The Burden of Foodborne Disease in the UK 2018

Food Standards Agency

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Authors: Nicholas Daniel, Nuria Casadevall, Pei Sun, Daniel Sugden, Vanna Aldin

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Prepared by: Analytics Unit, Food Standards Agency and London School of Hygiene & Tropical Medicine

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Acronyms

CtB	Cost to Britain
COI	Cost of illness
CV	Contingent valuation
DALY	Disability adjusted life year
DCE	Discrete choice experiment
DfT	Department for Transport
EQ-5D-3L	EuroQol five-dimensional questionnaire three levels of severity
FBD	Foodborne diseases
FSA	Food Standards Agency
FSS	Food Standards Scotland
FDEM	Foodborne disease estimation model
HES	Hospital episode statistics
HSE	Health & Safety Executive
IID	Infectious intestinal disease
LSHTM	London School of Hygiene & Tropical Medicine
MTM	Markov transition model
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NoVAS	Norovirus attribution study
ONS	Office for National Statistics
QALYs	Quality adjusted life years
UFI	Unattributed foodborne illness
VOLYs	Value of life years
VPF	Value of a prevented fatality
WTA	Willingness to accept
WTP	Willingness to pay

Glossary

Contingent valuation	A stated preference approach to valuing non-market goods and services where individuals are asked what they are willing to pay (or accept) for a change in provision of a non-market good or service.
Disability adjusted life years (DALYs)	The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.
Disturbance costs to businesses	Work-reorganisation costs to the employer due to employee sick absence related to a foodborne related illness.
Discrete choice experiment	Stated preference method and form of choice modelling in which respondents are presented with a series of alternatives and asked to choose their most preferred.
EuroQol - 5 Dimensional - 3 Level of severity (EQ-5D-3L)	Descriptive system of health-related quality of life states consisting of five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) each of which can take one of three responses stating the levels of severity.
Foodborne diseases (FBDs)	Disease commonly transmitted through ingested food. FBDs comprise a broad group of illnesses, and may be caused by microbial pathogens, parasites, chemical contaminants and biotoxins.
Financial cost	The actual costs of the illness to individuals, employers and government. The information is based on data collection on expenses incurred as a result of the disease.

Human cost	The impact on the individual's quality of life.
Quality adjusted life years (QALYs)	A measure of the state of health of a person or group in which the benefits, in terms of length of life, are adjusted to reflect the quality of life. QALYs are calculated by estimating the years of life remaining and weighting each year with a quality-of-life score (on a 0 to 1 scale). One QALY is equal to 1 year of life in perfect health.
Non-financial cost	Monetary estimates of the value to individuals of the pain, grief and suffering caused due to the disease.
Pain grief and suffering	Non-tangible aspects associated with foodborne disease.
Pathogen	Biological agent that causes disease or illness to its host.
Sequelae	A condition which is the consequence of a previous disease or injury
Unattributed foodborne illness	Cases for which a pathogen causing an episode could not be identified
Vignette	Descriptive system of health-related quality of life states, typically providing a description of symptoms using their medical definition.
Willingness to accept	The monetary measure of the value to accept to abandon the provision of good or service not available in the market.
Willingness to pay	The monetary measure of the value of obtaining a gain (or avoiding a loss) in the provision of good or service not available in the market.

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Executive summary

Microbiological foodborne disease (FBD) places both a public health and financial burden on society. In 2018 there were estimated to be 2.4 million FBD-related cases in the UK. *Norovirus* accounts for the highest number of cases at around 383,000, followed by *Campylobacter* and *Clostridium perfringens* with around 299,000 and 85,000 cases respectively. *Listeria monocytogenes* has the least number of estimated cases at 162 a year, but has the highest proportion of fatalities (26 fatalities out of a total of 162 cases).

Cost of foodborne disease to society

Based on 2018 case estimates, FBD costs society approximately £9.1bn a year. Financial costs account for over 20% of this figure, estimated at £2.0bn. The majority of this £2.0bn is accounted for by lost earnings, at £1.8bn, followed by disturbance costs to businesses at £157.5m. Direct financial costs were relatively minor, with medical costs at £60m, costs associated with absence from school at £34.3m and individual expenses at £32.0m.

The non-financial monetary estimates of the human cost of pain, grief & suffering is estimated at £7.1bn, accounting for almost 80% of the total burden of FBD to the UK. Illness, including their long-term complications and sequelae, make up a significant share of the cost; estimated at £6.8bn, followed by fatalities valued at £221.0m.

Cost bearers

Individuals and carers are the group bearing the largest cost of FBD, estimated at £8.9bn. As would be expected, non-financial human costs (pain, grief & suffering) are entirely borne by the individual sufferer. Financial costs are also predominately borne by individuals and carers, comprising lost earnings due to sickness absence and individual expenses.

There are additional costs to businesses associated with production disturbance caused by sickness absence. These are related to the required re-organization of the business to reallocate resources during the absence, creating a friction in the regular functioning of the enterprise. In 2018, the cost to businesses were estimated at £157.5m; approximately 2% of the total costs of FBD to the UK.

The group bearing the least cost is the government, with a total cost of £95.0m (1% of the total cost of FBD). These costs stem largely from NHS resource use (£60.0m per year) and costs associated with absence from school (£34.3m per year).

Cost by pathogen

The total burden of FBD in the UK is predominantly driven by the number of individual cases, i.e. the estimated amount of people infected by each pathogen. Of known cases, Norovirus imposes the greatest burden at an estimated annual cost of £1.7bn followed by *Campylobacter.* (£712.6m) and *Salmonella* (£2120.0m); while E. coli O157 (£3.9m) and *Cryptosporidium* (£2.1m) impose the least burden. However, unattributed foodborne illness cases account for 60% of total FBD cases, with an estimated cost of £6.0bn and by far impose the greatest burden when compared to known cases.

Update to past estimates of total burden of foodborne illness in the UK

The FSA, in collaboration with the London School of Hygiene and Tropical Medicine (LSHTM), have made significant revisions and updates to the approach and methods used for previous estimations of the burden of foodborne illness. These include innovative approaches and improvements drawing extensively on outputs from recently commissioned FSA research. The research included estimating the number of FBD cases, the valuation of the pain, grief and suffering attributed to FBD through the elicitation of Quality Adjusted Life Years (QALY) and Willingness to Pay (WTP) values.

For the first time, the FSA is able to provide:

- estimates of the UK financial and societal burden attributed to 13 individual foodborne pathogens plus unattributed foodborne illness;
- estimates of WTP to avoid pain, grief and suffering associated with illness specifically related to FBD. Previously the FSA relied on non-fatal injury valuations related to road traffic accidents derived from the Department of Transport (DfT), which were not well-suited to FBD related illnesses;
- revised estimates for norovirus cases, giving us a greater understanding of the true role of food in the transmission of norovirus; and
- estimates for disturbance costs to businesses, and costs associated with absence from school for children aged 16 and under, in terms of school days lost due to sick absence.

Based on latest (2018) human FBD estimates of 2.4m cases per year, the COI model allow us to estimate that the total burden for the UK from foodborne illness is £9.1bn (£3.1bn for known cases and £6.0bn for unattributed cases).

Non-monetised measure of foodborne disease burden

While the COI model reflects the monetary estimates of the financial and societal impact of FBD, including monetised WTP estimates of the pain, grief and suffering to individuals of the disease, the consideration of Quality Adjusted Life Years (QALY's) provides a complementary non-monetary assessment of this intangible element.

To capture the non-financial effects of FBD, the COI model uses pathogen specific WTP estimates instead of uniformed monetised value of QALYs losses. This allows the model to capture individuals' valuations on the conditions associated with specific pathogens – such as vomiting or hospitalisation – which should be more sensitive than to simply attribute an average monetary value to the QALY losses wherever they occur.

Listeria monocytogenes is the pathogen reflecting the highest QALY loss per case with an expected loss of 4.03 QALYs per case. This was four times the size of the expected burden of *Giardia* which has the second highest burden per case (1.01 QALYs). *Clostridium perfringens* was the least severe pathogen, with an expected QALY loss of 0.004 per case, while *Cryptosporidium* (0.023 QALYs lost per case) and *Shigella* (0.027 QALYs lost per case) also had low burden of illness per case.

