# FCC Consortium

# Analysis of the costs and benefits of setting a target for the reduction of *Salmonella* in pigs at slaughterhouse level

**The EUROPEAN COMMISSION**

**Directorate-General for Health and Consumers**

**SANCO/E2/2009/SI2.534057**

**FINAL REPORT**

**July 2013**

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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 |
| IBD | Inflammatory bowel disease |
| IID | Infectious Intestinal Disease |
| IRR | Internal rate of return |
| MPN | Most Probable Number |
| 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 |
| ReA | Reactive Arthritis |
| RIVM | Centre for Infectious Disease Control Netherlands, Rijksinstituut voor Volksgezondheid en Milieu (National Institute of Public Health and the Environment |
| 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 assignment on the 'Analysis of the costs and benefits of setting a target for reduction of *Salmonella* in pigs at slaughterhouse level' has been undertaken by the FCC Consortium led by Food Control Consultants Ltd. (FCC) of the UK on behalf of DG SANCO. The project is part of a programme set up under Regulation (EC) No 2160/2003, which foresees the setting of targets for a reduction of *Salmonella* in pigs in order to reduce human salmonellosis due to consumption of pig meat. When defining each Community target, the Commission shall provide an analysis of its expected costs and benefits.

2) The incidence of salmonellosis in humans has fallen by 27% in three years. Germany accounts for over half of this reduction. EFSA attributes this to success in poultry and egg controls, consistent with the continued drop in S. enteritidis.

3) A range of potential methods is used to make the link between sources of *Salmonella* and prevalence in humans. These include microbial sub-typing, analytical epidemiology, use of outbreak data, comparative exposure assessment and structured expert opinion.

4) Attribution figures show considerable volatility, with the most recent figure (EFSA 2012) attributing 56.8% of human salmonellosis to pigs, based on Hald et al (2012). This nearly quadruples an earlier assumption of 15% (QMRA, 2009). Other estimates include 26.9% (Pires, de Knegt and Hald, 2011) and 35% (used by FCC on the advice of DG SANCO in March 2011). Hald et al (2012) are cautious about the potential strength and application of their results, since their mathematical model is not tested by empirical observation. The implication in the opinion of this study is that the model generated by Hald et al (2012) needs to be tested empirically. Consequently, a range of modelling calculations has been made to examine all these attribution assumptions (15%, 26.9%, 35%, 56.8%).

5) Salmonellosis is a notifiable disease, meaning that identified cases are reported to the public health surveillance bodies in each Member State. The number of cases formally reported each year is known, but these represent a fraction of the cases that are presented to general practitioners (GPs). The mild nature of the disease in some cases means that many are not presented at all to the general practitioners although there may be an economic consequence, for example in terms of time off work. The total number of cases in the community is therefore unknown and multiplying factors are used to make best estimates. FCC has used a ratio of 1 : 2.3 : 7.3 for reported cases of *Salmonella;* general practitioner referred cases; and cases in the community. This ratio is much lower than some estimates but is consistent with earlier FCC work (based on consultation with EU-27 Member States) and with other studies. Recent literature suggests a much higher community-factor which has also been considered in this study.

6) Previous cost-benefit assessments of pre-harvest interventions carried out in 2009 and 2010 (FCC, 2010; 2011) indicated that the feasibility of managing and reducing *Salmonella* in breeding and slaughter pigs was neither easy nor clear, and did not show positive cost-benefits. Various studies have shown that practices and technology used during slaughter have a huge impact on the prevalence of *Salmonella* on carcasses. This analysis examines whether slaughterhouse interventions can make a difference that justifies the additional costs.

7) Three areas of interventions are considered technically feasible: washing, singeing and blast chilling (freezing) of the carcasses. Estimates have been made of the costs of these interventions per carcass, and details have been collected on the relative information on the presence of such practices in current slaughterhouses. The estimates of investment in infrastructure assume that well over half of the current slaughter capacity across the EU already has some of the interventions in place, even where estimates of *Salmonella* attribution from the pig meat systems are high.

8) In addition to the measures at the slaughterhouse, a control programme will need to have a monitoring system to ensure that targets are met on *Salmonella* carcass contamination. A baseline measure was derived from the regulations used to export pig carcasses and meat to markets with strict requirements. Again it as assumed that a high proportion of the current slaughter capacity is already employing such measures. Finally, a cost estimate has been included for a support/coordination unit.

9) Four different scenarios were developed for the cost estimates for the EU, based on increasing levels of intervention:

   1. Basic minimum national level coordination unit with the investment coming from the public sector; whose actions would have an impact on private practices at slaughterhouse level – discounted costs €108 million over ten years.
   2. A national coordination unit plus private sector monitoring costs to maintain information on the carcass prevalence – discounted costs €174 million over ten years.
   3. A national coordination unit with private sector monitoring plus additional investments in slaughterhouses to reduce *Salmonella* carcass prevalence – discounted costs €347 million over ten years.
   4. Based on scenario 3 but with higher costs of monitoring and slaughterhouse intervention and less pessimistic assumptions on the current practices – discounted costs €628 million over ten years.

10) Cost-benefit analyses were carried out on each scenario with different estimates of the impact of the measures on human health, as follows:

   - 50% reduction in human health impacts over a 10 year period;
   - 90% reduction in human health impacts over a 10 year period;
   - an estimate of the annual reduction in human health impact to achieve a break-even economic profitability.

   Each of these was tested against attribution rates of *Salmonella* from pork meat products of 15%, 29.6%, 35% and 56.8% - see point 4 above.

11) The cost-benefit analyses indicate that the economic profitability of the measures required to successfully reduce *Salmonella* carcass prevalence is strongly dependent on the extent of those measures, the assumptions on the attribution of the human health burden coming from *Salmonella* in pigs and the speed of reduction in human health impacts.

12) Scenario 1 with very minimal costs relating to a Member State level coordination unit created and paid for by the competent authorities indicates a positive economic return at EU level for all attribution levels, but not in all Member States. Even with the most optimistic assumptions of an attribution level of 56.8% and a 90% reduction in prevalence, five Member States still show negative cost-benefit analyses. Overall, this very basic scenario of investment in a coordination unit is unlikely to generate a rapid change in carcass prevalence and subsequent reductions in human health impacts, but it does give an indication of the level of investment that is affordable to return an economic benefit with the improved control of *Salmonella* in the pig meat system.

13) Scenario 2 produced a negative cost benefit analysis for the attribution level of 15% with a 50% reduction in the human health impacts over ten years. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that seven individual Member States would have a negative cost-benefit analysis.

14) Scenario 3 produced a negative cost benefit analysis for the attribution level of 15% with both a 50% and 90% reduction in the human health impacts over ten years. It also produced a negative cost benefit analysis for the 29.6% attribution level with a 50% reduction in human health impact over ten years. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that twelve Member States would have a negative cost-benefit analysis.

15) Scenario 4 produced a negative cost benefit analysis for all attribution levels of 15% with a 50% reduction in the human health impacts over ten years. It also produced a negative cost benefit analysis for the attribution of 15% with a reduction of 90% in human impacts over ten years. Even setting the complete elimination of human health impacts at this attribution level did not produce a positive cost benefit analysis. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that fourteen Member States would have a negative cost-benefit analysis.

16) Member States that have positive net present values (NPVs) and benefit-cost ratios (BCRs) in most scenarios have very specific characteristics which are:

    1. they have a comprehensive *Salmonella* control programme in place and are therefore assumed to have no additional costs;
    2. they import a significant amount of their pig meat, and/or;
    3. they have significantly high levels of *Salmonella* and therefore gain from larger benefit streams.

    Member States falling under points 1 and 2 above benefit from the investments of other Member States, so are capturing a positive externality from others.

17) The assessment of the control of *Salmonella* in the pig meat production systems in Europe is complicated by the variation of attribution rates of human salmonellosis. Therefore, the cost-benefit analyses performed have looked at all reported attributions. The cost-benefit analysis has also been divided into four different investment scenarios.

18) A very basic public investment on improved coordination was examined assuming that the private sector across Europe was already investing and implementing to some extent in monitoring and slaughterhouse interventions to reduce *Salmonella* carcass prevalence. The benefits in terms of reductions of human health impacts were assumed to be derived from the companies improving their control of *Salmonella* through better guidance and enforcement from the competent authorities. This produced positive cost benefit analyses for all attribution levels if it is assumed that *Salmonella* burdens can be reduced by 50% and 90% in the human population. However the likelihood of such investments being realistic are not strong and this scenario should be treated as a bare minimum investment cost.

19) A further scenario includes public investment in coordination and improved private investment in monitoring. Similarly this scenario produces a positive economic assessment across the EU, but negative outcomes for a high proportion of individual Member States. Again this scenario assumes that *Salmonella* impact can take place with relatively minor investments.

20) Scenarios three and four have investments in coordination, monitoring and slaughterhouse improvements. Scenario three is based on an optimistic level of costs for monitoring and slaughterhouse change and the assumption that a relatively high proportion of the slaughter capacity does not need additional investment. Scenario four assumes high unit costs of monitoring and cleaning carcasses in the slaughterhouse. With the high levels of attribution and a 90% reduction in human health impacts there is a positive EU benefit, but a high proportion of individual Member States are negatively impacted.

21) The results create a difficult process of interpretation. They indicate the lack of clarity on attribution rates, yet they do indicate in general that the human health impacts are not adequately large to engage in a high investment programme to improve *Salmonella* in the pig meat system.

22) The EU legislation requires targets to be set on *Salmonella* control in pig meat production. The logic of the legislation is based on salmonellosis being one of the most important food borne pathogens present in the poultry and pig sectors in the EU, and that technologies for reductions are available.

23) The pig sector is less clear cut than the poultry sector. The attribution of salmonellosis from pig meat production is in a process of on-going debate and as presented in the present study has estimates ranging from 15% to 56%.

24) The study team has considered the results of the analysis and identified possible areas that might need further discussion before attempting to set targets. The following questions may be asked:

    1. Could further work on attribution enable more precise application of pre- and post-harvest measures at the level of individual Member States, which may reduce their control costs and show better overall returns?

        - The current study has not attempted to include reduced pre-harvest costs as a benefit stream because the attribution of human salmonellosis from the environment versus food borne spread from pig meat production systems into humans is not adequately understood.

        - Inevitably the study has been obliged to extrapolate results of best practice *Salmonella* control measures from a limited number of Member States, which may not necessarily be the most appropriate combination of controls along the food chain for all national situations, especially when intra-EU trade is also taken into account.

    2. Has the EU reached a point with Salmonella control in pigs where the marginal cost-benefits calculated under the current state of knowledge need to be accompanied by a greater focus on a holistic ‘One Health’ approach?

        - It is important that some of the controls have to be placed into an ecological, social and economic context.

    3. Would a wider focus on general improvement of pig health across a range of disease and health issues show better returns?

        - Many of the pre- and post-harvest Salmonella control measures are not specific to Salmonella and have wider benefits - the costs could perhaps be allocated more widely.

        - The pig industry is under pressure from external competition, so improving overall efficiencies at production and slaughter levels through general improvements in health and welfare would give a critical trade advantage.

25) Further thought in these areas may produce more robust cost-benefits for setting targets.

# 2. INTRODUCTION

## 2.1 Background to the project

The assignment on the 'Analysis of the costs and benefits of setting a target for reduction of *Salmonella* in pigs at slaughterhouse level' has been undertaken by the FCC Consortium led by Food Control Consultants Ltd. (FCC) of the UK on behalf of DG SANCO.

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* | Independent | Veterinary epidemiology support |
| T. Crilly | Crystal Blue Consulting | Public Health Economist |
| D. Dewar | Food Control Consultants Ltd. | Contract Manager |
| H. Christensen | Danish Meat Research Institute | Process technology and slaughter hygiene |
| O. Valsson | Food Control Consultants Ltd. | Public Health Veterinarian |

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

The contract for the work was signed on 21 December 2012 for a period of six months ending on 20 June 2013. This document is the final report of the assignment.

## 2.2 Structure of the report

The report comprises the following main reporting chapters:

Chapter 2 Introduction
Chapter 3 Human health impact of *Salmonella* in pigs and attribution
Chapter 4 Slaughterhouse interventions and their costs
Chapter 5 Cost-benefit analysis
Chapter 6 Discussion and conclusions
Chapter 7 Bibliography

## 2.3 Objectives

The wider objective is to reduce human salmonellosis due to consumption of pig meat.

This project is part of a programme set up under Regulation (EC) No 2160/2003, which foresees the setting of targets for a reduction of *Salmonella* in pigs in order to reduce human salmonellosis due to consumption of pig meat. When defining each Community target, the Commission shall provide an analysis of its expected costs and benefits.

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

The analysis builds on previous economic assessments carried out by the FCC Consortium of interventions on slaughter and breeding pigs for *Salmonella* serotypes with public health significance in these populations. It thus broadens the scope of reducing human salmonellosis and improving public health and allows an examination of where the most effective points - or combinations of points - for intervention in the food chain can be achieved.

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 the 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;
- requirements and trends concerning breeding and production systems.

The cost-benefit analysis is important to food chain operators as the main responsibility and costs for food safety lies with them, whereas the principal benefits (i.e. improved human health) accrue to the consumer. The analysis will therefore provide the economic profitability of the change in *Salmonella* status along the food chain and give an indication of the public and private sector roles within the implementation of a *Salmonella* control policy.

## 2.4 Context of the analysis

To provide a reference point for comparison of future trends in the prevalence of *Salmonella* in poultry and pig populations, baseline surveys in pig populations have been carried out across the European Community. A survey was carried out to determine the prevalence of *Salmonella* in slaughter pigs. The Part A report[1] by the Task Force on Zoonoses Data Collection was published by EFSA in June 2008 and a Part B report[2] followed in November 2008. This was followed by a survey for *Salmonella* in breeding pigs.

As a supplement to this work, EFSA produced a quantitative microbial risk assessment for *Salmonella* across the food chain, including slaughter and breeding pigs, the slaughter point and food processing.

The FCC Consortium was awarded and completed contracts for the cost-benefit analysis of setting targets for the reduction of *Salmonella* in slaughter and breeding pigs, which were completed in January and July 2010 respectively. These analyses used a model that estimated the costs of interventions at Member State levels, the benefits in terms of a reduction in salmonellosis in humans and the possibility that benefits could be generated in pig production.

This assignment concerns a cost-benefit analysis of setting a target for the reduction of *Salmonella* in pigs at the slaughterhouse level. The analysis uses an extended version of the model developed by the FCC Consortium in the slaughter and breeding pig assessments. It also draws on the significant studies on interventions at slaughter level carried out in Denmark and the Netherlands, and refers to the EFSA quantitative microbial risk assessment and other studies where appropriate.

## 2.5 Analysis carried out

The analysis carried out within this contract aimed to:

[1] 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

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

1. Evaluate the correlation between the prevalence of *Salmonella* serotypes with public health significance in pigs at slaughter and the prevalence of *Salmonella* in pig meat at the end of the slaughter line.
2. Estimate the efficacy of the different control options and combinations of control options and established CCPs (critical control points) in terms of reduction of prevalence in the slaughter line.
3. Calculate the cost of monitoring by food business operators. Two or three different sampling schemes should be considered in consultation with the Commission.
4. Calculate the cost of monitoring by competent authorities to verify correct implementation by food business operators.
5. Calculate the additional costs at the slaughterhouse and/or cutting plant to comply with various possible process hygiene or food safety criteria including the costs of establishing training, the purchase of capital equipment and the ongoing maintenance costs.
6. Establish the relations of the incurring costs of measures in the slaughterhouse if complemented by measures in the primary production.
7. Calculate the costs of potential withdrawal or recall of products taking into account realistic scenarios (e.g. potential consumption before the result is known.
8. Estimate the expected social impact e.g. losses of sales due to loss of consumer confidence.
9. Calculate the impact on import of pig meat.
10. Calculate the reduction of human health burden (deaths, hospitalisation, treatment costs, economic losses, etc.)
11. Use the available data and models on *Salmonella* in the slaughterhouse to estimate the costs of respectively a 50% and 90% reduction of the mean prevalence at EU and at Member States level over a period of 5 to 10 years.
12. Coordinate with the cost/benefit analyses on *Salmonella* in slaughter and breeding pigs to guarantee that all studies are complementary.
13. Take into account the different production systems (e.g. outdoor versus intensive, large scale versus small scale holdings etc.) and prevalence levels in the Member States.

## 2.6 Reference to the terms of reference

| Term of Reference | Page Number | Comment |
|---|---|---|
| 1. Evaluate the correlation between the prevalence of *Salmonella* serotypes with public health significance in pigs at slaughter and the prevalence of *Salmonella* in pig meat at the end of the slaughter line. | Page 44 – evidence from Baptista et al (2010) study graphic of animal prevalence and carcass prevalence with associated text. | Carcass prevalence is influenced by pig prevalence, but in some countries and in some slaughterhouses management practice can both positively and negatively affected prevalence. In conclusion correlation cannot be defined in absolute either in specific locations or at any specific time. |
| 2. Estimate the efficacy of the different control options and combinations of control options and established CCPs (critical control points) in terms of reduction of prevalence in the slaughter line. | See section 4.3 that covers the critical control points and the possible interventions with costs | A range of options have been indicated, these will be combined for high-level intervention versus minimal additional interventions |
| 3. Calculate the cost of monitoring by food business operators. Two or three different sampling schemes should be considered in consultation with the Commission. | See section 4.5 that details the known costs of surveillance under the strictest conditions of exporting to a country with no salmonella at carcass level | The scenarios tested will be no additional surveillance beyond current levels, some additional surveillance and a gold plated level of surveillance |
| 4. Calculate the cost of monitoring by competent authorities to verify correct implementation by food business operators. | See section 4.6 that details the cost for an estimated coordination unit to run the programme | |
| 5. Calculate the additional costs at the slaughterhouse and/or cutting plant to comply with various possible process hygiene or food safety criteria including the costs of establishing training, the purchase of capital equipment and the ongoing maintenance costs. | See Section 4.3 for the costs of individual interventions. See section 4.7 for the estimates of cost for at member state level. This section includes the assumptions used in the analysis | |
| 6. Establish the relations of the incurring costs of measures in the slaughterhouse if complemented by measures in the primary | Section 4.3 indicates that there is little to be gained by significantly lowering the input of salmonella free pigs based on | No complementarity identified and published in the literature |

| | | |
|---|---|---|
| production. | evidence from Denmark | |
| 7. Calculate the costs of potential withdrawal or recall of products taking into account realistic scenarios (e.g. potential consumption before the result is known. | See section 5.3.1 | No conclusive evidence that salmonella and pig meat products cause recalls |
| 8. Estimate the expected social impact e.g. losses of sales due to loss of consumer confidence. | See section 5.3.2 | No evidence of salmonella in pig meat products causing losses |
| 9. Calculate the impact on import of pig meat. | See section 5.3.3 | Europe is a successful exporter of pig meat products and unlikely to gain anything on the use of salmonella as a trade barrier |
| 10. Calculate the reduction of human health burden (deaths, hospitalisation, treatment costs, economic losses, etc.) | Section Chapter 3 | |
| 11. Use the available data and models on *Salmonella* in the slaughterhouse to estimate the costs of respectively a 50% and 90% reduction of the mean prevalence at EU and at Member States level over a period of 5 to 10 years. | See section 4.7 for the costs of different scenarios with the different estimates on the reduction of the prevalence in humans | Please note this is not based on an epidemiological model that clarifies attribution across the food system. It is based on assumptions of reduction in human health impacts with changes in slaughterhouse practices leading to reduced carcass prevalence |
| 12. Coordinate with the cost/benefit analyses on *Salmonella* in slaughter and breeding pigs to guarantee that all studies are complementary. | Chapters 3, 4 and 5 mirror the analyses from the previous cost benefit analyses | Scenarios updated to mirror the previous pieces of work |
| 13. Take into account the different production systems (e.g. outdoor versus intensive, large scale versus small scale holdings etc.) and prevalence levels in the Member States. | Section 4.3 indicates that salmonella prevalence in pigs impacts on the carcass prevalence but does not create a huge level of reduction. The assumption that outdoor pigs are more likely to be salmonella carriers is not backed by current scientific data | No evidence is available that there will be any different in carcass meat prevalence with different production systems |

# 3. HUMAN HEALTH IMPACT OF *SALMONELLA* IN PIGS

## 3.1 Human salmonellosis – reported cases

**Summary:** Reported cases of salmonellosis in humans have been reducing. EFSA attributes this to success in poultry and egg controls, consistent with the continued drop in S. enteritidis.

### *3.1.1 Reducing trend of reported human salmonellosis*

The most recent published data are 2011 figures are drawn from the "EU summary report on zoonotic agents and food-borne outbreaks 2011" published in the EFSA Journal 2013. Earlier 2008 figures are drawn from EFSA sources that were reported in the FCC Consortium 2011 study on breeding pigs.

The number of reported (confirmed) cases of salmonellosis in the human population is falling. In 2008 there were 131 468 confirmed cases for the EU-27. By 2011 there were 95 548. This represents a 27% reduction over the 3 year period. Germany accounted for 53% of the 35 920 drop in incidence (although it is still above the EU average with 29 cases per 100 000 population compared to 19/100 000 in the EU-27).

**Table 1. Incidence of reported (confirmed) human salmonellosis cases**

| | *Salmonella* reported cases 2008 | Incidence reported cases per 100 000 population 2008 | *Salmonella* reported cases 2011 | Incidence reported cases per 100 000 population 2011 | Change in no. reported cases | % change in reported cases | Change as % of EU 2008-2011 total change |
|---|---|---|---|---|---|---|---|
| EU 27 | 131,468 | 26.4 | 95,548 | 19.0 | -35,920 | -27% | 100% |
| Austria | 2,310 | 27.8 | 1,433 | 17.1 | -877 | -38% | 2% |
| Belgium | 3,831 | 35.9 | 3,177 | 28.9 | -654 | -17% | 2% |
| Bulgaria | 1,516 | 19.8 | 924 | 12.5 | -592 | -39% | 2% |
| Cyprus | 169 | 21.4 | 110 | 13.1 | -59 | -35% | 0% |
| Czech Rep. | 10,707 | 103.1 | 8,499 | 81.0 | -2,208 | -21% | 6% |
| Denmark | 3,669 | 67.0 | 1,170 | 21.0 | -2,499 | -68% | 7% |
| Estonia | 647 | 48.2 | 375 | 28.0 | -272 | -42% | 1% |
| Finland | 3,126 | 59.0 | 2,082 | 38.7 | -1,044 | -33% | 3% |
| France | 7,186 | 11.2 | 8,685 | 13.4 | +1,499 | +21% | -4% |
| Germany | 42,909 | 52.2 | 23,982 | 29.3 | -18,927 | -44% | 53% |
| Greece | 1,039 | 9.3 | 469 | 4.1 | -570 | -55% | 2% |
| Hungary | 6,637 | 66.1 | 6,169 | 61.8 | -468 | -7% | 1% |
| Ireland | 447 | 10.2 | 311 | 6.8 | -136 | -30% | 0% |
| Italy | 3,232 | 5.4 | 3,344 | 5.5 | +112 | +3% | 0% |
| Latvia | 1,229 | 54.1 | 998 | 48.1 | -231 | -19% | 1% |
| Lithuania | 3,308 | 98.3 | 2,294 | 75.1 | -1,014 | -31% | 3% |
| Luxembourg | 202 | 41.8 | 125 | 24.4 | -77 | -38% | 0% |
| Malta | 161 | 39.2 | 129 | 31.0 | -32 | -20% | 0% |
| Netherlands | 1,627 | 15.5 | 1,284 | 12.0 | -343 | -21% | 1% |
| Poland | 9,149 | 24.0 | 8,400 | 21.8 | -749 | -8% | 2% |
| Portugal | 332 | 3.1 | 174 | 1.6 | -158 | -48% | 0% |
| Romania | 624 | 2.9 | 989 | 4.6 | +365 | +58% | -1% |
| Slovakia | 6,849 | 126.8 | 3,897 | 72.3 | -2,952 | -43% | 8% |
| Slovenia | 1,033 | 51.4 | 400 | 19.5 | -633 | -61% | 2% |
| Spain | 3,833 | 8.5 | 3,786 | 32.8 | -47 | -1% | 0% |
| Sweden | 4,185 | 45.6 | 2,887 | 30.7 | -1,298 | -31% | 4% |
| UK | 11,511 | 18.8 | 9,455 | 15.1 | -2,056 | -18% | 6% |

## 3.2 Attribution

### *3.2.1 Attribution link between animals and humans*

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

- **Outbreak data** among humans provides a cause-effect audit trail but is particular and cannot with certainty reflect the sporadic or general endemic risk of *Salmonella* in the community.
- **Microbiological sub-typing** of serovars and phages focuses on the reservoir or source level in animals, and attributes pathology in animals to infection in human patients: "the closer the resemblance of animal and food isolates with human isolates, the greater the likelihood that these were the sources of infection" (EFSA, 2008, p19). The method has the strength of focusing on the primary source of exposure but "does not provide any information on the transmission route" (EFSA, 2008, p22).
- **Microbiological Sub-typing – General.** Broad generalisation allows links between S. typhimurium and pig meat/pig herds and between S. enteritidis and poultry and eggs. Phage-typing through microbiological methods supports this, e.g. Van Duijkeren et al (2002) found that Serovar Typhimurium pt 510 was the most prevalent serovar Typhimurium phage type in both humans and pigs, while Serovar enteritidis phage type 4 (pt 4) was the most common phage type in humans and chickens. EFSA reports that 33% of serovars in pig meat and 32% in pig herds are S. typhimurium, forming the largest identifiable serovar in each (see tables below relating to pig meat and pork herds). Bovine meat is also an important reservoir of infection, since 26% of S. cases in bovine animals and 25% of S. cases in bovine meat are S. typhimurium.
- **Microbiological Sub-typing – Spatial nuance.** The spatial distribution of serovars gives a more nuanced picture. Among the named serovars found in pig meat, Slovakia and Latvia are weighted towards S Enteriditis and in the Czech Republic towards S. Derby. This implies that S. enteritidis could be attributed to pigs rather than poultry in Slovakia, since the dominant serovar (40% of isolates) in pig meat is S Enteriditis.
- **Microbiological Sub-typing – EFSA Approach.** The EU-wide picture is presented in an uncomplicated fashion: "Overall, reported data from 2008 support the generally accepted perception that the main sources of *Salmonella* infections in humans are from different types of meat and eggs in the EU" (The EFSA Journal, 2010, p99).

The following tables, drawn from EFSA (2013) and EFSA (2010) support the assertions above.

