undiscounted	Discounted
1. Feed	189	146
2. Breeding Farm	6	4
3. Fattening Farm	408	316
4. Transport	0	0
5. Slaughterhouse	0	0
6. Monitoring	220	163
7. Support Unit	152	124
Total	**974**	**752**

Figure: Proportion of the costs by intervention for scenario 3 from the slaughter pig analysis.

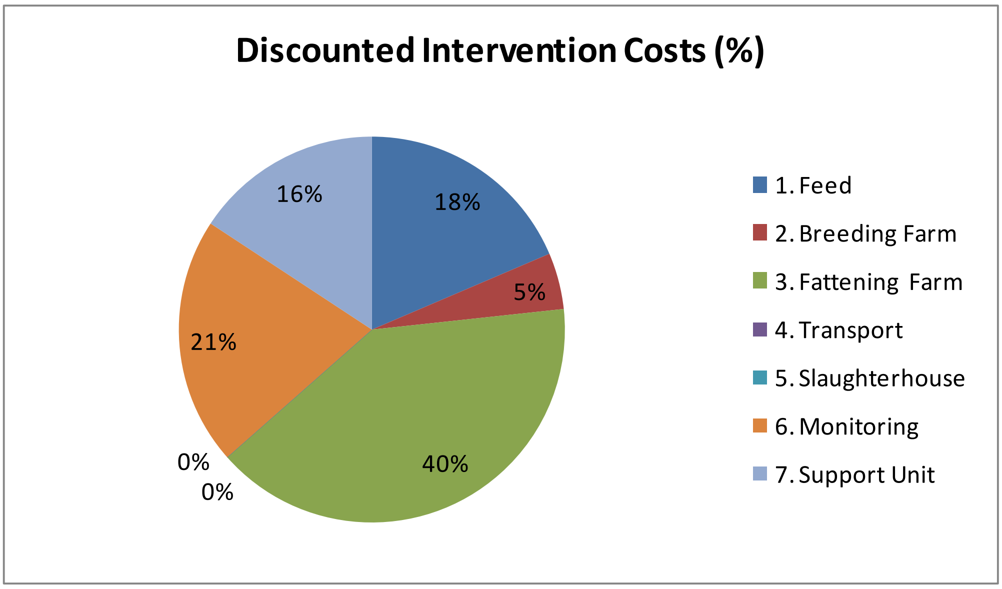


As can be seen only around 1% of the costs were estimated to be related to on-farm measures for the breeding pigs. With the new estimates calculated based on production parameters of fertility and mortality the costs increase substantially (see Table and Figure below).

Table: Costs for the different interventions for scenario 3 with revised piglet population estimates.

Intervention	Costs (million €)	
	Undiscounted	Discounted
1. Feed	189	146
2. Breeding Farm	48	37
3. Fattening Farm	408	316
4. Transport	0	0
5. Slaughterhouse	0	0
6. Monitoring	220	163
7. Support Unit	152	124
Total	**1,017**	**785**

Figure: Proportion of the costs by intervention for scenario 3 with revised piglet population estimates.



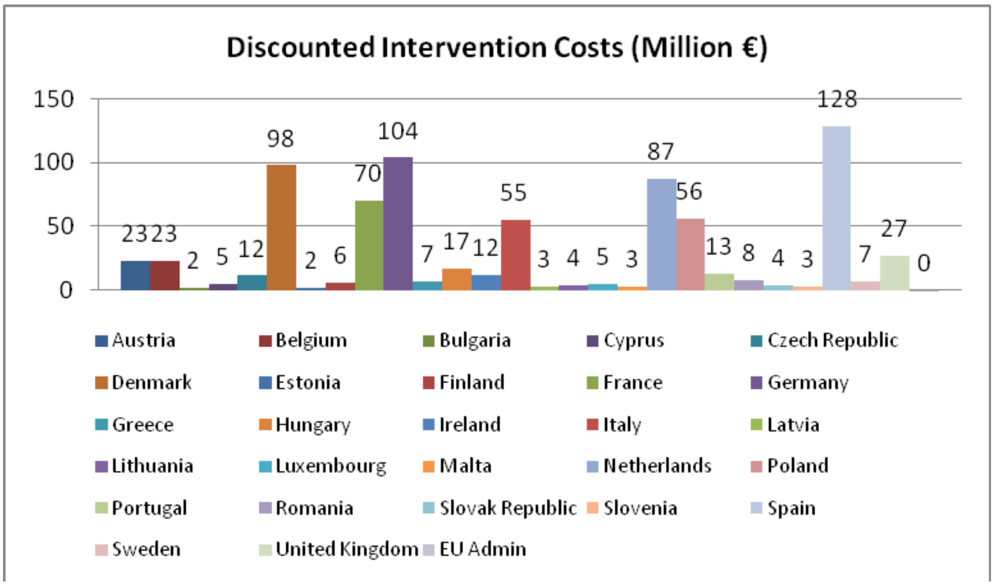
The model also calculates that clean pigs in all countries are being produced, i.e. the breeding farms that are negative to *Salmonella* tests produce clean piglets. No cost has been added to these pigs as it is assumed these farms already have in place management practices that produce clean piglets. The additional clean piglets are therefore ones that would have come from a *Salmonella*-infected farm and from the interventions the farms become clean and produce clean piglets. The model has been set to assume that the increase in the number of piglets that were dirty and are now clean is 10% per year for the ten year analysis period, i.e. costs are spread across the years.

4.5.2.4 Results of the analysis

The model estimates that a total of € 785 million of discounted costs will be incurred with the reworked Scenario 3, and of those costs 5% are incurred at the breeding farm level (see following Figures).

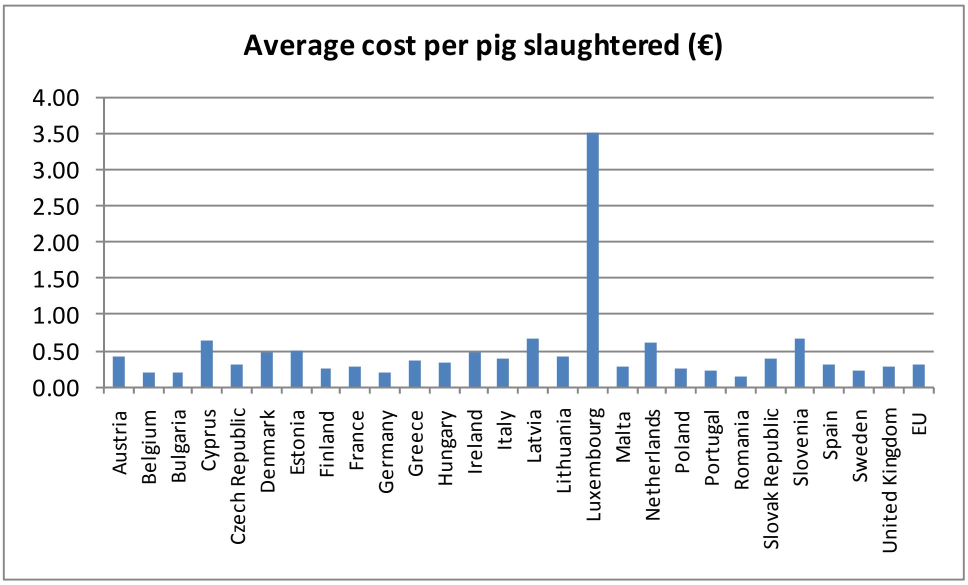
A major proportion of the costs are borne by the countries with the largest pig populations and levels of production: Germany, Spain, Denmark and France (see Figure below).

Figure: Intervention costs by Member State for reworked scenario 3



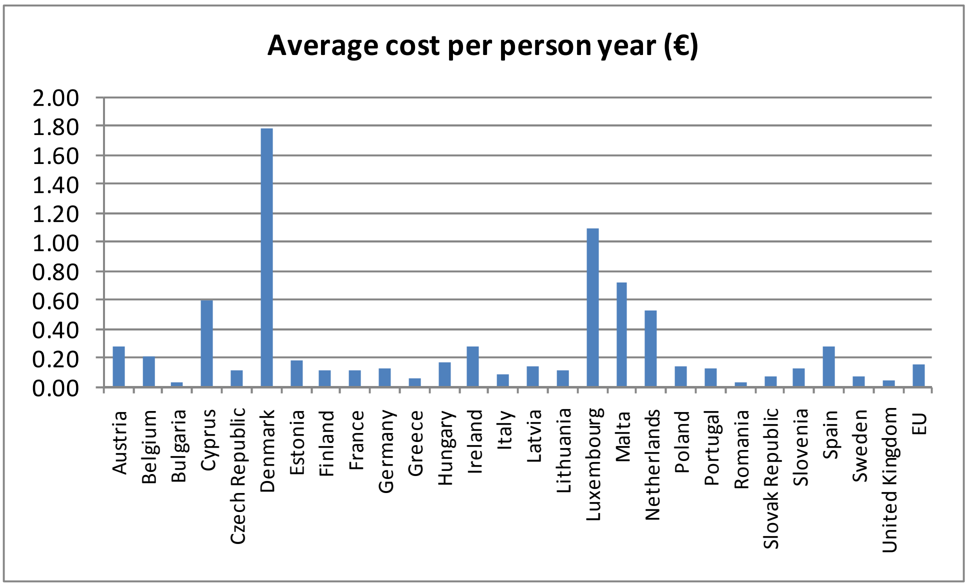
The average cost per pig slaughtered for scenario 3 is € 0.31 with a high of € 3.51 in Luxembourg and a low of €0.14 in Romania (see below).