Conclusion

The cost of illness model for foodborne disease represents a major milestone. For the first time, the FSA has a robust methodology to estimate the annual burden to society for the overall prevalence of foodborne illness among the UK population. Robust and reliable cost of illness estimates enhance its ability to assess the cost effectiveness of food safety policy interventions, improve impact assessment analysis, appraisals and evaluation. Moreover, it can identify the burden by the main cost bearers, namely: individuals and carers, businesses and government. There are however, limitations with its application: for example, the COI model only presents a UK average of the burden and cost of illness, hence it is not possible to identify country-level costs of foodborne illness; nor can it be used to estimate spill-over effects from foodborne outbreaks (e.g. local authority enforcement) or identify vulnerable groups facing a greater disease burden.

The estimation of the cost of foodborne illness is an ongoing area for research for food safety regulators around the world. There are still significant gaps in the underlying data and several assumptions are required to fill these gaps. In turn, this increases the uncertainty and the degree of comparability.

The scope of further research is predicated on understanding the burden and costs across different demographics and socioeconomic groups within the UK population. This would enable the FSA to identify key vulnerable groups (by age or socio-economic group) facing the highest burden, for example, identification of loss of earnings, individual expenses and medical costs where reductions in the number of FBD cases could potentially have the greatest impact on the costs incurred by society.

In addition to the work presented here on FBD, a further programme of work estimating the burden of other food safety related hazards in the UK is underway, namely the COI for food hypersensitivities and the cost of food crime and food authenticity.

1. Introduction

1.1 Background

Microbiological foodborne disease (FBD) places both a public health and financial burden on society. There are an estimated 2.4 million cases who suffer from an FBD in the UK; approximately 16,300 receive hospital treatment with over 180 reported deaths. The burden of FBD is felt by those individuals infected and their families, health care services, businesses and society. In monetary terms the costs can be substantial.

The Food Standards Agency (FSA) is the competent authority in England, Wales and Northern Ireland responsible for protecting consumers' interests in relation to food by ensuring that it is safe and authentic[1]. Through risk assessment, regulation and other interventions, the FSA dedicates resources to reducing the number of cases, and burden, of FBD.

To assess the most efficient and effective ways to do this, the FSA needs to ensure it has a good understanding of both the costs and benefits to enable it to undertake robust and reliable assessments using an evidence-based approach to allocate resources. Areas of oversight includes prevention and control of foodborne risks, monitoring and evaluation of food safety measures, and developing new food safety standards. A critical component of this is to fully understand the impacts of FBD to provide a baseline estimate to assess the impact of interventions and policies to address FBD. This estimate is provided by the FSA's COI model.

1.2 FSA Cost of Illness model

The COI model identifies and measures the full social cost of FBD, including both its financial (medical and personal costs) and monetary estimates of its non-financial impacts (pain, grief and suffering). This enables outputs from the model to be expressed in monetary terms, thus providing an estimate of the total burden of annual UK FBD cases. The existing FSA COI model was extensively revised and updated, to enable more refined and robust cost estimates of the financial and societal burden of FBD.

[1] Authentic food is food (or drink) that exactly meets its description and also meets a person's reasonable assumption of its ingredients.

1.3 Revisions to Cost of Illness model

The basic COI model prior to revisions detailed here relied on data (GP, hospital costs and loss of earnings) derived from the Report of The Study of Infectious Intestinal Disease in England (IID1 study)[2] to calculate and estimate the burden of annual UK FBD cases. This previous COI model had several shortcomings that have now been addressed in the new and revised model, namely:

- Financial cost estimates were based on data from the original IID1 study (2000). Data sources went back as far as 1994, thus failing to reflect the demographic, socio-economic and structural changes over the last two decades. Previous estimates did not take account of, for example, recent NHS reforms, advancement in treatment and medicine, changes in consumer preference and household consumption patterns.
- While estimates were available for the overall total cost of FBDs, a cost breakdown at a pathogen-specific level was only available for a few pathogens. An individual pathogen breakdown would allow monitoring or estimating the cost and benefit of reducing specific sources of foodborne disease through various forms of government intervention that may opt to promote health and reduce the number of fatalities, morbidity rates, or permanent disability. The IID1 study only included details for a few pathogen-specific level costs.
- The IID1 study did not include information on long-term health consequences of FBD.
- Cost by severity of FBD was only weighted and estimated by the number of days of illness obtained from the IID1 study, neglecting intensity of resource use such as type of treatment and care. For example, if a specialist ward or medical equipment/procedure is required to treat patients with a specific food related FBD.

The FSA, in collaboration with the London School of Hygiene and Tropical Medicine (LSHTM), have made significant revisions and updates to the COI model, addressing the

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[2] Food Standards Agency (2000). Report of The Study of Infectious Intestinal Disease in England (IID1 Study). www.food.gov.uk/sites/default/files/media/document/iid1_study_final_report.pdf

shortcomings from the previous model. The new model incorporates innovative approaches and improvements drawing extensively on outputs from recently commissioned FSA research in estimating FBD incidents, and the valuation of the pain, grief and suffering attributed to FBD through the elicitation of Quality Adjusted Life Years (QALY) and Willingness to Pay (WTP) values[3].

For the first time, the FSA is able to provide estimates of the UK societal burden attributed to 13 individual foodborne pathogens plus unattributed foodborne illness. The model includes the WTP to avoid pain and suffering associated with illness specifically related to FBD. Previously the FSA relied on non-fatal injury valuations related to road traffic accidents derived from the Department of Transport (DfT), which were not well-suited to FBD related illnesses (discussed in section 3.3). The model now also accounts for those costs associated with absence from school for children aged 16 and under, in terms of costs per hour of school. As the majority of school costs are fixed (housing, personnel and materials) a child missing school does not result in actual savings. Medical costs now rely on the latest NHS reference costs data, which are based on unit costs to the NHS for providing defined services, including direct costs such as medical staffing costs, the delivery of patient care, and costs of support services[4].

As a result of these updates to the model, the FSA can provide revised estimates to the previously published £1bn annual cost of FBD[5]. The increase of the figure to £9.1bn is

[3] Food Standards Agency (2017). Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2). www.food.gov.uk/sites/default/files/media/document/fs102087p2finrep.pdf

[4] We use NHS reference costs data for England as a proxy to scale up cost to the NHS at a UK level, where we assume the number of cases and outcome of FBD is the same in Wales, Scotland and Northern Ireland.

[5] Food Standards Agency, Ensuring food safety and standards, National Audit Office (NAO), June 2019 - www.nao.org.uk/wp-content/uploads/2019/06/Ensuring-food-safety-and-standards.pdf

mainly driven by the recent revision on the estimated number of cases[6], as well as by the increase in the magnitude of non-financial costs.

1.4 Quality adjusted life years (QALYs)

QALYs are a generic non-monetary measure to quantify the disease burden, taking account of both the quality and the quantity of life lived. The worse the condition or the severity of illness, the higher the QALY loss. While the COI model reflects the monetary and societal impact of FBD, including monetised WTP estimates of the pain, grief and suffering to individuals of the disease; the consideration of QALYs provides a complementary non-monetary assessment of this intangible element. The use of QALY allows the FSA to align with NICE and the NHS in their valuation and comparison of interventions. Further details are presented in Section 4.

The COI model does not include monetised figures of QALY losses into its estimates. This is because of the FSA's methodological preference for using the available context-specific monetary valuations of FBD non-financial impacts. Nevertheless, the consideration of QALYs provide another measure which may be useful in other settings for which context specific valuations do not exist. For instance, the FSA would be able to provide comparable figures using the standard monetary value per QALY loss currently applied in cost-benefit analysis in government.

1.5 Report structure

The report contains five sections:

- Section 2 provides an overview of the FSA's Cost of Illness (COI) model giving details on the scope and methodology of the model.
- Section 3 provides estimates of the number of cases and cost of FBD in the UK for the year 2018.
- Section 4 presents QALY estimates related to FBD; focusing on alternative non-monetised approaches for quantifying disease burden.

[6] Food Standards Agency (2020). Foodborne Disease Estimates for the United Kingdom in 2018. www.food.gov.uk/sites/default/files/media/document/foodborne-disease-estimates-for-the-united-kingdom-in-2018.pdf

- Section 5 focuses on priorities for future FSA research in modelling and estimating the burden for food safety risks.
- Section 6 presents the conclusions of the report with recommendations for policy and future work in the area of FBD.

2. Scope and methodology of Cost of Illness analysis

2.1 Approach to calculating the Cost of Illness

A bottom-up approach is used to calculate and estimate the cost of foodborne illness. This means that estimates of the prevalence and severity of foodborne disease are used as a base for the number of cases and level of severity of foodborne illness. These quantities are matched by a price vector based on the monetary value per case of FBD, taking into account the outcomes of such an illness.