**Table 2. Distribution of number of *Salmonella* isolates from pigs and pig meat, by serovar (10 most frequent serovars) in the EU and non-MSs, 2004–2011**[3]

| ***Salmonella* Servars** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| S Typhimurium | 3 726 | 3 069 | 3 220 | 4 068 | 3 156 | 2 002 | 2 077 | 1 907 | 23 225 |
| Other serovars | 242 | 290 | 440 | 451 | 896 | 1 371 | 1 188 | 960 | 5 838 |
| S Derby | 691 | 525 | 741 | 760 | 947 | 320 | 417 | 734 | 5 135 |
| Monophasic S. Typhmurium | 107 | 157 | 198 | 420 | 175 | 179 | 748 | 489 | 2 473 |
| S group B | 1 | 40 | 118 | 32 | 210 | 214 | 39 | 318 | 972 |
| S infants | 166 | 151 | 85 | 135 | 168 | 109 | 97 | 148 | 1 059 |
| S rissen | 58 | 46 | 69 | 207 | 181 | 97 | 107 | 105 | 870 |
| S London | 69 | 86 | 94 | 97 | 253 | 94 | 90 | 69 | 852 |
| S Enteritidis | 53 | 71 | 176 | 210 | 184 | 58 | 41 | 61 | 854 |
| S Cholerasuis | 32 | 35 | 63 | 51 | 119 | 162 | 181 | 53 | 696 |
| Not typable | 71 | 25 | 76 | 114 | 69 | 15 | 31 | 42 | 443 |
| Total number in MSs | 16 | 18 | 18 | 22 | 21 | 20 | 20 | 23 | |
| Total number in non-MSs | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | |

- The table is ranked according to the number of *Salmonella* serovars in 2011
- Other *Salmonella* serovars were reported in "other *Salmonella* serotypes" from 2004 to 2009
- In 2009 "other serovars" includes *Salmonella* spp reported data

[3] Page 70, EFSA Journal 2013

**Table 3. Distribution[1] of the ten most common *Salmonella* serovars in pig meat, 2008[4]**

| Country | Number of isolates serotyped | % positive | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S Typhimurium | S Derby | S Agona | S Infantis | S London | S Bredeney | S Rissen | S Enteritidis | S Livingston | S Brandenburg | Other servars non-typable and unsepecified |
| **Total no. of isolates** | 1 417 | 469 | 280 | 55 | 49 | 48 | 46 | 37 | 21 | 20 | 9 | 383 |
| Czech Republic | 57 | 12.3 | 29.8 | 14.0 | 8.8 | 3.5 | | | 7.0 | | | 24.6 |
| Denmark | 199 | 44.2 | 28.1 | 1.0 | 5.5 | | | | | 3.0 | | 18.1 |
| Germany | 197 | 49.7 | 1.5 | 0.5 | 0.5 | | | | 0.5 | 1.5 | 3.0 | 42.6 |
| Hungary | 128 | 37.5 | 23.4 | 0.8 | 20.3 | 1.6 | 3.9 | 5.5 | 0.8 | 0.8 | | 5.5 |
| Ireland | 201 | 47.3 | 11.4 | 17.4 | 2.5 | 8.0 | 6.0 | 0.5 | 1.0 | | 0.5 | 5.5 |
| Italy | 532 | 19.4 | 27.6 | | | 5.3 | 3.6 | 4.9 | 0.9 | 0.6 | | 37.8 |
| Latvia | 17 | 5.9 | 5.9 | | | | 5.9 | | 17.6 | | | 64.7 |
| Netherlands | 12 | 50.0 | 8.3 | | | | | | 8.3 | 16.7 | 8.3 | 8.3 |
| Romania | 64 | 34.4 | 1.6 | 12.5 | 1.6 | | 14.1 | 4.7 | | 7.8 | | 23.4 |
| Slovakia | 10 | 10.0 | 10.0 | | | | | | 40.0 | | 10.0 | 30.0 |
| Proportion of serotyped isolates | | 33.1 | 19.8 | 3.9 | 3.5 | 3.4 | 3.2 | 2.6 | 1.5 | 1.4 | 0.6 | 27.0 |

[4] There is no update of this table in the EFSA Journal 2013

**Table 4. Distribution of the ten most common *Salmonella* serovars in pig herds, 2008**

| Country | Number of isolates serotyped | % positive | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | S Typhimurium | S Derby | S London | S 1,4,5, 12:i:- | S Livingstone | S Cholerasuis | S Infantis | S Enteritidis | S Rissan | S Anatum | Other servars non-typable and unsepecified |
| **Total no. of isolates** | **4 897** | **1544** | **646** | **177** | **154** | **127** | **119** | **118** | **112** | **109** | **101** | **1 690** |
| Austria | 69 | 29.0 | 15.9 | | | 13.0 | | 4.3 | 1.4 | | | 36.2 |
| Belgium | 1 010 | 48.8 | 15.7 | 0.8 | | 3.4 | | 3.0 | 0.4 | 3.8 | 2.2 | 22.0 |
| Czech Republic | 73 | 26.0 | 12.3 | 2.7 | | | | 1.4 | 8.2 | | | 49.3 |
| Estonia | 21 | 9.5 | | | | | 33.3 | 9.5 | 9.5 | | | 38.1 |
| Germany | 1 318 | 33.1 | 7.1 | 1.6 | | 0.9 | 0.5 | 1.5 | 2.1 | | 1.1 | 52.0 |
| Hungary | 61 | 21.3 | 14.8 | | | 4.9 | 16.4 | 19.7 | | | | 23.0 |
| Ireland | 18 | 72.2 | 11.1 | | | | | | | | | 16.7 |
| Italy | 634 | 17.7 | 16.7 | | 24.3 | 1.4 | 9.9 | | 0.5 | | | 29.5 |
| Luxembourg | 21 | 52.4 | 33.3 | | | | | 4.8 | | | | 9.5 |
| Netherlands | 758 | 16.5 | 22.7 | 14.8 | | 7.7 | | 4.4 | 1.5 | | 3.8 | 28.6 |
| Poland | 82 | 39.0 | 12.2 | | | | 8.5 | | 15.9 | | | 24.4 |
| Romania | 60 | 18.3 | 1.7 | | | | 33.3 | | | | | 46.7 |
| Slovakia | 82 | 24.4 | 17.1 | 4.9 | | | 4.9 | | 22.0 | | | 26.8 |
| Slovenia | 55 | 14.5 | 1.8 | | | | 1.8 | 18.2 | 34.5 | | | 29.1 |
| Spain | 385 | 16.1 | 10.1 | 5.2 | | 0.5 | | 0.8 | 1.0 | 18.4 | 9.1 | 38.7 |
| Sweden | 31 | 64.5 | | | | | | 6.5 | | | | 29.0 |
| United Kingdom | 219 | 67.1 | 5.9 | 4.6 | | | | 0.5 | 1.4 | | | 20.5 |
| Proportion of serotyped isolates | | 31.5 | 13.2 | 3.6 | 3.1 | 2.6 | 2.4 | 2.4 | 2.3 | 2.2 | 2.1 | 34.5 |

### *3.2.2 EFSA links trend to Salmonella controls in poultry – detailed justification*

EFSA (2013) states that S. enteritidis is associated with eggs while S. typhimurium is associated with meat:

> "In the EU, *S. enteritidis* and *S. typhimurium* are the serovars most frequently associated with human illness. Human *S. enteritidis* cases are most commonly associated with the consumption of contaminated eggs and poultry meat, while *S. typhimurium* cases are mostly associated with the consumption of contaminated pig, bovine and poultry meat." (p19)

S. enteritidis accounts for the drop in human salmonellosis cases. EFSA uses this trend, plus the association between S. enteritidis and eggs, to find that "the reduction of S Enteritidis in laying hen flocks and of *Salmonella spp*. in table eggs is likely to have contributed to the decline of S. enteritidis cases in humans." (EFSA 2013, p62):

> "At the EU level, the proportion of *S. enteritidis*-infected laying hen flocks during the production period decreased steadily from 3.9 % in 2007 (19 reporting MSs) to 1.3 % in 2011

(27 reporting MSs). During the same period the proportion of *Salmonella* spp.-positive table eggs decreased from 0.8 % in 2007 (16 reporting MSs) to 0.1 % in 2011 (13 reporting MSs). In the same period, a 60.5 % drop in the notification rate of human *S. enteritidis* cases per 100 000 population was observed (from 21.0 to 8.3). A corresponding 42.3 % reduction in the number of *Salmonella* spp. food-borne outbreaks caused by eggs and egg products was reported in the EU from 2007 to 2011 (a decrease from 248 to 143 outbreaks). The decline in the occurence of *S. enteritidis* continued in 2011 both in laying hens and their eggs and in the human cases."

### 3.2.3 S. enteritidis is the major serovar in humans

Based on 25 Member States, the two most commonly reported *Salmonella* serovars in 2011 were S. Enteriditis (44.4%) and S. typhimurium (29.6% if we include monophasic S. Typhimuirum).

S. enteritidis reduced by 2 081 (5.7%) between 2010 and 2011. S. typhimurium reduced by 9% but increased overall by 1.2% from 22 649 (27.4% of total) to 22 916 (29.6% of total) including monophasic S. typhimurium.

In summary, for S. typhimurium (including monophasic) the 2010/11 trend shows +267 (+1.2%) additional reported cases and a rise in the share of overall cases from 27.4% to 29.6%.

**Table 5. Distribution of reported confirmed cases of human salmonellosis by serovar (10 most frequent serovars) in the EU, 2010–2011**

| 2011 | | | 2010 | | |
|---|---|---|---|---|---|
| **Serovars** | **N** | **%** | **Serovars** | **N** | **%** |
| S. Enteritidis | 34 385 | 44.4 | S. Enteritidis | 36 466 | 44.2 |
| S Typhimurium | 19 250 | 24.9 | S Typhimurium | 21 223 | 25.7 |
| S Typhimurium monophasic 1,4, [5], 12:i:- | 3 666 | 4.7 | S Infantis | 1 793 | 2.2 |
| S Infantis | 1 676 | 2.2 | S Typhimurium monophasic 1,4, [5], 12:i:- | 1 426 | 1.7 |
| S Newport | 771 | 1.0 | S Newport | 839 | 1.0 |
| S Derby | 704 | 0.9 | S Derby | 783 | 0.9 |
| S Kentucky | 559 | 0.7 | S Kentucky | 689 | 0.8 |
| S Poona | 548 | 0.7 | S Poona | 665 | 0.8 |
| S Vichow | 467 | 0.6 | S Vichow | 471 | 0.6 |
| S Agona | 459 | 0.6 | S Agona | 445 | 0.5 |
| Other | 14 936 | 19.3 | Other | 17 657 | 21.4 |
| **Total** | **77 421** | **100** | **Total** | **82 457** | **100** |
| *Source: 25 MS* | | | | | |

### 3.2.4 S. typhimurium is increasing

The 2010-2011 table above shows an increase in S. typhimurium. It follows earlier trends where overall reported cases fell from 217 775 in 2005 to 127 296 in 2008. S. typhimurium was the only serovar to consistently increase. It accounted for 9.3% of known serovars in 2005 and rose to 21.9% in 2009, with the absolute numbers increasing from 15 058 to 26 423. S. enteritidis nevertheless continued to be the major serovar in the human population, with 70 091 cases in 2008 compared to 26 423 confirmed cases of S. typhimurium (*QMRA, 2009, p408).*

## 3.3 Attribution to Pork

### *3.3.1 The range of attribution is broad*

This section summarises the literature reprised in EFSA 2008 (used in previous FCC Consortium studies relating to slaughter and breeding pigs) and brings it up to date. Attribution figures show considerable volatility, with the most recent figure (EFSA 2012) attributing 56.8% of *Salmonella* to pigs. This nearly quadruples the earlier assumption of 15%.

- 15% - Previous work by the FCC Consortium on *Salmonella* targets relating to slaughter and breeding pigs used the November 2009 QMRA report (QMRA, 2009), which suggests that 10%-20% of salmonellosis in humans can be attributed to pork. On that basis, the FCC cost-benefit analysis model assumed 15% of human salmonellosis could be attributed to pork.
- 26.9% - Pires, de Knegt and Hald (2011) at the Danish Technical University National Food Institute, submitted to EFSA an estimation that: laying hens were the biggest source of *Salmonella* in humans (43.8% with a narrow 95% confidence interval of 43.2% – 44.4%); pigs were the second largest with 26.9% attribution (95% confidence interval of 26.3 – 27.6%). Turkeys and broilers contributed 4.0% and 3.4% respectively, whilst 9.2% of cases were linked to travel and 3.6% were part of outbreaks with unknown sources.
- 35% - In March 2011 FCC provided an annex to the cost-benefit analysis for slaughter/breeding pigs using 35% attribution, at the request of DG SANCO as the commissioning body (SANCO/2008/E2/056). This anticipated the volatility in attribution that was emerging from microbial sub-typing models.
- 56.8% - Hald, Pires and de Knegt (2012) produced a further attribution model for EFSA, the Turkey Target *Salmonella* Attribution Model (TT-SAM). This was used as the basis of EFSA's BIOHAZ Scientific Opinion (EFSA, 2012). It stated that pigs were the largest source of *Salmonella* with 56.8% attribution (95% confidence interval of 48.2% – 65.8%), laying hens (eggs) 17.0% (95% confidence interval of 11.3% – 24.0%); broilers 10.6% (95% confidence interval of 5.1% – 18.3%).

The following table summarises the range of opinion about the proportion of *Salmonella* in humans that is thought to be linked to pork consumption.

**Table 6. Percentage attribution of pork to human salmonellosis – summarising the literature**

| Description | Source | % |
|---|---|---|
| EU Turkey Target *Salmonella* Attribution Model (TT_SAM) Bayesian approach based on microbial sub-typing, using 2010 EU data | EFSA BIOHAZ Scientific Opinion, 2012 based on Hald, Pires and de Knegt, 2012 | 56.8% |
| BT-SAM microbial sub-typing | EFSA Panel on Biological Hazards, 2011a; Vose et al 2011 | 28% |
| EU *Salmonella* Surveillance data 2006-2009 based on microbial sub-typing | Pires, de Knegt and Hald, (2011) Danish TU Food National Institute | 26.9% |
| *% of different reservoirs in Netherlands | Van Pelt et al., 1999, Valkenburgh et al., 2007, EFSA 2008[5] | 21% |
| *Denmark | DZC | 10% - 21%, so 15% of all 20% of known |
| General | QMRA, 2009 | 10%-20% |
| *Netherlands | Vargas-Galindo, 2007 | 8% (14% of foodborne S. which is 55%) |
| * *Salmonella* outbreaks related to meat and meat products | | 6% (11/179) |
| *USA, expert estimate | Hoffman et al, 2006; 2007 | 6% |
| *USA, outbreak data | Hoffman et al, 2006; 2007 | 3% |

* Source: EFSA, 2008

## 3.4 Discussion - Why has attribution to pork risen sharply?

Two papers by the same team of authors (Hald, Pires and de Knegt, 2012; and Pires, de Knegt and Hald, 2011) produce radically different results. Why?

The 2011 paper used two source attribution approaches: 1) Bayesian modelling based on microbial sub-typing and 2) analysis of data from foodborne outbreak data.

- The model uses: i) the number of laboratory-confirmed infections caused by each *Salmonella* serovar; ii) the prevalence of each serovar in the different sources, and; iii) the amount of food sources available for consumption in each country broken down by the country of origin.

[5] Estimated contribution (%) of different reservoirs to laboratory confirmed salmonellosis in the Netherlands (Van Pelt et al., 1999, Valkenburgh et al., 2007) (in EFSA, 2008, p20)

| Reservoir | 1994-98 | 2001-02 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|
| Pig | 24 | 25 | 26 | 23 | 24 | 21 |
| Cattle | 10 | 14 | 12 | 11 | 11 | 13 |
| Chicken | 19 | 15 | 11 | 13 | 14 | 14 |
| Layers | 37 | 35 | 37 | 37 | 32 | 36 |
| Travel/ other | 9 | 11 | 13 | 15 | 19 | 16 |

- Reduction in the number of human salmonellosis S. Enteriditis cases is attributed to improved surveillance and control of S. enteritidis in breeding hens and in laying hens (p12). The implication of this chain of causation is that hens and eggs are the major source of salmonellosis in humans (since S. enteritidis is the most prevalent serovar). The results of the study are consistent with this thinking.
- Attribution to pork was lower in the outbreak data (6.1% in 2008 compared to 26.9% based on microbial sub-typing). This was "likely to be a consequence of the distinct points of attribution for the methods: pork and pork products are traditionally consumed well cooked, and thus the risk of salmonellosis after consumption of a contaminated product decreases after heat-processing." (p40).

A regional difference was observed:

> "The laying hen reservoir (i.e. eggs) was estimated to be the most important source of salmonellosis in 13 countries (Austria, Czech Republic, Estonia, Germany, Greece, Hungary, Latvia, Lithuania, Luxembourg, Slovenia, Slovakia, Spain and the United Kingdom), whereas pigs were the larger contributor for salmonellosis in eight (Belgium, Cyprus, Finland, France, Ireland, Italy, Poland and Sweden); the proportion of disease attributed to layers and pigs were similar in the Netherlands. In Denmark, the most important food-animal source was estimated to be turkeys, and broilers were the major source in Portugal. It should be noted that country-specific estimates for domestically acquired cases include both domestically produced and imported food. In Finland and Sweden, the majority of *Salmonella* infections were estimated to be travel-related. Travel was also an important factor, although to a lower extent, in Ireland, the UK and Denmark."

Hald et al (2012) uses the same team of researchers but produces markedly different results. The data employed included: i) the results from the harmonized EU monitoring in turkey, broiler and laying-hen flocks in 2010; ii) the results from the EU-wide *Salmonella* Baseline Surveys on slaughter pigs; iii) the reported cases of human salmonellosis in EU in 2010 as provided by the European Centre for Disease Prevention and Control (ECDC), and; iv) the amount of each food source available for consumption by Member States as estimated from different data sources on production, import and export.

The key difference in the model specification appears to be the application of an under-reporting factor (based on Swedish travel data) i.e. the parameter "country-specific under-reporting factor for human cases". It is not clear the extent to which changes to data sources involved in microbial sub-typing have impacted upon the results. (For instance, tonnage of food is an input to the model, which includes the full weight of pig carcasses rather than just meat. However, presumably this was also a factor in the earlier Pires et al [2011] model).

Points to note are that:

- the 'under-reporting' factor is very high at 60:1. It suggests that 1 in 10 people in the EU get salmonellosis every year, i.e. more than 5 million people. The mean under-reporting factor, according to the model, in Sweden is 0.5, Finland 0.4, while in Portugal is 2084.
    - The FCC model uses the term 'community multiplier' – which implies that mild cases exist in the community which are not serious enough to take to the doctor (and be subsequently analysed). Based on responses from Member States the multiplier was reduced from 11.5 to 7.3 on average.

- A logic is applied, arguing that improved control in monitoring and surveillance of eggs and poultry justifies the sudden change to attributing the majority of *Salmonella* cases to pork. However, S. enteritidis continues to be the biggest serovar in absolute numbers and in percentage terms. There has been a reduction, but not so great that pork could suddenly pick up the burden.
  - The logic requires that the microbial sub-typing attribution argument needs to change, i.e. S. enteritidis must be attributed to pork and not mainly to eggs/poultry. This is indeed the case; see the table below.
- The paper suggests that 'although the number of cases attributed to pig meat may have been over-estimated, pig meat is likely to be the most important source in a majority of Member States" (p28).

The results are based on a mathematical model rather than observable, testable data. The authors are aware that: a) the results are at odds with their own previous work; b) the 'multiplier' or 'under-reporting factor' is significantly higher than estimates previously found in the literature; c) attribution bears no relationship with outbreak data which indicates that cooked food (and pork is consumed mainly as cooked rather than raw food) is likely to be free of *Salmonella*.

It should be noted that the BIOHAZ panel has incorporated the results of a single paper into its Scientific Opinion. Earlier EFSA publications (e.g. EFSA 2008) include a synthesis of evidence, and presumably at some point EFSA will update its review.

**Table 7. Estimated number and percentage of human cases of *Salmonella* in the EU attributable to the four main animal reservoirs included in the baseline model of Hald et al (2012)**

| | **Estimated number of human cases** | | | | **Percentage of human cases** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Median** | **2.5%** | **97.5%** | **Mean** | **Medium** | **2.5%** | **97.5%** |
| Pigs | 3 099 000 | 2 900 000 | 1 627 000 | 5 783 000 | 56.8 | 56.8 | 48.2 | 65.8 |
| Broilers | 559 300 | 515 100 | 267 100 | 1 112 000 | 10.6 | 10.2 | 5.1 | 18.3 |
| Laying hens | 928 000 | 847 700 | 443 100 | 1 878 000 | 17.0 | 16.7 | 11.3 | 24.0 |
| Turkeys | 135 100 | 121 000 | 60 790 | 293 600 | 2.6 | 2.3 | 1.2 | 5.2 |
| Unknown/ travel | 692 600 | 742 200 | 366 200 | 1 281 000 | - | - | - | - |
| **Total cases** | **5 414 000** | **5 126 000** | **2 764 190** | **10 347 600** | - | - | - | - |

**Table 8. Number of human cases by serovar and animal reservoir as estimated by the TT-SAM model**

| | Pigs | Broilers | Layers | Turkeys |
|---|---|---|---|---|
| S Enteritidis | 1 313 000 | 459 600 | 806 000 | 29 770 |
| S. Typhimurium | 1 543 000 | 15 440 | 17 030 | 20 010 |
| S Infantis | 29 500 | 36 170 | 29 650 | 6 820 |
| S Virchow | 13 270 | 4 250 | 20 540 | 9 110 |
| S Newport | 33 170 | 4 470 | 6 878 | 10 030 |
| S Kentucky | 0 | 2 347 | 8 207 | 22 970 |
| S Derby | 30 400 | 187 | 48 | 2 445 |
| S Mbandaka | 5 620 | 12 800 | 6 362 | 2 046 |
| S Hadar | 14 780 | 11 270 | 4 930 | 7 274 |
| S Agona | 9 136 | 873 | 2 481 | 2 923 |
| S Saintpaul | 293 | 662 | 39 | 8 439 |
| S Bovimorbificans | 25 420 | 557 | 2 288 | 1 095 |
| S Branderup | 5 840 | 316 | 7 227 | 0 |
| S Montevideo | 5 615 | 1 214 | 7 371 | 850 |
| S Brandenburg | 12 200 | 441 | 19 | 112 |
| S Rissen | 33 530 | 295 | 462 | 39 |
| S Senftenberg | 134 | 269 | 206 | 1 437 |
| S Bredeney | 6 669 | 2 180 | 680 | 4 924 |
| S Kottbus | 2 495 | 389 | 265 | 2 907 |
| S London | 9 867 | 0 | 671 | 317 |
| S Livingstone | 1 706 | 2 428 | 4 209 | 307 |
| S Heidelberg | 177 | 2 703 | 2 313 | 1 157 |
| S Anatum | 3 686 | 421 | 78 | 143 |
| **Total** | **3 099 508** | **559 282** | **927 954** | **135 125** |

## 3.5 Under-reporting or multipliers

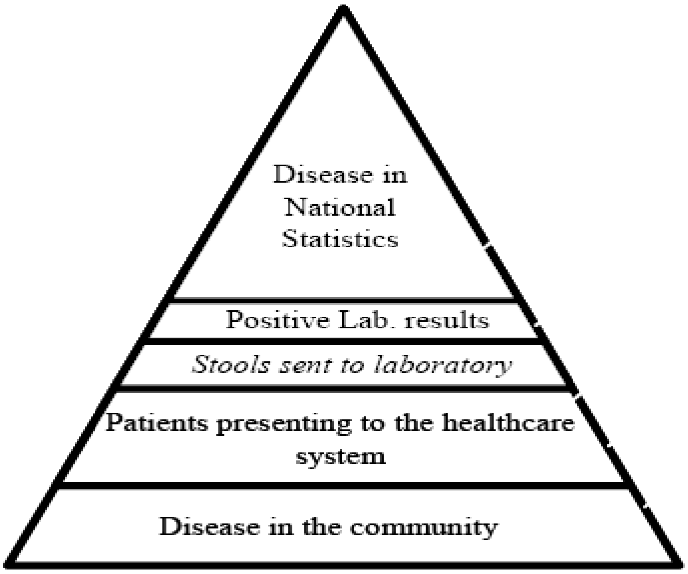
### *3.5.1 Burden of illness pyramid in humans*

Salmonellosis is a notifiable disease, meaning that identified cases are reported to the public health surveillance bodies in each Member State. The number of cases formally reported each year is known, but these represent a fraction of the cases that are presented to general practitioners (GPs).

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* species. The total number of cases in the community is unknown. The mild nature of many cases 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 when there is no visit to the doctor. Even where the illness is severe or leads to death, the cause of death (e.g. salmonellosis) may not be investigated.

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

**Figure 1 Surveillance pyramid showing the multipliers for *Salmonella* in England and the Netherlands**




### *3.5.2 Community multiplier*

The potential scale of variation in these estimates is very large indeed. EFSA (2012) notes that ratios vary from 4.7 for the UK (Tam et al, 2012) to 29.3 for the USA (Scallan et al, 2011).

The variation in *Salmonella* estimates may be due to: a) different levels of morbidity; b) different methods of detection and reporting; or a combination of the two. In other words, without special surveys we have no means of establishing the true incidence of *Salmonella* in the community for each Member State.

The earlier FCC slaughter pig model (Stage 1) used the relationship between (a) reported cases, (b) numbers presenting to general practitioners and (c) mild cases in the community as 1 : 2.3 : 11.5 across all EU-27 Member States, based on literature from UK, US and the Netherlands. This was subsequently revised downwards (Stage 2) to 1 : 2.3 : 7.3 after asking Member States to supply their own multipliers. We took the average of the figures returned from 7 MSs, i.e. Estonia 2.5, United Kingdom 3.2, Sweden 6.1, Ireland 8.0, Denmark 8.3, Lithuania 13.9, Denmark 16.5.

The TT-SAM attribution model (Hald et al, 2012) underpinning the EFSA BIOHAZ Scientific Opinion (EFSA 2012) uses a multiplier equivalent to 60 for the EU-27 with a range from 0.4 (Finland) to 2084 (Portugal). It is derived from a model based on Swedish travel. The implication for the population of Europe is that over 5 million people are estimated to be contracting salmonellosis, i.e. 1% of the population every year. This figure rises to 9% of the population in Bulgaria, 7% in Malta and 5% in Greece (see Table 20). This estimate of (un-notified) disease is extremely high, especially when compared with the model's prediction of 0.016% annual incidence in Sweden and Finland, and when considering that Salmonellosis is not even the largest zoonotic disease. (There are more than twice as many reported cases of Campylobacteriosis in humans compared to Salmonellosis, according to EFSA Journal 2013, 11[4]:3129).

#### 3.5.3 Comparing results with the UK IID Report 2012

A major study of infectious intestinal diseases (IID) was published in 2012 and referenced as IID (2) to distinguish it from an earlier study published in 2001 and known as IID (1). It shows that salmonellosis is a small part of the burden of IID. Viral (as opposed to bacterial) forms of illness are much more important. Specifically, only 0.6 cases of *Salmonella* in the community appeared compared to 274 (or 277) total IID cases per 1 000 person years. Put it another way, only 1 in 1 667 people would contract salmonellosis in the UK even though 1 in 4 people would experience some form of IID. According to that study, *Salmonella* is a small part of the overall burden of disease.

### 3.6 The FCC cost of illness model

A cost of illness model was developed and then extended for the previous slaughter and breeding pig projects. The model estimates the cost of salmonellosis in the human population across the EU-27. It then applies a single rate of attribution to estimate how much of this cost can be linked to pork.

The model involved a number of choices which were ultimately agreed among Member States, e.g. community multiplier, exclusion of chronic sequelae costs, inclusion of cost of death (which is the major component of costs) based on productivity indices, i.e. 20 years of average wage within Member States.

The structure and underlying assumptions have been retained (as agreed in determining the brief for this project). Figures that have been updated include:

- Incidence of salmonellosis, i.e. number of cases in the human population, based on zoonotic trends in 2011 (EFSA, 2012).
- Labour market indices, adjusting wage costs for 3 years from 2008 to 2011.
- Attribution of salmonellosis to pork and pig meat. This is the most important change. Results are modeled against four attribution rates.