Figure: Intervention costs per pig slaughtered for the reworked scenario 3



The average cost per person year for scenario 3 is € 0.16 with the lowest being for Bulgaria at € 0.03 and the highest in Denmark at € 1.79 (see below).

Figure: Intervention costs per person year for the reworked scenario 3



Scenario 3 cost estimates will be combined with estimates of the benefits of *Salmonella* control interventions in the following Chapter.

4.5.3 Scenario 4 with reworked figures on the breeding pigs

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 € 1,491 million of discounted costs will be incurred with Scenario 4, and of those costs almost 40% are due to transport (see Table below).

Table: Estimated undiscounted and discounted costs for scenario 4.

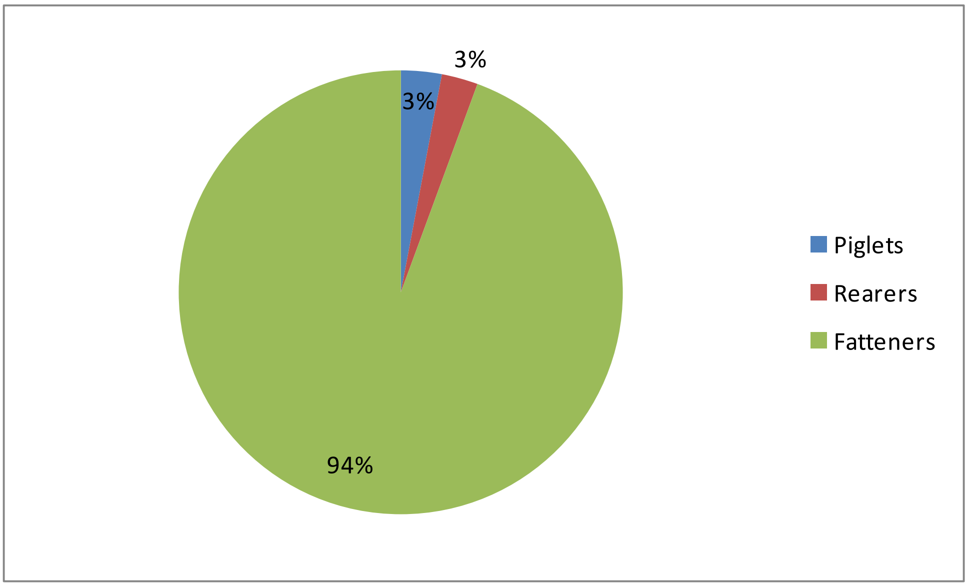
Intervention	Costs (million €)	
	Undiscounted	Discounted
Feed	189	146 (9.78%)
Breeding Farm	48	37 (2.49%)
Fattening Farm	408	316 (21.16%)
Transport	750	579 (38.83%)
Slaughterhouse	164	127 (8.51%)
Monitoring	220	163 (10.94%)
Support Unit	152	124 (8.29%)
Total	**1,930**	**1,491 (100.00%)**

The breakdown of the transport costs is shown in the following Table and Figure.

Table: Transport costs for the different types of pig.

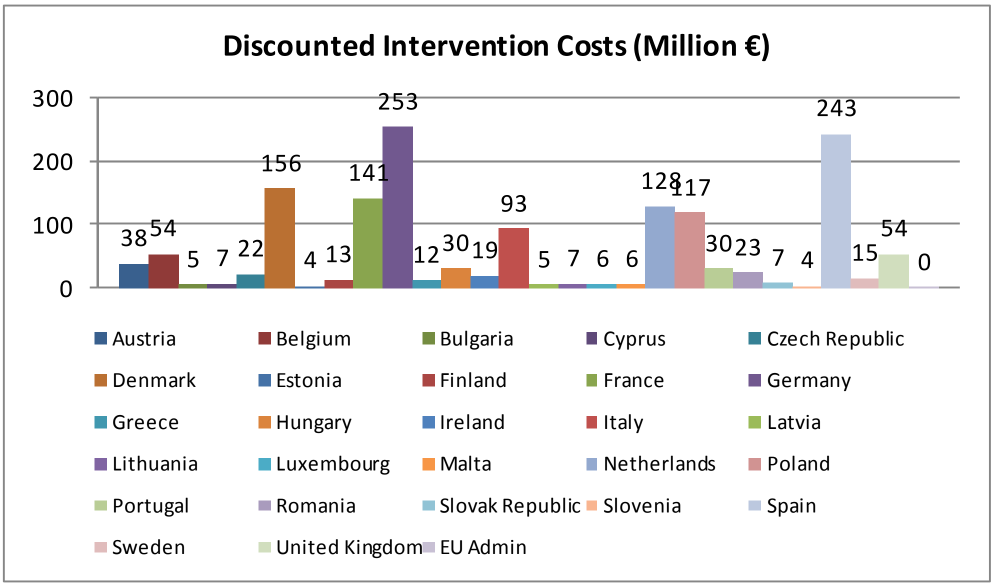
	Estimated additional transport costs (€)	
Pig type	Undiscounted	Discounted
Piglets	22,245,522	17,184,222
Rearers	19,791,284	15,288,372
Fatteners	707,483,949	546,517,239
Total	749,520,756	578,989,833

Figure: Proportion of estimated additional transport costs by pig type



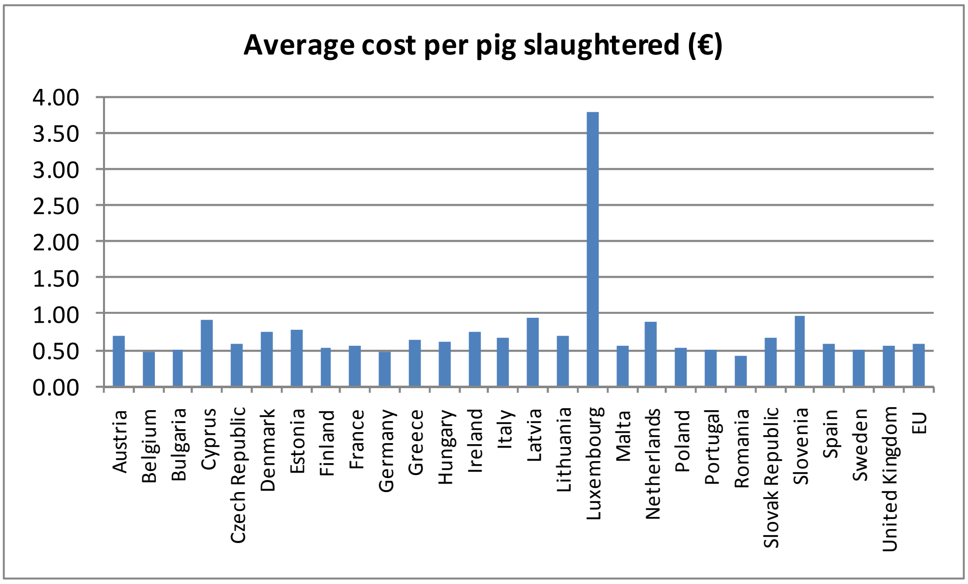
The major proportion of the costs is borne by the countries with the largest pig populations and levels of production, so Germany, Spain, Denmark and France (see Figure below).

Figure: Intervention costs by Member State for scenario 4



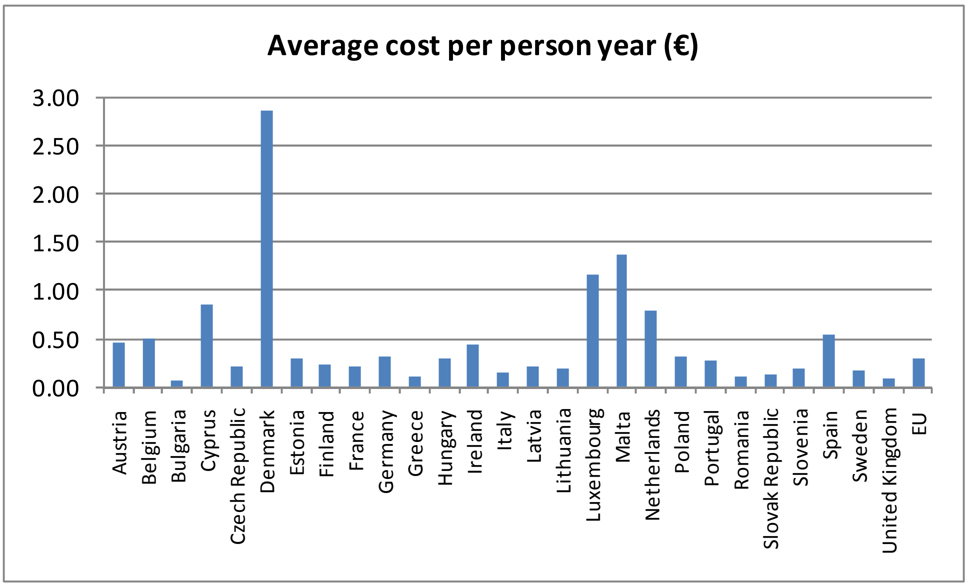
The average cost per pig slaughtered for scenario 4 is € 0.58 (original analysis € 0.57) with a high of € 3.79 in Luxembourg and a low of € 0.42 in Romania (see below).