Figure 1: Formula for Cost of Illness Model

$$\text{Total Cost} = \sum_{p=1}^{14} [(\text{PRICE} * \text{USAGE}) * \text{number of FBD cases}_p]$$

Costs are estimated separately for 13 individual pathogens plus unattributed foodborne illness (hence p=1-14), using the COI formula in Figure 1. A pathogen-specific cost vector, containing prices and estimated costs, is multiplied by the usage of the identified components; this product is then match to the relevant number of cases occurring in 2018. When aggregated, an estimate of the total cost of the burden of FBD in the UK is obtained. The list of individual pathogens included in the COI model is presented in Table 1.

Table 1: List of pathogens included in the Cost of Illness model

1. Campylobacter
2. Clostridium perfringens
3. E. coli O157
4. Listeria monocytogenes
5. Salmonella
6. Shigella
7. Cryptosporidium
8. Giardia
9. Adenovirus
10. Astrovirus
11. Norovirus
12. Rotavirus
13. Sapovirus (SRSV)
14. Unattributed foodborne illness

The choice of pathogens was predicated on pathogenicity, significance and the availability of data from the different data sources including incidence data from the *Report of The Study of Infectious Intestinal Disease in England* (IID1 study)[7], "The Second Study of Infectious Intestinal Disease in the Community" (IID2 Study)[8], the FSA's "Costed extension

[7] Food Standards Agency (2000). Report of The Study of Infectious Intestinal Disease in England (IID1 Study). www.food.gov.uk/sites/default/files/media/document/iid1_study_final_report.pdf

[8] Tam, C.C., Rodrigues, L.C., Viviani, L., Dodds, J.P., Evans, M.R., Hunter, P.R., Gray, J.J., Letley, L.H., Rait, G., Tompkins, D.S. & O'Brien, S.J. (2012). Longitudinal study of infectious intestinal disease in the UK (IID2 Study): incidence in the community and presenting to general practice. www.food.gov.uk/sites/default/files/media/document/711-1-1393_IID2_FINAL_REPORT.pdf

to the Second Study of Infectious Intestinal Disease in the Community" (IID2 extension)[9] and outbreak data for food attribution.

Though unattributed foodborne illness is not a pathogen, it is included in order to get an overall FBD cost burden figure, which will include various different pathogens including some of the pathogens listed in Table 1. Our choice for the selection of pathogens followed the approach from the IID2 study.

Cost model

A detailed spreadsheet model was developed and constructed in Microsoft Excel[10] by the FSA to calculate the cost of individual pathogens, aggregate costs and appraisal values. The model, including its outputs, has been independently quality assured and independently peer reviewed[11].

There are longer term plans to develop an online COI calculator for estimating the cost of each of the 13 foodborne pathogens, plus for unattributed foodborne illness. The calculator will be an interactive tool that will enable users to input and modify FBD case numbers by pathogen to calculate the burden for a particular foodborne pathogen.

2.2 Data

Number of foodborne disease cases

Estimates of the number of cases of illness[12] resulting from foodborne disease in the UK have been recently revised following the publication of both the FSA's Foodborne Disease

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[9] Tam, C; Larose, T; O'Brien, S J (2014). Costed extension to the Second Study of Infectious Intestinal Disease in the Community: Identifying the proportion of foodborne disease in the UK and attributing foodborne disease by food commodity (IID2 Study Extension). www.food.gov.uk/sites/default/files/media/document/IID2 extension report - FINAL 25 March 2014.pdf

[10] To be published in the future following the publication of this report.

[11] The COI model was both quality assured and independently peer reviewed by Professor Richard Smith, University of Exeter and assistant Professor Andreia Costa Santos, London School of Hygiene & Tropical Medicine (LSHTM).

[12] For this work we look at incidence cases rather than prevalence (i.e. how many new cases arose in 2018).

Estimation Model (FDEM) and Norovirus Attribution Study (NoVAS)[13]. Previous estimates were based on the IID2 studies to identify the proportion of infectious intestinal disease that is due to food. The FDEM provides estimates of the number of foodborne disease cases, GP presentations, hospitalisations and deaths, covering 13 of the main pathogens. It adopts and uses the model and approach developed in the IID2 Extension, which aimed to estimate the burden of UK-acquired foodborne disease. The Norovirus Attribution Study (NoVAS), commissioned by FSA in (2014) and recently published,[14] has led to the number of foodborne norovirus cases being estimated separately. The rationale for this approach stems from the nature of norovirus not leading to reliable presentations at GPs and hospitals, and a need to better understand the role of food in norovirus transmissions.

NoVAS was based on a series of retail surveys capturing data on the sale of foods known to be high risk[15]. An innovative modelling approach was used to combine the results with data routinely collected by the FSA on UK eating habits and data from other sources.

Results from NoVAS were modelled to estimate the likely number of foodborne norovirus cases in the UK. This revision of foodborne norovirus estimates indicate that food is likely to be involved in transmission in many more cases than previously thought; although human-to-human transmission continues to remain a much larger cause than foodborne.

Price/cost data

To date the burden of FBD has been estimated using cost data on intestinal illness from the IID1 study. As indicated earlier, this has several shortcomings, and extensive revisions to the COI model now mean that more relevant and contemporary data sources are being used to reflect the demographic, socio-economic and structural changes that have emerged

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[13] Food Standards Agency (2020). Foodborne Disease Estimates for the United Kingdom in 2018. www.food.gov.uk/sites/default/files/media/document/foodborne-disease-estimates-for-the-united-kingdom-in-2018.pdf

[14] Food Standards Agency (2020). Foodborne Disease Estimates for the United Kingdom in 2018. www.food.gov.uk/sites/default/files/media/document/foodborne-disease-estimates-for-the-united-kingdom-in-2018.pdf

[15] oysters, lettuce and raspberries.

over the last 25 years, reflecting NHS reforms, advancement in treatment and medicine, changes in consumer preferences and household consumption patterns.

COI estimates presented in this report are based on over 16 data sources including routinely available NHS Reference Cost Data, Hospital Episode Statistics (HES) and Office for National Statistics (ONS) survey data on earnings. These data sets are discussed in more detail in Appendix A.

2.3 Cost components

The COI model is comprised of two main components: financial and non-financial costs borne by individuals and carers, businesses and government.

Financial costs

Financial costs are structured under two broad categories:

- **Direct costs** Includes medical care expenditures associated with diagnosis, treatment, management and other financial costs directly related to the illness. This includes resource use and costs to the NHS and personal expenses.
- **Indirect costs** Includes loss of earnings due to illness for the affected individuals and their carers and disturbance costs to business related to the in-house reorganization of the workload. The model derives lost earning due to FBD based on number of cases and length of the disease, as well as, production disturbance costs to businesses. The model has also been extended to reflect those costs associated with absence from school for children of primary and secondary school age.

The financial cost components are summarised and presented in Table 2. For detailed assumptions, methodology and data sources, please refer to Appendix A.

Table 2: Cost of Illness model - financial cost components

Direct cost

Medical cost	GP cost	Includes GP visits, home visits, prescriptions, telephone and follow-up calls, and laboratory costs. NHS 111 helpline services are also costed.
	Hospital cost	Includes inpatients, outpatients and A&E components.
Individual cost	Transportation costs	Costs incurred by patients while travelling to seek medical care and attention.
	Out-of-pocket expenses	The out-of-pocket expenditures for patients per prescription. Waived amounts are deducted.
	Over the counter (OTC) medications	Assumed to apply to the patients who opt not to attend a GP.
	Funeral costs	Discounted present value cost of funeral expenses brought forward due to premature fatalities attributed directly to FBD.

Indirect cost

Lost earnings	Lost earnings for individuals / carers	The estimates consider the length of illnesses of FBD and the labour cost - loss of earnings were estimated for non-GP visitors, GP visitors and hospitalised patients and their possible carers.
Costs associated with absence from school	Costs for patients under 15	Costs associated with absence from school due to school absenteeism for patients who are 15 years and under are considered for primary and secondary education.
Disturbance cost	Disturbance costs to businesses	Work-reorganisation costs to the employer due to employee sick absence related to an FBD related illness.

Non-financial cost - human cost of pain, grief & suffering

The full social cost of the burden of FBD extends far beyond the financial consequences. The HM Treasury Green Book Guidance[16] is clear that wider social and environmental impacts must be brought into any cost-benefit assessment as far as possible.

The non-financial component of the COI model accounts for the intangible valuation of the 'pain, grief & suffering' - the human cost of foodborne related illness and fatalities, which are concepts difficult to measure on a monetary basis as they represent a 'non-market cost' and thus needs to be valued by other means. In such circumstances, where market prices do not exist or where they are unattributed, there are other "non-market valuation" methods that can be used to estimate its value.