Figures that, significantly, remain the same include:

- Mulitplier: the ratio of 1 : 2.3 : 7.3 for reported cases of *Salmonella*, general practitioner referred cases, and cases in the community is retained . The 1 : 7.3 ratio stands out against the much higher 1 : 60 ratio noted in Hald et al 2012 and EFSA 2013. However, the FCC figures are consistent with the consultation which took place with Member States during earlier stages of investigation in 2010/2011. They also compare reasonably with UK IID (2) which shows that salmonellosis is a small component of the overall burden of infectious intestinal diseases.

Sensitivity to the under-reporting factor is tested through an extra scenario that restructures the model to link fatalities and GP visits to confirmed cases (rather than all cases in the community).

The model is divided into six modules:

**Table 9. Structure of the FCC cost of illness model**

| | Module |
|---|---|
| 1 | Total number of cases:<br>- Pyramid of illness<br>- Incidence<br>- Outcome Severity |
| 2 | Productivity costs:<br>- Labour market cost and participation<br>- Days absent from work by outcome severity |
| 3 | Healthcare utilisation costs:<br>- GP Visit<br>- Emergency Department<br>- Outpatients<br>- Hospital Admission |
| 4 | Premature death |
| 5 | Total costs |
| 6 | Attribution to pork:<br>- Cases and costs associated with pork |

For a detailed description of the model, please refer to earlier FCC reports on analysis of the costs and benefits of setting targets for the reduction of *Salmonella* in slaughter pigs and breeding pigs. The issue of premature death is dealt with below, along with discussion of chronic sequelae which are excluded from the model, by reprising earlier narratives. There is a potential trade-off between the two sets of costs, i.e. cost of fatality, accounting for three quarters of the overall cost of illness, offsets absence of chronic sequelae costs. (Many models, e.g. Santos et al (2010), omit the cost of fatality).

## 3.7 Premature death (i.e. fatality due to salmonellosis)

The model incorporates 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[6] used in the UK for food safety). The US cost calculator uses $5 million as the value per statistical life, based on WTP estimates[7]. Parity with earnings built into this model is consistent with income-elasticity observed in a survey of 68 studies across 13 countries (Miller, 2000) measuring values of statistical life.

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

[7] 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

In earlier versions of the model (i.e. pre-harvest slaughter pig) 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 Member State; (c) use the current modelling assumption of 20 years average earnings for each Member State (because it is transparent and consistent); (d) other?". Member States responded in the following way:

- 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 Member States 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.

### 3.7.1 Friction Cost

Kemmeren et al 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 through which 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 slaughter pig model which uses a value per statistical life.

## 3.8 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].

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 model does not include an estimate of the impact of chronic sequelae. The implications are discussed here and we draw on the work of RIVM.

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discounted value of a healthy day (along with information on duration) to calculate a dollar measure of utility loss per case.

[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.

### *3.8.1 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.

### *3.8.2 Comparing RIVM findings with FCC 2008 cost of illness model*

We compared the output of the earlier slaughter-pig model (2008 cost of illness) with the findings of RIVM to gain some insight into how much adjustment to make to take account of chronic sequelae and concluded that the cost of illness model underestimates burden of disease but does not underestimate cost:

- The FCC cost of illness 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 FCC cost of illness 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 the cost of illness model[11], but costs of fatalities are still higher in the FCC 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.

**Table 10. 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 | | | | | |

[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 FCC Cost of Illness model at 2008 was 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

| | | | | | | |
|---|---|---|---|---|---|---|
| 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 |

**Table 11. Linking DALYs (Kemmeren et al, RIVM, 2006) to FCC 2008 Slaughter-Pig Cost of Illness Model**

| | RIVM Report | DALY- weighted Cost using RIVM data | | FCC Slaughter Pig 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 |

## 3.9 Results

The results of the modelling are presented in the following tables:

## Table 12. Results: Number of cases (all *Salmonella*)

| | Salmonella reported cases 2011 | 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 cases |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU-27 | 95548 | 19.0 | | 2.3 | 7.3 | 68.13% | 31.87% | 29.13% | 2.66% | 0.08% | 219,760 | 689,589 | 469,828 | 200,736 | 18,491 | 533 | 44.2 | 139 | 0.107 | 0.56% |
| Austria | 1433 | 17.1 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 3,296 | 10,604 | 7,308 | 3,011 | 277.3 | 8.0 | 39.6 | 127 | 0.096 | 0.56% |
| Belgium | 3177 | 28.9 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 7,307 | 23,510 | 16,203 | 6,675 | 614.8 | 17.7 | 68.5 | 220 | 0.166 | 0.56% |
| Bulgaria | 924 | 12.5 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 2,125 | 6,838 | 4,712 | 1,941 | 178.8 | 5.2 | 27.8 | 89 | 0.068 | 0.56% |
| Cyprus | 110 | 13.1 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 253 | 814 | 561 | 231 | 21.3 | 0.6 | 32.1 | 103 | 0.078 | 0.56% |
| Czech Republic | 8499 | 81.0 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 19,548 | 62,893 | 43,345 | 17,855 | 1644.8 | 47.4 | 188.3 | 606 | 0.457 | 0.56% |
| Denmark | 1170 | 21.0 | 1.0 | 2.3 | 8.3 | 72.29% | 27.71% | 25.31% | 2.33% | 0.07% | 2,691 | 9,711 | 7,020 | 2,458 | 226.4 | 6.5 | 49.1 | 177 | 0.119 | 0.56% |
| Estonia | 375 | 28.0 | 1.0 | 2.3 | 2.5 | 8.00% | 92.00% | 84.04% | 7.74% | 0.22% | 863 | 938 | 75 | 788 | 72.6 | 2.1 | 64.3 | 70 | 0.156 | 0.56% |
| Finland | 2082 | 38.7 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 4,789 | 15,407 | 10,618 | 4,374 | 402.9 | 11.6 | 90.3 | 291 | 0.219 | 0.56% |
| France | 8685 | 13.4 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 19,976 | 64,269 | 44,294 | 18,246 | 1680.8 | 48.5 | 31.2 | 100 | 0.076 | 0.56% |
| Germany | 23982 | 29.3 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 55,159 | 177,467 | 122,308 | 50,384 | 4641.2 | 133.9 | 67.1 | 216 | 0.163 | 0.56% |
| Greece | 469 | 4.1 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 1,079 | 3,471 | 2,392 | 985 | 90.8 | 2.6 | 9.6 | 31 | 0.023 | 0.56% |
| Hungary | 6169 | 61.8 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 14,189 | 45,651 | 31,462 | 12,960 | 1193.9 | 34.4 | 141.2 | 454 | 0.343 | 0.56% |
| Ireland | 311 | 6.8 | 1.0 | 2.3 | 8.0 | 71.25% | 28.75% | 26.26% | 2.42% | 0.07% | 715 | 2,488 | 1,773 | 653 | 60.2 | 1.7 | 16.3 | 57 | 0.039 | 0.56% |
| Italy | 3344 | 5.5 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 7,691 | 24,746 | 17,054 | 7,025 | 647.2 | 18.7 | 12.9 | 42 | 0.031 | 0.56% |
| Latvia | 998 | 48.1 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 2,295 | 7,385 | 5,090 | 2,097 | 193.1 | 5.6 | 101.1 | 325 | 0.245 | 0.56% |
| Lithuania | 2294 | 75.1 | 1.0 | 2.3 | 13.9 | 83.45% | 16.55% | 15.11% | 1.39% | 0.04% | 5,276 | 31,887 | 26,610 | 4,819 | 444.0 | 12.8 | 156.7 | 947 | 0.380 | 0.56% |
| Luxembourg | 125 | 24.4 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 288 | 925 | 638 | 263 | 24.2 | 0.7 | 59.4 | 191 | 0.144 | 0.56% |
| Malta | 129 | 31.0 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 297 | 955 | 658 | 271 | 25.0 | 0.7 | 72.3 | 233 | 0.176 | 0.56% |
| Netherlands | 1284 | 12.0 | 1.0 | 2.3 | 16.5 | 86.06% | 13.94% | 12.73% | 1.17% | 0.03% | 2,953 | 21,186 | 18,233 | 2,698 | 248.5 | 7.2 | 18.0 | 129 | 0.044 | 0.56% |
| Poland | 8400 | 21.8 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 19,320 | 62,160 | 42,840 | 17,647 | 1625.6 | 46.9 | 50.7 | 163 | 0.123 | 0.56% |
| Portugal | 174 | 1.6 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 400 | 1,288 | 887 | 366 | 33.7 | 1.0 | 3.8 | 12 | 0.009 | 0.56% |
| Romania | 989 | 4.6 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 2,275 | 7,319 | 5,044 | 2,078 | 191.4 | 5.5 | 10.6 | 34 | 0.026 | 0.56% |
| Slovakia | 3897 | 72.3 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 8,963 | 28,838 | 19,875 | 8,187 | 754.2 | 21.8 | 166.0 | 534 | 0.403 | 0.56% |
| Slovenia | 400 | 19.5 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 920 | 2,960 | 2,040 | 840 | 77.4 | 2.2 | 45.8 | 147 | 0.111 | 0.56% |
| Spain | 3786 | 32.8 | 1.0 | 2.3 | 7.4 | 68.92% | 31.08% | 28.39% | 2.62% | 0.08% | 8,708 | 28,016 | 19,309 | 7,954 | 732.7 | 21.1 | 19.2 | 62 | 0.047 | 0.56% |
| Sweden | 2887 | 30.7 | 1.0 | 2.3 | 6.1 | 62.30% | 37.70% | 34.44% | 3.17% | 0.09% | 6,640 | 17,611 | 10,971 | 6,065 | 558.7 | 16.1 | 72.3 | 192 | 0.176 | 0.56% |
| United Kingdom | 9455 | 15.1 | 1.0 | 2.3 | 3.2 | 28.13% | 71.88% | 65.65% | 6.05% | 0.17% | 21,747 | 30,256 | 8,510 | 19,864 | 1829.8 | 52.8 | 35.5 | 49 | 0.086 | 0.56% |

**Table 13. Total costs of all *Salmonella* infection**

TOTAL COSTS OF ALL SALMONELLA INFECTION

| | | 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 |
| EU 27 | 689,589 | € 35,858,909 | € 52 | € 7,508,116 | € 25.49 | € 2,629,019 | € 101.98 | € 9,793,549 | € 152.96 | € 48,364,884 | € 2,549.38 | € 340,659,122 | € 638,657 | € 444,813,599 | € 645 |
| Austria | 10,604 | € 814,216 | € 77 | € 164,744 | € 37.30 | € 57,686 | € 149.19 | € 214,891 | € 223.79 | € 1,061,228 | € 3,729.83 | € 7,474,785 | € 934,377 | € 9,787,551 | € 923 |
| Belgium | 23,510 | € 1,630,641 | € 69 | € 386,838 | € 39.50 | € 135,454 | € 158.01 | € 504,589 | € 237.02 | € 2,491,886 | € 3,950.36 | € 17,551,651 | € 989,624 | € 22,701,058 | € 966 |
| Bulgaria | 6,838 | € 40,481 | € 6 | € 10,108 | € 3.55 | € 3,539 | € 14.20 | € 13,185 | € 21.29 | € 65,113 | € 354.91 | € 458,625 | € 88,911 | € 591,051 | € 86 |
| Cyprus | 814 | € 39,942 | € 49 | € 8,193 | € 24.17 | € 2,869 | € 96.66 | € 10,687 | € 144.99 | € 52,779 | € 2,416.55 | € 371,750 | € 605,380 | € 486,221 | € 597 |
| Czech Republic | 62,893 | € 1,156,164 | € 18 | € 241,029 | € 9.20 | € 84,398 | € 36.80 | € 314,397 | € 55.20 | € 1,552,632 | € 920.08 | € 10,935,996 | € 230,494 | € 14,284,616 | € 227 |
| Denmark | 9,711 | € 938,298 | € 97 | € 159,877 | € 44.33 | € 55,982 | € 177.33 | € 208,542 | € 266.00 | € 1,029,874 | € 4,433.27 | € 7,253,943 | € 1,110,600 | € 9,646,515 | € 993 |
| Estonia | 938 | € 23,300 | € 25 | € 6,597 | € 5.71 | € 2,310 | € 22.83 | € 8,605 | € 34.24 | € 42,493 | € 570.71 | € 299,303 | € 142,971 | € 382,607 | € 408 |
| Finland | 15,407 | € 1,043,739 | € 68 | € 197,503 | € 30.78 | € 69,157 | € 123.11 | € 257,622 | € 184.66 | € 1,272,250 | € 3,077.64 | € 8,961,120 | € 770,994 | € 11,801,390 | € 766 |
| France | 64,269 | € 3,650,434 | € 57 | € 789,465 | € 29.49 | € 276,437 | € 117.96 | € 1,029,774 | € 176.95 | € 5,085,482 | € 2,949.09 | € 35,819,704 | € 738,791 | € 46,651,296 | € 726 |
| Germany | 177,467 | € 13,893,147 | € 78 | € 2,718,126 | € 36.77 | € 951,771 | € 147.09 | € 3,545,511 | € 220.63 | € 17,509,302 | € 3,677.14 | € 123,327,156 | € 921,176 | € 161,945,013 | € 913 |
| Greece | 3,471 | € 139,265 | € 40 | € 28,326 | € 19.59 | € 9,919 | € 78.38 | € 36,949 | € 117.57 | € 182,469 | € 1,959.49 | € 1,285,226 | € 490,881 | € 1,682,154 | € 485 |
| Hungary | 45,651 | € 674,467 | € 15 | € 161,817 | € 8.51 | € 56,661 | € 34.04 | € 211,074 | € 51.06 | € 1,042,375 | € 851.01 | € 7,341,992 | € 213,191 | € 9,488,387 | € 208 |
| Ireland | 2,488 | € 201,155 | € 81 | € 35,824 | € 37.37 | € 12,544 | € 149.49 | € 46,729 | € 224.23 | € 230,770 | € 3,737.18 | € 1,625,431 | € 936,219 | € 2,152,454 | € 865 |
| Italy | 24,746 | € 1,346,266 | € 54 | € 339,749 | € 32.96 | € 118,965 | € 131.85 | € 443,166 | € 197.77 | € 2,188,552 | € 3,296.22 | € 15,415,113 | € 825,752 | € 19,851,811 | € 802 |
| Latvia | 7,385 | € 116,072 | € 16 | € 20,081 | € 6.53 | € 7,031 | € 26.11 | € 26,193 | € 39.17 | € 129,355 | € 652.80 | € 911,112 | € 163,535 | € 1,209,844 | € 164 |
| Lithuania | 31,887 | € 301,240 | € 9 | € 38,717 | € 5.48 | € 13,557 | € 21.90 | € 50,503 | € 32.85 | € 249,405 | € 547.57 | € 1,756,688 | € 137,174 | € 2,410,111 | € 76 |
| Luxembourg | 925 | € 74,637 | € 81 | € 17,440 | € 45.26 | € 6,107 | € 181.06 | € 22,748 | € 271.59 | € 112,341 | € 4,526.43 | € 791,279 | € 1,133,937 | € 1,024,551 | € 1,108 |
| Malta | 955 | € 22,736 | € 24 | € 5,387 | € 13.55 | € 1,886 | € 54.19 | € 7,027 | € 81.29 | € 34,701 | € 1,354.80 | € 244,415 | € 339,397 | € 316,152 | € 331 |
| Netherlands | 21,186 | € 1,320,643 | € 62 | € 135,336 | € 34.20 | € 47,389 | € 136.78 | € 176,532 | € 205.18 | € 871,791 | € 3,419.59 | € 6,140,480 | € 856,656 | € 8,692,171 | € 410 |
| Poland | 62,160 | € 886,763 | € 14 | € 199,344 | € 7.70 | € 69,802 | € 30.80 | € 260,024 | € 46.20 | € 1,284,111 | € 769.93 | € 9,044,666 | € 192,878 | € 11,744,710 | € 189 |
| Portugal | 1,288 | € 40,796 | € 32 | € 7,782 | € 14.51 | € 2,725 | € 58.04 | € 10,150 | € 87.06 | € 50,126 | € 1,450.92 | € 353,066 | € 363,477 | € 464,646 | € 361 |
| Romania | 7,319 | € 70,244 | € 10 | € 15,954 | € 5.23 | € 5,586 | € 20.93 | € 20,811 | € 31.40 | € 102,772 | € 523.36 | € 723,876 | € 131,110 | € 939,244 | € 128 |
| Slovakia | 28,838 | € 432,898 | € 15 | € 90,056 | € 7.50 | € 31,534 | € 29.99 | € 117,468 | € 44.98 | € 580,111 | € 749.73 | € 4,086,023 | € 187,819 | € 5,338,090 | € 185 |
| Slovenia | 2,960 | € 44,573 | € 15 | € 8,454 | € 6.86 | € 2,960 | € 27.43 | € 11,028 | € 41.14 | € 54,459 | € 685.70 | € 383,582 | € 171,778 | € 505,055 | € 171 |
| Spain | 28,016 | € 1,217,041 | € 43 | € 246,189 | € 21.10 | € 86,205 | € 84.39 | € 321,128 | € 126.58 | € 1,585,873 | € 2,109.67 | € 11,170,134 | € 528,503 | € 14,626,571 | € 522 |
| Sweden | 17,611 | € 1,389,192 | € 79 | € 285,854 | € 32.12 | € 100,094 | € 128.49 | € 372,866 | € 192.74 | € 1,841,378 | € 3,212.35 | € 12,969,789 | € 804,740 | € 16,959,173 | € 963 |
| United Kingdom | 30,256 | € 4,350,559 | € 144 | € 1,189,325 | € 40.81 | € 416,451 | € 163.24 | € 1,551,350 | € 244.86 | € 7,661,255 | € 4,080.98 | € 53,962,219 | € 1,022,345 | € 69,131,159 | € 2,285 |

## Table 14. Total costs of *Salmonella* infection attributed to pork at 15%

**TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK**

**% Attribution 15%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 103,438 | € 5,378,836 | € 52 | € 1,126,217 | € 25 | € 394,353 | € 102 | € 1,469,032 | € 153 | € 7,254,733 | € 2,549.38 | € 51,098,868 | € 638,657 | € 66,722,040 | € 645 |
| Austria | 1,591 | € 122,132 | € 77 | € 24,712 | € 37 | € 8,653 | € 149 | € 32,234 | € 224 | € 159,184 | € 3,729.83 | € 1,121,218 | € 934,377 | € 1,468,133 | € 923 |
| Belgium | 3,526 | € 244,596 | € 69 | € 58,026 | € 40 | € 20,318 | € 158 | € 75,688 | € 237 | € 373,783 | € 3,950.36 | € 2,632,748 | € 989,624 | € 3,405,159 | € 966 |
| Bulgaria | 1,026 | € 6,072 | € 6 | € 1,516 | € 4 | € 531 | € 14 | € 1,978 | € 21 | € 9,767 | € 354.91 | € 68,794 | € 88,911 | € 88,658 | € 86 |
| Cyprus | 122 | € 5,991 | € 49 | € 1,229 | € 24 | € 430 | € 97 | € 1,603 | € 145 | € 7,917 | € 2,416.55 | € 55,763 | € 605,380 | € 72,933 | € 597 |
| Czech Republic | 9,434 | € 173,425 | € 18 | € 36,154 | € 9 | € 12,660 | € 37 | € 47,160 | € 55 | € 232,895 | € 920.08 | € 1,640,399 | € 230,494 | € 2,142,692 | € 227 |
| Denmark | 1,457 | € 140,745 | € 97 | € 23,981 | € 44 | € 8,397 | € 177 | € 31,281 | € 266 | € 154,481 | € 4,433.27 | € 1,088,091 | € 1,110,600 | € 1,446,977 | € 993 |
| Estonia | 141 | € 3,495 | € 25 | € 989 | € 6 | € 346 | € 23 | € 1,291 | € 34 | € 6,374 | € 570.71 | € 44,895 | € 142,971 | € 57,391 | € 408 |
| Finland | 2,311 | € 156,561 | € 68 | € 29,625 | € 31 | € 10,374 | € 123 | € 38,643 | € 185 | € 190,837 | € 3,077.64 | € 1,344,168 | € 770,994 | € 1,770,208 | € 766 |
| France | 9,640 | € 547,565 | € 57 | € 118,420 | € 29 | € 41,466 | € 118 | € 154,466 | € 177 | € 762,822 | € 2,949.09 | € 5,372,956 | € 738,791 | € 6,997,694 | € 726 |
| Germany | 26,620 | € 2,083,972 | € 78 | € 407,719 | € 37 | € 142,766 | € 147 | € 531,827 | € 221 | € 2,626,395 | € 3,677.14 | € 18,499,073 | € 921,176 | € 24,291,752 | € 913 |
| Greece | 521 | € 20,890 | € 40 | € 4,249 | € 20 | € 1,488 | € 78 | € 5,542 | € 118 | € 27,370 | € 1,959.49 | € 192,784 | € 490,881 | € 252,323 | € 485 |
| Hungary | 6,848 | € 101,170 | € 15 | € 24,273 | € 9 | € 8,499 | € 34 | € 31,661 | € 51 | € 156,356 | € 851.01 | € 1,101,299 | € 213,191 | € 1,423,258 | € 208 |
| Ireland | 373 | € 30,173 | € 81 | € 5,374 | € 37 | € 1,882 | € 149 | € 7,009 | € 224 | € 34,615 | € 3,737.18 | € 243,815 | € 936,219 | € 322,868 | € 865 |
| Italy | 3,712 | € 201,940 | € 54 | € 50,962 | € 33 | € 17,845 | € 132 | € 66,475 | € 198 | € 328,283 | € 3,296.22 | € 2,312,267 | € 825,752 | € 2,977,772 | € 802 |
| Latvia | 1,108 | € 17,411 | € 16 | € 3,012 | € 7 | € 1,055 | € 26 | € 3,929 | € 39 | € 19,403 | € 652.80 | € 136,667 | € 163,535 | € 181,477 | € 164 |
| Lithuania | 4,783 | € 45,186 | € 9 | € 5,808 | € 5 | € 2,034 | € 22 | € 7,575 | € 33 | € 37,411 | € 547.57 | € 263,503 | € 137,174 | € 361,517 | € 76 |
| Luxembourg | 139 | € 11,195 | € 81 | € 2,616 | € 45 | € 916 | € 181 | € 3,412 | € 272 | € 16,851 | € 4,526.43 | € 118,692 | € 1,133,937 | € 153,683 | € 1,108 |
| Malta | 143 | € 3,410 | € 24 | € 808 | € 14 | € 283 | € 54 | € 1,054 | € 81 | € 5,205 | € 1,354.80 | € 36,662 | € 339,397 | € 47,423 | € 331 |
| Netherlands | 3,178 | € 198,097 | € 62 | € 20,300 | € 34 | € 7,108 | € 137 | € 26,480 | € 205 | € 130,769 | € 3,419.59 | € 921,072 | € 856,656 | € 1,303,826 | € 410 |
| Poland | 9,324 | € 133,014 | € 14 | € 29,902 | € 8 | € 10,470 | € 31 | € 39,004 | € 46 | € 192,617 | € 769.93 | € 1,356,700 | € 192,878 | € 1,761,706 | € 189 |
| Portugal | 193 | € 6,119 | € 32 | € 1,167 | € 15 | € 409 | € 58 | € 1,523 | € 87 | € 7,519 | € 1,450.92 | € 52,960 | € 363,477 | € 69,697 | € 361 |
| Romania | 1,098 | € 10,537 | € 10 | € 2,393 | € 5 | € 838 | € 21 | € 3,122 | € 31 | € 15,416 | € 523.36 | € 108,581 | € 131,110 | € 140,887 | € 128 |
| Slovakia | 4,326 | € 64,935 | € 15 | € 13,508 | € 7 | € 4,730 | € 30 | € 17,620 | € 45 | € 87,017 | € 749.73 | € 612,903 | € 187,819 | € 800,713 | € 185 |
| Slovenia | 444 | € 6,686 | € 15 | € 1,268 | € 7 | € 444 | € 27 | € 1,654 | € 41 | € 8,169 | € 685.70 | € 57,537 | € 171,778 | € 75,758 | € 171 |
| Spain | 4,202 | € 182,556 | € 43 | € 36,928 | € 21 | € 12,931 | € 84 | € 48,169 | € 127 | € 237,881 | € 2,109.67 | € 1,675,520 | € 528,503 | € 2,193,986 | € 522 |
| Sweden | 2,642 | € 208,379 | € 79 | € 42,878 | € 32 | € 15,014 | € 128 | € 55,930 | € 193 | € 276,207 | € 3,212.35 | € 1,945,468 | € 804,740 | € 2,543,876 | € 963 |
| United Kingdom | 4,538 | € 652,584 | € 144 | € 178,399 | € 41 | € 62,468 | € 163 | € 232,703 | € 245 | € 1,149,188 | € 4,080.98 | € 8,094,333 | € 1,022,345 | € 10,369,674 | € 2,285 |