Figure: Intervention costs per pig slaughtered for reworked scenario 4



The average cost per person year for scenario is € 0.30 (original estimate was € 0.29) with the lowest being for Bulgaria at € 0.06 and the highest in Denmark at € 2.85 (see Figure below).

Figure: 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.

4.6 Summary

The Chapter has presented information on the possible pre-harvest interventions to control and manage *Salmonella* in breeding pigs. It has identified three different categories of costs associated with the control of *Salmonella* in breeding pigs: feed; breeding pig and replacement stock and farm-level measures.

A cost analysis was presented using the model developed and described for the slaughter pig cost-benefit analysis. However, only scenario 3 and 4 were re-run as it was assumed that no additional costs would be borne in the inclusion of the breeding pigs for scenario 1 which was the establishment of a coordination and monitoring unit. In the case of scenario 2 the costs of improving feed management prior to delivery to the farm were assumed to be the same with the breeding pigs included.

For scenario 3 a modification was made in terms of the number of piglets produced per year. The original calculations used a standing population from Eurostat, the analysis in this report used an estimated number of piglets produced per year. The costs of breeding farm interventions increased from € 4 million to € 37 million of discounted costs, which represented around 5% of the total costs for this scenario. Scenario 4 was rerun with these new estimates of costs at breeding farm level, plus there was a calculation of the costs of transport of piglets from breeding to fattening units of € 17 million. Therefore in addition to the € 37 million estimated for on-farm breeding pig costs, there is an estimated € 17 million spent to improve the transport of piglets from the breeding to fattening units. A total of € 54 million is spent on *Salmonella* control improvements in breeding pigs from a total of € 1,491 million or 3.62% of the total costs for all pigs.

The total costs of scenarios 3 and 4 have varied very little from the original analysis presented in the slaughter pig report. The next Chapter will combine the cost estimates with the potential benefits from reducing *Salmonella* in pigs.

5 Cost Benefit Analysis

5.1 Introduction

This Chapter presents the application of the cost-benefit analysis model developed for the slaughter pig cost-benefit analysis with modified intervention scenarios 3 and 4, as described in the previous Chapter. There is also a presentation of a brief set of results for scenarios 1 and 2 as there are some changes in the value of human benefits included in the breeding pig analysis. To assist the reader a short description of the model is presented followed by a presentation of results from the analysis.

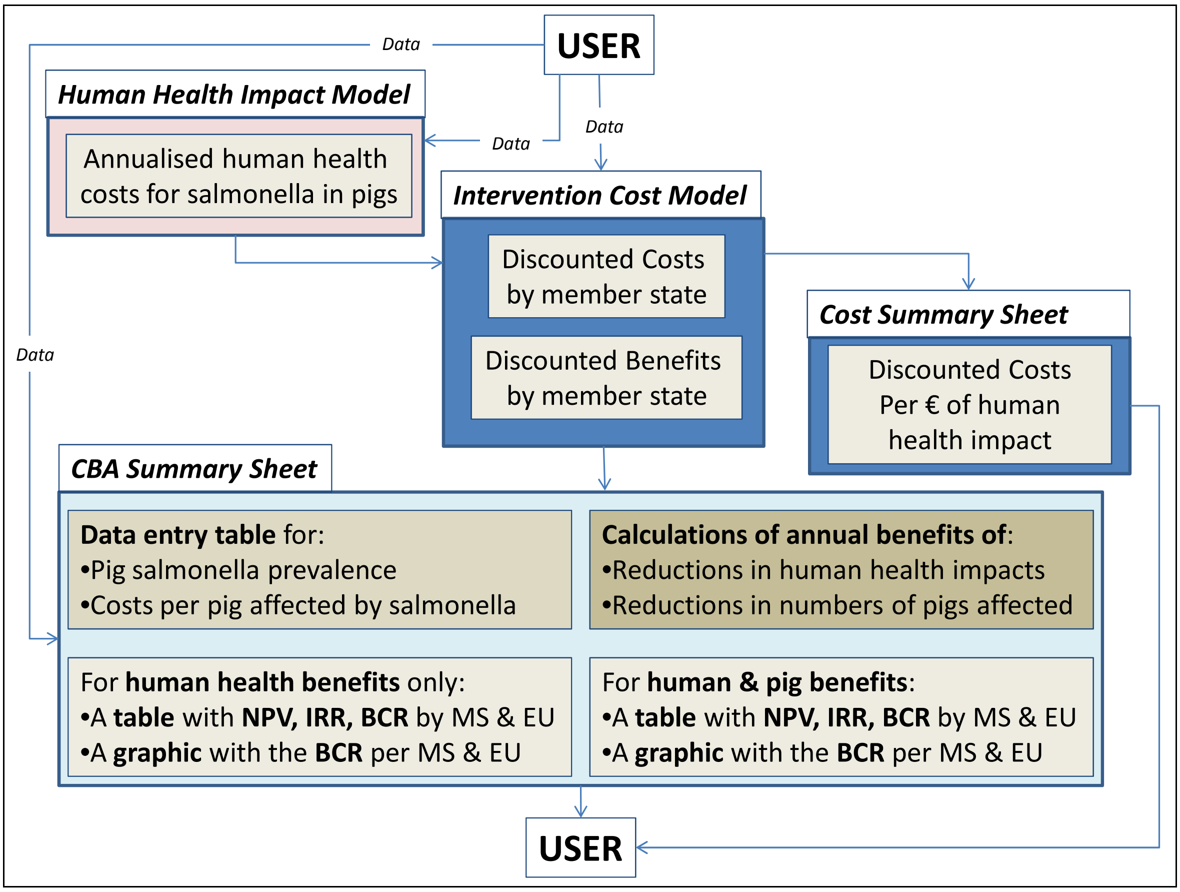
5.2 The model structure

The model used for the cost-benefit analysis is described in the slaughter pig report in detail. It contains 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 a cost-benefit analysis. The model structure is presented in the Figure below.

Figure: 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[19]. The discount rate used for the analysis is 4%, the normal discount rate for interventions with human health impacts (Oliver, undated). 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.

5.3 Results of the CBA for agreed scenarios to reduce human infection

5.3.1 Scenarios 1 and 2

A brief set of results are presented for scenarios 1 and 2 as the human health losses have been modified slightly, but the interventions have not been changed and nor have the estimation of benefits estimated in terms of pig production. Readers are reminded that significant sensitivity analysis was performed on the scenarios 1 and 2 which demonstrated that they were highly unlikely to generate positive economic returns even under the most favourable responses to a change in pre-harvest pigs and the attribution through the food chain. Those who have argued that costs of farm-level interventions should not be included in the analysis are referred to scenario 1 for the slaughter pig analysis presented in the previous report and show below in the following Tables with different estimates of how quickly benefits will be generated. In this scenario no costs are included except for coordination and monitoring, this is a minimum set of costs. The output generated indicates that even with these minimal costs there is no economic return with the inclusion of improvements in both human health and pig production.

Table: 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	-165,208,288	Could not be Calculated	0.42
Human health and pig production	-101,375,278	Could not be Calculated	0.65

Table: 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	-103,332,335	Could not be Calculated	0.64
Human health and pig production	15,391,630	Could not be Calculated	1.05

The analysis demonstrates that only when benefits for both human health impacts and pig production are assumed to occur rapidly will a minimum *Salmonella* programme generate a positive economic benefit.

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[19] 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.

The results for the modified scenario 2 are presented in the following Table.

Table: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 2 and a constant rate of reduction in human health losses and increase in pig productivity of 6%

Benefits included	NPV	IRR	BCR
Human health	-905,935,634	Could not be calculated	0.17
Human health and pig production	-787,211,669	Could not be calculated	0.28

No analysis was carried out with the rate reduction of *Salmonella* in pigs increasingly slowly.