Valuing the Human Cost of Foodborne Illnesses

Previously, the FSA did not have monetary valuations of the pain & suffering specifically related to FBD illnesses. To assess the cost of this burden, the FSA relied on non-fatal injury valuations related to road traffic accidents, derived from the Department of Transport (DfT); adjusted as per Health and Safety Executive (HSE) guidance[17].

A major shortcoming with this approach stemmed from having to rely on values based on road safety research and injury descriptions representative of a range of road injury types, not specifically related to food safety health outcomes, and which were difficult to map to foodborne related illnesses.

The COI model is now underpinned by substantially more robust monetised estimates of the pain & suffering of individuals with a foodborne illness. A valuation study commissioned by the FSA – *Estimating Quality Adjusted Life Years and Willingness to Pay Values for*

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[16] HM Treasury (2018). The Green Book. Central Government Guidance on Appraisal and Evaluation.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

[17] Health and Safety Executive (2011). The costs to Britain of workplace injuries and work-related ill in 2006/7. www.hse.gov.uk/research/rrpdf/rr897.pdf

Microbiological Foodborne Disease (Phase 2)[18] – provide WTP (monetary) estimates of pain & suffering specifically related to FBDs. Stated preference Discrete Choice Experiment (DCE) and Dichotomous Choice Contingent Valuation (CV) survey designs were employed to elicit WTP measures to avoid short-term and long-term illnesses caused by a select number of foodborne pathogens.

The guidance set by HM Treasury[19] discusses use of context specific values where appropriate. By using pathogen specific WTP estimates, the model provides a picture of the valuation individuals place on the discomfort associated with the specific diseases. If the non-financial valuation was derived from QALY losses, then the monetised value would reflect the average cost by unit of QALY lost but not the specific monetary valuation on the health condition identified by the individuals. However, there might be cases, when considering only the non-financial burden of individual foodborne pathogens, to refer to the monetary value for a QALY of £60,000 as per current guidance as long as the assumptions made are clear and transparent.

A concern with the approach chosen to monetise the human suffering component of the model was around the risk of the overstatement of values and double counting. This concern arose because the costs are not consequential, and respondents might look to factor in loss of earnings in their valuations. In the development of the survey design, the study developed materials to remind participants of their fixed budgets, other things their money could be spent on and that illness was part of normal life. They were also reminded to think only about the (value of) averted pain and suffering not the costs of childcare, lost wages etc.

Focus groups were conducted to test both survey design and establish whether bias was present. Results from the focus groups showed that participants said they could isolate other impacts such as loss of income, workdays lost, medical expenses, extra childcare

[18] Food Standards Agency (2017). Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2). www.food.gov.uk/sites/default/files/media/document/fs102087p2finrep.pdf

[19] HM Treasury (2005). Managing risks to the public: appraisal guidance. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/191518/Managing_risks_to_the_public_appraisal_guidance.pdf

expenses etc., and focus on, pain and suffering associated with FBD. More details on the WTP approach used is presented in Appendix B.1 of this report.

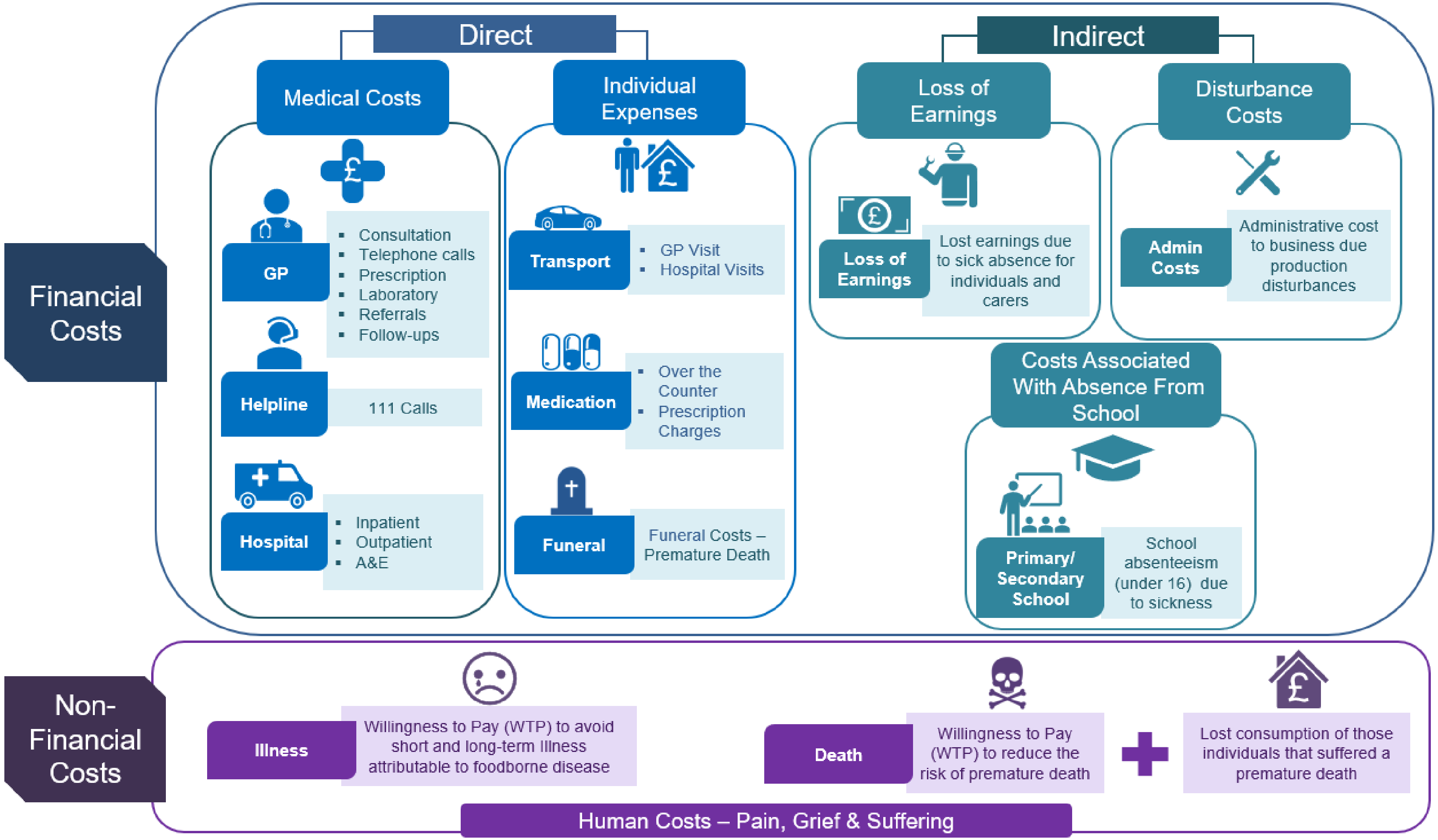
Valuing the human cost of fatalities

The above discussed WTP estimates do not include the pain, grief and suffering related to fatalities. The valuation of fatalities continues to be based on valuations estimated as part of the Department for Transport's (DfT) value of a prevented fatality (VPF) study, captured in the *'Managing risk to the public: appraisal guidance'* set by HM Treasury. It is consistent and in line with Health and Safety Executive (HSE) guidance on valuing the human cost of illness, as well as being consistent cross-government. The DfT study used stated preference techniques to elicit individual WTP to reduce the risk of a fatality in a road traffic accident.

Human costs are based on WTP values which for fatalities encompass the intrinsic cost of life enjoyment (excepting consumption of goods and services) up to standard life expectancy. More details on the WTP approach and the human costs associated with fatalities are set out in Appendix B.2 of this report. .

Cost components of the COI model are shown in Figure 2.