**Table 15. Total costs of *Salmonella* infection attributed to pork at 26.9%**

**TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK**

**% Attribution 26.9%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 185,499 | € 9,646,046 | € 52 | € 2,019,683 | € 25 | € 707,206 | € 102 | € 2,634,465 | € 153 | € 13,010,154 | € 2,549.38 | € 91,637,304 | € 638,657 | € 119,654,858 | € 645 |
| Austria | 2,853 | € 219,024 | € 77 | € 44,316 | € 37 | € 15,518 | € 149 | € 57,806 | € 224 | € 285,470 | € 3,729.83 | € 2,010,717 | € 934,377 | € 2,632,851 | € 923 |
| Belgium | 6,324 | € 438,642 | € 69 | € 104,059 | € 40 | € 36,437 | € 158 | € 135,735 | € 237 | € 670,317 | € 3,950.36 | € 4,721,394 | € 989,624 | € 6,106,585 | € 966 |
| Bulgaria | 1,839 | € 10,889 | € 6 | € 2,719 | € 4 | € 952 | € 14 | € 3,547 | € 21 | € 17,515 | € 354.91 | € 123,370 | € 88,911 | € 158,993 | € 86 |
| Cyprus | 219 | € 10,744 | € 49 | € 2,204 | € 24 | € 772 | € 97 | € 2,875 | € 145 | € 14,198 | € 2,416.55 | € 100,001 | € 605,380 | € 130,793 | € 597 |
| Czech Republic | 16,918 | € 311,008 | € 18 | € 64,837 | € 9 | € 22,703 | € 37 | € 84,573 | € 55 | € 417,658 | € 920.08 | € 2,941,783 | € 230,494 | € 3,842,562 | € 227 |
| Denmark | 2,612 | € 252,402 | € 97 | € 43,007 | € 44 | € 15,059 | € 177 | € 56,098 | € 266 | € 277,036 | € 4,433.27 | € 1,951,311 | € 1,110,600 | € 2,594,913 | € 993 |
| Estonia | 252 | € 6,268 | € 25 | € 1,774 | € 6 | € 621 | € 23 | € 2,315 | € 34 | € 11,431 | € 570.71 | € 80,512 | € 142,971 | € 102,921 | € 408 |
| Finland | 4,144 | € 280,766 | € 68 | € 53,128 | € 31 | € 18,603 | € 123 | € 69,300 | € 185 | € 342,235 | € 3,077.64 | € 2,410,541 | € 770,994 | € 3,174,574 | € 766 |
| France | 17,288 | € 981,967 | € 57 | € 212,366 | € 29 | € 74,361 | € 118 | € 277,009 | € 177 | € 1,367,995 | € 2,949.09 | € 9,635,500 | € 738,791 | € 12,549,199 | € 726 |
| Germany | 47,739 | € 3,737,256 | € 78 | € 731,176 | € 37 | € 256,026 | € 147 | € 953,742 | € 221 | € 4,710,002 | € 3,677.14 | € 33,175,005 | € 921,176 | € 43,563,208 | € 913 |
| Greece | 934 | € 37,462 | € 40 | € 7,620 | € 20 | € 2,668 | € 78 | € 9,939 | € 118 | € 49,084 | € 1,959.49 | € 345,726 | € 490,881 | € 452,499 | € 485 |
| Hungary | 12,280 | € 181,432 | € 15 | € 43,529 | € 9 | € 15,242 | € 34 | € 56,779 | € 51 | € 280,399 | € 851.01 | € 1,974,996 | € 213,191 | € 2,552,376 | € 208 |
| Ireland | 669 | € 54,111 | € 81 | € 9,637 | € 37 | € 3,374 | € 149 | € 12,570 | € 224 | € 62,077 | € 3,737.18 | € 437,241 | € 936,219 | € 579,010 | € 865 |
| Italy | 6,657 | € 362,146 | € 54 | € 91,392 | € 33 | € 32,002 | € 132 | € 119,212 | € 198 | € 588,720 | € 3,296.22 | € 4,146,665 | € 825,752 | € 5,340,137 | € 802 |
| Latvia | 1,987 | € 31,223 | € 16 | € 5,402 | € 7 | € 1,891 | € 26 | € 7,046 | € 39 | € 34,796 | € 652.80 | € 245,089 | € 163,535 | € 325,448 | € 164 |
| Lithuania | 8,577 | € 81,034 | € 9 | € 10,415 | € 5 | € 3,647 | € 22 | € 13,585 | € 33 | € 67,090 | € 547.57 | € 472,549 | € 137,174 | € 648,320 | € 76 |
| Luxembourg | 249 | € 20,077 | € 81 | € 4,691 | € 45 | € 1,643 | € 181 | € 6,119 | € 272 | € 30,220 | € 4,526.43 | € 212,854 | € 1,133,937 | € 275,604 | € 1,108 |
| Malta | 257 | € 6,116 | € 24 | € 1,449 | € 14 | € 507 | € 54 | € 1,890 | € 81 | € 9,334 | € 1,354.80 | € 65,748 | € 339,397 | € 85,045 | € 331 |
| Netherlands | 5,699 | € 355,253 | € 62 | € 36,405 | € 34 | € 12,748 | € 137 | € 47,487 | € 205 | € 234,512 | € 3,419.59 | € 1,651,789 | € 856,656 | € 2,338,194 | € 410 |
| Poland | 16,721 | € 238,539 | € 14 | € 53,624 | € 8 | € 18,777 | € 31 | € 69,946 | € 46 | € 345,426 | € 769.93 | € 2,433,015 | € 192,878 | € 3,159,327 | € 189 |
| Portugal | 346 | € 10,974 | € 32 | € 2,093 | € 15 | € 733 | € 58 | € 2,730 | € 87 | € 13,484 | € 1,450.92 | € 94,975 | € 363,477 | € 124,990 | € 361 |
| Romania | 1,969 | € 18,896 | € 10 | € 4,292 | € 5 | € 1,503 | € 21 | € 5,598 | € 31 | € 27,646 | € 523.36 | € 194,723 | € 131,110 | € 252,657 | € 128 |
| Slovakia | 7,757 | € 116,450 | € 15 | € 24,225 | € 7 | € 8,483 | € 30 | € 31,599 | € 45 | € 156,050 | € 749.73 | € 1,099,140 | € 187,819 | € 1,435,946 | € 185 |
| Slovenia | 796 | € 11,990 | € 15 | € 2,274 | € 7 | € 796 | € 27 | € 2,966 | € 41 | € 14,649 | € 685.70 | € 103,183 | € 171,778 | € 135,860 | € 171 |
| Spain | 7,536 | € 327,384 | € 43 | € 66,225 | € 21 | € 23,189 | € 84 | € 86,383 | € 127 | € 426,600 | € 2,109.67 | € 3,004,766 | € 528,503 | € 3,934,548 | € 522 |
| Sweden | 4,737 | € 373,693 | € 79 | € 76,895 | € 32 | € 26,925 | € 128 | € 100,301 | € 193 | € 495,331 | € 3,212.35 | € 3,488,873 | € 804,740 | € 4,562,018 | € 963 |
| United Kingdom | 8,139 | € 1,170,300 | € 144 | € 319,929 | € 41 | € 112,025 | € 163 | € 417,313 | € 245 | € 2,060,878 | € 4,080.98 | € 14,515,837 | € 1,022,345 | € 18,596,282 | € 2,285 |

**Table 16. Total costs of *Salmonella* infection attributed to pork at 35%**

TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK

**% Attribution 35%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 241,356 | € 12,550,618 | € 52 | € 2,627,840 | € 25 | € 920,157 | € 102 | € 3,427,742 | € 153 | € 16,927,709 | € 2,549.38 | € 119,230,693 | € 638,657 | € 155,684,760 | € 645 |
| Austria | 3,711 | € 284,976 | € 77 | € 57,660 | € 37 | € 20,190 | € 149 | € 75,212 | € 224 | € 371,430 | € 3,729.83 | € 2,616,175 | € 934,377 | € 3,425,643 | € 923 |
| Belgium | 8,228 | € 570,724 | € 69 | € 135,393 | € 40 | € 47,409 | € 158 | € 176,606 | € 237 | € 872,160 | € 3,950.36 | € 6,143,078 | € 989,624 | € 7,945,370 | € 966 |
| Bulgaria | 2,393 | € 14,168 | € 6 | € 3,538 | € 4 | € 1,239 | € 14 | € 4,615 | € 21 | € 22,790 | € 354.91 | € 160,519 | € 88,911 | € 206,868 | € 86 |
| Cyprus | 285 | € 13,980 | € 49 | € 2,868 | € 24 | € 1,004 | € 97 | € 3,741 | € 145 | € 18,473 | € 2,416.55 | € 130,113 | € 605,380 | € 170,177 | € 597 |
| Czech Republic | 22,012 | € 404,657 | € 18 | € 84,360 | € 9 | € 29,539 | € 37 | € 110,039 | € 55 | € 543,421 | € 920.08 | € 3,827,599 | € 230,494 | € 4,999,616 | € 227 |
| Denmark | 3,399 | € 328,404 | € 97 | € 55,957 | € 44 | € 19,594 | € 177 | € 72,990 | € 266 | € 360,456 | € 4,433.27 | € 2,538,880 | € 1,110,600 | € 3,376,280 | € 993 |
| Estonia | 328 | € 8,155 | € 25 | € 2,309 | € 6 | € 808 | € 23 | € 3,012 | € 34 | € 14,873 | € 570.71 | € 104,756 | € 142,971 | € 133,912 | € 408 |
| Finland | 5,392 | € 365,309 | € 68 | € 69,126 | € 31 | € 24,205 | € 123 | € 90,168 | € 185 | € 445,287 | € 3,077.64 | € 3,136,392 | € 770,994 | € 4,130,486 | € 766 |
| France | 22,494 | € 1,277,652 | € 57 | € 276,313 | € 29 | € 96,753 | € 118 | € 360,421 | € 177 | € 1,779,919 | € 2,949.09 | € 12,536,896 | € 738,791 | € 16,327,954 | € 726 |
| Germany | 62,113 | € 4,862,601 | € 78 | € 951,344 | € 37 | € 333,120 | € 147 | € 1,240,929 | € 221 | € 6,128,256 | € 3,677.14 | € 43,164,504 | € 921,176 | € 56,680,754 | € 913 |
| Greece | 1,215 | € 48,743 | € 40 | € 9,914 | € 20 | € 3,472 | € 78 | € 12,932 | € 118 | € 63,864 | € 1,959.49 | € 449,829 | € 490,881 | € 588,754 | € 485 |
| Hungary | 15,978 | € 236,063 | € 15 | € 56,636 | € 9 | € 19,832 | € 34 | € 73,876 | € 51 | € 364,831 | € 851.01 | € 2,569,697 | € 213,191 | € 3,320,935 | € 208 |
| Ireland | 871 | € 70,404 | € 81 | € 12,539 | € 37 | € 4,390 | € 149 | € 16,355 | € 224 | € 80,769 | € 3,737.18 | € 568,901 | € 936,219 | € 753,359 | € 865 |
| Italy | 8,661 | € 471,193 | € 54 | € 118,912 | € 33 | € 41,638 | € 132 | € 155,108 | € 198 | € 765,993 | € 3,296.22 | € 5,395,289 | € 825,752 | € 6,948,134 | € 802 |
| Latvia | 2,585 | € 40,625 | € 16 | € 7,028 | € 7 | € 2,461 | € 26 | € 9,168 | € 39 | € 45,274 | € 652.80 | € 318,889 | € 163,535 | € 423,445 | € 164 |
| Lithuania | 11,160 | € 105,434 | € 9 | € 13,551 | € 5 | € 4,745 | € 22 | € 17,676 | € 33 | € 87,292 | € 547.57 | € 614,841 | € 137,174 | € 843,539 | € 76 |
| Luxembourg | 324 | € 26,123 | € 81 | € 6,104 | € 45 | € 2,137 | € 181 | € 7,962 | € 272 | € 39,319 | € 4,526.43 | € 276,948 | € 1,133,937 | € 358,593 | € 1,108 |
| Malta | 334 | € 7,958 | € 24 | € 1,885 | € 14 | € 660 | € 54 | € 2,459 | € 81 | € 12,145 | € 1,354.80 | € 85,545 | € 339,397 | € 110,653 | € 331 |
| Netherlands | 7,415 | € 462,225 | € 62 | € 47,368 | € 34 | € 16,586 | € 137 | € 61,786 | € 205 | € 305,127 | € 3,419.59 | € 2,149,168 | € 856,656 | € 3,042,260 | € 410 |
| Poland | 21,756 | € 310,367 | € 14 | € 69,770 | € 8 | € 24,431 | € 31 | € 91,008 | € 46 | € 449,439 | € 769.93 | € 3,165,633 | € 192,878 | € 4,110,648 | € 189 |
| Portugal | 451 | € 14,279 | € 32 | € 2,724 | € 15 | € 954 | € 58 | € 3,553 | € 87 | € 17,544 | € 1,450.92 | € 123,573 | € 363,477 | € 162,626 | € 361 |
| Romania | 2,562 | € 24,586 | € 10 | € 5,584 | € 5 | € 1,955 | € 21 | € 7,284 | € 31 | € 35,970 | € 523.36 | € 253,357 | € 131,110 | € 328,735 | € 128 |
| Slovakia | 10,093 | € 151,514 | € 15 | € 31,520 | € 7 | € 11,037 | € 30 | € 41,114 | € 45 | € 203,039 | € 749.73 | € 1,430,108 | € 187,819 | € 1,868,331 | € 185 |
| Slovenia | 1,036 | € 15,600 | € 15 | € 2,959 | € 7 | € 1,036 | € 27 | € 3,860 | € 41 | € 19,061 | € 685.70 | € 134,254 | € 171,778 | € 176,769 | € 171 |
| Spain | 9,806 | € 425,964 | € 43 | € 86,166 | € 21 | € 30,172 | € 84 | € 112,395 | € 127 | € 555,056 | € 2,109.67 | € 3,909,547 | € 528,503 | € 5,119,300 | € 522 |
| Sweden | 6,164 | € 486,217 | € 79 | € 100,049 | € 32 | € 35,033 | € 128 | € 130,503 | € 193 | € 644,482 | € 3,212.35 | € 4,539,426 | € 804,740 | € 5,935,711 | € 963 |
| United Kingdom | 10,590 | € 1,522,695 | € 144 | € 416,264 | € 41 | € 145,758 | € 163 | € 542,973 | € 245 | € 2,681,439 | € 4,080.98 | € 18,886,776 | € 1,022,345 | € 24,195,905 | € 2,285 |

**Table 17. Total costs of *Salmonella* infection attributed to pork at 56.8%**

**TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK**

**% Attribution 56.8%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 391,686 | € 20,367,860 | € 52 | € 4,264,610 | € 25 | € 1,493,283 | € 102 | € 5,562,736 | € 153 | € 27,471,254 | € 2,549.38 | € 193,494,382 | € 638,657 | € 252,654,124 | € 645 |
| Austria | 6,023 | € 462,475 | € 77 | € 93,575 | € 37 | € 32,766 | € 149 | € 122,058 | € 224 | € 602,778 | € 3,729.83 | € 4,245,678 | € 934,377 | € 5,559,329 | € 923 |
| Belgium | 13,354 | € 926,204 | € 69 | € 219,724 | € 40 | € 76,938 | € 158 | € 286,607 | € 237 | € 1,415,391 | € 3,950.36 | € 9,969,338 | € 989,624 | € 12,894,201 | € 966 |
| Bulgaria | 3,884 | € 22,993 | € 6 | € 5,741 | € 4 | € 2,010 | € 14 | € 7,489 | € 21 | € 36,984 | € 354.91 | € 260,499 | € 88,911 | € 335,717 | € 86 |
| Cyprus | 462 | € 22,687 | € 49 | € 4,654 | € 24 | € 1,630 | € 97 | € 6,070 | € 145 | € 29,979 | € 2,416.55 | € 211,154 | € 605,380 | € 276,173 | € 597 |
| Czech Republic | 35,723 | € 656,701 | € 18 | € 136,904 | € 9 | € 47,938 | € 37 | € 178,578 | € 55 | € 881,895 | € 920.08 | € 6,211,646 | € 230,494 | € 8,113,662 | € 227 |
| Denmark | 5,516 | € 532,953 | € 97 | € 90,810 | € 44 | € 31,798 | € 177 | € 118,452 | € 266 | € 584,969 | € 4,433.27 | € 4,120,239 | € 1,110,600 | € 5,479,221 | € 993 |
| Estonia | 533 | € 13,234 | € 25 | € 3,747 | € 6 | € 1,312 | € 23 | € 4,887 | € 34 | € 24,136 | € 570.71 | € 170,004 | € 142,971 | € 217,321 | € 408 |
| Finland | 8,751 | € 592,844 | € 68 | € 112,182 | € 31 | € 39,281 | € 123 | € 146,329 | € 185 | € 722,638 | € 3,077.64 | € 5,089,916 | € 770,994 | € 6,703,189 | € 766 |
| France | 36,505 | € 2,073,447 | € 57 | € 448,416 | € 29 | € 157,016 | € 118 | € 584,912 | € 177 | € 2,888,554 | € 2,949.09 | € 20,345,592 | € 738,791 | € 26,497,936 | € 726 |
| Germany | 100,801 | € 7,891,307 | € 78 | € 1,543,896 | € 37 | € 540,606 | € 147 | € 2,013,850 | € 221 | € 9,945,284 | € 3,677.14 | € 70,049,824 | € 921,176 | € 91,984,767 | € 913 |
| Greece | 1,971 | € 79,103 | € 40 | € 16,089 | € 20 | € 5,634 | € 78 | € 20,987 | € 118 | € 103,642 | € 1,959.49 | € 730,008 | € 490,881 | € 955,463 | € 485 |
| Hungary | 25,930 | € 383,097 | € 15 | € 91,912 | € 9 | € 32,184 | € 34 | € 119,890 | € 51 | € 592,069 | € 851.01 | € 4,170,251 | € 213,191 | € 5,389,404 | € 208 |
| Ireland | 1,413 | € 114,256 | € 81 | € 20,348 | € 37 | € 7,125 | € 149 | € 26,542 | € 224 | € 131,077 | € 3,737.18 | € 923,245 | € 936,219 | € 1,222,594 | € 865 |
| Italy | 14,056 | € 764,679 | € 54 | € 192,977 | € 33 | € 67,572 | € 132 | € 251,718 | € 198 | € 1,243,097 | € 3,296.22 | € 8,755,784 | € 825,752 | € 11,275,829 | € 802 |
| Latvia | 4,195 | € 65,929 | € 16 | € 11,406 | € 7 | € 3,994 | € 26 | € 14,878 | € 39 | € 73,473 | € 652.80 | € 517,511 | € 163,535 | € 687,191 | € 164 |
| Lithuania | 18,112 | € 171,104 | € 9 | € 21,991 | € 5 | € 7,700 | € 22 | € 28,686 | € 33 | € 141,662 | € 547.57 | € 997,799 | € 137,174 | € 1,368,943 | € 76 |
| Luxembourg | 525 | € 42,394 | € 81 | € 9,906 | € 45 | € 3,469 | € 181 | € 12,921 | € 272 | € 63,810 | € 4,526.43 | € 449,446 | € 1,133,937 | € 581,945 | € 1,108 |
| Malta | 542 | € 12,914 | € 24 | € 3,060 | € 14 | € 1,071 | € 54 | € 3,991 | € 81 | € 19,710 | € 1,354.80 | € 138,828 | € 339,397 | € 179,574 | € 331 |
| Netherlands | 12,034 | € 750,125 | € 62 | € 76,871 | € 34 | € 26,917 | € 137 | € 100,270 | € 205 | € 495,177 | € 3,419.59 | € 3,487,793 | € 856,656 | € 4,937,153 | € 410 |
| Poland | 35,307 | € 503,681 | € 14 | € 113,227 | € 8 | € 39,647 | € 31 | € 147,693 | € 46 | € 729,375 | € 769.93 | € 5,137,370 | € 192,878 | € 6,670,995 | € 189 |
| Portugal | 731 | € 23,172 | € 32 | € 4,420 | € 15 | € 1,548 | € 58 | € 5,765 | € 87 | € 28,472 | € 1,450.92 | € 200,542 | € 363,477 | € 263,919 | € 361 |
| Romania | 4,157 | € 39,899 | € 10 | € 9,062 | € 5 | € 3,173 | € 21 | € 11,820 | € 31 | € 58,374 | € 523.36 | € 411,162 | € 131,110 | € 533,491 | € 128 |
| Slovakia | 16,380 | € 245,886 | € 15 | € 51,152 | € 7 | € 17,911 | € 30 | € 66,722 | € 45 | € 329,503 | € 749.73 | € 2,320,861 | € 187,819 | € 3,032,035 | € 185 |
| Slovenia | 1,681 | € 25,317 | € 15 | € 4,802 | € 7 | € 1,681 | € 27 | € 6,264 | € 41 | € 30,933 | € 685.70 | € 217,874 | € 171,778 | € 286,871 | € 171 |
| Spain | 15,913 | € 691,279 | € 43 | € 139,836 | € 21 | € 48,964 | € 84 | € 182,401 | € 127 | € 900,776 | € 2,109.67 | € 6,344,636 | € 528,503 | € 8,307,892 | € 522 |
| Sweden | 10,003 | € 789,061 | € 79 | € 162,365 | € 32 | € 56,853 | € 128 | € 211,788 | € 193 | € 1,045,903 | € 3,212.35 | € 7,366,840 | € 804,740 | € 9,632,810 | € 963 |
| United Kingdom | 17,185 | € 2,471,117 | € 144 | € 675,537 | € 41 | € 236,544 | € 163 | € 881,167 | € 245 | € 4,351,593 | € 4,080.98 | € 30,650,540 | € 1,022,345 | € 39,266,498 | € 2,285 |

## 3.10 Summary of human health impact

- Incidence of salmonellosis in humans has reduced by 27% in three years
- Germany accounts for over half of this reduction
- EFSA associates the improvement across EU-27 with successful *Salmonella* control programmes in poultry and eggs
- S. enteritidis has reduced (by 5.7%) while S. typhimurium has increased slightly (by 1.2%) between 2010 and 2011
- The cost of illness model has been updated in the following way: (1) incidence of salmonellosis in humans; (2) indexing costs for inflation; (3) revised attribution percentages. The structure and underlying assumptions in the model have remained unchanged. Of the three changes, attribution has the greatest impact.
- Four attribution assumptions are used:
  - 15% as in the breeding pig model
  - 29.6% (Pires et al, 2011)
  - 35% as in the annex to the breeding pig model
  - 56.8% (Hald et al, 2012)
- EFSA (2012) has incorporated 58.6% into its BIOHAZ Scientific Opinion, based on Hald et al (2012)
- Hald et al (2012) themselves are cautious about potential strength and application of their results, since their mathematical model is not tested by empirical observation.
- Hald et al (2012) apply a community multiplier, labelled 'under-reporting factor' of 60, ranging from 0.4 in Finland to 2084 in Portugal. The implication is that five million people annually suffer from salmonellosis in the EU annually. We are concerned that this may significantly overestimate the true burden of disease. The under-reporting factor predicts that 9%, 7% and 5% of the population in Bulgaria, Malta and Greece respectively will contract salmonellosis per year. This is a very high forecast, especially when we consider that salmonellosis ranks second to campylobacteriosis, which has more than twice as many reported human cases annually in EU-27, and also when we note that viral forms of infectious intestinal disease, e.g. norovirus, may be greater public health risks than bacterial sources of IID.
- The implication in our opinion is that the model generated by Hald et al (2012) needs to be tested empirically. Nevertheless, given the status of the pork- attribution of 56.8% accorded by EFSA, we have included the figure in our modelling.
- Costs saved by reducing all pig/pork sourced *Salmonella* cases in humans (compared to 2008 figure of € 86m at € 600 per case based on 15% attribution):
  - cost per case rose to € 645 per case (based on 7.5% inflation, which was lower than overall inflation because of reduction in high cost countries, in particular Germany)
  - Attribution 15% = € 67 million cost; (compare to € 86m based on 2008)
  - Attribution 29.6% = € 132 million cost;
  - Attribution 35% = € 156 million cost;
  - Attribution 56.8% = € 253 million cost.

## 3.11 Summary of model - cost of salmonellosis in humans

The model estimates the cost of human salmonellosis caused by pork and pork products. It uses a cost of illness approach, expressing the cost per case in Euros for each EU-27 Member State. It updates previous work based on 2008 data, using data from 2011, which is the most recently published period.

**Table 18. Summary of model - cost of salmonellosis in humans**

| ***Salmonella* in Humans** | |
|---|---|
| The structure of the model remains unchanged:<br>▪ Total Number of Cases (Module 1)<br>- Pyramid of illness<br>- Incidence<br>- Outcome severity: (1) cases do not see a GP (mild); (2) see a GP but not hospitalised (medium); (3) see a GP and hospitalised (severe); (4) see a GP and died<br>▪ Productivity Costs (Module 2)<br>- Labour market cost and participation<br>- Days absent from work by outcome severity<br>▪ Healthcare utilisation costs (Module 3)<br>- GP visit<br>- Emergency department<br>- Outpatients<br>- Hospital admission<br>▪ Premature death (Module 4)<br>▪ Total costs (Module 5)<br>▪ Attribution to pork (Module 6)<br>- Cases and costs associated with pork | The cost of illness approach assembles an economic inventory of costs.<br>▪ Total number of cases is updated from 131 468 reported cases in 2008 to 95 548 in 2011. This is a 27% drop in reported cases over the period. 53% of the 36 000 drop took place in Germany where reported cases reduced by 19 000.<br>▪ The pyramid of illness assumptions remain constant (with an average community multiplier of 7.3 cases and 2.3 presenting to the GP per 1 reported case); total estimated cases falls from 955 784 in 2008 to 689 589 in 2011.<br>▪ Severity mix retained<br>▪ Productivity has been updated by applying movement in labour costs 2008-2011, based on Eurostat Labour Cost Index. There is an estimated 11% average increase in labour costs over the period.<br>▪ A 20% increase in notional healthcare utilisation costs has been applied (the model is not sensitive to this assumption)<br>▪ Premature death costs are linked to wage inflation<br>▪ Attribution of S. to pork has increased according to recent studies. Four attribution rates are considered:<br>- 15% (as in previous study) \| 29.6% \| 35% \| 56.8%<br>▪ Total costs of salmonellosis are estimated to have dropped by 22% due to morbidity (incidence). Attribution assumptions mean that costs of illness associated with pigs have risen. |
| **Costs saved by reducing all pig/pork sourced *Salmonella* cases in humans** (compared to 2008 figure of € 86m at € 600 per case based on 15% attribution)<br>▪ cost per case rose to € 645 per case (7.5% inflation lower than overall inflation, because of reduction in high cost countries, in particular Germany)<br>▪ Attribution 15% = € 67 million cost \| Attribution 29.6% = € 132 million cost \| Attribution 35% = € 156 million cost \| Attribution 56.8% = € 253 million cost | |

**Table 19. Summary of incidence and costs for human salmonellosis**

| | Salmonella reported cases 2011 | Incidence Report Cases per 100,000 Population | Attribution 15% | Attribution 29.6% | Attribution 35% | Pig & Pork Attribution 56.8% | Cost per Case |
|---|---|---|---|---|---|---|---|
| EU 27 | 95548 | 19.0 | € 66,722,040 | € 131,664,825 | € 155,684,760 | € 252,654,124 | € 645 |
| Austria | 1433 | 17.1 | € 1,468,133 | € 2,897,115 | € 3,425,643 | € 5,559,329 | € 923 |
| Belgium | 3177 | 28.9 | € 3,405,159 | € 6,719,513 | € 7,945,370 | € 12,894,201 | € 966 |
| Bulgaria | 924 | 12.5 | € 88,658 | € 174,951 | € 206,868 | € 335,717 | € 86 |
| Cyprus | 110 | 13.1 | € 72,933 | € 143,921 | € 170,177 | € 276,173 | € 597 |
| Czech Republic | 8499 | 81.0 | € 2,142,692 | € 4,228,246 | € 4,999,616 | € 8,113,662 | € 227 |
| Denmark | 1170 | 21.0 | € 1,446,977 | € 2,855,369 | € 3,376,280 | € 5,479,221 | € 993 |
| Estonia | 375 | 28.0 | € 57,391 | € 113,252 | € 133,912 | € 217,321 | € 408 |
| Finland | 2082 | 38.7 | € 1,770,208 | € 3,493,211 | € 4,130,486 | € 6,703,189 | € 766 |
| France | 8685 | 13.4 | € 6,997,694 | € 13,808,784 | € 16,327,954 | € 26,497,936 | € 726 |
| Germany | 23982 | 29.3 | € 24,291,752 | € 47,935,724 | € 56,680,754 | € 91,984,767 | € 913 |
| Greece | 469 | 4.1 | € 252,323 | € 497,918 | € 588,754 | € 955,463 | € 485 |
| Hungary | 6169 | 61.8 | € 1,423,258 | € 2,808,562 | € 3,320,935 | € 5,389,404 | € 208 |
| Ireland | 311 | 6.8 | € 322,868 | € 637,126 | € 753,359 | € 1,222,594 | € 865 |
| Italy | 3344 | 5.5 | € 2,977,772 | € 5,876,136 | € 6,948,134 | € 11,275,829 | € 802 |
| Latvia | 998 | 48.1 | € 181,477 | € 358,114 | € 423,445 | € 687,191 | € 164 |
| Lithuania | 2294 | 75.1 | € 361,517 | € 713,393 | € 843,539 | € 1,368,943 | € 76 |
| Luxembourg | 125 | 24.4 | € 153,683 | € 303,267 | € 358,593 | € 581,945 | € 1,108 |
| Malta | 129 | 31.0 | € 47,423 | € 93,581 | € 110,653 | € 179,574 | € 331 |
| Netherlands | 1284 | 12.0 | € 1,303,826 | € 2,572,883 | € 3,042,260 | € 4,937,153 | € 410 |
| Poland | 8400 | 21.8 | € 1,761,706 | € 3,476,434 | € 4,110,648 | € 6,670,995 | € 189 |
| Portugal | 174 | 1.6 | € 69,697 | € 137,535 | € 162,626 | € 263,919 | € 361 |
| Romania | 989 | 4.6 | € 140,887 | € 278,016 | € 328,735 | € 533,491 | € 128 |
| Slovakia | 3897 | 72.3 | € 800,713 | € 1,580,075 | € 1,868,331 | € 3,032,035 | € 185 |
| Slovenia | 400 | 19.5 | € 75,758 | € 149,496 | € 176,769 | € 286,871 | € 171 |
| Spain | 3786 | 32.8 | € 2,193,986 | € 4,329,465 | € 5,119,300 | € 8,307,892 | € 522 |
| Sweden | 2887 | 30.7 | € 2,543,876 | € 5,019,915 | € 5,935,711 | € 9,632,810 | € 963 |
| United Kingdom | 9455 | 15.1 | € 10,369,674 | € 20,462,823 | € 24,195,905 | € 39,266,498 | € 2,285 |

## 3.12 Sensitivity to alternative multiplier assumptions – extra scenario

We add a further scenario (entitled 'extra scenario') to extend the impact of the Hald et al (2012) model. So far we have applied the higher attribution factor of 56.8% (above) which is nearly quadruple the 15% used in our earlier studies and supported by EFSA (2008) and QMRA (2009) evidence.