Only Sweden had a BCR greater than 1 for both scenarios 1 and 2 which can be explained in that no additional feed costs were included for Sweden as this is already in place and minimal costs for coordination and monitoring were included for this country. It should also be recognised that the benefits generated for Sweden are optimistic both from human health and pig production given the low prevalence levels of *Salmonella* in the pig population.

Both scenarios 1 and 2 present a bleak picture in generating an *economic profit* from the control of *Salmonella* in pre-harvest pigs even with minimal levels of expenditure and relatively optimistic impacts on human and pig health.

5.3.2 Scenario 3 – Cost-benefit analysis

The analysis presented below is based on a modification for the cost-benefit analysis for scenarios 3 and 4, as described in Chapter 4.

5.3.2.1 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 4.

The following data have been entered to calculate the benefits:

- Human health benefits
    - The losses from human health are those presented in Chapter 3.
    - 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.

5.3.2.2 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 in humans Finland, Germany, Sweden and the UK have a positive CBA.

The BCR results for both benefit scenarios are shown in the Figures below and the general results for the EU are shown in the Table below.

Figure: Benefit cost ratios by Member State and the EU for scenario 3 with only the human health benefits

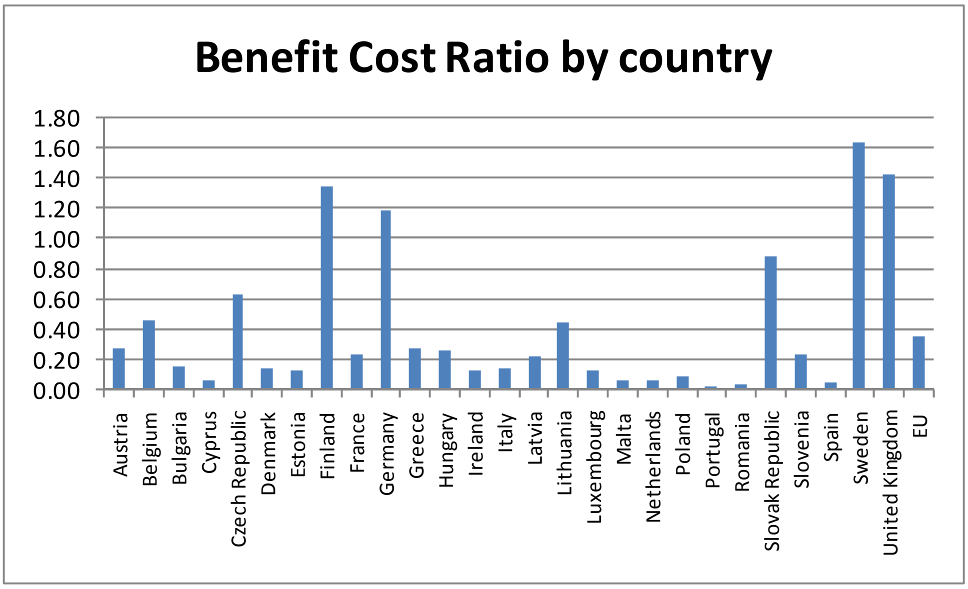

Figure: Benefit cost ratios by Member State and the EU for scenario 3 with human health and pig benefits

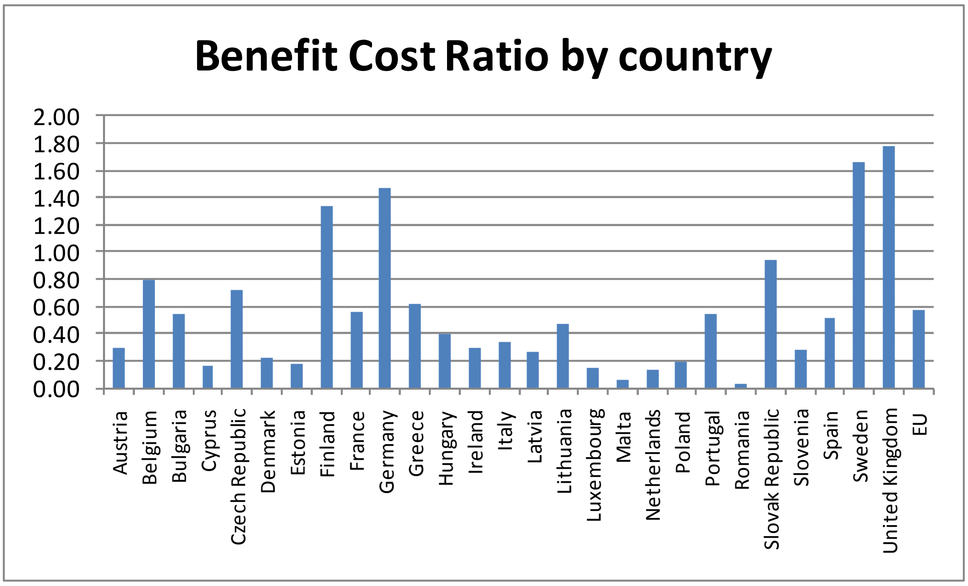

Table: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 3

Benefits included	NPV	IRR	BCR
Human health	-510,123,976	Could not be Calculated	0.35
Human health and pig production	-332,054,387	Could not be calculated	0.58

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 a poor BCR of 0.89 demonstrating the difficulties of achieving a positive economic return with a *Salmonella* programme.

5.3.3 Scenario 4 – Cost-benefit analysis

5.3.3.1 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 4.

The following data have been entered to calculate the benefits:

- Human health benefits
    - The losses from human health are those presented in Chapter 3.
    - 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.

5.3.3.2 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 arguably 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 the Figures below and the general results for the EU are shown in the following Table.

Figure: Benefit cost ratios by Member State and the EU for scenario 4 with only the human health benefits

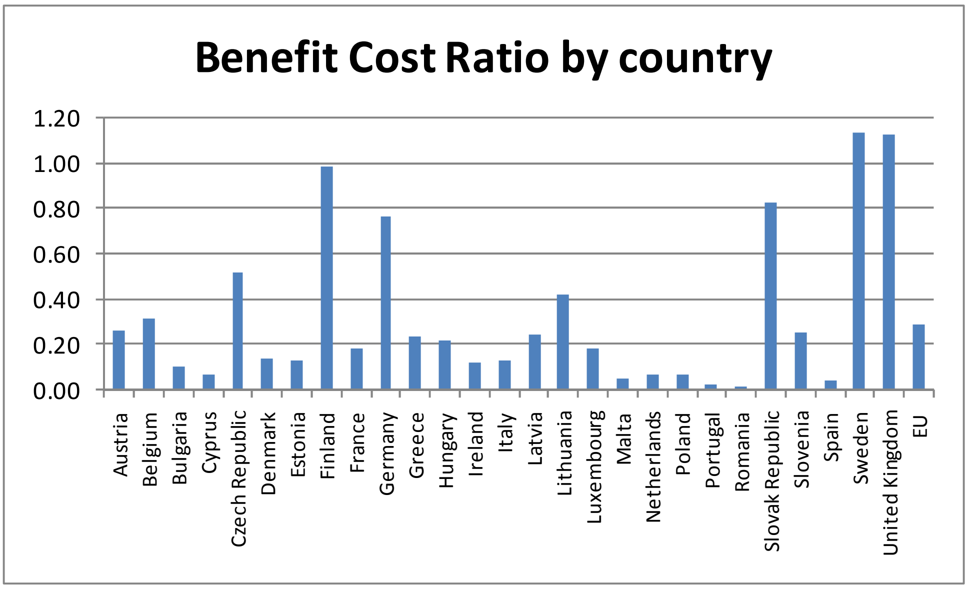

Figure: Benefit cost ratios by Member State and the EU for scenario 4 with human health and pig benefits

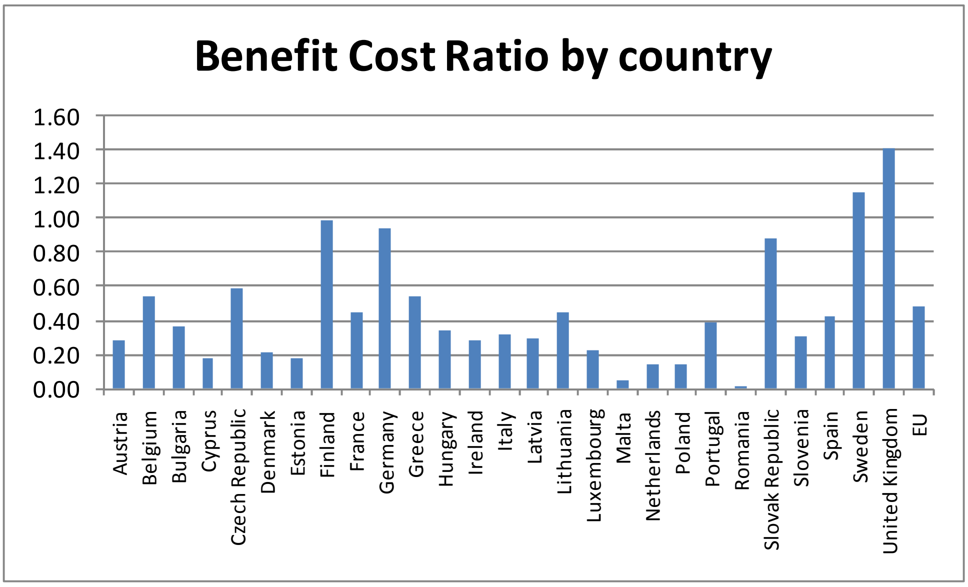

Table: Net present value, internal rate of return and benefit cost ratio for the EU, scenario 4

Benefits included	NPV	IRR	BCR
Human health	-1,059,076,242	Could not be calculated	0.29
Human health and pig production	-779,468,713	Could not be calculated	0.48

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.