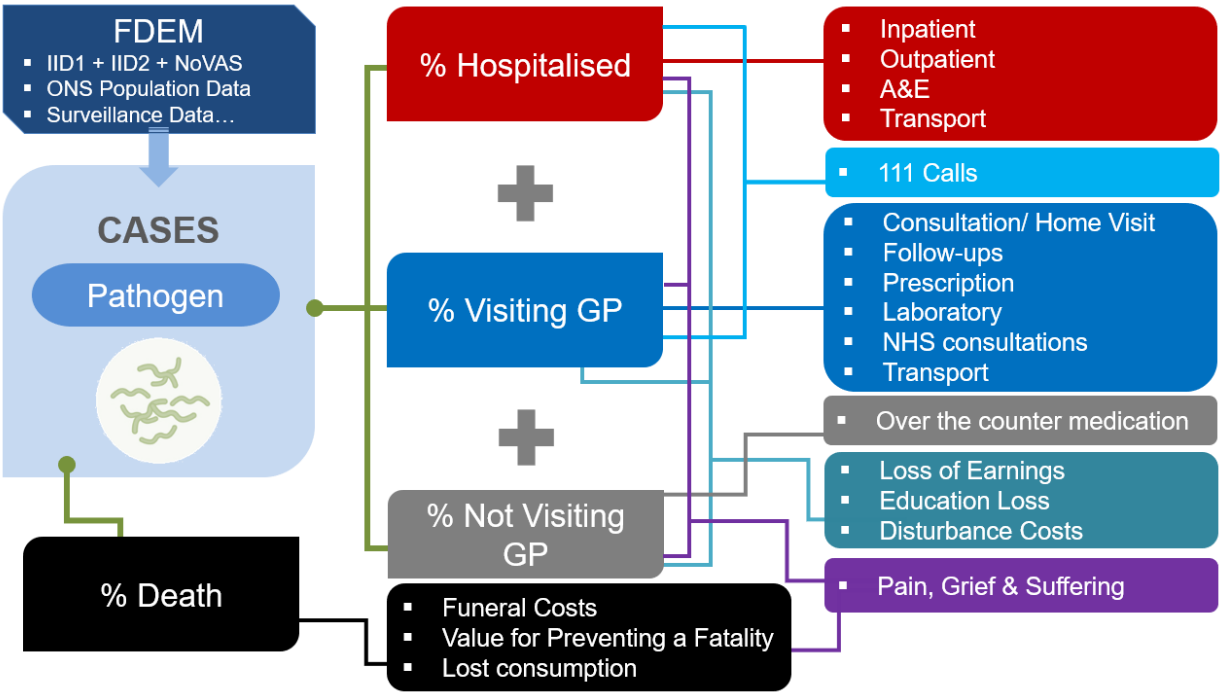
Figure 2: Cost of Illness components



2.4 Cost of Illness framework

As discussed in section 2.2, the FDEM provides estimates for the number of foodborne disease cases, based on GP presentations, non-GP presentations, hospitalisations and deaths, which feeds into the COI model (see section 2.3). This is to calculate the burden that foodborne disease places on the UK, including healthcare resources, individual expenses, loss of earnings and pain, grief & suffering (see Figure 3).

Figure 3: Attributing and costing foodborne disease cases – financial costs



2.5 Affected groups – cost bearers

Costs underpinning the COI model impact on three distinct groups:

Figure 4: Cost bearers

The COI model presents a bottom up approach that does not consider income flows between agents, but reflect the costs associated to each individual stakeholder as an independent body.

Figure 5: Summary of illness cost components by affected group

Affected Groups	Medical Costs	Individual Expenses	Loss of Earnings	School Absence	Disturbance Costs	Human Cost
Individuals and Carers	✗	✓	✓	✗	✗	✓
Business	✗	✗	✗	✗	✓	✗
Government	✓	✗	✗	✓	✗	✗

(COI Cost Components)

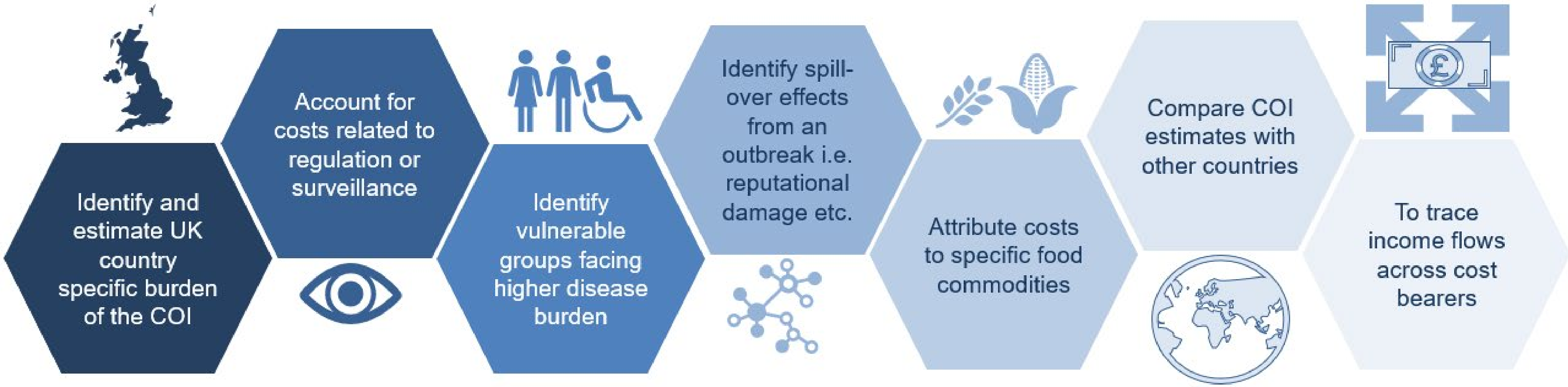
2.6 Application of Cost of Illness model

Robust and reliable cost of illness estimates allow the FSA to enhance and improve its ability to:

Figure 6: Cost of Illness – Its applications

However, COI estimates cannot be used to:

Figure 7: Cost of Illness - What is out of scope



2.7 Cost of Illness approach in other countries

The FSA is not alone in the use and application of the COI model approach. Organisations such as the United States Department of Agriculture - Economic Research Service (USDA-ERS), Canadian Food Inspection Agency (CFIA), Food Standards Australia New Zealand (FSANZ) and the Dutch National Institute for Public Health and the Environment (RIVM) all use and have developed COI models to identify and measure all the costs of a particular foodborne disease, including the direct, indirect, and intangible dimensions – all expressed in monetary terms in estimating the total burden of a particular disease to society.

The USDA-ERS produces cost estimates of foodborne illnesses caused by 15 known major pathogens that account for over 94% of foodborne disease incidence in the United States (US) from identifiable pathogens[20]. Estimates are comprised of associated outpatient and inpatient expenditures on medical care, loss of earnings and individuals' WTP to reduce mortality risk associated with these foodborne illnesses. Foodborne pathogens are estimated to impose an economic burden on US citizens each year of over $15.5 billion in 2013[21] (equivalent to £12.5bn, 2018). This does not include the value of avoided pain and suffering from morbidity. As is the case for our COI model, the cost per case varies significantly across pathogens.

Alternative estimates for the US were derived by Scharff (2012)[22.] Costs to the US were estimated at a substantial $77.7 billion in 2010 (equivalent to £66.7bn, 2018). This consists of $32.5bn for known cases from 31 identified pathogens (equivalent to £27.9bn

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[20] Hoffman, S., Maculloch, B., & Batz, M. (2015). Economic burden of major foodborne illnesses acquired in the United States (No. 1476-2016-120935). www.ers.usda.gov/webdocs/publications/43984/52807_eib140.pdf

[21] To note that the $15.5bn estimate is for, attributed the foodborne illness cases only (approximately 9.4 million cases) based on 15 known pathogens. This figure takes no account for those unattributed cases which represent 80% of the total annual cases – approximately 48 million.

[22] Scharff, R. L. (2012). Economic Burden from Health Losses due to Foodborne Illness in the United States. *Journal of food protection*, *75*(1), 123-131. https://meridian.allenpress.com/jfp/article-pdf/75/1/123/1683871/0362-028x_jfp-11-058.pdf

in 2018) and $45.2bn for unattributed cases in 2010 (equivalent to £38.8bn in 2018)[23]. This figure includes an estimate for WTP to avoid pain and suffering from morbidity based on estimates of consumer WTP to reduce risk of mortality.

In Canada, the CFIA adopts a similar approach in estimating the annual economic cost of foodborne illnesses for pathogen-specific illness cases that require hospitalisation, a visit to the GP or do not seek medical care. WTP values are also elicited to account for the costs of loss of quality of life and the cost of death[24]. CFIA estimates, considered as conservative, quantify the burden of FBD to the national economy and the health care system at around $2.8 billion in 2012 Canadian dollars (equivalent to £1.8bn in 2018) of 30 identified pathogens.