In this extra scenario we change the drivers of the model by using the following assumptions:

- change the 'community multiplier' or 'under-reporting factor' from the 7.3 average applied in previous work to the higher figures based on an average multiplier of 60:1:
  - the effect is to raise the number of community cases in all but six countries;
- change fatalities from 0.08% of all cases[12] to 0.12% of confirmed cases (EFSA 2013, p20):

[12] This was derived from assumptions in earlier stages of the Cost of Illness model. The audit trail is as follows: (a) the United States Department of Agriculture applied a rate of 0.03% died, equivalent to 1 in 412 cases that reported to the general practitioner; (b) we maintained this relationship with GP cases, giving equivalence of 0.05% total cases died; (c) a subsequent adjustment to the model raised this to 0.08% of total cases. This rate of 0.08% total cases in the community (reported+unreported) is equivalent to 0.56% of reported confirmed cases. It is higher than published fatality rates.

- here the driver of the model changes from 'all community cases' to 'reported' or 'confirmed' cases
- this change was necessary to avoid the anomalous result where the number of deaths from *Salmonella* exceeded the number of notified confirmed cases of salmonellosis in countries where the community multiplier was very high;
- the effect of applying 0.12% is to reduce fatalities from 533 to 115[13];

- Change the hospitalisation rate from an average of 2.66% of all cases to 45.7% of confirmed cases (EFSA 2013, p20)
- Retain the multiplier of 2.3 cases visiting the GP for every 1 confirmed reported case, or use the under-reporting factor where this is below 2.3

The overall effect of the changes in the extra scenario is to:

a) reduce the total cost of salmonellosis in the human population by 28% from € 444 813 599 to €318 817 901:
   - because the number of fatalities reduced;

b) reduce the unit cost from €645 to €56 per case:
   - because the severity weighting has reduced (since the total number of cases increased while fatalities reduced);

c) value the pork-attributed salmonellosis at € 181 088 568:
   - using attribution of 56.8%.

This extra scenario suggests that the Hald et al (2012) model is consistent with a range of off-setting assumptions: volume of salmonellosis cases in the human population rises, but number of fatalities reduces (to retain coherent assumptions). Attribution of 56.8% is consistent with a cost of illness across EU-27 of € 181 088 568. (These lower costs are presented as part of the sensitivity analysis; higher costs based on pro rata attribution in Table 19 are applied in the cost benefit analysis).

A further variant on this scenario, retaining fatalities at 533, estimates cost per case at € 103 and total costs of illness due to pork consumption at € 333,572,583. A table of summary costs is included for completeness.

This sensitivity analysis shows that assumptions relating to fatalities and statistical value of life can have a marked impact on results. We have noted that our model contains a high number of fatalities compared to published rates and that studies (e.g. Santos et al, 2010) that exclude cost of death produce lower unit costs of illness. The sensitivity analysis is illustrative and has not been factored into the cost benefit analysis.

[13] This reduction from 533 to 115 estimated fatalities may seem counter-intuitive. It is a consequence of amending the structure of the model to accommodate a higher under-reporting factor, applying published fatality rates to reported confirmed cases. 533 exceeds the published level of fatalities. In 2009, for example, when reported cases for salmonellosis was 14% higher at 108,614, the EFSA Journal 2011 reported that there were an estimated 90 deaths due to salmonellosis (based on reported fatality rates and reported confirmed cases).

**Table 20. Number of Cases in Extra Scenario**

| | Salmonella reported cases 2011 | Incidence Report Cases per 100,000 Population 2008 | Reported cases | Presenting to GP | Community Cases | % of Cases Hospitalised Severity 3 OF CONFIRMED CASES | % fatality Severity 4 OF CONFIRMED CASES | Estimated cases presenting to GP | Estimated Cases in Community | Estimated cases in community who did not present to GP | Visited GP and survived | Hospital Cases | Fatalities | Community Incidence per 100,000 Pop |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EU 27 | 95548 | 19.0 | | | 59.5 | 45.70% | 0.12% | 210,608 | 5,680,419 | 5,469,811 | 166,828 | 43,665 | 115 | 1141 |
| Austria | 1433 | 17.1 | 1.0 | 2.3 | 11.0 | 45.70% | 0.12% | 3,296 | 15,763 | 12,467 | 2,639 | 654.9 | 1.7 | 189 |
| Belgium | 3177 | 28.9 | 1.0 | 2.3 | 3.5 | 45.70% | 0.12% | 7,307 | 11,120 | 3,812 | 5,851 | 1451.9 | 3.8 | 104 |
| Bulgaria | 924 | 12.5 | 1.0 | 2.3 | 718.4 | 45.70% | 0.12% | 2,125 | 663,802 | 661,676 | 1,702 | 422.3 | 1.1 | 8688 |
| Cyprus | 110 | 13.1 | 1.0 | 2.3 | 173.3 | 45.70% | 0.12% | 253 | 19,063 | 18,810 | 203 | 50.3 | 0.1 | 2415 |
| Czech Republic | 8499 | 81.0 | 1.0 | 2.3 | 28.9 | 45.70% | 0.12% | 19,548 | 245,621 | 226,073 | 15,653 | 3884.0 | 10.2 | 2366 |
| Denmark | 1170 | 21.0 | 1.0 | 2.3 | 4.4 | 45.70% | 0.12% | 2,691 | 5,148 | 2,457 | 2,155 | 534.7 | 1.4 | 94 |
| Estonia | 375 | 28.0 | 1.0 | 2.3 | 16.9 | 45.70% | 0.12% | 863 | 6,338 | 5,475 | 691 | 171.4 | 0.5 | 473 |
| Finland | 2082 | 38.7 | 1.0 | 0.4 | 0.4 | 45.70% | 0.12% | 833 | 833 | 0 | -121 | 951.5 | 2.5 | 16 |
| France | 8685 | 13.4 | 1.0 | 2.3 | 26.9 | 45.70% | 0.12% | 19,976 | 233,627 | 213,651 | 15,996 | 3969.0 | 10.4 | 365 |
| Germany | 23982 | 29.3 | 1.0 | 2.3 | 9.8 | 45.70% | 0.12% | 55,159 | 235,024 | 179,865 | 44,170 | 10959.8 | 28.8 | 286 |
| Greece | 469 | 4.1 | 1.0 | 2.3 | 1229.0 | 45.70% | 0.12% | 1,079 | 576,401 | 575,322 | 864 | 214.3 | 0.6 | 5140 |
| Hungary | 6169 | 61.8 | 1.0 | 2.3 | 66.8 | 45.70% | 0.12% | 14,189 | 412,089 | 397,901 | 11,362 | 2819.2 | 7.4 | 4102 |
| Ireland | 311 | 6.8 | 1.0 | 2.3 | 5.4 | 45.70% | 0.12% | 715 | 1,679 | 964 | 573 | 142.1 | 0.4 | 38 |
| Italy | 3344 | 5.5 | 1.0 | 2.3 | 71.8 | 45.70% | 0.12% | 7,691 | 240,099 | 232,408 | 6,159 | 1528.2 | 4.0 | 403 |
| Latvia | 998 | 48.1 | 1.0 | 2.3 | 44.3 | 45.70% | 0.12% | 2,295 | 44,211 | 41,916 | 1,838 | 456.1 | 1.2 | 1947 |
| Lithuania | 2294 | 75.1 | 1.0 | 2.3 | 59.1 | 45.70% | 0.12% | 5,276 | 135,575 | 130,299 | 4,225 | 1048.4 | 2.8 | 4027 |
| Luxembourg | 125 | 24.4 | 1.0 | 2.3 | 4.4 | 45.70% | 0.12% | 288 | 550 | 263 | 230 | 57.1 | 0.2 | 114 |
| Malta | 129 | 31.0 | 1.0 | 2.3 | 222.6 | 45.70% | 0.12% | 297 | 28,715 | 28,419 | 238 | 59.0 | 0.2 | 6999 |
| Netherlands | 1284 | 12.0 | 1.0 | 2.3 | 26.2 | 45.70% | 0.12% | 2,953 | 33,641 | 30,688 | 2,365 | 586.8 | 1.5 | 205 |
| Poland | 8400 | 21.8 | 1.0 | 2.3 | 114.0 | 45.70% | 0.12% | 19,320 | 957,600 | 938,280 | 15,471 | 3838.8 | 10.1 | 2512 |
| Portugal | 174 | 1.6 | 1.0 | 2.3 | 2084.0 | 45.70% | 0.12% | 400 | 362,616 | 362,216 | 320 | 79.5 | 0.2 | 3415 |
| Romania | 989 | 4.6 | 1.0 | 2.3 | 350.2 | 45.70% | 0.12% | 2,275 | 346,348 | 344,073 | 1,822 | 452.0 | 1.2 | 1609 |
| Slovakia | 3897 | 72.3 | 1.0 | 2.3 | 53.1 | 45.70% | 0.12% | 8,963 | 206,931 | 197,968 | 7,177 | 1780.9 | 4.7 | 3831 |
| Slovenia | 400 | 19.5 | 1.0 | 2.3 | 40.5 | 45.70% | 0.12% | 920 | 16,200 | 15,280 | 737 | 182.8 | 0.5 | 806 |
| Spain | 3786 | 32.8 | 1.0 | 2.3 | 214.2 | 45.70% | 0.12% | 8,708 | 810,961 | 802,253 | 6,973 | 1730.2 | 4.5 | 1791 |
| Sweden | 2887 | 30.7 | 1.0 | 0.5 | 0.5 | 45.70% | 0.12% | 1,444 | 1,444 | 0 | 121 | 1319.4 | 3.5 | 16 |
| United Kingdom | 9455 | 15.1 | 1.0 | 2.3 | 7.3 | 45.70% | 0.12% | 21,747 | 69,022 | 47,275 | 17,414 | 4320.9 | 11.3 | 113 |

**Table 21. Total Cost of All *Salmonella* in Extra Scenario**

TOTAL COSTS OF ALL SALMONELLA INFECTION- ADJUSTED FOR HALD ET AL (2012) UNDER-REPORTING, HOSPITALISATION AND DEATHS

| | | 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 |
| EU 27 | 5,680,419 | € 115,435,404 | € 20 | € 6,658,985 | € 25.20 | € 3,018,438 | € 101.23 | € 8,895,261 | € 151.27 | € 111,582,913 | € 2,549.38 | € 73,226,900 | € 638,657 | € 318,817,901 | € 56 |
| Austria | 15,763 | € 1,137,728 | € 72 | € 154,980 | € 37.30 | € 68,765 | € 149.19 | € 206,583 | € 223.79 | € 2,448,366 | € 3,729.83 | € 1,606,754 | € 934,377 | € 5,623,176 | € 357 |
| Belgium | 11,120 | € 1,270,749 | € 114 | € 363,911 | € 39.50 | € 161,467 | € 158.01 | € 485,079 | € 237.02 | € 5,749,044 | € 3,950.36 | € 3,772,842 | € 989,624 | € 11,803,093 | € 1,061 |
| Bulgaria | 663,802 | € 2,661,636 | € 4 | € 9,509 | € 3.55 | € 4,219 | € 14.20 | € 12,675 | € 21.29 | € 150,223 | € 354.91 | € 98,584 | € 88,911 | € 2,936,846 | € 4 |
| Cyprus | 19,063 | € 600,252 | € 31 | € 7,708 | € 24.17 | € 3,420 | € 96.66 | € 10,274 | € 144.99 | € 121,767 | € 2,416.55 | € 79,910 | € 605,380 | € 823,331 | € 43 |
| Czech Republic | 245,621 | € 3,308,358 | € 13 | € 226,744 | € 9.20 | € 100,606 | € 36.80 | € 302,241 | € 55.20 | € 3,582,086 | € 920.08 | € 2,350,764 | € 230,494 | € 9,870,799 | € 40 |
| Denmark | 5,148 | € 770,357 | € 150 | € 150,401 | € 44.33 | € 66,733 | € 177.33 | € 200,479 | € 266.00 | € 2,376,029 | € 4,433.27 | € 1,559,282 | € 1,110,600 | € 5,123,282 | € 995 |
| Estonia | 6,338 | € 65,929 | € 10 | € 6,206 | € 5.71 | € 2,753 | € 22.83 | € 8,272 | € 34.24 | € 98,037 | € 570.71 | € 64,337 | € 142,971 | € 245,534 | € 39 |
| Finland | 833 | € 296,638 | € 356 | € 15,354 | € 30.78 | € 33,740 | € 123.11 | € 28,519 | € 184.66 | € 2,935,215 | € 3,077.64 | € 1,926,251 | € 770,994 | € 5,235,718 | € 6,287 |
| France | 233,627 | € 9,611,227 | € 41 | € 742,676 | € 29.49 | € 329,525 | € 117.96 | € 989,958 | € 176.95 | € 11,732,746 | € 2,949.09 | € 7,699,679 | € 738,791 | € 31,105,811 | € 133 |
| Germany | 235,024 | € 17,992,568 | € 77 | € 2,557,032 | € 36.77 | € 1,134,554 | € 147.09 | € 3,408,423 | € 220.63 | € 40,395,816 | € 3,677.14 | € 26,509,976 | € 921,176 | € 91,998,370 | € 391 |
| Greece | 576,401 | € 12,540,400 | € 22 | € 26,648 | € 19.59 | € 11,823 | € 78.38 | € 35,520 | € 117.57 | € 420,976 | € 1,959.49 | € 276,268 | € 490,881 | € 13,311,635 | € 23 |
| Hungary | 412,089 | € 3,940,801 | € 10 | € 152,227 | € 8.51 | € 67,543 | € 34.04 | € 202,912 | € 51.06 | € 2,404,870 | € 851.01 | € 1,578,209 | € 213,191 | € 8,346,563 | € 20 |
| Ireland | 1,679 | € 185,812 | € 111 | € 33,701 | € 37.37 | € 14,953 | € 149.49 | € 44,922 | € 224.23 | € 532,410 | € 3,737.18 | € 349,397 | € 936,219 | € 1,161,196 | € 691 |
| Italy | 240,099 | € 8,714,365 | € 36 | € 319,613 | € 32.96 | € 141,812 | € 131.85 | € 426,031 | € 197.77 | € 5,049,221 | € 3,296.22 | € 3,313,579 | € 825,752 | € 17,964,621 | € 75 |
| Latvia | 44,211 | € 438,821 | € 10 | € 18,891 | € 6.53 | € 8,382 | € 26.11 | € 25,181 | € 39.17 | € 298,435 | € 652.80 | € 195,849 | € 163,535 | € 985,559 | € 22 |
| Lithuania | 135,575 | € 980,409 | € 7 | € 36,423 | € 5.48 | € 16,161 | € 21.90 | € 48,550 | € 32.85 | € 575,403 | € 547.57 | € 377,612 | € 137,174 | € 2,034,557 | € 15 |
| Luxembourg | 550 | € 63,597 | € 116 | € 16,406 | € 45.26 | € 7,279 | € 181.06 | € 21,869 | € 271.59 | € 259,183 | € 4,526.43 | € 170,091 | € 1,133,937 | € 538,425 | € 979 |
| Malta | 28,715 | € 400,951 | € 14 | € 5,068 | € 13.55 | € 2,249 | € 54.19 | € 6,755 | € 81.29 | € 80,058 | € 1,354.80 | € 52,539 | € 339,397 | € 547,619 | € 19 |
| Netherlands | 33,641 | € 1,968,956 | € 59 | € 127,315 | € 34.20 | € 56,490 | € 136.78 | € 169,706 | € 205.18 | € 2,011,315 | € 3,419.59 | € 1,319,936 | € 856,656 | € 5,653,718 | € 168 |
| Poland | 957,600 | € 8,581,492 | € 9 | € 187,530 | € 7.70 | € 83,207 | € 30.80 | € 249,970 | € 46.20 | € 2,962,581 | € 769.93 | € 1,944,210 | € 192,878 | € 14,008,989 | € 15 |
| Portugal | 362,616 | € 6,732,241 | € 19 | € 7,320 | € 14.51 | € 3,248 | € 58.04 | € 9,758 | € 87.06 | € 115,647 | € 1,450.92 | € 75,894 | € 363,477 | € 6,944,108 | € 19 |
| Romania | 346,348 | € 2,052,863 | € 6 | € 15,009 | € 5.23 | € 6,659 | € 20.93 | € 20,006 | € 31.40 | € 237,106 | € 523.36 | € 155,602 | € 131,110 | € 2,487,244 | € 7 |
| Slovakia | 206,931 | € 2,080,853 | € 10 | € 84,718 | € 7.50 | € 37,590 | € 29.99 | € 112,926 | € 44.98 | € 1,338,377 | € 749.73 | € 878,317 | € 187,819 | € 4,532,782 | € 22 |
| Slovenia | 16,200 | € 161,473 | € 10 | € 7,953 | € 6.86 | € 3,529 | € 27.43 | € 10,601 | € 41.14 | € 125,642 | € 685.70 | € 82,453 | € 171,778 | € 391,651 | € 24 |
| Spain | 810,961 | € 21,399,764 | € 26 | € 231,599 | € 21.10 | € 102,760 | € 84.39 | € 308,712 | € 126.58 | € 3,658,778 | € 2,109.67 | € 2,401,093 | € 528,503 | € 28,102,705 | € 35 |
| Sweden | 1,444 | € 468,709 | € 325 | € 35,206 | € 32.12 | € 52,543 | € 128.49 | € 57,970 | € 192.74 | € 4,248,255 | € 3,212.35 | € 2,787,941 | € 804,740 | € 7,650,625 | € 5,300 |
| United Kingdom | 69,022 | € 7,008,455 | € 102 | € 1,118,838 | € 40.81 | € 496,428 | € 163.24 | € 1,491,367 | € 244.86 | € 17,675,327 | € 4,080.98 | € 11,599,531 | € 1,022,345 | € 39,389,947 | € 571 |

### Table 22. Cost of Salmonellosis in Human Population Attributed to Pork – Extra Scenario

**TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK**

**% Attribution Pork: 56.8%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 3,226,478 | € 65,567,310 | € 20 | € 3,782,303 | € 25 | € 1,714,473 | € 101 | € 5,052,508 | € 151 | € 63,379,095 | € 2,549.38 | € 41,592,879 | € 638,657 | € 181,088,568 | € 56 |
| Austria | 8,953 | € 646,230 | € 72 | € 88,029 | € 37 | € 39,058 | € 149 | € 117,339 | € 224 | € 1,390,672 | € 3,729.83 | € 912,636 | € 934,377 | € 3,193,964 | € 357 |
| Belgium | 6,316 | € 721,785 | € 114 | € 206,702 | € 40 | € 91,713 | € 158 | € 275,525 | € 237 | € 3,265,457 | € 3,950.36 | € 2,142,974 | € 989,624 | € 6,704,157 | € 1,061 |
| Bulgaria | 377,039 | € 1,511,809 | € 4 | € 5,401 | € 4 | € 2,396 | € 14 | € 7,199 | € 21 | € 85,326 | € 354.91 | € 55,996 | € 88,911 | € 1,668,129 | € 4 |
| Cyprus | 10,828 | € 340,943 | € 31 | € 4,378 | € 24 | € 1,943 | € 97 | € 5,836 | € 145 | € 69,164 | € 2,416.55 | € 45,389 | € 605,380 | € 467,652 | € 43 |
| Czech Republic | 139,513 | € 1,879,147 | € 13 | € 128,791 | € 9 | € 57,144 | € 37 | € 171,673 | € 55 | € 2,034,625 | € 920.08 | € 1,335,234 | € 230,494 | € 5,606,614 | € 40 |
| Denmark | 2,924 | € 437,563 | € 150 | € 85,428 | € 44 | € 37,904 | € 177 | € 113,872 | € 266 | € 1,349,585 | € 4,433.27 | € 885,672 | € 1,110,600 | € 2,910,024 | € 995 |
| Estonia | 3,600 | € 37,448 | € 10 | € 3,525 | € 6 | € 1,564 | € 23 | € 4,698 | € 34 | € 55,685 | € 570.71 | € 36,543 | € 142,971 | € 139,463 | € 39 |
| Finland | 473 | € 168,490 | € 356 | € 8,721 | € 31 | € 19,164 | € 123 | € 16,199 | € 185 | € 1,667,202 | € 3,077.64 | € 1,094,111 | € 770,994 | € 2,973,888 | € 6,287 |
| France | 132,700 | € 5,459,177 | € 41 | € 421,840 | € 29 | € 187,170 | € 118 | € 562,296 | € 177 | € 6,664,200 | € 2,949.09 | € 4,373,418 | € 738,791 | € 17,668,101 | € 133 |
| Germany | 133,493 | € 10,219,779 | € 77 | € 1,452,394 | € 37 | € 644,427 | € 147 | € 1,935,985 | € 221 | € 22,944,824 | € 3,677.14 | € 15,057,667 | € 921,176 | € 52,255,074 | € 391 |
| Greece | 327,396 | € 7,122,947 | € 22 | € 15,136 | € 20 | € 6,716 | € 78 | € 20,175 | € 118 | € 239,114 | € 1,959.49 | € 156,920 | € 490,881 | € 7,561,009 | € 23 |
| Hungary | 234,067 | € 2,238,375 | € 10 | € 86,465 | € 9 | € 38,364 | € 34 | € 115,254 | € 51 | € 1,365,966 | € 851.01 | € 896,423 | € 213,191 | € 4,740,848 | € 20 |
| Ireland | 954 | € 105,541 | € 111 | € 19,142 | € 37 | € 8,493 | € 149 | € 25,516 | € 224 | € 302,409 | € 3,737.18 | € 198,457 | € 936,219 | € 659,559 | € 691 |
| Italy | 136,376 | € 4,949,759 | € 36 | € 181,540 | € 33 | € 80,549 | € 132 | € 241,986 | € 198 | € 2,867,957 | € 3,296.22 | € 1,882,113 | € 825,752 | € 10,203,904 | € 75 |
| Latvia | 25,112 | € 249,250 | € 10 | € 10,730 | € 7 | € 4,761 | € 26 | € 14,303 | € 39 | € 169,511 | € 652.80 | € 111,242 | € 163,535 | € 559,797 | € 22 |
| Lithuania | 77,007 | € 556,872 | € 7 | € 20,688 | € 5 | € 9,179 | € 22 | € 27,576 | € 33 | € 326,829 | € 547.57 | € 214,483 | € 137,174 | € 1,155,628 | € 15 |
| Luxembourg | 312 | € 36,123 | € 116 | € 9,319 | € 45 | € 4,135 | € 181 | € 12,421 | € 272 | € 147,216 | € 4,526.43 | € 96,611 | € 1,133,937 | € 305,826 | € 979 |
| Malta | 16,310 | € 227,740 | € 14 | € 2,878 | € 14 | € 1,277 | € 54 | € 3,837 | € 81 | € 45,473 | € 1,354.80 | € 29,842 | € 339,397 | € 311,047 | € 19 |
| Netherlands | 19,108 | € 1,118,367 | € 59 | € 72,315 | € 34 | € 32,086 | € 137 | € 96,393 | € 205 | € 1,142,427 | € 3,419.59 | € 749,724 | € 856,656 | € 3,211,312 | € 168 |
| Poland | 543,917 | € 4,874,288 | € 9 | € 106,517 | € 8 | € 47,261 | € 31 | € 141,983 | € 46 | € 1,682,746 | € 769.93 | € 1,104,311 | € 192,878 | € 7,957,106 | € 15 |
| Portugal | 205,966 | € 3,823,913 | € 19 | € 4,158 | € 15 | € 1,845 | € 58 | € 5,542 | € 87 | € 65,687 | € 1,450.92 | € 43,108 | € 363,477 | € 3,944,253 | € 19 |
| Romania | 196,726 | € 1,166,026 | € 6 | € 8,525 | € 5 | € 3,783 | € 21 | € 11,363 | € 31 | € 134,676 | € 523.36 | € 88,382 | € 131,110 | € 1,412,755 | € 7 |
| Slovakia | 117,537 | € 1,181,925 | € 10 | € 48,120 | € 7 | € 21,351 | € 30 | € 64,142 | € 45 | € 760,198 | € 749.73 | € 498,884 | € 187,819 | € 2,574,620 | € 22 |
| Slovenia | 9,202 | € 91,716 | € 10 | € 4,517 | € 7 | € 2,004 | € 27 | € 6,021 | € 41 | € 71,365 | € 685.70 | € 46,834 | € 171,778 | € 222,458 | € 24 |
| Spain | 460,626 | € 12,155,066 | € 26 | € 131,548 | € 21 | € 58,368 | € 84 | € 175,348 | € 127 | € 2,078,186 | € 2,109.67 | € 1,363,821 | € 528,503 | € 15,962,337 | € 35 |
| Sweden | 820 | € 266,227 | € 325 | € 19,997 | € 32 | € 29,844 | € 128 | € 32,927 | € 193 | € 2,413,009 | € 3,212.35 | € 1,583,550 | € 804,740 | € 4,345,555 | € 5,300 |
| United Kingdom | 39,204 | € 3,980,803 | € 102 | € 635,500 | € 41 | € 281,971 | € 163 | € 847,097 | € 245 | € 10,039,586 | € 4,080.98 | € 6,588,533 | € 1,022,345 | € 22,373,490 | € 571 |