5.4 Cost benefit analyses with the new benefits

The cost benefit analyses were re-run using the human health benefits that were estimated in the annex. Scenario 3 is economically profitable if an improvement in pig productivity is included, but 18 of the the 27 member states are reported to have a negative economic profit. Scenario 4 generates a negative economic return for the EU and only 7 countries report a positive return.

5.5 Summary

The Chapter presented the cost-benefit analysis of all scenarios 1 to 4 with only brief results presented for scenarios 1 and 2. Only scenario 1 with the optimistic assumption of a relatively rapid reduction in *Salmonella* impacts in humans and pigs generated an economic profit over a 10 year period. Experiences of running limited programmes in European countries would suggest that to have a strong impact on human and pig health with regards *Salmonella* requires much more investment than a programme with only a coordination and monitoring unit.

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.

6 Discussion and Conclusions

6.1 Introduction

The discussion and conclusions section is broken into four sections:

- Summary of analysis and results
- Issues raised by the people who have read and commented on the earlier analysis and participated in discussions during the current study
- Lessons learned and possible future control options
- Conclusions

6.2 Summary of analysis and results

6.2.1 Background

This analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in breeding pigs follows a similar analysis in slaughter pigs, also undertaken by the FCC Consortium. Both analyses are part of a sequence of studies leading up to the setting of targets for the reduction of *Salmonella* in live pigs, as required by Regulation (EC) No 2160/2003.

The breeding pigs' analysis has been undertaken in the knowledge that the cost-benefit analysis in slaughter pigs did not show an economic benefit in any of the intervention scenarios at pre-harvest level. This knowledge guided the analysis to focus on areas where economic benefits are most likely. It is recommended that readers refer to the methodology presented for that analysis as a similar approach is used for the breeding pig analysis.

The cost-benefit analysis in breeding pigs takes into account two major studies that to some extent pointed out the relevant role of the breeding herds as a source of *Salmonella* infection in slaughtering pigs: the EFSA baseline survey on the prevalence of *Salmonella* in holdings with breeding pigs in the EU (2008), and the Quantitative Microbiological Risk Assessment on *Salmonella* in Slaughter and Breeder Pigs (2009).

The EFSA baseline study found an average prevalence of *Salmonella*-positive holdings on EU farms with breeding pigs of 31.8%. The same study estimated a prevalence of EU *Salmonella*-positive production holdings (holdings housing breeding pigs and selling mainly pigs for fattening or slaughter) of 33.3%. The basis for sampling was random pooled faecal samples (whereas the baseline survey of slaughter pigs used individual lymph node samples taken at slaughter).

The QMRA predicted a theoretical reduction of 70-80% of the slaughter pig lymph node prevalence in Member States with high breeding pig herd prevalence if a reduction in *Salmonella* prevalence in the breeder pig herds could be achieved (QMRA, 2009).

6.2.2 Human health impact

The cost of human salmonellosis caused by pork and pork products was assessed using a Cost of Illness approach, expressing the cost per case of illness in Euros for each EU-27 Member State. The chronology of the work allowed us to develop a model in two stages to cover both the slaughter pigs' and breeding pigs' studies. A model was generated in stage 1 (slaughter pigs report) using common assumptions across the EU-27 and refined in stage 2 (breeding pigs report) to incorporate locally determined variables. (The term 'Consortium model' is used to describe the overall output).

There are significant gaps in the scientific knowledge base around biological and epidemiological determinants of risk between humans and animals.

In comparing and contrasting Stages 1 and 2, the first question to be addressed is: "does *Salmonella* in pigs at the breeding stage of the food chain generate a human health impact which is different or distinguishable from *Salmonella* at the slaughter stage?" The answer is largely "no".

The Stage 1 analysis segmented the disease chain between source (attribution to pigs) and outcome (disease in the human population). We attributed 15% of all human *Salmonellosis* to pork and pork products (based on literature, e.g. QMRA, 2009), linked mainly to food consumption, but with acknowledgement that cross-contamination can take place throughout the production cycle.

Logic suggests that control or reduction of *Salmonella* spp. would have greatest impact near to the point of consumption in the human food chain. According to a vertical model of transmission, control of *Salmonella* in breeding pigs (which contribute to food consumption mainly through their offspring) would have less human health impact than control of *Salmonella* in slaughter pigs, partly due to the risk of re-introduction of the pathogen during the production cycle. At the same time, we acknowledged that benefits of *Salmonella* control are likely to vary between Member States. Where prevalence of *Salmonella* in pigs is low at the point of slaughter (e.g. Finland and Sweden) then control measures early in the chain will produce greater benefit through prevention and maintenance than in Member States where prevalence of Salmonella in pigs is known to be high (e.g. Spain).

The relationship between the human health model and industry costs of intervention are affected by the slaughter/breeding distinction as follows:

- The total human health costs of *Salmonellosis* do not vary between breeding and slaughter. The assumption of 15% attribution (i.e. 15% of human salmonellosis cases being attributable to pork) relates to the whole farm-fork chain;
- There is no evidence to attribute human Salmonellosis to particular elements of the production cycle. However, in modelling terms, we map the human health benefits (reduced cost of illness) across multiple interventions, i.e. at both breeding and slaughter.
- The net effect is to reduce the attributable benefit of intervention at slaughter stage because some benefit needs to be attributed to the breeding stage.

The model changed in response to consultation with EU-27 Member States at Stage 1. The main changes are as follows:

- A reduction in the estimate of unreported cases. In Stage 1 we assumed that for every 1 reported case there were 11.5 cases of salmonellosis in the community. This 'Community Multiplier' was reduced to 7.3 in Stage 2, based on lower local estimates. It has the effect of reducing the predicted volume of cases by 37%;
- Increase in severity since the 37% volume reduction takes place among Severity 1 category cases (mild cases of people who do not visit a physician);
- 3% reduction in estimated total costs of *Salmonella* changing from € 88.7 million to € 86.1 million associated with *Salmonella* in pork;
- 53% increase in unit costs from € 391 (min € 40 and max € 680) in Stage 1 to € 600 per case (min € 60 and max € 2,173) in Stage 2

- 15% attribution has been retained in the model, but Member States are encouraged to estimate their local attribution of *Salmonella* to pigs and pork as the model is sensitive to this assumption.

We have compared the output of our Consortium model with the findings of the RIVM institute in the Netherlands to gain some insight into how much adjustment to make to take account of chronic sequelae. We have mapped the RIVM's total cost-of-illness estimate (uprated to 2008) to the DALY distribution and linked it to our Consortium estimates. Our conclusion is that the Consortium model underestimates burden of disease (since 8% of cases are likely to experience chronic sequelae such as reactive arthritis), but the model does not underestimate cost as it uses a relatively high cost per fatality. If the model were to exclude the cost of premature death (in common with cost of illness studies in general) then it would be necessary to increase the cost estimates by approximately 20%. However, inclusion of cost of premature death gives a heavy weight to fatality, and accounts for 75% of the model's costs (consistent with the weight of DALYs in RIVM's work). It more than compensates for omission of chronic sequelae and for this reason, although we acknowledge the heavy disease burden it imposes, we discuss sequelae as a significant sensitivity factor, rather than adding it to the final cost estimate.

Comparison with other relevant studies suggests that the estimates of human health impacts of *Salmonella* in pigs and pork in this study are more likely to be overstated than understated. The unit cost per illness is comparatively high due to inclusion of cost of premature death. The main factors determining volume of benefits are the attribution of human cases to pigs and pork (15% of human cases) and the assumption of a linear relationship (as in the QMRA study) between changes in lymph node prevalence at slaughter and incidence in humans.

6.2.3 Pre-harvest interventions and their costs

Pre-harvest interventions identified in the slaughter pig study have been extrapolated to breeding pigs, as follows:

a. Provide feed free of *Salmonella* contamination.
b. Purchase of *Salmonella* free new stock replacement
c. On farm strategies aiming to prevent infection from external sources. Strategies being classified into:
    i)Hygiene and Biosecurity measures
    ii)Feed strategies

There are no generic control measures that can be applied in all contexts.