In the case of the Netherlands, the RVIM calculates the cost of illness (COI) related to 14 food-related pathogens, including medical costs, costs for the individual and their family / carers, and costs to other sectors such as work absence; which is broadly in line with other approaches. The intangible element owed to pain, grief and suffering is captured using Disability Adjusted Life Years (DALYs)[25]. The food-related cost of illness was

[23] The difference between Scharff's 2012 estimates and USDA estimates is primarily driven by: i) number of pathogens included. Scharff (2012) included estimates for foodborne illnesses caused by 30 of 31 identifiable pathogens plus foodborne illnesses for which no pathogen source can be identified. By contrast, USDA included estimates for foodborne illness caused by only 15 identifiable pathogens; ii) valuation method – Scharff 2012 included monetized quality-adjusted life years (QALYs) to account for pain and suffering caused by foodborne illness as well as the illnesses' impact on daily activities, such as employment. USDA used a cost-of-illness estimate for nonfatal outcomes and a Willingness to Pay (for reducing deaths) measure for fatal outcomes.

[24] Canadian Food Inspection Agency (2017). Safe Food for Canadians Regulations - A Cost-Benefit Analysis and The "One-for-One" Rule & Small Business Lens Analyses. www.tonu.org/tonu/MyFiles/MF048_CFR2017.pdf

[25] National Institute for Public Health and the Environment (2017). Disease burden of food-related pathogens in the Netherlands, 2017. www.rivm.nl/en/disease-burden-of-food-related-pathogens-in-netherlands-2017

estimated to be €163.0m in 2017 (equivalent to £146.0m in 2018), accounting for a 4,200 DALYs burden.

In summary, the approach and methodology used for calculating and estimating the cost of illness related to foodborne disease appears broadly similar across countries and food safety regulatory bodies. However, these examples are for illustrative purpose only as it is not possible to directly compare figures between countries on a like-for like basis. This is because of differences in methodologies and approaches; scope in terms of pathogens and type of costs covered; and variation in data availability by country.

3. Estimates of the burden of foodborne disease

3.1 Average cost per foodborne disease case

In 2018 the average cost per case for FBD in the UK was £4,000 as shown in Chart 1. Variation in the average cost per FBD case is highly dependent on the composition of cases according to type of pathogen and its varying degree of severity, which could change year on year. Each pathogen is defined by their own cost profile reflecting population characteristics such as age.

Cost per case by pathogen is also shown in Chart 1. *Listeria monocytogenes* has the highest cost per case estimate for 2018 at £230,700, driven primarily by the high proportion of fatalities . This is 27 times the size of E. coli O157 which has the second highest cost per case estimate at £8,400. *Cryptosporidium* has the lowest cost per case figure at £1,000, while *Campylobacter* and *Clostridium perfringens* also report relative low cost per case figures at £2,400 and £1,200 respectively.

3.2 Estimates of foodborne disease

In 2018 there were an estimated 2.4 million (95% Credible Intervals (CI) 1.8m to 3.1m) new FBD related cases in the UK. Of known cases, *Norovirus* accounts for the highest number of cases at around 383,000[26], followed by *Campylobacter* and *Clostridium perfringens* with around 299,000 (95% CI 127,000 to 571,000) and 85,000 (95% CI 32,000 to 225,000) cases respectively[27]. *Listeria monocytogenes* has the least number of estimated cases at 162 (95% CI 150 to 170) a year but accounts for the highest proportion of fatalities (26 fatalities out of a total of 162 cases).

[26] Credible intervals for norovirus were not possible for cases due to the modelling approach. This does not mean that there is no uncertainty in these estimates. There were a number of parameters used in the NoVAS study which, while based on the best science currently available, were acknowledged to have uncertain values. Sensitivity analysis undertaken as part of the study showed that changes to the values of these parameters could make big differences to the overall estimates.

[27] *Campylobacter* estimates overlap with norovirus estimates at the credible interval, hence any conclusion from this ranking needs to be made with caution.

On average, although highly dependent on the type of pathogen, around 10% of food-related cases seek medical attention. Out of 2.4 million FBD cases, there were 222,000 (95% CI 150,000 to 322,000) cases going to see their GP; of which 16,400 (95% CI 11,300 to 26,000) needed to be hospitalised due to severity of symptoms or vulnerability of sufferers (elderly and small children); and contributing to around 180 deaths (95% CI 110 to 360).

Table 3 presents a breakdown at pathogenic level and by case type of the number of FBD related cases in 2018 that are estimated to have occurred in the UK.

Chart 1: Cost per case by pathogen 2018

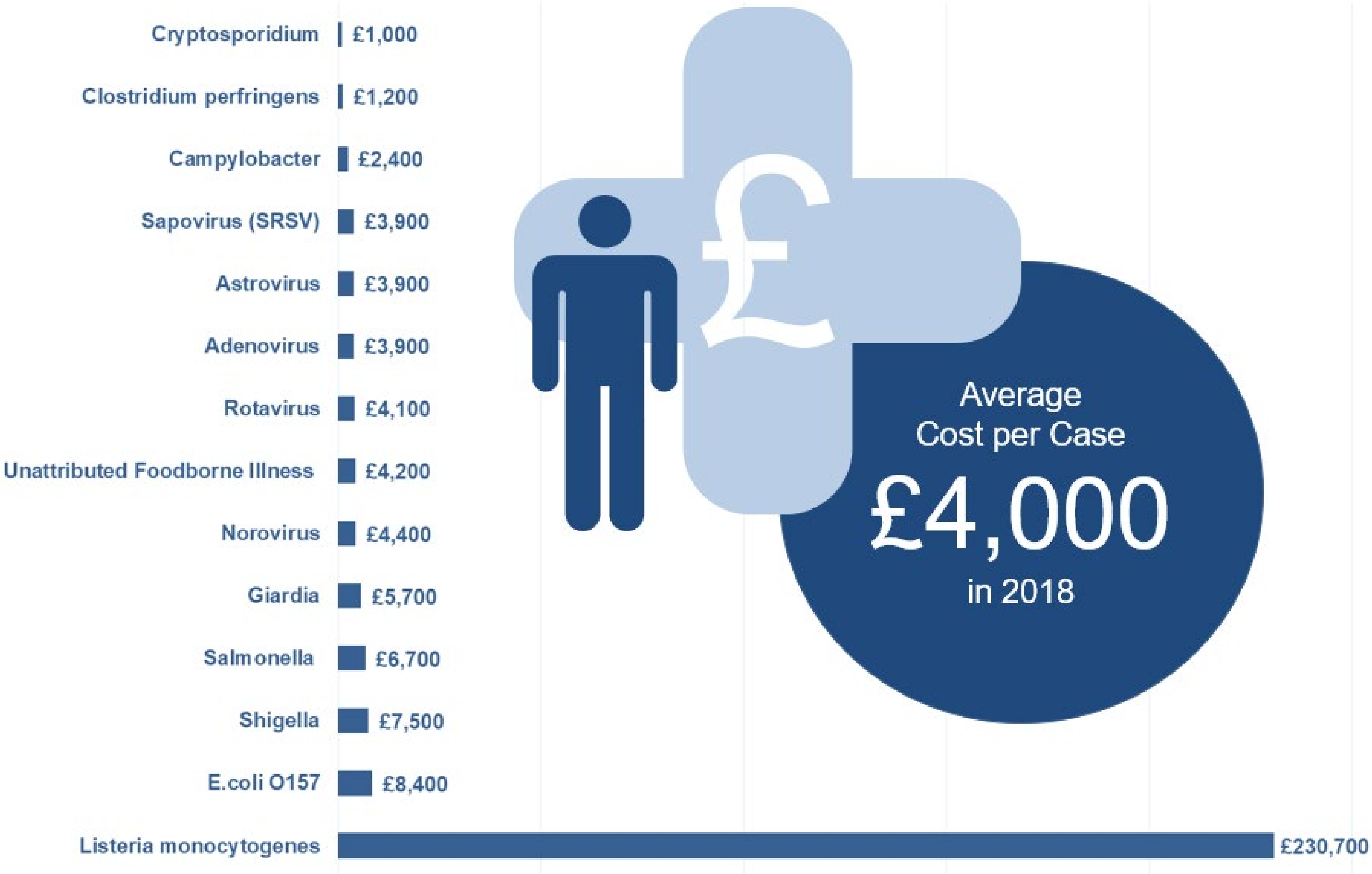


Table 3: Number of UK foodborne disease (FBD) cases in 2018

Pathogen	Food-related cases			Food-related GP Presentations			Food-related Hospitalisations			Deaths		
	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI
Bacteria												
Campylobacter	299,392	127,128	571,332	42,506	18,683	75,857	3,505	1,352	7,641	21	8	47
Clostridium perfringens	84,854	32,044	224,637	13,458	6,145	29,327	376	104	1,250	25	1	163
E.coli O157	468	303	628	468	303	628	146	95	196	1	1	1
Listeria monocytogenes	162	146	170	162	146	170	139	126	146	26	24	28
Salmonella	31,601	6,781	147,158	11,484	4,590	28,620	2,097	444	9,904	33	7	159
Shigella	1,634	110	4,973	1,634	110	4,973	29	1	158	0	0	1
Parasites												
Cryptosporidium	2,072	320	12,201	712	168	2,544	55	8	341	0	0	3
Giardia	13,142	2,034	71,127	1,512	269	6,830	28	1	328	0	0	1