**Table 23. Cost of Salmonellosis in Human Population Attributed to Pork – Extra Scenario**

**TOTAL COSTS OF SALMONELLA INFECTION ATTRIBUTED TO PORK - MAINTAINING FATALITIES AT 533 VOLUME**

**% Attribution Pork: 56.8%**

| | | 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 | Pig & Pork Attribution | Cost per Case |
| EU 27 | 3,226,478 | € 65,605,313 | € 20 | € 3,779,878 | € 25 | € 1,719,324 | € 101 | € 5,048,870 | € 151 | € 63,924,817 | € 2,549.38 | € 193,494,382 | € 638,657 | € 333,572,583 | € 103 |
| Austria | 8,953 | € 647,034 | € 72 | € 87,976 | € 37 | € 39,165 | € 149 | € 117,259 | € 224 | € 1,402,646 | € 3,729.83 | € 4,245,678 | € 934,377 | € 6,539,758 | € 730 |
| Belgium | 6,316 | € 723,384 | € 115 | € 206,577 | € 40 | € 91,963 | € 158 | € 275,338 | € 237 | € 3,293,574 | € 3,950.36 | € 9,969,338 | € 989,624 | € 14,560,173 | € 2,305 |
| Bulgaria | 377,039 | € 1,511,846 | € 4 | € 5,398 | € 4 | € 2,403 | € 14 | € 7,195 | € 21 | € 86,061 | € 354.91 | € 260,499 | € 88,911 | € 1,873,402 | € 5 |
| Cyprus | 10,828 | € 340,982 | € 31 | € 4,375 | € 24 | € 1,948 | € 97 | € 5,832 | € 145 | € 69,759 | € 2,416.55 | € 211,154 | € 605,380 | € 634,050 | € 59 |
| Czech Republic | 139,513 | € 1,880,290 | € 13 | € 128,713 | € 9 | € 57,300 | € 37 | € 171,556 | € 55 | € 2,052,144 | € 920.08 | € 6,211,646 | € 230,494 | € 10,501,649 | € 75 |
| Denmark | 2,924 | € 438,469 | € 150 | € 85,376 | € 44 | € 38,008 | € 177 | € 113,795 | € 266 | € 1,361,205 | € 4,433.27 | € 4,120,239 | € 1,110,600 | € 6,157,092 | € 2,106 |
| Estonia | 3,600 | € 37,486 | € 10 | € 3,523 | € 6 | € 1,568 | € 23 | € 4,695 | € 34 | € 56,164 | € 570.71 | € 170,004 | € 142,971 | € 273,441 | € 76 |
| Finland | 473 | € 169,578 | € 358 | € 8,657 | € 31 | € 19,292 | € 123 | € 16,103 | € 185 | € 1,681,558 | € 3,077.64 | € 5,089,916 | € 770,994 | € 6,985,104 | € 14,767 |
| France | 132,700 | € 5,462,895 | € 41 | € 421,585 | € 29 | € 187,680 | € 118 | € 561,914 | € 177 | € 6,721,581 | € 2,949.09 | € 20,345,592 | € 738,791 | € 33,701,247 | € 254 |
| Germany | 133,493 | € 10,233,838 | € 77 | € 1,451,516 | € 37 | € 646,183 | € 147 | € 1,934,667 | € 221 | € 23,142,389 | € 3,677.14 | € 70,049,824 | € 921,176 | € 107,458,417 | € 805 |
| Greece | 327,396 | € 7,123,096 | € 22 | € 15,127 | € 20 | € 6,734 | € 78 | € 20,162 | € 118 | € 241,173 | € 1,959.49 | € 730,008 | € 490,881 | € 8,136,299 | € 25 |
| Hungary | 234,067 | € 2,239,054 | € 10 | € 86,413 | € 9 | € 38,469 | € 34 | € 115,176 | € 51 | € 1,377,728 | € 851.01 | € 4,170,251 | € 213,191 | € 8,027,090 | € 34 |
| Ireland | 954 | € 105,746 | € 111 | € 19,131 | € 37 | € 8,517 | € 149 | € 25,499 | € 224 | € 305,013 | € 3,737.18 | € 923,245 | € 936,219 | € 1,387,149 | € 1,454 |
| Italy | 136,376 | € 4,951,071 | € 36 | € 181,430 | € 33 | € 80,769 | € 132 | € 241,821 | € 198 | € 2,892,652 | € 3,296.22 | € 8,755,784 | € 825,752 | € 17,103,527 | € 125 |
| Latvia | 25,112 | € 249,375 | € 10 | € 10,723 | € 7 | € 4,774 | € 26 | € 14,293 | € 39 | € 170,970 | € 652.80 | € 517,511 | € 163,535 | € 967,647 | € 39 |
| Lithuania | 77,007 | € 557,098 | € 7 | € 20,676 | € 5 | € 9,204 | € 22 | € 27,558 | € 33 | € 329,643 | € 547.57 | € 997,799 | € 137,174 | € 1,941,977 | € 25 |
| Luxembourg | 312 | € 36,196 | € 116 | € 9,313 | € 45 | € 4,146 | € 181 | € 12,413 | € 272 | € 148,484 | € 4,526.43 | € 449,446 | € 1,133,937 | € 659,998 | € 2,113 |
| Malta | 16,310 | € 227,764 | € 14 | € 2,877 | € 14 | € 1,281 | € 54 | € 3,834 | € 81 | € 45,865 | € 1,354.80 | € 138,828 | € 339,397 | € 420,447 | € 26 |
| Netherlands | 19,108 | € 1,119,217 | € 59 | € 72,271 | € 34 | € 32,174 | € 137 | € 96,327 | € 205 | € 1,152,263 | € 3,419.59 | € 3,487,793 | € 856,656 | € 5,960,045 | € 312 |
| Poland | 543,917 | € 4,875,174 | € 9 | € 106,452 | € 8 | € 47,390 | € 31 | € 141,886 | € 46 | € 1,697,235 | € 769.93 | € 5,137,370 | € 192,878 | € 12,005,509 | € 22 |
| Portugal | 205,966 | € 3,823,954 | € 19 | € 4,155 | € 15 | € 1,850 | € 58 | € 5,539 | € 87 | € 66,253 | € 1,450.92 | € 200,542 | € 363,477 | € 4,102,293 | € 20 |
| Romania | 196,726 | € 1,166,095 | € 6 | € 8,520 | € 5 | € 3,793 | € 21 | € 11,356 | € 31 | € 135,836 | € 523.36 | € 411,162 | € 131,110 | € 1,736,761 | € 9 |
| Slovakia | 117,537 | € 1,182,355 | € 10 | € 48,091 | € 7 | € 21,409 | € 30 | € 64,099 | € 45 | € 766,744 | € 749.73 | € 2,320,861 | € 187,819 | € 4,403,559 | € 37 |
| Slovenia | 9,202 | € 91,763 | € 10 | € 4,515 | € 7 | € 2,010 | € 27 | € 6,017 | € 41 | € 71,979 | € 685.70 | € 217,874 | € 171,778 | € 394,158 | € 43 |
| Spain | 460,626 | € 12,156,291 | € 26 | € 131,468 | € 21 | € 58,527 | € 84 | € 175,229 | € 127 | € 2,096,080 | € 2,109.67 | € 6,344,636 | € 528,503 | € 20,962,231 | € 46 |
| Sweden | 820 | € 267,816 | € 327 | € 19,905 | € 32 | € 30,029 | € 128 | € 32,789 | € 193 | € 2,433,786 | € 3,212.35 | € 7,366,840 | € 804,740 | € 10,151,165 | € 12,381 |
| United Kingdom | 39,204 | € 3,987,448 | € 102 | € 635,116 | € 41 | € 282,739 | € 163 | € 846,520 | € 245 | € 10,126,031 | € 4,080.98 | € 30,650,540 | € 1,022,345 | € 46,528,395 | € 1,187 |

# 4. SLAUGHTERHOUSE INTERVENTIONS AND THEIR COSTS

## 4.1 Introduction

The previous chapter has demonstrated that *Salmonella* in pigs has an impact on human health and that this appears to be transmitted through the food system. Assessments of pre-harvest interventions carried out in 2009 and 2010 (FCC, 2010; 2011) indicated that the technical feasibility of managing and reducing *Salmonella* in pre-harvest pigs was neither easy nor clear.

Cost-benefit analysis of these methods indicated that it would not be economically profitable across the EU Member States to run a programme based on pre-harvest interventions. However, the legislation indicates a need to set targets to limit *Salmonella* impacts and therefore a search has been carried out to examine if slaughterhouse interventions can make a difference.

This chapter covers the material available on how to reduce *Salmonella* burdens in the slaughterhouse, and estimates the costs of such interventions at an individual pig level and across the European Union.

## 4.2 Options to control *Salmonella* in slaughterhouses

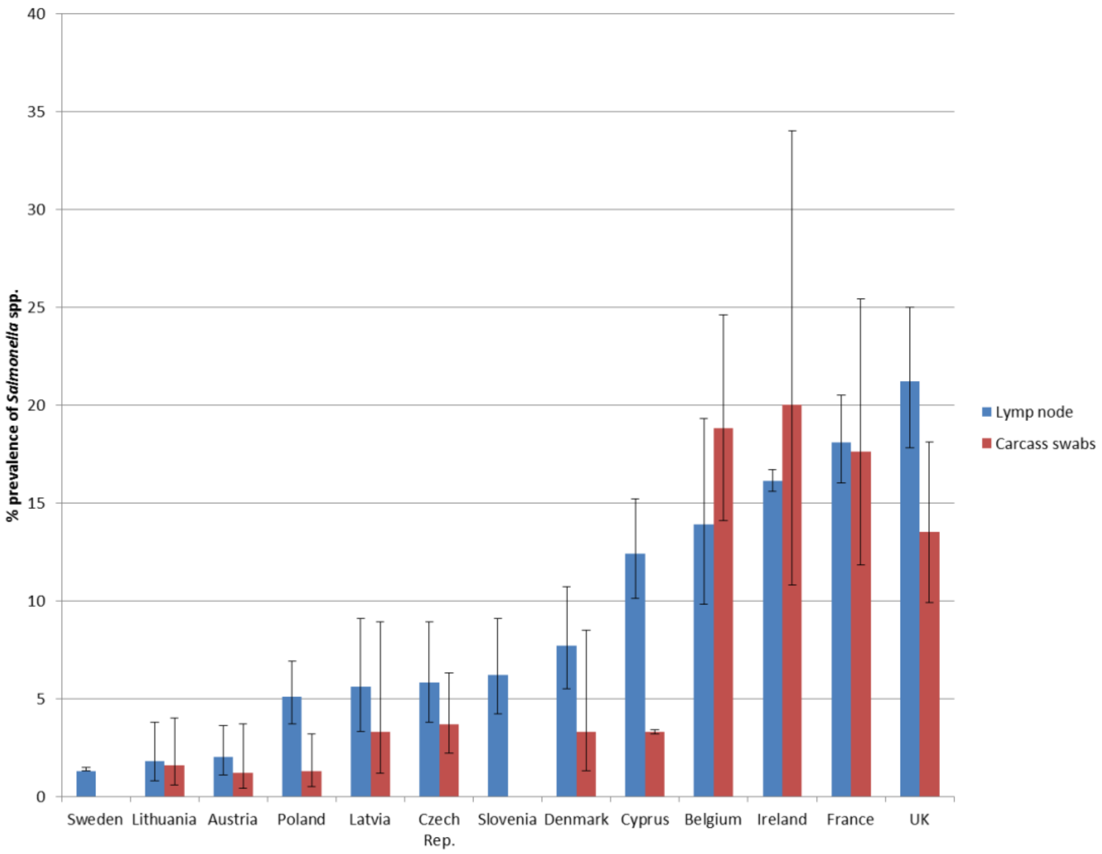
### *4.2.1 Potential for controlling Salmonella in slaughterhouses*

Baptista et al (2010) investigated factors associated with *Salmonella* carcass prevalence in Denmark. Their study covered the period from October 2002 to December 2008 and included data from 23 slaughterhouses. They found that there were large differences in carcass prevalence between slaughterhouses with comparable input of *Salmonella*: input being estimated on the basis of meat juice serology. Looking at slaughterhouses where the total number of pooled carcass swabs is >1000 (n=5 per pool), the percentage of positive pooled carcass swabs varied between 0.3 % and 5.0 %.

Baptista et al (2010) found that the most important, and only significant factor, on the change in prevalence of carcass prevalence with the probability of one pig within a slaughter pool being seropositive to *Salmonella*. Interpretation would be that the seropositive pig indicates a source of contamination within the slaughterhouse and that the practices allow other carcasses to be contaminated. The authors go on to describe that carcass prevalence cannot be reduced by large reductions in seropositivity of pigs. Their work emphasised that the difference in carcass prevalence can be attributed to differences in slaughter practices and/or slaughter technology. And it illustrates that practices and technology used during slaughter have a huge impact on the prevalence of *Salmonella* on the carcasses.

In the baseline study carried out in the EU during 2006-2007 (Anon, 2008) samples were taken from both carcasses and lymph nodes in 13 countries. The results are shown in the following figure.

**Figure 2. Weighted prevalence estimates and 95 % confidence intervals for *Salmonella* positive carcass swabs and *Salmonella* positive lymph nodes**




From Figure 2 the average prevalence of *Salmonella* in pig lymph nodes is higher than the average prevalence of *Salmonella* detected on carcasses (% positive carcass swabs) in a majority of the member states. However, for France and Lithuania the prevalence levels in pigs and for carcass are very similar and in Belgium and Ireland the prevalence of *Salmonella* on carcass is higher than the pig prevalence. Sweden, Slovenia, Cyprus and possibly Poland have results that suggest that slaughterhouse activities can reduce carcass prevalence regardless of the levels of *Salmonella* in the pigs coming into the slaughter plant.

What can be concluded from these data is that the pig prevalence as measured by detection of *Salmonella* in lymph nodes is a good indicator of the carcass prevalence in most member states. The dataset lacks some of the largest producers of pigs such as Germany, Italy and Spain in the Union.

Firm conclusions cannot be drawn due to large confidence intervals, but the results indicate that slaughter practices also affect *Salmonella* prevalence on carcasses in countries where the prevalence of *Salmonella* in slaughter pigs is relatively high.

Interpreting these data and the conclusions from Baptista et al (2010) in terms of attribution is not easy. In some countries and in some slaughterhouses there is a link between pigs with *Salmonella* entering the slaughterhouse and the prevalence of carcasses leaving it. Yet it is also clear that slaughterhouse practice can influence the carcass prevalence both positively and negatively. In summary, and in agreement with Baptista et al, good slaughterhouse practice is important for carcass prevalence. Carcass prevalence is therefore dependent on slaughterhouse management which can vary both in geographical location and in time as many of the aspects of hygiene are human behaviour related.

## 4.3 Operations during transport, lairage, slaughter and cooling and their influence on the number of *Salmonella* bacteria on carcasses

From a hygiene point of view, the critical control points of operations from "farm to chilled carcass" can be divided as follows:

- Transport and lairage
- The unclean area – sticking, scalding, de-hairing, flaming/singeing, rind treatment
- Clean area – evisceration, splitting, etc.
- Chilling

Transport and lairage affects the prevalence of *Salmonella* in the live animal. The operations in the unclean area affects the prevalence of *Salmonella* on the outer surface of the carcass. The operations in the clean area affects spread of *Salmonella* from the digestice tract. The influence of these "operations" on occurrence of *Salmonella* on the carcass is described in more detail below.

During transport and lairage *Salmonella* is spread between animals thereby infecting animals from *Salmonella*-free herds (Swanenburg et al., 2001a, Boughton et al. 2007, De Busser et al.,2011). There is therefore a potential for reducing the spreading of *Salmonella* by holding *Salmonella*-free and *Salmonella*-infected animals apart from each other during transport and lairage. Unfortunately there are several barriers to overcome before this becomes feasible.

Firstly, no systems are in place to identify the animals/ herds, which are *Salmonella* free. Negative serology against *Salmonella* on the animal level does not ensure that animals are *Salmonella*-free at the time of slaughter. Bacteriological examinations in the farm close to the time of delivering, is at present the only way to get a reasonable degree of certainty that animals delivered to slaughter are *Salmonella*-free.

Secondly, it seems that proper cleaning and disinfection is not enough to get rid of *Salmonella* in lairages (Schmidt et al., 2007; Swanenburg et al.,2010b).

Among the operations in the unclean area it is especially de-hairing and singeing/flaming that affects the number of *Salmonella* on the rind side of the carcass. During de-hairing manure is pressed out of the rectum, and growth of *Salmonella* in the machines is a risk that has to be handled. Gill and Bryant (1993) sampled detritus from de-hairing machines in two abattoirs and isolated *Salmonella* spp. in 50 % of the samples in quantities up to $10^5$ cfu/g.

Singeing/flaming will reduce the numbers of bacteria on the rind side of the carcass. The reduction will depend on the intensity of the singeing/flaming and the time used (Borch et al. 1996). Snijders et al. (1976) carried out a study in eight slaughterhouses and found a reduction in the aerobic count of 2-3 log-units depending on the technology used. Gill and Bryant (1993) found a 2 log reduction in the numbers of *E. Coli* during singeing. Silva et al. (2012) carried out a study in three slaughterhouses and found the numbers of *Salmonella* to vary on the rind after de-hairing, and in the slaughterhouse with high numbers of *Salmonella* after de-hairing and high prevalence of positive carcasses after de-hairing, the prevalence of positive carcasses was also high after singeing. Pearce et al. (2011) swabbed carcasses after bleeding, scalding, de-hairing, singeing, polishing and evisceration. The prevalence after bleeding was 31 %, after scalding 1 %, after de-haring 7 %, after singeing 0 %, after polishing 0 % and after evisceration 7 %. This confirms that de-hairing can be a source of contamination, but it also shows that the combined effect of de-haring and singeing can result in low prevalence on the carcass after the unclean area.

From a hygiene point of view the important operations in the clean area relate to evisceration. It is obvious that contamination of the carcass with contents from the intestinal tract should be avoided as much as possible. When contamination occurs, further spread to other carcasses must be avoided. The effect of contamination on prevalence of *Salmonella* is difficult to quantify as it depends on a large number of factors. Daily cleaning and disinfection must be efficient, and tools coming into contact with carcasses should be cleaned/disinfected between carcasses. Inefficient daily cleaning combined with inefficient disinfection of tools between carcasses can proliferate in equipment leading to outbreaks (Bertrand et al., 2010).

Chilling affects the prevalence of *Salmonella* on carcasses (O'Conner, 2012, Barron, 2008). Both O'Conner (2012) and Barron (2008) have reviewed a large number of publications. Apart from showing that chilling reduces the prevalence of *Salmonella*, the reviews also show big variations in the reduction. This may be due to the differences in technology used for chilling of carcasses, or due to differences in numbers of *Salmonella* on the carcasses before chilling.

Chilling technologies can be divided into three groups: conventional chilling, blast chilling and spray chilling. During conventional chilling carcasses are exposed to air at temperatures above 0 °C. Blast chilling involves initial blasting carcasses with air at temperatures below -15 °C resulting in a surface that is frozen. During spray chilling air temperatures are kept above 0 °C and carcasses are sprayed with water at intervals. Due to the freezing of the surface, blast chilling can be expected to give the biggest reduction in the prevalence of *Salmonella* on carcasses. In Denmark it is estimated, that blast chilling reduces the number of *Salmonella* to below the detection limit on 50 % of the contaminated carcasses (unpublished data).

## 4.4 Potential areas of slaughterhouse interventions

### *4.4.1 Improving practices and/or changing technology*

In theory it is possible to reduce the prevalence of contaminated carcasses by reducing the spread of *Salmonella* between animals during transport and lairage. This is however not an option as: i) contaminated animals and herds cannot be identified without sampling close to the time of delivery; ii) lairages cannot be properly cleaned between herds.

If sufficient amounts of water is used during dehairing and sufficient gas is used at singeing/flaming it is possible to run the operations in the unclean area in a way that reduces the numbers of *Salmonella* on the rind side of the carcass to a level close to zero; i.e. the occurrence of *Salmonella* before evisceration is restricted to the intestinal tract. This implies running de-hairing machines in a way that excludes growth of *Salmonella* in the equipment, and by heat treating the rind by flaming or singeing to a degree that eliminates *Salmonella* on the rind. Traditionally singeing is the term for the heat treating process that gives the biggest reduction in the numbers of bacteria, therefore singeing is used for this intervention. In some slaughterhouses it will not be possible to run the operations as stated above without investing in new equipment or lowering the throughtput.

Verifying the effect of the processes in the unclean area can be done by sampling carcasses immediately after the unclean area and analysing for the presence of *Salmonella.* As methods for detecting *Salmonella* are qualitative, and that the prevalence is close to zero, the necessary numbers of samples involved is large. Assuming that the prevalence of *Salmonella* follows the binomial distribution it is necessary to analyse 225 samples with a negative result to ensure with a certainty of 90% that the prevalence is less or equal to to 1%.

For verification purposes it is recommended to analyse quantitatively for the presence of *E. coli* as an indicator of bacteria originating from the digestive tract that has survived on the surface of the carcass after scalding, de-hairing and flaming/singeing. After leaving the unclean area *E. coli* should only be found on few carcasses and in low numbers. For process control, parameters like occurrence and amount of faecal material on carcasses after de-hairing, and colour of the rind after flaming/singeing can be used. It should be noted that prevalence of *Salmonella* on the carcass is a result of the combined effect of de-hairing and flaming/singeing. Therefore *Salmonella* can be found on carcasses singed to a degree, that leaves the rind dark brown; and rind where the colour only changes slightly during flaming is not necessarily an indication of a high prevalence of *Salmonella.*

Performance of the operations in the clean area can have an effect on the prevalence of *Salmonella* on carcasses. However no data has been found that quantifies the costs and benefits, and it is assumed, that if the rules found in Regulation (EC) No 853/2004 ("laying down specific hygiene rules for food of animal origin") are followed, the benefits of additional measures will be limited. Therefore, interventions in the clean area before chilling have not been included as a part of the cost-benefit analysis.

Chilling can affect the prevalence on carcasses. Experience from Denmark shows that blast chilling can reduce *Salmonella* on carcasses. Therefore blast-chilling is included as an intervention for the cost-benefit analysis.

Verifying and monitoring the combined effect of chilling and the operations performed in the clean area can be done in a manner as described for the process hygiene criteria for meat (Commission Regulation (EC) No 2073/2005). But sampling should be carried out after chilling, since chilling can have an effect and it is the chilled meat that reaches the consumer. Each individual slaughterhouse can link the results for the process hygiene criteria with the results from monitoring for *Salmonella* and thereby track improvements.

### *4.4.2 Decontamination*

Decontamination of carcasses can reduce the prevalence of *Salmonella*. Hot water washing has been used on a routine basis since 2001 in Denmark to decontaminate carcasses originating from "level-3 herds" according to the Danish national *Salmonella* surveillance program, (Alban and Sørensen, 2010).

The reduction in numbers of *E. coli* during hot water washing is less than or equal to 2 log-units (Jensen, 2001). Based on the reduction in the numbers of *E. coli* and data on the numbers of *Salmonella* on carcasses after slaughter of level-3 herds (Olsen et al., 2001), Jensen (2001) estimated that hot water washing could reduce the numbers of *Salmonella* to below the detection limit on approximately 90 % of the contaminated carcasses. During the years 2001 and 2002, 10 386 samples were taken in five slaughterhouses slaughtering animals from level-3 herds without the use of hot water washing, among these *Salmonella* was found on 13.3% of the carcasses (unpublished data). The prevalence of *Salmonella*-positive carcasses after hot water washing was found to be 0.9% (Alban and Sørensen, 2010).

Based on a sample covering 1 400 $cm^2$ (pelvic duct, the medial part of the hind leg including 5 cm of the adjoining rind and the cut face on the belly and sternum including 5 cm of the adjoining rind) Olsen et al. (2001) found that numbers of *Salmonella* were less than 0.014/$cm^2$ on 50% of the positive carcasses, between 0.014/$cm^2$ and 0.14/$cm^2$ on 30% of the positive carcasses, and higher than 0.14/$cm^2$ on 20 % of the positive carcasses.

Information about the numbers of *Salmonella* on carcasses in European countries other than Denmark is sparse. But in a recent study from a Dutch slaughterhouse with a high throughput, 16.2% and 29.9% of the exterior and interior samples tested positive for *Salmonella* when sampling before chilling. Mean numbers of *Salmonella* on carcasses testing positive were -0.43 log MPN/$cm^2$ and -0.32 log MPN/$cm^2$ (Hoek, et al., 2012), which is more than 10 times higher than those found by Olsen et al. (2001). If numbers of *Salmonella* on carcasses are very high, hot water washing will not reduce them to a level below the detection limit. Therefore hot water washing in some cases cannot be used as the only intervention, and is considered in this study only in connection with other interventions i.e. on top of good hygiene.

Hot water washing implies use of large amounts of water. In the equipment used in Denmark it is possible to recirculate the water, but it is still an open question whether recirculation of water will be permitted in the EU. With recirculation the consumption of water is 18 litres/carcass; without recirculation, the consumption is 68 litres/carcass.

### 4.4.3 Costs of the interventions

The interventions used for the costs per carcass are the use of hot water, singeing, and chilling of the carcass. The following table details the costs for a slaughterhouse with a throughput of 400 pigs per hour, which is likely to be a higher throughput than many facilities across the EU.

**Table 24. Cost per carcass for treatment to reduce *Salmonella* contamination**

| Intervention | Cost (€/carcass) | | Comments |
|---|---|---|---|
| | Low | High | |
| Hot Water | 0.26 | 0.43 | Difference is dependent on the circulation of water |
| Singeing | 0.084 | 0.14 | Difference is dependent on investment |
| Blast chilling | 0.87 | 1.30 | Difference is dependent on the throughput |

For the hot water wash the variable costs account for 69% of the total costs. There will be a variation between Member States in terms of the costs of water, labour and energy. The higher cost estimate in the above table relates to not recycling the water and this increases the water consumption from 18 litres per carcass to 66 litres, at a cost of water being taken as € 3.35/m$^3$. Baptista (2010) estimated hot water costs to be €0.21 per pig in large slaughterhouses going up to €0.62 per pig in small slaughterhouses. Given that in many Member States pig slaughter will be in small slaughterhouses the costs are likely to be at the higher end of the range, and the table above provides a very conservative level of cost per pig.

The singeing costs vary depending on the need for investment in equipment and buildings. The blast chilling is taken as an estimate on the need for a €8 million investment with a working life of 10 years and a throughput of around 600 carcasses per hour.

The costs are conservative in terms of estimating what needs to be done to equip a slaughterhouse to reduce risks of *Salmonella* contamination. There would also need to be an investment in training and management of staff, plus potentially incentive structures to ensure that procedures are maintained.

For the analysis presented in the later sections of the document a conservative figure of €0.52 per carcass is used as the investment needed per carcass. The cost is assumed to be a flat cost with no initial investments. It is recognized that this is not an ideal assumption, but detailed information is lacking on the number of slaughterhouses that would need to make significant investments.

## 4.5 Monitoring *Salmonella* contamination on the carcass

In order to run a programme that targets the slaughterhouse there has to be a monitoring scheme with the collection and analysis of samples to ensure that targets are met. The question posed is what type of monitoring scheme would this be?

When exporting pork to Finland, Sweden and Norway, samples have to be drawn from each batch and analysed for the presence of *Salmonella.* If positive samples are found, the batch involved cannot be exported to Finland, Sweden and Norway; but it can be sold without restrictions in other European countries. The number of samples is between 20 and 60 depending on batch size[14]. The sampling scheme lined out in Regulation (EC) No 1688/2005 was originally designed in Sweden with the intention to guarantee that the prevalence of *Salmonella* in a given batch was below5 % with a

[14] Details can be found in Commission Regulation (EC) No 1688/2005 of 14 October 2005 implementing Regulation (EC) No 853/2004 of the European Parliament and of the Council as regards special guarantees concerning Salmonella for consignments to Finland and Sweden of certain meat and eggs.

confidence level of 90 %. This type of monitoring involves a relatively low number of samples, possible only because the number of positive samples accepted is zero.