QMRA (2010) identified a number of potential sources of infection for fattening and breeding pigs pre-harvest which can be broken down into: feed, on-farm circulation of *Salmonella* and potential infection during transport and lairage. The slaughter pig study used these along with expert opinion to examine different scenarios to reduce the risk of foodborne illnesses.

The analysis produced information on the possible pre-harvest interventions to control and manage *Salmonella* in breeding pigs. It identified three different categories of costs associated with the control of *Salmonella* in breeding pigs: feed; breeding pig and replacement stock and farm-level measures.

The following scenarios were assessed:

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 prevalences above the EU average.
        i. Clean replacement pigs
    b. Low prevalence – countries with slaughter pig prevalences below the EU average
        i. Feed control measures
4. Scenario 3 plus all transport and slaughterhouse measures.

A cost analysis was presented using the model developed and described for the slaughter pig cost-benefit analysis. It was assumed that no additional costs would be borne in the inclusion of the breeding pigs for scenario 1 which was the establishment of a coordination and monitoring unit. In the case of scenario 2 the costs of improving feed management prior to delivery to the farm were assumed to be the same with the breeding pigs included. These scenarios were re-run only to update some figures that had been re-valued and not to reflect the inclusion of breeding pigs.

For scenario 3 a modification was made in terms of the number of piglets produced per year. The original calculations used a standing population from Eurostat, the analysis in this report used an estimated number of piglets produced per year. The costs of breeding farm interventions increased from €4 to €37 million of discounted costs, which represented around 5% of the total costs for this scenario. Scenario 4 was rerun with these new estimates of costs at breeding farm level, plus there was a calculation of the costs of transport of piglets from breeding to fattening units of €17 million. Therefore in addition to the €37 million estimated for on-farm breeding pig costs, there is an estimated €17 million spent to improve the transport of piglets from the breeding to fattening units. A total of €54 million is spent on *Salmonella* control improvements from a total of €1,491 million or 3.62% of the total costs.

The total costs of scenarios 3 and 4 have varied very little from the original analysis presented in the slaughter pig report.

6.2.4 Cost-benefit analysis

The cost-benefit analysis model developed for the slaughter pig CBA was re-run with modified intervention scenarios.

Scenarios 1 and 2 were re-run as there were some changes in the value of human benefits included in the breeding pig analysis. Both re-run scenarios did not show favourable economic responses at EU level when using realistic assumptions, even with minimum levels of expenditure and exclusion of costs for general farm hygiene measures.

Scenario 3 was re-run using the following data:

- Human health benefits
    - The losses from human health are those presented in Chapter 3
    - 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.

At EU level, the cost-benefit analysis generates a negative NPV and a BCR less than one. For the benefit scenario that includes only the losses saved in humans Finland, Germany, Sweden and the UK have a positive CBA.

Scenario 4 was re-run using the following data:

- Human health benefits
  - The losses from human health are those presented in Chapter 3
  - 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.

Overall the EU cost-benefit analysis for a change in interventions and control of *Salmonella* in pigs under Scenario 4 was negative. Finland, Sweden and the United Kingdom show a BCR greater than 1, but these countries are special cases. Finland and Sweden have small additional interventions, and the UK imports around a half of its pig meat and therefore benefits from investments in controls in other countries.

The analysis presented in the report has covered in more detail the costs of interventions in the breeding pig population and has responding to comments made since the slaughter pig report was produced in the middle of 2010. The main conclusions from this work are as follows:

- An update of the human health impacts of *Salmonella* in pigs produced a slightly lower figure of €86 million (original €88.6 million).
- Data and information available on interventions at breeding population level do not allow the formulation of a concrete set of actions, and have variable impacts on *Salmonella* in pigs in different contexts. This is borne out by the very variable results of national campaigns in Europe.
- Interventions in terms of coordination, monitoring and feed were assumed to be the same as for the slaughter pig analysis.
- The numbers of piglets produced per year by the breeding farms was updated with an estimate of the total piglets produced per year rather than a standing population estimate used for the slaughter pig analysis.
- The direct costs of interventions in the breeding stock farms are estimated to be €37 million with a discount rate of 4% over a ten year period. Whilst this may appear to be

a significant sum, it only represents around 5% of the costs for scenario 3 and 2.5% of the costs for scenario 4.

- An estimate was made of €17 million needs to improve the transportation of piglets from breeding to fattening facilities. Therefore a total discounted cost of actions relating to the breeding pigs is €54 million over a ten year period.
- The cost-benefit analyses for the four scenarios described in the slaughter pig report were repeated. The only analysis that produced an economic profit (a positive NPV and a BCR greater than 1) was scenario 1 with benefits for *Salmonella* control included from rapid and fixed improvements in pig and human health. This scenario only includes costs for coordination and monitoring, and it is questioned whether the assumptions on the reductions in *Salmonella* in both pigs and humans are likely given the variable responses to similar real programmes in Europe.
- More detailed cost-benefit analyses of scenarios 3 and 4 produced negative returns to the investments, which is not surprising given that this analysis has slightly lower benefits from human health changes and slightly higher costs for breeding farm interventions. The analysis for scenario 4 did not produce a positive return even if it is assumed that all disease is removed from pigs and humans from day one of a programme.

These results do not contradict similar analyses for pre-harvest slaughter interventions (VLA, 2010) nor the variability of actual programmes in Europe. The only programmes that have succeeded are well funded, well researched and strongly implemented actions in Sweden and Finland.

6.3 Issues raised in comments and discussions

The slaughter pig report spent some time explaining what an economic analysis sets out to achieve and why we would adopt such a method of analysis to improve our decision making. This largely is about weighing the costs and benefits of possible actions in order to see which achieve the best returns.

The following paragraphs highlight some discussion points that have arisen in comments on the slaughter pig report and during meetings with scientists and industry representatives as part of the breeding pig study. We reflect comments (edited and unattributed) and indicate how we have addressed them during the study.

6.3.1 Lack of data

Data issues are a major theme among commentators:

- Comment: There is a lack of data for evaluating the cost of interventions to decrease the prevalence of *Salmonella* in lymph nodes of fattening pigs. As differences between Member States can also be expected, it is important that further work is done in individual MS to get more knowledge about the cost of interventions. Individual MS should use the model to run their own data.

  Our Response: We agree. The model is structured at Member State level and can be adapted to local assumptions.

- Comment: Difference in reporting systems mean that like-for-like comparisons between countries may not be possible.

Our Response: We are aware that diagnostic and reporting disciplines vary between Member States. We nevertheless continue to use reported cases to drive the human health model as it is the best available data, but agree that inter-country comparisons need to be treated with caution.

- Comment: The multipliers from reported to true number of cases will vary between MS.

  Our response: We have addressed this by consulting Member States and giving them the opportunity to vary the multiplier. Extrapolation of MS responses produces a 37% reduction in estimated volume of cases, mainly among the unreported mild cases in the community.

6.3.2 Scientific Challenge

- Comment: Davies (2010) states: “Development of valid and reliable pre-harvest interventions to control bacterial food borne pathogens remains the pre-eminent challenge for researchers in pork safety and one that may indeed endure for several decades even for the most researched pathogens”
- Our Response: this area of research will continue to make progress, and any cost-benefit analysis will need to be revisited in the future to take account of scientific advances.

6.3.3 Valuing life and the sequelae

- Comment: A scenario using Willingness to Pay methods to evaluate the value of lost life would be interesting. Such a scenario is expected to give a higher benefit. In the present analysis the effect of unemployment is included giving a value of life that is lower in countries with high unemployment.

  Our Response: Willingness to Pay methods tend to produce costs that are twice as high as those estimated by other approaches, but they still also vary according to national labour markets and wage levels. Use of WtP would raise the cost of mortality, dominating the model to an even greater extent. It would increase the benefit of intervention. Member States did not opt for a WtP approach during the Stage 1 consultation.

- Comment: The issue with sequelae is not trivial. The analysis should justify the parameters in more depth and perhaps consider including the sequelae in the sensitivity analysis.
- Comment: One important chronic sequel is missing: *Salmonella* as a focal infection in large vessels including heart and aorta with risk for aorta aneurysm – a severe complication that requires costly preventive actions.

  Our response: We have addressed this deficit by looking in detail at the evidence related to chronic sequelae and have referenced the body of important work in this area. The human cost of salmonellosis would need to be increased by 20% if we were focusing only on morbidity (or treating mortality through a friction cost approach which produces low financial values but large DALY values). Comparison with other studies suggests that our unit cost per case is relatively high, due to the model’s treatment of mortality. Sensitivity analysis indicates that there is compensating variation between exclusion of chronic sequelae and inclusion of cost of fatality (using our approach based on a labour cost index), and for this reason alone we have not restructured the model.