Table 3: Number of UK foodborne disease (FBD) cases in 2018 continued

Pathogen	Food-related cases			Food-related GP Presentations			Food-related Hospitalisations			Deaths		
	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI
Virus												
Adenovirus	12,454	3,085	34,672	1,028	245	3,070	192	42	639	0	0	2
Astrovirus	2,552	573	7,993	192	41	659	36	1	274	0	0	0
Norovirus**	383,182	N/A	N/A	16,915	11,206	25,544	2,167	1,467	3,061	56	32	92
Rotavirus	2,065	518	5,670	220	54	615	32	7	105	0	0	0
Sapovirus (SRSV)	43,621	28,934	64,705	2,625	1,606	4,224	245	141	419	0	0	0

Notes: **Credible intervals for norovirus were not possible for cases due to the modelling approach. This does not mean that there is no uncertainty in these estimates. There were a number of parameters used in the NoVAS study which, while based on the best science currently available, were acknowledged to have uncertain values. Sensitivity analysis undertaken as part of the study showed that changes to the values of these parameters could make big differences to the overall estimates

Table 3: Number of UK foodborne disease (FBD) cases in 2018 continued

Pathogen	Food-related cases			Food-related GP Presentations			Food-related Hospitalisations			Deaths		
	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI
Total FBD*	**909,375**	**702,281**	**1,225,152**	**96,884**	**67,218**	**135,872**	**9,731**	**6,157**	**18,120**	**180**	**114**	**361**
Unattributed Foodborne Illness (UFI)	1,449,168	1,046,506	1,991,612	124,102	70,914	201,947	6,439	4,347	9,429	0	0	0
Total FBD including UFI*	**2,362,262**	**1,795,083**	**3,149,740**	**222,207**	**149,964**	**322,347**	**16,439**	**11,410**	**26,119**	**180**	**114**	**361**

Source: FSA FDEM

Notes: *The reported total number of cases for FBD is the result of the simulation based on median estimates of overall cases. It is a different figure from the sum-up of the reported number of cases across pathogens, which was used to calculate the cost per case; and we took the same approach for GP presentation, hospitalisations and deaths.

3.3 Total cost by pathogen

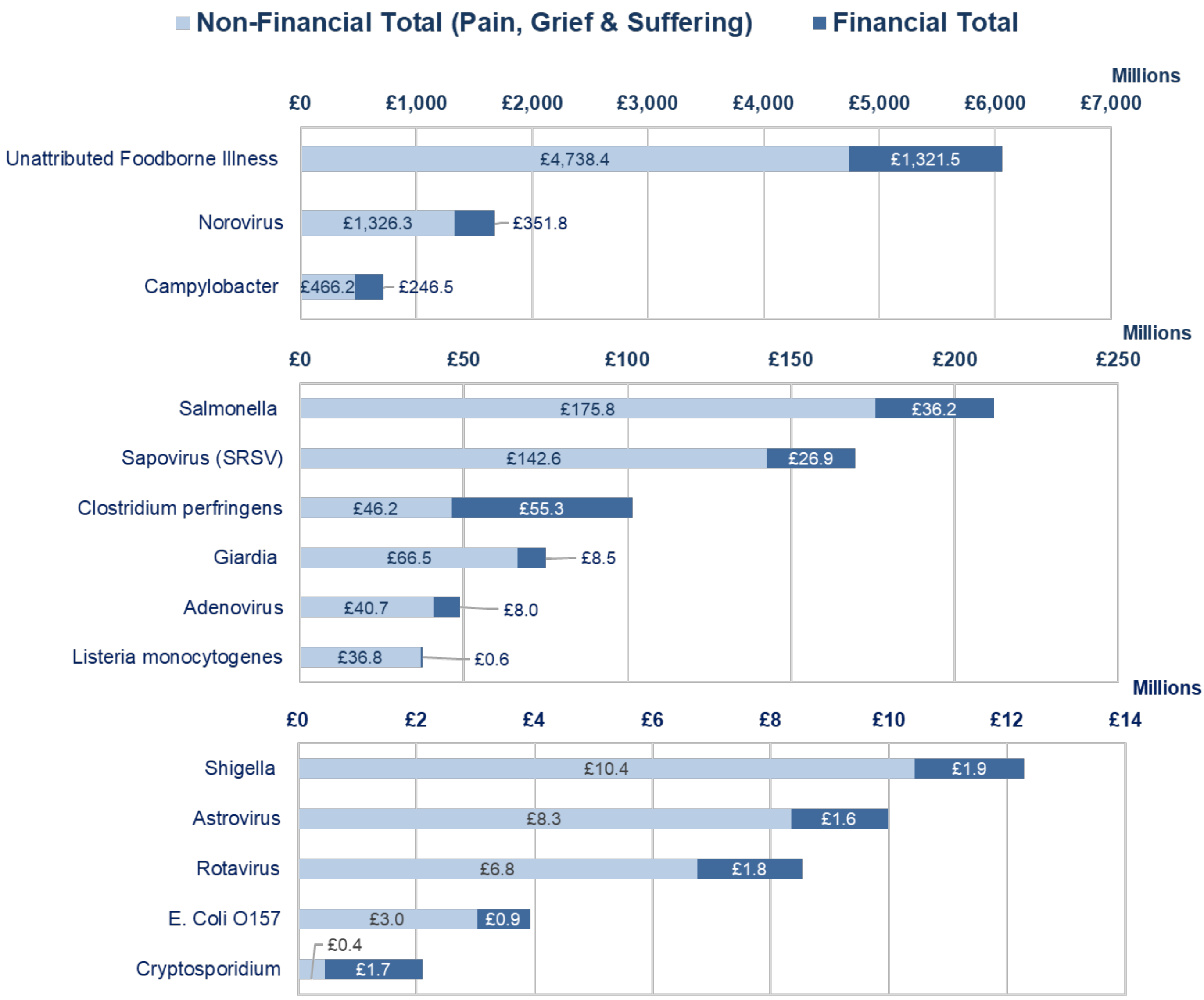
Table 4 and Chart 2 present total costs for each of the 13 pathogens plus unattributed foodborne illness. These are based on median estimates of the number of cases, which present, to a certain extent some uncertainty. Hence, where credible intervals overlap, ranking needs to be undertaken with caution.

Table 4 Total cost by pathogen 2018

Pathogen	Total cost by pathogen £(m)		
	Median	Lower 95% CI	Upper 95% CI
Bacteria			
Campylobacter	£712.6	£298.4	£1,355.8
Clostridium perfringens	£101.5	£25.3	£385.0
E.coli O157	£3.9	£3.0	£4.6
Listeria monocytogenes	£37.4	£34.4	£40.8
Salmonella	£212.0	£45.6	£954.8
Shigella	£12.3	£0.8	£38.3
Parasites			
Cryptosporidium	£2.1	£0.3	£15.3
Giardia	£75.0	£11.6	£406.0
Virus			
Adenovirus	£48.7	£12.0	£138.2
Astrovirus	£10.0	£2.2	£31.6
Norovirus	£1,678.2	£238.6	£1,943.6
Rotavirus	£8.5	£2.1	£23.5
Sapovirus (SRSV)	£169.5	£112.4	£251.7
Total FBD	**£3,071.7**	**£786.7**	**£5,589.2**
Unattributed Foodborne Illness (UFI)	£6,060.0	£4,471.3	£7,988.8
Total FBD including UFI	**£9,131.7**	**£5,258.0**	**£13,578.0**

The total burden of FBD in the UK is predominantly driven by the number of individual cases. Of known cases, norovirus imposes the greatest societal burden at an estimated annual cost of £1.7bn followed by Campylobacter (£712.6m) and Salmonella (£212.0m); while E. coli O157 (£3.9m) and Cryptosporidium (£2.1m) impose the least burden. With unattributed cases accounting for 60% of total FBD cases with an estimated cost of £6.0bn, this by far imposes the greatest burden when compared to known cases.