With a target, that is greater than zero, monitoring schemes for slaughterhouses throughout Europe must allow for positive samples, otherwise huge quantities of meat would have to be rejected. The allowed number of positive samples among a given number of samples will depend on the target, the confidence level and the burden of proof – all political questions. How the burden of proof affects the allowed number of positives among a given number of samples can be illustrated with the following example:

- If it is to be demonstrated that the prevalence of *Salmonella* during a period of 30 days is less than or equal to 5% with a level of confidence of 95 %, the allowed number of positive samples among a total of 100 samples are 2 (assuming that the prevalence of *Salmonella* follows the binomial distribution). If it is to be demonstrated that the prevalence of *Salmonella* during a period of 30 days is above 5% with a level of confidence that is 95 %, it is necessary that 12 of 100 samples are positive.

The following table presents information around the present national costs in Denmark with details of how this is split and who is responsible. The information comes from the Denmark *Salmonella* Action Plan – Cost of enforcement and monitoring, 2011 (Anon, 2012)

**Table 25. Direct costs related to the Danish *Salmonella* action plan paid by slaughterhouses and/or producers.**

| Activity | Amount (€) paid by: | | |
|---|---|---|---|
| | Producers | Slaughterhouses | Slaughter pig levy* |
| Blood samples and microbiological samples from breeding and multiplier herds | 94 000 | | |
| Microbiological samples from sow herds | 121 000 | | |
| Microbiological samples from herds producing pigs for slaughter | 67 000 | | |
| Serological surveillance | | 228 000 | 201 000 |
| "Fresh meat" surveillance – sampling from carcasses | | 215 000 | |
| Slaughter of carcasses from herds in level 3 (high level of antibodies against *Salmonella*) | | 497 000 | |
| Administration | | | 403 000 |
| **Total:** | **1 826 000** | | |

**Indirectly paid by producers and slaughterhouses*

This study has used this monitoring process as a 'gold standard': one that needs to be achieved to ensure that carcasses have minimal risk of leaving the slaughterhouse contaminated by *Salmonella*, and one that will encourage the slaughterhouse employees to maintain standards on a day to day basis.

The table below presents compiled information showing how it will be used in the cost modelling estimates presented at the end of this chapter.

**Table 26. Costs of monitoring carcass for the presence of *Salmonella* types and phages**

| Test | Test cost (€/sample) | | | % carcasses sampled* |
|---|---|---|---|---|
| | Low | High | Average | |
| Initial | 8.05 | 17.35 | 12.7 | 8.0% |
| Screen | 5.37 | 19.33 | 12.35 | 1.0% |
| Serotype | 62.28 | | 62.28 | 0.5% |
| Phage type | 46.31 | 61.07 | 53.69 | 0.1% |

** Assumes that batches needs to be sampled and therefore there is a high level of sampling required*

## 4.6 Competent authority costs – the coordination unit

A national level disease management programme has to be coordinated. The minimum requirement for such coordination would be an office, manager/coordinator, and administration support staff. The costs of the programme in Denmark are presented in the following table to give an example of the size and cost associated with such a coordination and data processing unit:

**Table 27. Total[*] cost related to the Danish *Salmonella* Action Plan**

| Activity | Amount (€) paid by: | | |
|---|---|---|---|
| | Producers and slaughterhouses | Danish Veterinary and Food Administration | The Danish Technological University (DTU) |
| *Salmonella* Action plan (SHIV) | 1 826 000 | 295 000 | 7 000 |
| **Total:** | **2 128 000** | | |

** The figures do not include costs for extra measures at farms with "Salmonella-problems" (extra sampling, altered feeding strategies) or slaughterhouses where the frequency of Salmonella positive carcasses exceeds the goals (extra sampling, preventive measures at slaughter)*

Well-equipped countries such as Denmark would not require significant additional coordination as a programme targeted at slaughterhouse level could be incorporated into existing structures. However, many other Member States do not have this level of investment and would need to establish coordinating units. The minimum requirements used in the costing exercise are presented below:

**Table 28. Parameters used in the costs of coordination by the competent agency of the control programme.**

| Item | Parameter | Comment |
|---|---|---|
| Manager | 1 | For some MS this is likely to be an underestimate |
| Additional veterinarians (assumes '000 pigs/vet) | 10 000 | |
| Admin staff per vet manager | 2 | |
| Office space (m2) | 1 000 | |
| Annual wage (€) | 33 823 | Based on the average across the EU, adjusted for skillset and wage index of MS |
| Wage index | Member State | Each MS applies its own index |
| Set up costs (€/'000 pigs) | 15.00 | |

In the above table, adjustments have been made to recognise different levels of current investment for each Member State, but each will incur a coordination cost[15] with the establishment of a new programme, even countries with well-funded *Salmonella* activities.

## 4.7 Costs across the EU for four scenarios

The previous FCC analyses for breeding and slaughter pigs presented a range of scenarios for different levels of intervention. The analysis carried out for the slaughterhouse interventions will also use four scenarios as follows:

1. A minimal change in the current systems of pig management through the implementation of a national coordination unit by the competent authorities across all Member States.
2. Scenario 1 plus the implementation of a more thorough surveillance system with private sector costs (using low costs for surveillance in Table 25).
3. Scenario 2 plus the implementation of improved slaughterhouse practices using a single intervention of hot water with low average costs (see Table 23)
4. Scenario 1 with very rigorous implementation of slaughterhouse surveillance (using the high costs in Table 25) and slaughterhouse intervention using single intervention of hot water at the higher estimated cost (see Table 23).

All scenarios have been tested for the four levels of potential human health impact and with an assumption that these impacts can be reduced either by 50 or 90% by the different scenarios.

[15] In some countries there may be a reallocation of existing staff, which in economic terms implies an opportunity cost as this time and resource could be occupied in other activities, that prior to a programme were assumed to be more valuable.

### 4.7.1 Key parameters used in the cost estimates

Tables in the preceding section provide the critical parameters used in the prices of slaughterhouse interventions per carcass and monitoring tests respectively.

The following table indicates the parameters used on the proportion of pigs slaughtered under good conditions at the present time. These estimates are based on the collection of information from Member States, but recognising that there are gaps, which could be improved with a more rigorous process of data collection. As a result the same standards have been applied to all Member States apart from Denmark, Finland and Sweden, which are known to have markedly better control conditions under all scenarios. Unfortunately the present study did not allow for this level of detail, although it is important to recognise that the study uses generous assumptions on the current levels of slaughter practices to reduce *Salmonella* across the European Union.

**Table 29. Slaughterhouse parameters for the cost estimates**

| Country | Number pigs slaughtered ('000) | % of good slaughter facilities by scenario | | | | Rate of improvement per year |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | |
| Austria | 4 845 | 100% | 100% | 60% | 50% | 50% |
| Belgium | 11 442 | 100% | 100% | 60% | 50% | 50% |
| Bulgaria | 957 | 100% | 100% | 60% | 50% | 50% |
| Cyprus | 724 | 100% | 100% | 60% | 50% | 50% |
| Czech Republic | 2 542 | 100% | 100% | 60% | 50% | 50% |
| Denmark | 29 315 | 100% | 100% | 85% | 90% | 50% |
| Estonia | 643 | 100% | 100% | 60% | 50% | 50% |
| Finland | 2 130 | 100% | 100% | 100% | 100% | NA |
| France | 24 774 | 100% | 100% | 60% | 50% | 50% |
| Germany | 46 337 | 100% | 100% | 60% | 50% | 50% |
| Greece | 1 902 | 100% | 100% | 60% | 50% | 50% |
| Hungary | 4 122 | 100% | 100% | 60% | 50% | 50% |
| Ireland | 3 647 | 100% | 100% | 60% | 50% | 50% |
| Italy | 12 106 | 100% | 100% | 60% | 50% | 50% |
| Latvia | 446 | 100% | 100% | 60% | 50% | 50% |
| Lithuania | 1 255 | 100% | 100% | 60% | 50% | 50% |
| Luxembourg | 132 | 100% | 100% | 60% | 50% | 50% |
| Malta | 70 | 100% | 100% | 60% | 50% | 50% |
| Netherlands | 23 950 | 100% | 100% | 60% | 50% | 50% |
| Poland | 16 950 | 100% | 100% | 60% | 50% | 50% |
| Portugal | 4 869 | 100% | 100% | 60% | 50% | 50% |
| Romania | 4 836 | 100% | 100% | 60% | 50% | 50% |
| Slovak Republic | 855 | 100% | 100% | 60% | 50% | 50% |
| Slovenia | 244 | 100% | 100% | 60% | 50% | 50% |
| Spain | 43 077 | 100% | 100% | 60% | 50% | 50% |
| Sweden | 2 678 | 100% | 100% | 100% | 100% | NA |
| United Kingdom | 9 704 | 100% | 100% | 60% | 50% | 50% |

The following table indicates the amount of testing currently being carried out at the present time and the rate of increase in the testing that would be required to manage the control programme effectively. Once again standard figures have been applied to all Member States apart from Denmark, Finland and Sweden, which are known to have particularly intensive monitoring and testing.

**Table 30. Monitoring practices for the different scenarios**

| Country | Current monitoring levels of scenarios | | | | Target proportion sampled | Rate of improvement per year |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | |
| Austria | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Belgium | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Bulgaria | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Cyprus | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Czech Republic | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Denmark | 1.00% | 0.70% | 0.70% | 0.75% | 1.0% | 50% |
| Estonia | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Finland | 1.00% | 1.00% | 1.00% | 1.00% | 1.0% | NA |
| France | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Germany | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Greece | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Hungary | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Ireland | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Italy | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Latvia | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Lithuania | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Luxembourg | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Malta | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Netherlands | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Poland | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Portugal | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Romania | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Slovak Republic | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Slovenia | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Spain | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |
| Sweden | 1.00% | 1.00% | 1.00% | 1.00% | 1.0% | NA |
| United Kingdom | 1.00% | 0.60% | 0.60% | 0.50% | 1.0% | 50% |

### *4.7.2 Results of the analysis*

The summary of the costs across the EU for the different interventions, slaughterhouse, monitoring and support unit, are shown in the table below for the four different scenarios

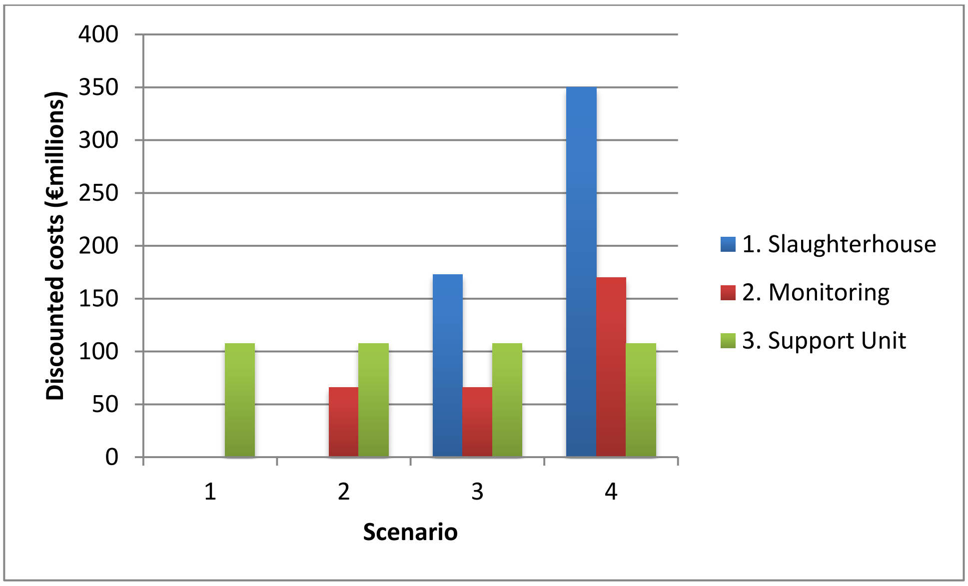
**Table 31. Estimated undiscounted and discounted costs for the control of *Salmonella* in pigs using slaughterhouse interventions**

| | Costs (million €) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Scenario 1 | | Scenario 2 | | Scenario 3 | | Scenario 4 | |
| Intervention | UD | D | UD | D | UD | D | UD | D |
| 1. Slaughterhouse | 0 | 0 | 0 | 0 | 217 | 173 | 438 | 350 |
| 2. Monitoring | 0 | 0 | 82 | 66 | 82 | 66 | 210 | 170 |
| 3. Support Unit | 132 | 108 | 132 | 108 | 132 | 108 | 132 | 108 |
| Total | 132 | 108 | 214 | 174 | 431 | 347 | 780 | 628 |

*UD=Undiscounted; D=Discounted*

Figure 3 provides an impression of the relative importance of the different costs with the different scenarios:

**Figure 3. Estimates of the discounted costs by scenario and type of cost**




The importance of the distribution of the costs relates to who will need to pay. Support or coordination units will generally fall within the remit of government and therefore be a tax payer contribution to the programme.

The slaughterhouse interventions will be private investment and monitoring in infrastructure, management and training. The balance between these different components is dependent on the level of current investments, and any additional costs might be passed through to consumer, the major beneficiary of this change, through product price increases.

Figure 4 and 5 indicates where these costs will be borne across the EU for scenario 3 and 4:

**Figure 4. Estimated costs for Scenario 3 by Member State**

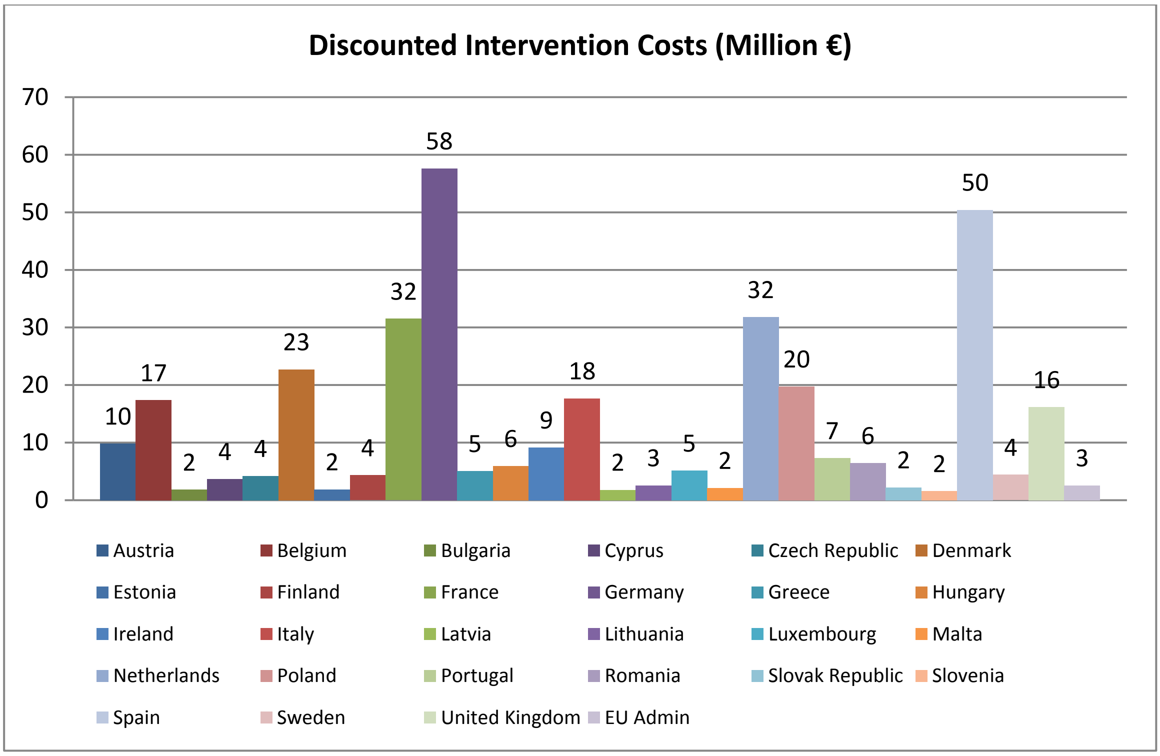
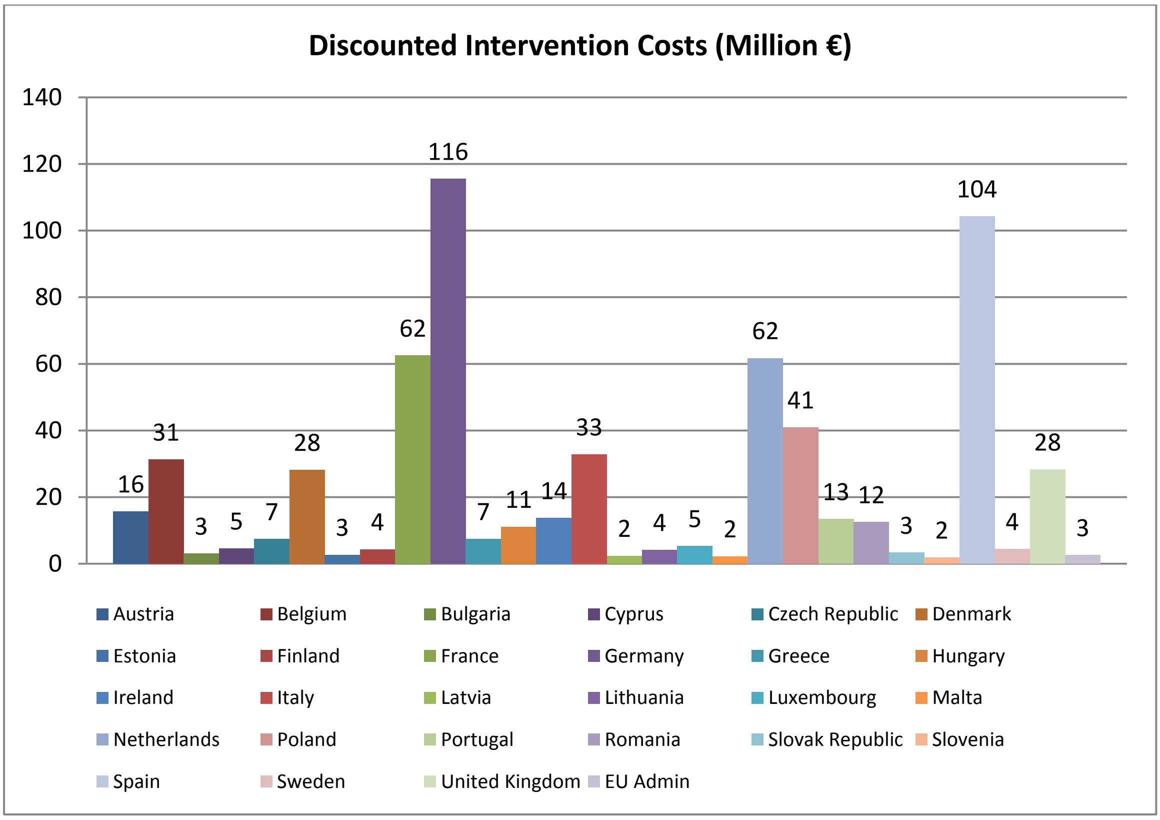



**Figure 5. Estimated costs for Scenario 4 by Member State**




As would be expected the major costs are borne by the largest producers of pig meat in the EU, such as Germany, Spain and the Netherlands. This pattern is similar for the other two scenarios.

## 4.8 Summary

The chapter summarises information on the possible slaughterhouse interventions to reduce *Salmonella* contamination in carcasses:

1. Investments in a coordination unit by the competent authorities of the Member States.
2. Costs of monitoring the prevalence of *Salmonella* on carcasses at slaughterhouse level.
3. Changes in the practices in the slaughterhouse to reduce the prevalence of *Salmonella* of the carcass.

For the slaughterhouse three areas of interventions are considered technically feasible: washing, singeing and blast freezing of the carcass. Given the information available, hot washing was taken as the core issue for managing *Salmonella*, and that this required an investment whose cost per pig was related to the scale of the slaughter business.

The estimates and investment in infrastructure assume that well over half of the current slaughter capacity across the EU already has some of the interventions in place, even where estimates of *Salmonella* attribution from the pig meat systems are high.

In addition to the measures at the slaughterhouse, a control programme will need to have a monitoring system to ensure that targets are met on *Salmonella* carcass contamination. A baseline measure was derived from the regulations used to export pig carcasses and meat to markets with strict requirements. Again it as assumed that a high proportion of the current slaughter capacity is already employing such measures.

Four different scenarios were examined:

1. Basic minimum of a national level coordination unit with the investment coming from the public sector and their actions would have an impact on private practice at slaughterhouse level – discounted costs €108 million over ten years.

2. A coordination unit with private sector monitoring costs to maintain information on the carcass prevalence – discounted costs €174 million over ten years.

3. A coordination unit with private sector monitoring and additional investments in slaughterhouses to reduce *Salmonella* carcass prevalence – discounted costs €347 million over ten years.

4. Based on scenario 3 but with higher costs of monitoring and slaughterhouse intervention and less pessimistic assumptions on the current practices – discounted costs €628 million euros over ten years.

Cost information is important in decision making, but needs to be compared with the benefits generated to lead to a rational decision process. The following chapter will look at the costs and benefits of the possible scenarios.

# 5. COST-BENEFIT ANALYSIS

## 5.1 Introduction

This chapter presents a cost-benefit analysis based on a modified version of the FCC model developed for the previous slaughter and breeding pig cost-benefit analyses. Results for each of four scenarios are included. To assist the reader a short description of the model is presented followed by a presentation of results from the analysis.

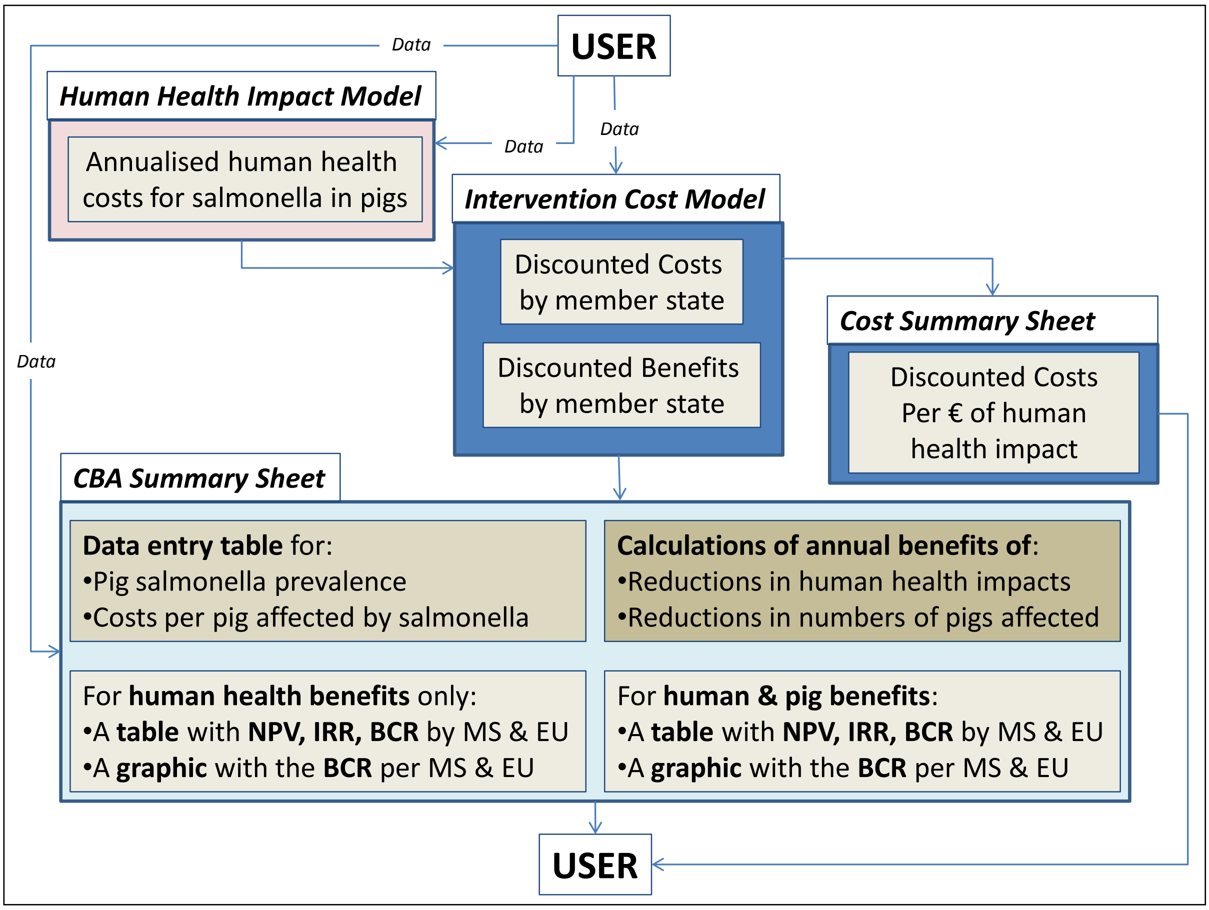
## 5.2 The model structure

The model used for the cost-benefit analysis is described in the FCC 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 6. 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 is reasonable taking into account the time required to make changes significant enough to have an impact on pig *Salmonella*[16]. 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.

For the application of the model to slaughterhouse interventions the following modifications were made:

- All pre-harvest costs were set to zero;
- The support unit costs were reduced by allowing a greater number of carcasses to be supervised by a single veterinarian;
- Additional cost items were included for slaughterhouse interventions and monitoring in the slaughterhouse.

One area that was not explored was the possibility that a concentration on slaughterhouse intervention would lead to savings on pre-harvest interventions. This would be a potential area for further work, but only if the relative attributions between environmental and food borne *Salmonella*s from pig meat systems can be adequately estimated.

## 5.3 Market impact

### *5.3.1 Product recall costs*

Product recalls have become an important component of the food system as the value chains have lengthened and the produce eaten has been processed, refined and mixed before the consumer purchases it. Of the major food recall incidents recently many have been related to E.coli in beef, *Salmonella* on vegetables and vegetable products such as peanut butter and in Europe some incidences around the detection of dioxins in meat. This is not to downplay the frequent and smaller scale problems across the EU.

A recent report by the Irish Economy is critical of two aspects of the recall problems in Europe:

- The costs of recall are strongly related to the traceability systems in place:
    - if traceability is poor then large amounts of product have to be recalled that are likely to be unaffected by the problem.
- The costs of the recalls have been subsidised or completely covered by public sector money, in the example discussed this was a combination of Irish Government money supplemented by EU money for a dioxin recall.

[16] 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.