6.3.4 Disease Attribution

- Comment: Assumption of a linear relationship between lymph nodes and human cases is derived from the QMRA risk assessment. The level of uncertainty surrounding this assumption should be highlighted.
- Comment: The relation between actions taken and the expected change in prevalence of positive lymph nodes is not known and it seems difficult (as you state) or impossible to estimate the costs for a certain decrease (50%, 90%) in lymph node prevalence. Furthermore there is no correlation between risk for humans and prevalence of Salmonella in lymph nodes although the QMRA concludes that it is a linear relation. There is however a relation between swab samples of carcasses and risk for humans, but only a limited number of countries include swabbing of carcasses in the baseline survey.

  Our response: Attribution is highly problematic. We recognize that the assumptions in our model, based on the literature, are strong and that they should not be regarded as having certainty.

- Comment: Note that the assessment of attribution is 10-20% to the porcine reservoir of Salmonella. This is not attributable to the consumption of pig meat only. Consequently, measures pre-harvest will have larger benefits than measures at harvest or post-harvest.

  Our Response: We have noted that preventative intervention among low prevalence countries will have large benefits early in the production stage (starting with feed) whereas among high prevalence countries the human health benefit is likely to be weighted towards the harvest/post-harvest stage.

6.3.5 Cost Loading

- Comment: Costs for normal hygiene, such as cleaning and disinfection of transport vehicles, seem to be included whereas they should not be included as this is normal hygiene.

  Our Response: The model includes zero costs for normal hygiene (see 5.3.1). There is nevertheless a general case for spreading any additional costs of biosecurity across a range of diseases, and not loading them entirely upon Salmonella-control.

- Comment: In the EU 15% of human Salmonella cases are assumed to be caused by pork/pigs. In Sweden it was estimated that 0.08% (approx 0.1%) of all Salmonella cases were caused by pork. Thereby you may assume that the Swedish control program had not been in place we would also have had 15% attributed to pork. Given that you can conclude that the control program has decreased the pork associated Salmonella cases in humans from 15% to 0.1%, a reduction with 14.9%. So the reduction expressed as % would be 14.9%/15%=99%. The cost for this reduction is the cost of the Swedish Salmonella control program. (Wahlström H, Andersson Y, Plym-Forshell L, Pires SM. Source attribution of human Salmonella cases in Sweden. Epidemiology and Infection. 2010:1-8.)

  Our response: This is an interesting approach. We have not explored it in detail but acknowledge that it is worthy of further investigation.

6.3.6 Discount rate

- Oliver (forthcoming) suggests that the standard approach to discounting is arbitrary and that discount rates tend to be too high:

  "Given the uncertainties of the future, the view expressed here is that the only relevant factor to consider in discounting health outcomes is to account for the possibility of future catastrophic events, if the future absolute value of health is the only concern. However, the view is also taken that it is legitimate for policy makers to place more weight on current than on future constituencies, which is an argument that is not directly welfare-related. Although the rates chosen to account for these two factors are to some extent arbitrary, it is proposed here that the total discount rate on health outcomes should not exceed 0.3% per annum. Compared to the current standard of 3.5%, this rate would allow for a more sensible evaluation of policies that impact on future generations.

  In sum, using preference elicitation exercises to inform the chosen discount rate on health outcomes for health-related policy appraisal is misguided, because such preferences are unlikely to reflect the appropriate normative response. The author hopes that this finding will serve to highlight that much caution ought to be exercised with considering population (and even expert) preferences as inputs into any aspect of policy appraisal. "

  Our response: It is useful to question the rationale of discounting. The model can vary the rate to any level including zero. The lower the discount rate, the higher the cumulative (net present value) costs and the lower the BCR.

6.4 Lessons Learned

The specific purpose of this study is to provide an analysis of the costs and benefits in the EU of setting a target for reduction of *Salmonella* infections in breeding pigs, in accordance with Regulation (EC) No 2160/2003. The focus is on benefits for human health. The accompanying slaughter pigs' study, also carried out by the FCC Consortium, provided the same analysis for slaughter pigs. The point of reference for breeding pig prevalence is pooled faecal samples for serological testing, and for slaughter pigs it is individual lymph node samples for bacteriological testing.

Neither of the two studies demonstrates robust economic benefits from interventions to control *Salmonella* in pigs at the pre-harvest stages of the production chain at EU level. The broad findings are supported by other studies. Although it is technically possible to achieve and maintain a very low level (0 – 2%) of *Salmonella* prevalence in pigs as demonstrated in the Scandinavian countries, this might not bean economically justifiable objective for most Member States in the mid-term at the very least.

The epidemiology of salmonellosis in pigs makes it a very difficult infection to control at national and EU level and some Member States have been unable to reach such very low levels.

Nevertheless, human cases of Salmonella attributed to pigs remain a significant cause of disease at EU level costing an estimated €86 million per annum or €600 per human case, as calculated by this study.

The EU strategy to protect human health against zoonotic diseases requires coherent farm-to-table controls and monitoring at the level of primary production. However, the ability of *Salmonella* spp. to multiply and spread at different stages of the production chain means that actions taken at one point can easily be negated at a later stage of production, processing or distribution.

Testing difficulties and the expense of routine testing at points along the chain make it difficult to apply effective monitoring and control at different stages. The effect is that costs of control and monitoring may be incurred at different stages of production without cumulative impact on the prevalence of *Salmonella*.

The logical response is to apply an effective control as close as possible to the point of consumption. Traditionally this was achieved by thorough cooking of pork and pork products immediately before consumption. Commercial food chain operators are able to achieve this by, for example, hot washing of carcasses at the end of the slaughter rail. This is acknowledged to be an acceptable short-term measure in medium and high prevalence countries to protect human health whilst other controls are put in place. To achieve and maintain a state of low prevalence, food chain controls are necessary to limit sources of re-infection. Furthermore, end point measures do not fulfil the field to fork EU principle of applying controls at each stage of production under the responsibility of individual operators ensuring that end product controls are not used as an excuse to reduce efforts further up the food chain.

Despite the technical difficulties and low return indicated by the cost-benefit analysis, there are reasons to be optimistic about developing pre-harvest controls over a period of time.

For a control and monitoring programme to work in pre-harvest pigs a number of issues need to be addressed:

- Economical tests are required to demonstrate *Salmonella* freedom (or acceptable control) at a herd or farm level. If these could be made available then it is possible to set a precondition for Salmonella control. Farmers can be incentivised by a combination of price, access to markets and regulation.
- Interventions need to be separated into:
  - Management issues that require training and constant monitoring. These may be relatively inexpensive, but would require some skillset change. This will require:
    - Management plans similar those produced in the UK and other countries.
    - Testing of the validity of these plans both in technical, logistical and economic terms[20]
  - Infrastructural issues where building and equipment design needs to be altered to facilitate improved cleaning processes in order to reduce *Salmonella* spread between animals and reduce environmental contamination. Given the low economic returns of reducing *Salmonella* in pigs these might be brought in slowly first through research grants for better designs and once these have been thoroughly tested through building and equipment regulations on pig units. It may even be feasible only for new or refurbished buildings.
- A holistic analysis and whole chain approach is needed across the pig and feed sector, covering both pre and post harvest operations and taking multiple pathogens and productivity into account. This is critical in terms of assigning pathogen burden at different points in the pork value chain, determining risks of contamination and identifying the most cost-effective means of reducing pathogen load at point of consumption. It is suggested that control measures are linked to pathogen burden at the point of consumption (with the proxy being carcass contamination and ultimately reported human cases).

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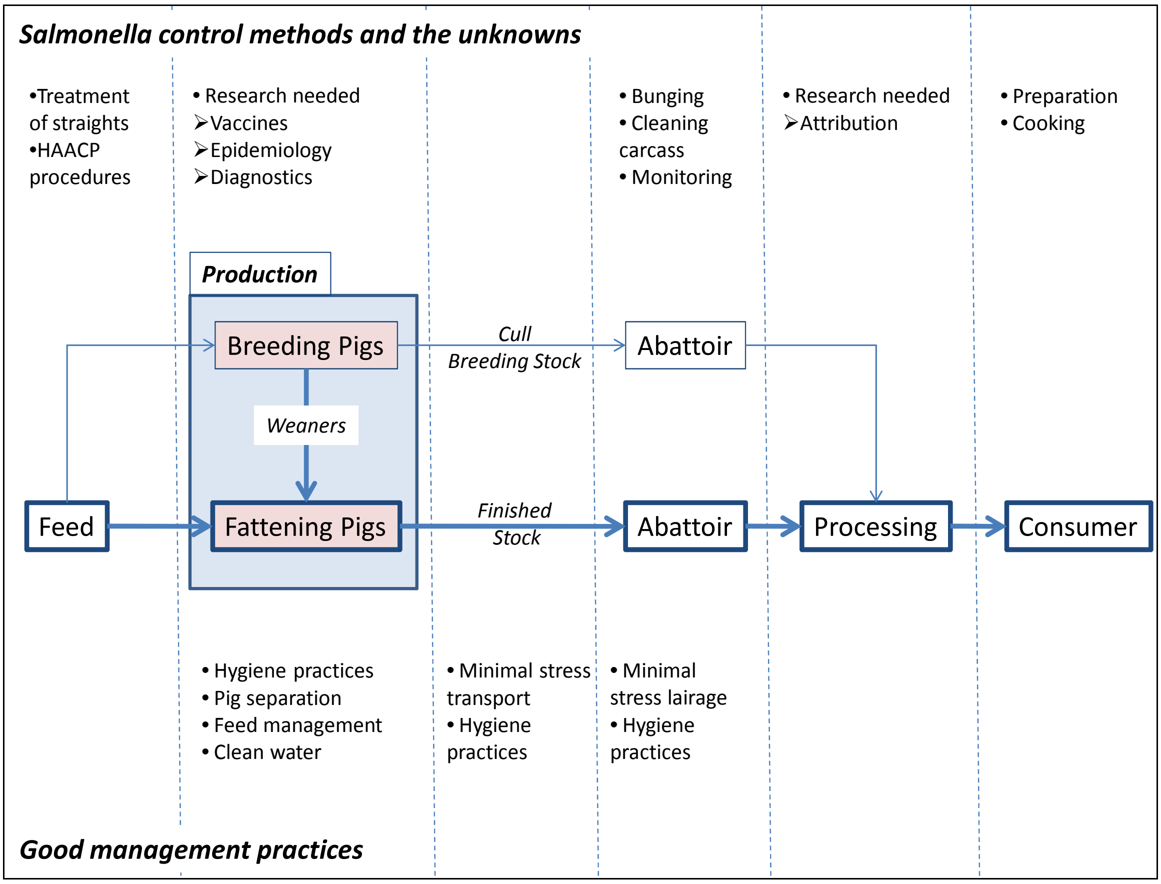
[20] Whilst the plan for the UK may be technically valid it has not produced desired results and many farmers appear to treat it as optional indicating it is possibly too difficult and/or too expensive. A large part of this expense may be time rather than money.

- Further investigation of the immune response to Salmonella and development of measures to improve both gut health and the resistance of the animals to these pathogens.

The following diagram gives some guidance on where it might be important to focus both new research and additional measures. The diagram also indicates that zoonotic disease in the pig sector is more complicated than the simple 'farm-to-fork' message suggests. This is due to: the different manifestations of infection in the live animal (interaction between pathogenicity and immune response); the possibilities for both increasing and reducing prevalence during the various pre-harvest production stages; and, the possibilities for both increasing and reducing contamination along the entire food chain from feed ingredients to different foods (not only pork or meat) on the plate.

Figure: Summary of where work needs to be done in terms of research and actual actions across the pork value chain.



Another point worth considering where benefit streams are small is where interventions can be concentrated in small groups of people or companies. The current structure of the pig industry has fewer feed and slaughter plants than production units, which would suggest that these are points that need careful consideration for analysis.

6.5 Conclusions

An analysis of the costs and benefits in the EU of setting a target for the reduction of *Salmonella* infections in breeding pigs has been carried out in coordination with a similar analysis in slaughter pigs.

The analysis took into account the findings of previous studies including a harmonised baseline survey on the prevalence of *Salmonella* in breeding pigs (*EFSA Journal 2009; 7(12):1377)*, the

Opinon of the Scientific Panel on Biological Hazards on Risk assessment and mitigation options of Salmonella in pig production (*EFSA Journal (2006), 341, 1-131)*, and a Quantitative Microbiological Risk Assessment on Salmonella in Slaughter and Breeder pigs (2010).

The analysis in breeding pigs was undertaken as a continuation of the preceding analysis in slaughter pigs (also carried out by the FCC Consortium) and the reader is referred to the earlier report[21] for detailed information on the development of the cost-benefit model and analytical techniques.

Although a considerable amount of information and analysis is available from the reference studies, it is widely acknowledged that there remains a lack of sufficient accurate and comprehensive data and knowledge. This lack of data is partly due to the epidemiology of *Salmonella* spp. This has necessitated an analytical approach that takes account of the data shortcomings.

Both studies have found that, on the basis of current scientific advice and the data provided, it is not possible at this time to demonstrate cost-beneficial interventions to reduce *Salmonella* infections in either breeding pigs or slaughter pigs, or in combinations of both herds. Sensitivity analyses indicate that positive cost-benefits can be found only in extreme scenarios.

Literature review as well as communication and discussion with the European Commission, EFSA, scientists and industry representatives during the study has confirmed that the findings are consistent with other studies and can be considered robust.

Although the cost-benefit analysis does not provide quantitative evidence to support the setting of *Salmonella* reduction targets in pigs at this time, *Salmonella* derived from pigs continues to be a significant cause of human disease in the European Union. Food chain operators in the EU have a responsibility to control zoonoses at all levels of production. The report therefore includes expert comment and discussion that may be useful in indicating possible steps to develop cost-effective *Salmonella* control and monitoring along the pig production chain over a period of time.

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[21] http://ec.europa.eu/food/food/biosafety/*Salmonella*/impl_reg_en.htm

ANNEX - ALTERNATIVE ASSUMPTIONS BASED ON FORTHCOMING EFSA OPINION

% Attribution Pork: 0.35

	Salmonella reported cases 2008	Incidence Report Cases per 100,000 Population 2008	Community Multiplier (Under-reporting factor)	Estimated Cases in Community	Total Cost	Annex Assumptions Based on Revised Attribution	Cost per Case
European Union (27 countries)	131468	26.4	47.5	6,240,270	€ 608,392,245	€ 213,545,678	€ 97
Austria	2310	27.8	13.2	30,483	€ 13,698,611	€ 4,808,212	€ 449
Belgium	3831	35.9	2.8	10,837	€ 21,792,131	€ 7,649,038	€ 2,011
Bulgaria	1516	19.8	591.0	895,981	€ 3,115,806	€ 1,093,648	€ 3
Cyprus	169	21.4	137.3	23,208	€ 1,133,291	€ 397,785	€ 49
Czech Republic	10707	103.1	28.3	302,687	€ 17,106,968	€ 6,004,546	€ 57
Denmark	3669	67.0	2.5	9,303	€ 26,905,206	€ 9,443,727	€ 2,892
Estonia	647	48.2	6.8	4,424	€ 670,619	€ 235,387	€ 152
Finland	3126	59.0	0.3	868	€ 1,955,646	€ 686,432	€ 2,253
France	7186	11.2	26.0	186,480	€ 38,509,522	€ 13,516,842	€ 207
Germany (including ex-GDR from 1991)	42909	52.2	7.2	306,835	€ 255,215,407	€ 89,580,608	€ 832
Greece	1039	9.3	476.5	495,092	€ 14,420,143	€ 5,061,470	€ 29
Hungary	6637	66.1	59.1	392,537	€ 11,483,124	€ 4,030,577	€ 29
Ireland	447	10.2	4.0	1,803	€ 2,995,530	€ 1,051,431	€ 1,661
Italy	3232	5.4	92.2	298,102	€ 22,936,066	€ 8,050,559	€ 77
Latvia	1229	54.1	28.7	35,223	€ 1,732,429	€ 608,082	€ 49
Lithuania	3308	98.3	36.9	121,925	€ 4,202,804	€ 1,475,184	€ 34
Luxembourg (Grand-Duché)	202	41.8	3.6	730	€ 1,312,725	€ 460,767	€ 1,798
Malta	161	39.2	171.5	27,611	€ 696,702	€ 244,543	€ 25
Netherlands	1627	15.5	19.5	31,677	€ 11,318,640	€ 3,972,843	€ 357
Poland	9149	24.0	106.2	972,052	€ 17,584,196	€ 6,172,053	€ 18
Portugal	332	3.1	1380.2	458,231	€ 8,282,154	€ 2,907,036	€ 18
Romania	624	2.9	619.6	386,606	€ 2,345,307	€ 823,203	€ 6
Slovakia	6849	126.8	32.5	222,436	€ 9,268,346	€ 3,253,190	€ 42
Slovenia	1033	51.4	24.0	24,830	€ 1,362,697	€ 478,307	€ 55
Spain	3833	8.5	240.5	921,871	€ 32,923,772	€ 11,556,244	€ 36
Sweden	4185	45.6	0.4	1,508	€ 3,446,426	€ 1,209,696	€ 2,285
United Kingdom	11511	18.8	6.7	76,930	€ 81,977,975	€ 28,774,269	€ 1,066

Cost Benefit Analyses with new Benefits

Productivity change	Scenario	NPV	IRR	BCR	Number of countries with BCR<1
No Change	1	168,393,117	95%	1.59	14
	2	-634,210,181	Not possible to calculate	0.42	22
	3	-102,573,187	Not possible to calculate	0.87	19
	4	-419,133,850	No possible to calculate	0.72	20
Change	1	287,117,082	190%	2.00	13
	2	-515,486,216	Not possible to calculate	0.53	22
	3	75,496,402	Not possible to calculate	1.10	18
	4	-139,526,320	Not possible to calculate	0.91	20

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