**Table 32. Significant product recalls across the world.**

| Product | Problem | Country / Region | Impact | Year | Comment |
|---|---|---|---|---|---|
| Pig ears for pets | *Salmonella* | USA | 2 700 boxes of product withdrawn | 2011 and 2012 | |
| Peanut butter | *Salmonella* | USA | US$70 million | 2009 | |
| Pork | Dioxin | Ireland | €200 million | 2008 | Costs largely borne by government |
| Tomato | *Salmonella* | USA | US$250 million | 2008 | Wrong product identified |
| Beef | Welfare and fear of BSE | USA | US$117 million | 2008 | |
| Pet food | Melamine | USA | US$42 million | 2007 | |
| Peanut butter | *Salmonella* | USA | US$72 million on the recall; US$55 million in lost sales | 2007 | |
| Spinach | E.coli | USA | US$350 million recall costs and lost sales | 2006 | |
| Deli products and hot dogs | Listeria | USA | US$76 million on recalls and US$25 million on factory refit | 1999 | |
| Beef | E.coli | USA | US$25 million on recalls plus significant loss in company value | 1997 | |
| Apple juice | E.coli | USA | US$12 million | 1996 | |
| Beefburgers | E.coli | USA | US$160 million | 1992 | |

The information compiled indicates that *Salmonella* has yet to make a significant impact in terms of product recalls for pork products that are used for human consumption. Potential reasons for this are that *Salmonella* can be removed from the product with thorough cooking and most cuisine across Europe thoroughly cooks pork products. Another possible reason may be the difficulties of attribution. Whatever the reason, it seems that *Salmonella* in pig meat has never been a food scare issue

### *5.3.2 Market shock*

The possibility that consumers are made aware of *Salmonella* risks from cooking and eating pork products could have an impact on the markets for these products. However the evidence to date is not strong that this will take place, for example there does not seem to have been an associated reaction with the emergence of *Salmonella* DT104 strains that could well have emerged from the food system and in some cases could be linked to pig production. In the case of a market shock the most likely problems are a disruption in the food system which may:

- make some businesses go bankrupt;
- lead to loss of employment;
- lead to restructuring of the industry.

Only BSE has led to a significant drop in consumption of a product beyond the short-term; all other scares have been relatively short lived with consumption soon returning back to previous levels.

#### *5.3.3 Import impacts*

The EU is a major world pig producer and exports a significant proportion of its output. Less than one per cent of output comes into the Union as imports and the overall self-sufficiency ratio was between 106 and 108% between 2005 and 2007 (see table below).

**Table 33. Pig meat production, imports and exports in Europe between 2005 and 2007**

| Year | Millions of tonnes | | | | Percentage of imports relative to output (%) | Self sufficiency (%) |
|---|---|---|---|---|---|---|
| | Output | Export | Import | Trade balance | | |
| 2007 | 22.8 | 1.894 | 0.043 | 1.851 | 0.19% | 106.9% |
| 2006 | 21.3 | 2.077 | 0.032 | 2.045 | 0.15% | 108.2% |
| 2005 | 21.1 | 1.930 | 0.022 | 1.908 | 0.10% | 107.6% |
| 2004 | 21.2 | 1.830 | 0.044 | 1.786 | 0.21% | 107.0% |

*Data from EC Agriculture and Rural Development: http://ec.europa.eu/agriculture/markets/pig/*

Given the overall situation of surplus pig production and low level of imports it is unlikely that stricter requirements on *Salmonella* status would significantly affect the success of the European industry.

However stricter import controls may have an impact on individual countries exporting to the EU market if they were unable to meet the *Salmonella* control requirements.

#### *5.3.4 Summary*

Given the general lack of evidence that *Salmonella* in pigs has caused a significant recall or market shock issue in the past this has not been considered in the analysis of potential benefit streams from the improved management of *Salmonella* in pig meat systems. The assessment of the status of *Salmonella* management as an issue for trade protection has also not been considered given that the EU is a successful exporter of pig meat products.

## 5.4 Results of the CBA for the scenarios to reduce human infections

All scenarios were run with different estimates of the impact of the measures on human health, as follows:

- 50% reduction in human health impacts over a 10 year analysis period;
- 90% reduction in human health impacts over a 10 year period;
- an estimate of the annual reduction in human health impact to achieve a break-even economic profitability.

Each of these was tested against attribution rates of *Salmonella* from pork meat products of 15%, 29.6%, 35% and 56.8%.

### *5.4.1 Scenario 1*

With scenario 1 all the attribution levels produce a positive net present value (NPV)[17] indicating that the basic process of having a coordination unit would be affordable across the EU. However, not all the individual Member States would have positive results and even with the most optimistic assumptions of an attribution of 56.8% and a 90% reduction five Member States still show negative cost-benefit analyses (see table below).

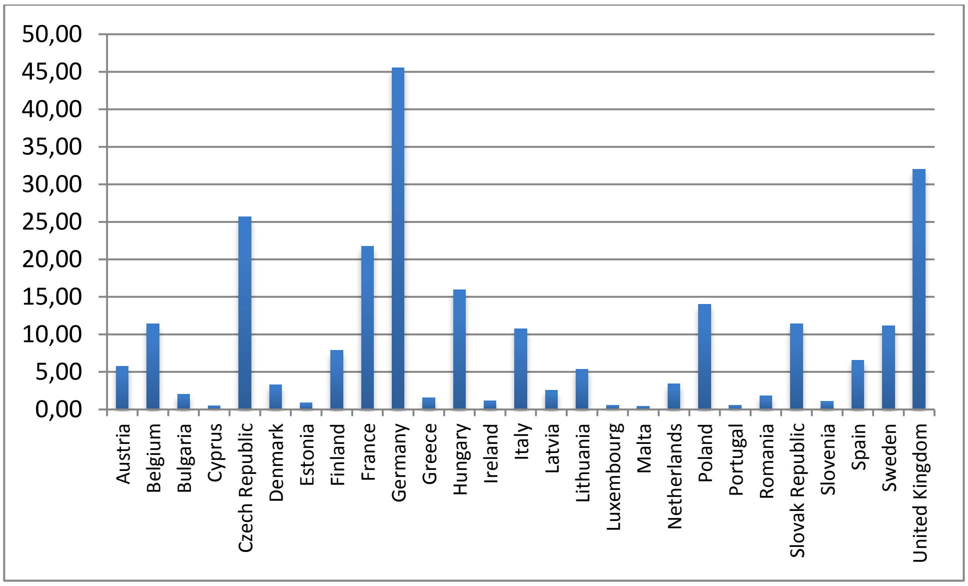
**Table 34. Summary of the cost-benefit analyses for scenario 1.**

| Item | Pork attribution level to human health | | | |
|---|---|---|---|---|
| | 15% | 29.6% | 35% | 56.8% |
| ***50% reduction*** | | | | |
| Annual decrease in human health impact | 6.65% | 6.65% | 6.65% | 6.65% |
| NPV (€ million) | 47 | 197 | 253 | 478 |
| BCR | 1.44 | 2.84 | 3.36 | 5.45 |
| Number of MS with -ve NPV | 17 | 13 | 13 | 10 |
| ***90% reduction*** | | | | |
| Annual decrease in human health impact | 20.50% | 20.50% | 20.50% | 20.50% |
| NPV (€ million) | 231 | 562 | 684 | 1,177 |
| BCR | 3.15 | 6.22 | 7.36 | 11.94 |
| Number of MS with -ve NPV | 13 | 9 | 8 | 5 |
| ***Break-evenpoint for EU NPV*** | | | | |
| Rate of improvement in human health | 4.34% | 2.06% | 1.73% | 1.05% |
| Number of MS with -ve NPV | 21 | 21 | 21 | 21 |

Figure 7 presents the benefit cost ratios for the Member States for scenario 1 with the assumptions that the attribution is 56.8% and that a reduction of 90% in human health impacts would be achievable. Unsurprisingly the larger pig producing nations would receive the largest benefit for this investment through economies of scale as the fixed cost of having a national unit is borne across a large number of pigs that are slaughtered. The countries with BCRs less than one are Cyprus, Estonia, Luxembourg, Malta and Portugal.

[17] The NPV is the difference between the present value of benefits and the present value of costs of a control programme. If NPV is greater than zero then a control programme can be said to be *economically profitable*, it however does not state if the measures described would be socially acceptable and politically manageable.

**Figure 7. Benefit cost ratios by Member State and the EU for scenario 1 with 56.8% attribution and 90% reduction in *Salmonella* human health impacts over 10 years**




### *5.4.2 Scenario 2*

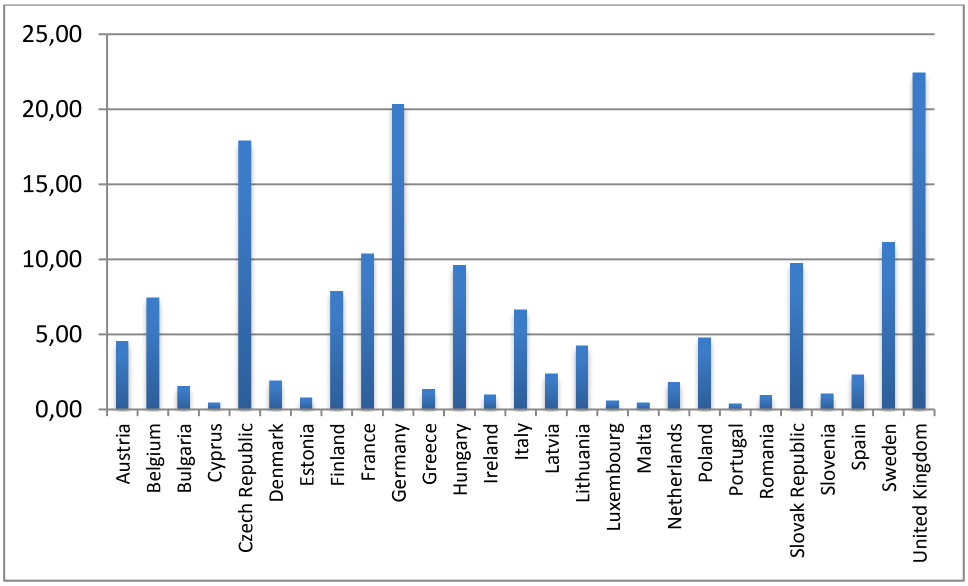
Scenario 2 analysis produced a negative cost benefit analysis for the attribution level of 15% and a 50% reduction in the human health impacts over ten years. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that seven Member States would have a negative cost-benefit analysis (see table below).

**Table 35. Summary of the cost-benefit analyses for scenario 2**

| Item | Pork attribution level to human health | | | |
|---|---|---|---|---|
| | 15% | 29.6% | 35% | 56.8% |
| ***50% reduction*** | | | | |
| Annual decrease in human health impact | 6.65% | 6.65% | 6.65% | 6.65% |
| NPV (€ million) | -19 | 131 | 187 | 412 |
| BCR | 0.89 | 1.76 | 2.08 | 3.37 |
| Number of MS with -ve NPV | 20 | 14 | 14 | 12 |
| ***90% reduction*** | | | | |
| Annual decrease in human health impact | 20.50% | 20.50% | 20.50% | 20.50% |
| NPV (€ million) | 165 | 495 | 617 | 1,111 |
| BCR | 1.95 | 3.85 | 4.55 | 7.37 |
| Number of MS with -ve NPV | 14 | 11 | 10 | 7 |
| ***Break-evenpoint for EU NPV*** | | | | |
| Rate of improvement in human health | 7.68% | 3.47% | 2.89% | 1.72% |
| Number of MS with -ve NPV | 18 | 18 | 18 | 18 |

Figure 8 presents the benefit cost ratios for the Member States for scenario 2 with the assumptions that the attribution is 56.8% and that a reduction of 90% in human health impacts would be achievable. The larger pig producing nations receive the largest benefit for this investment through economies of scale. The countries with BCRs less than one are Cyprus, Estonia, Ireland, Luxembourg, Malta, Portugal and Romania.

**Figure 8. Benefit cost ratios by Member State and the EU for scenario 2 with 56.8% attribution and 90% reduction in *Salmonella* human health impacts over 10 years**




### *5.4.3 Scenario 3*

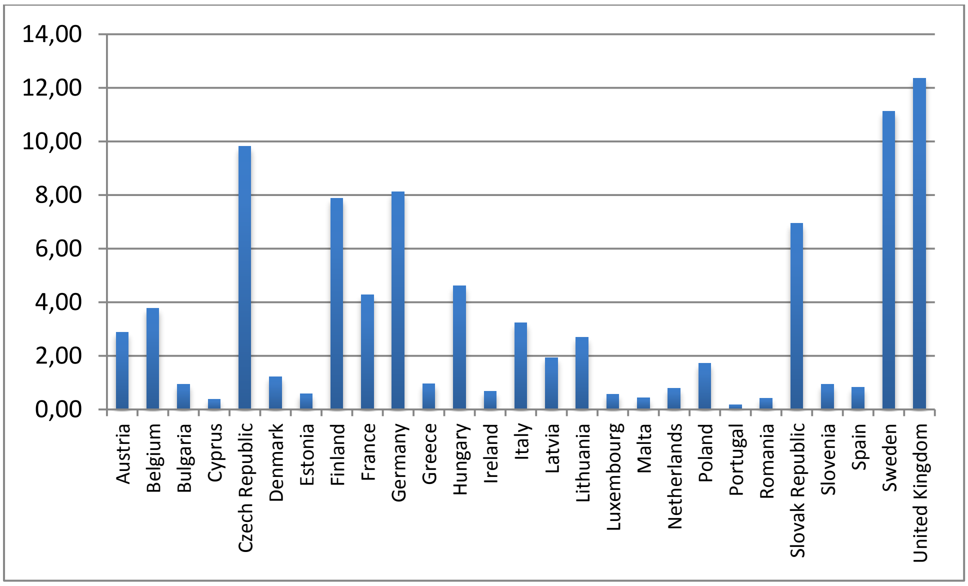
Scenario 3 analysis produced a negative cost benefit analysis for the attribution level of 15% and a 50% and 90% reduction in the human health impacts over ten years. It also produced a negative cost benefit analysis for the 29.6% attribution with a 50% reduction in human health impact over ten years. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that twelve Member States would have a negative cost-benefit analysis (see table below).

**Table 36. Summary of the cost-benefit analyses for the scenario 3**

| Item | Pork attribution level to human health | | | |
|---|---|---|---|---|
| | 15% | 29.6% | 35% | 56.8% |
| ***50% reduction*** | | | | |
| Annual decrease in human health impact | 6.65% | 6.65% | 6.65% | 6.65% |
| NPV (€ million) | -192 | -41 | 14 | 239 |
| BCR | 0.45 | 0.88 | 1.04 | 1.69 |
| Number of MS with -ve NPV | 24 | 19 | 18 | 15 |
| ***90% reduction*** | | | | |
| Annual decrease in human health impact | 20.50% | 20.50% | 20.50% | 20.50% |
| NPV (€ million) | -7 | 322 | 444 | 938 |
| BCR | 0.98 | 1.93 | 2.38 | 3.70 |
| Number of MS with -ve NPV | 19 | 14 | 13 | 12 |
| ***Break-even point for EU NPV*** | | | | |
| Rate of improvement in human health | 21.37% | 7.78% | 6.33% | 3.62% |
| Number of MS with -ve NPV | 18 | 18 | 18 | 18 |

Figure 9 presents the benefit cost ratios for the Member States for scenario 3 with the assumptions that the attribution is 56.8% and that a reduction of 90% in human health impacts would be achievable. The Member States that import pork and those that have an existing comprehensive *Salmonella* control programme are the greatest beneficiaries. The countries with BCRs less than one are Bulgaria, Cyprus, Estonia, Greece, Ireland, Luxembourg, Malta, Netherlands, Portugal, Romania, Slovenia and Spain.

**Figure 9. Benefit cost ratios by Member State and the EU for scenario 3 with 56.8% attribution and 90% reduction in *Salmonella* human health impacts over 10 years**




### *5.4.4 Scenario 4*

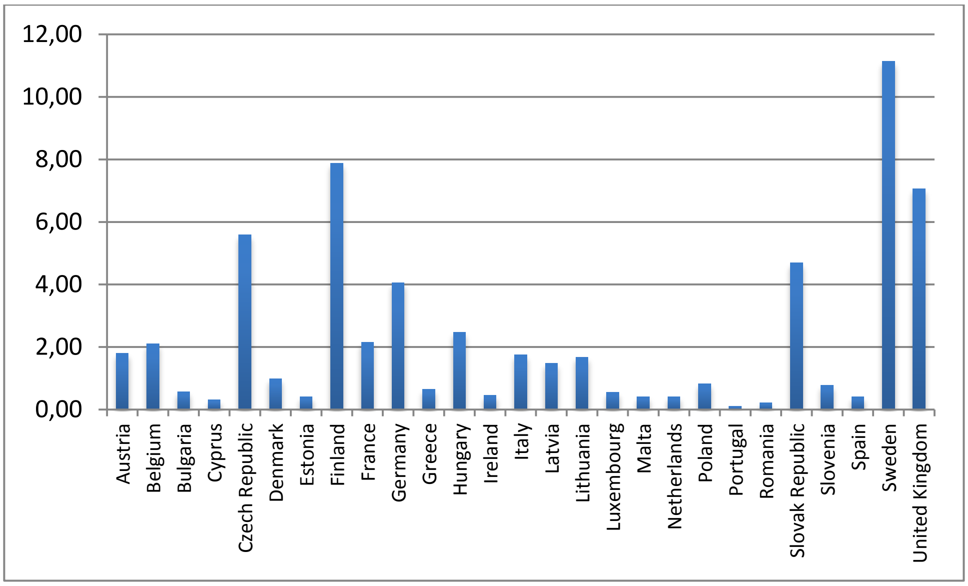
Scenario 4 analysis produced a negative cost benefit analysis for all attribution levels of 15% with a 50% reduction in the human health impacts over ten years. It also produced a negative cost benefit analysis for the attribution of 15% with a reduction of 90% in human impacts over ten years. Even setting the complete elimination of human health impacts at this attribution level did not produce a positive cost benefit analysis. All the other analyses were positive at EU level, yet even the most optimistic outcome indicated that fourteen Member States would have a negative cost-benefit analysis (see table below).

**Table 37. Summary of the cost-benefit analyses for scenario 4**

| Item | Pork attribution level to human health | | | |
|---|---|---|---|---|
| | 15% | 29.6% | 35% | 56.8% |
| ***50% reduction*** | | | | |
| Annual decrease in human health impact | 6.65% | 6.65% | 6.65% | 6.65% |
| NPV (€ million) | -472 | -321 | -265 | -40 |
| BCR | 0.25 | 0.49 | 0.58 | 0.93 |
| Number of MS with -ve NPV | 26 | 22 | 21 | 20 |
| ***90% reduction*** | | | | |
| Annual decrease in human health impact | 20.50% | 20.50% | 20.50% | 20.50% |
| NPV (€ million) | -287 | 42 | 164 | 657 |
| BCR | 0.54 | 1.07 | 1.26 | 2.05 |
| Number of MS with -ve NPV | 21 | 18 | 15 | 14 |
| ***Break-even point for EU NPV*** | | | | |
| Rate of improvement in human health | Not possible | 18.23% | 13.91% | 7.22% |
| Number of MS with -ve NPV | Not possible | 18 | 18 | 18 |

Figure 10 presents the benefit cost ratios for the Member States for scenario 4 with the assumptions that the attribution is 56.8% and that a reduction of 90% in human health impacts would be achievable. The importing Member States, those with existing comprehensive control programmes and those with high *Salmonella* human health burdens receive the largest benefit for this investment. The Member States with BCRs less than one are Bulgaria, Cyprus, Denmark, Estonia, Greece, Ireland, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia and Spain.

**Figure 10. Benefit cost ratios by Member State and the EU for scenario 4 with 56.8% attribution and 90% reduction in *Salmonella* human health impacts over 10 years**




## 5.5 Summary of the cost-benefit analysis

The cost-benefit analyses of the improved management of *Salmonella* in slaughterhouses indicates that the economic profitability of the measures required to successfully reduce *Salmonella* carcass prevalence is strongly dependent on the extent of those measures, the assumptions on the attribution of the human health burden coming from *Salmonella* in pigs and the speed of reduction in human health impacts.

The scenario with very minimal costs relating to a Member State level coordination unit created and paid for by the competent authorities indicates that this would give a positive economic return across the EU, but not a positive return in each Member State. This very basic investment scenario is unlikely to generate a rapid change in carcass prevalence and subsequent reductions in human health impacts, but it does give an indication of the level of investments that are affordable to return an economic benefit with the improved control of *Salmonella* in the pig meat system.

All other scenarios, with higher investments by both the public and private sector indicate that the economic returns are lower and that there is an increase in the number of Member States with a negative economic return.

Member States that have positive NPVs and BCRs in most scenarios have very specific characteristics which are:

1. they have a comprehensive *Salmonella* control programme in place and are therefore assumed to have no additional costs;
2. they import a significant amount of their pig meat, and/or;
3. they have significantly high levels of *Salmonella* and therefore gain from larger benefit streams.

Member States falling under points 1 and 2 above benefit from the investments of other Member States, so are capturing a positive externality from others.

# 6. DISCUSSION AND CONCLUSIONS

The assessment of the control of *Salmonella* in the pig meat production systems in Europe is complicated by the variation of attribution rates of human salmonellosis. Therefore, the cost-benefit analyses performed have looked at all possible attributions reported. The cost-benefit analysis has also been divided into four different investment scenarios.

A very basic public investment on improved coordination was examined assuming that the private sector across Europe was already investing and implementing to some extent in monitoring and slaughterhouse interventions to reduce *Salmonella* carcass prevalence. The benefits in terms of reductions of human health impacts were assumed to be derived from the companies improving their control of *Salmonella* through better guidance and enforcement from the competent authorities. This produced positive cost benefit analyses for all attribution levels if it is assumed that *Salmonella* burdens can be reduced by 50% and 90% in the human population. However the likelihood of such investments being realistic are not strong and this scenario should be treated as a bare minimum investment cost.

A further scenario includes public investment in coordination and improved private investment in monitoring. Similarly this scenario produces a positive economic assessment across the EU, but negative outcomes for a high proportion of individual Member States. Again this scenario assumes that *Salmonella* impact can take place with relatively minor investments.

Scenarios three and four have investments in coordination, monitoring and slaughterhouse improvements. Scenario three is based on an optimistic level of costs for monitoring and slaughterhouse change and the assumption that a relatively high proportion of the slaughter capacity does not need additional investment. Scenario four assumes high unit costs of monitoring and cleaning carcasses in the slaughterhouse. With the high levels of attribution and a 90% reduction in human health impacts there is a positive EU benefit, but a high proportion of individual Member States are negatively impacted.

The results create a difficult process of interpretation. They indicate the lack of clarity on attribution rates, yet they do indicate in general that the human health impacts are not adequately large to cover as the only source of funding a high investment programme to improve *Salmonella* in the pig meat system.

The EU legislation requires targets to be set on *Salmonella* control in pig meat production . The logic of the legislation is based on salmonellosis being one of the most important food borne pathogens present in the poultry and pig sectors in the EU, and that technologies for reductions are available.

The pig sector is less clear cut than the poultry sector. The attribution of salmonellosis from pig meat production is in a process of on-going debate and as presented in the present study has estimates ranging from 15% to 56%. In addition the pre-harvest control measures in pigs are technically unproven, whereas those in slaughterhouses are much clearer.

The team has considered the results of the analysis and identified areas that might need further discussion before attempting to set targets. The following questions may be asked:

1. Could further work on attribution enable more precise application of pre- and post-harvest measures at the level of individual Member States, which may reduce their control costs and show better overall returns?
    - The current study has not attempted to include reduced pre-harvest costs as a benefit stream because the attribution from environment versus food borne spread from pig meat systems into humans is not adequately understood.

- Inevitably the study has been obliged to extrapolate results of best practice control measures from a limited number of Member States, which may not necessarily be the most appropriate combination of controls along the food chain for all national situations, especially when intra-EU trade is also taken into account.

2. Has the EU reached a point with Salmonella control in pigs where the marginal cost-benefits under the current state of knowledge need to be accompanied by a greater focus on a holistic 'One Health' approach?

    - The team considers it important that some of the controls might have to be placed into an ecological, social and economic context.

3. Would a wider focus on general improvement of pig health across a range of disease and health issues show better returns?

    - Many of the pre- and post-harvest *Salmonella* control measures are not specific to *Salmonella* and have wider benefits - the costs could perhaps be allocated more widely.

    - The pig industry is under pressure from external competition, so improving efficiencies at production and slaughter levels through general improvements in health and welfare would give a critical trade advantage.

Further thought in these areas may produce more robust cost-benefits of setting targets.

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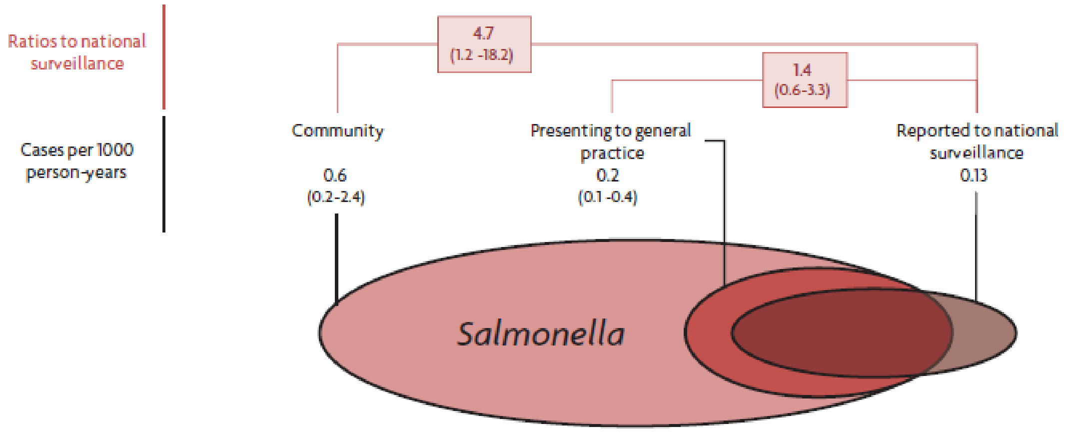
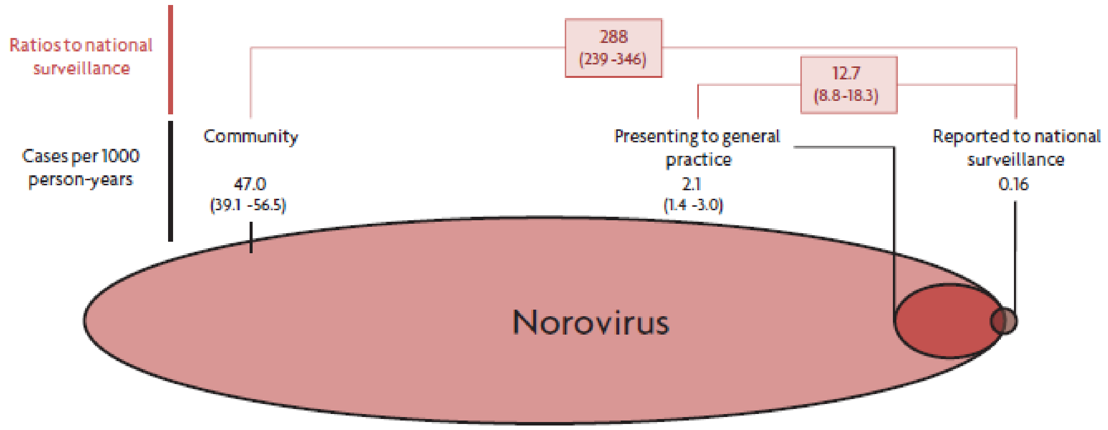
## APPENDIX – SUMMARY OF IID 2

### Figure 11. Reporting ellipse for IID due to *Salmonella*




### Figure 12. Reporting pattern of IID due to norovirus




### Figure 13. Reporting patterns for overall IID in England