Chart 2: Total cost by pathogen 2018

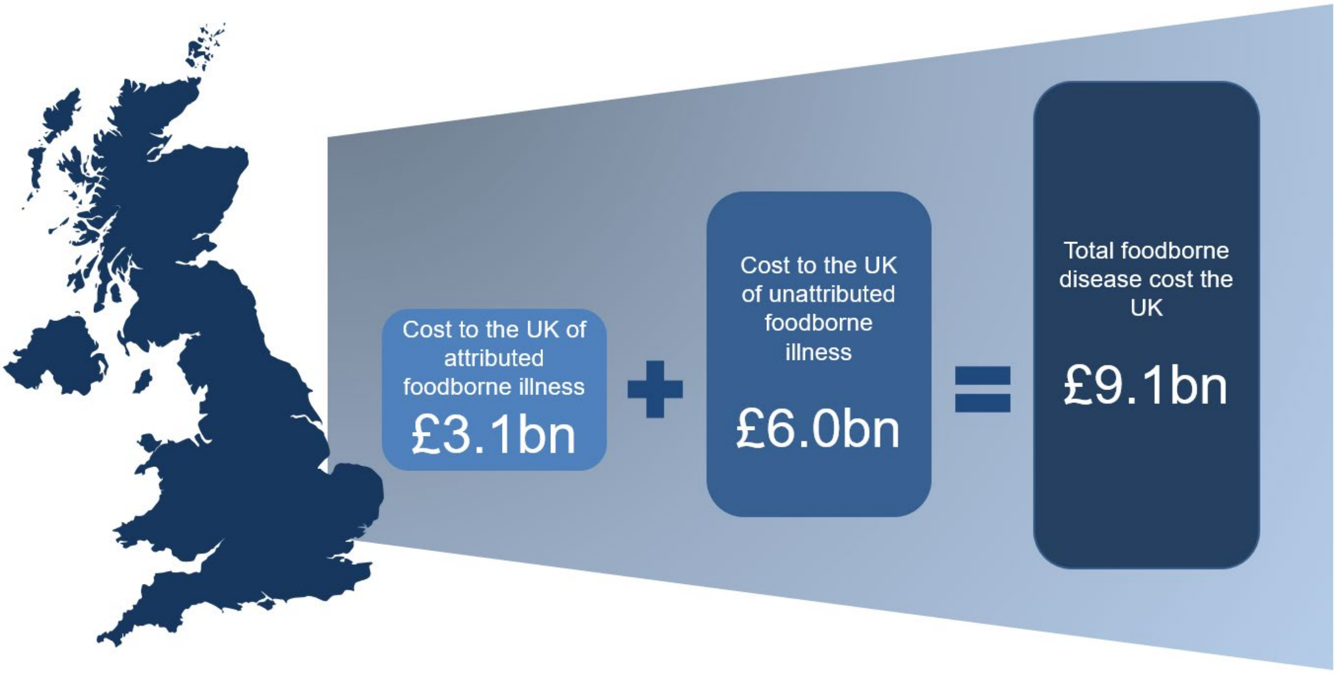


A detailed breakdown of total cost per pathogen can be found in Appendices D and E.

3.4 Total costs

Based on 2018 case estimates, foodborne disease costs society approximately £9.1bn (95% CI £5.3bn to £13.6bn), from which £6.0bn (95% CI £4.5bn to £8.0bn) are related to unattributed foodborne illnesses, whereas the remaining £3.1bn (95% CI £787.0m to £5.6bn) refer to the costs associated to identified pathogens as shown in Figure 8.

Figure 8: Total cost to UK society of foodborne disease in 2018



Total FBD cost estimates are based on 13 pathogens plus unattributed foodborne illness. The new COI model allows for the quantification and monetisation of the impact of unattributed foodborne illness previously excluded from published FBD cost estimates.. Details on the method and approach used to estimate the cost of unattributed foodborne illness related cases is provided in Appendix C of this report.

3.5 Cost by Cost of Illness components

The COI model is comprised of seven main cost components that fall under two broad categories: Financial and Non-financial.

Financial costs

Financial costs account for almost a quarter (£2.1bn) of the total burden of FDB. The largest financial cost component is lost earnings, estimated at £1.8bn for 2018, followed by disturbance costs to businesses at £157.5m. Medical costs accounts for the third highest proportion of financial costs at £60.5m followed by costs associated with absence from school at £34.3m. Individual expenses accounted for the smallest share estimated as £32.0m.

Non-financial – human cost of pain, grief & suffering

The human cost of pain, grief and suffering attributed to foodborne illness and related fatalities was estimated at £7.1bn for 2018, accounting for almost 80% of the total burden of FBD to the UK. Illness including long-term complications and sequelae, made up the majority of the cost, estimated at £6.8bn, followed by fatalities valued at £221.0m.

A summary breakdown of the total cost of FBD to society is presented in Chart 3, with the percentage breakdown by cost component presented in Chart 4.

Chart 3: Breakdown of foodborne disease cost components 2018

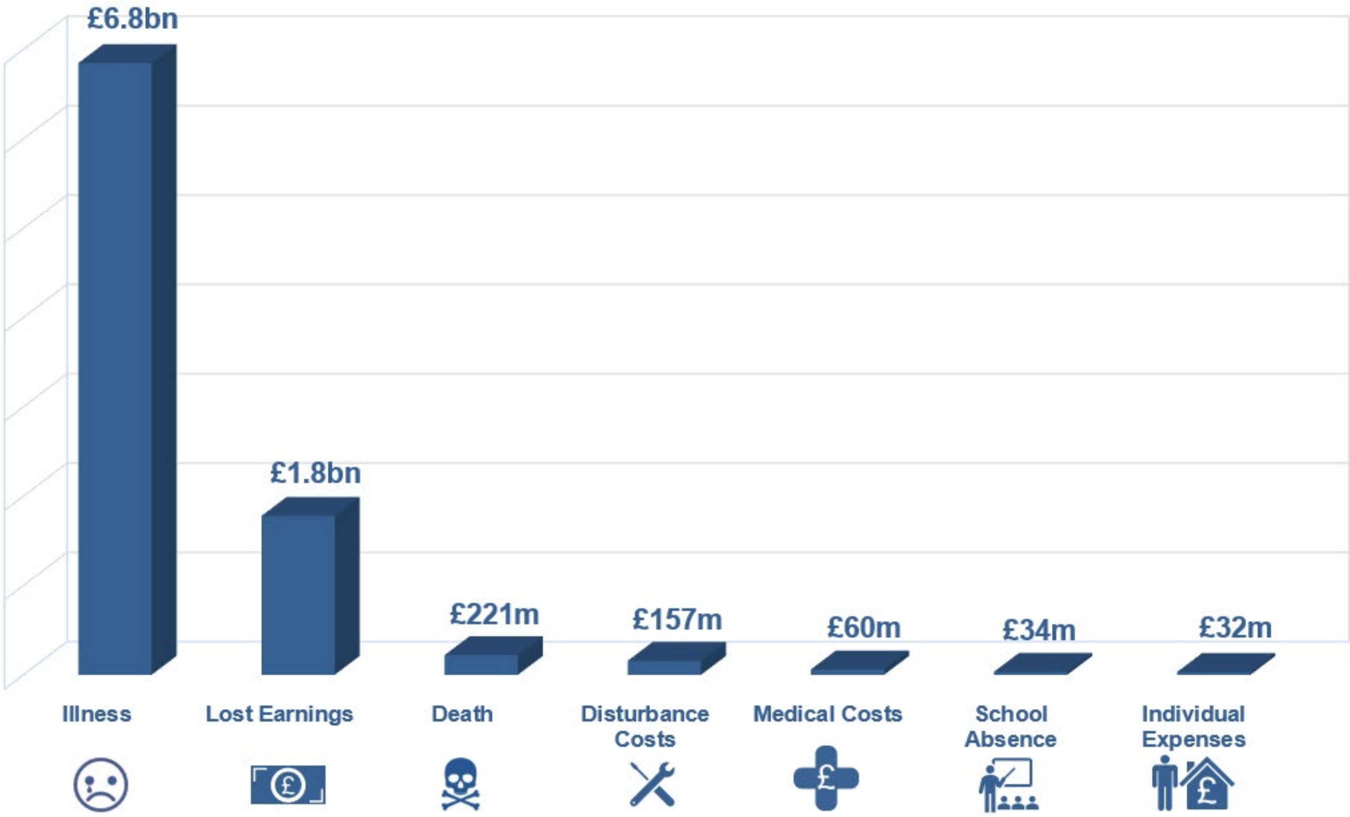
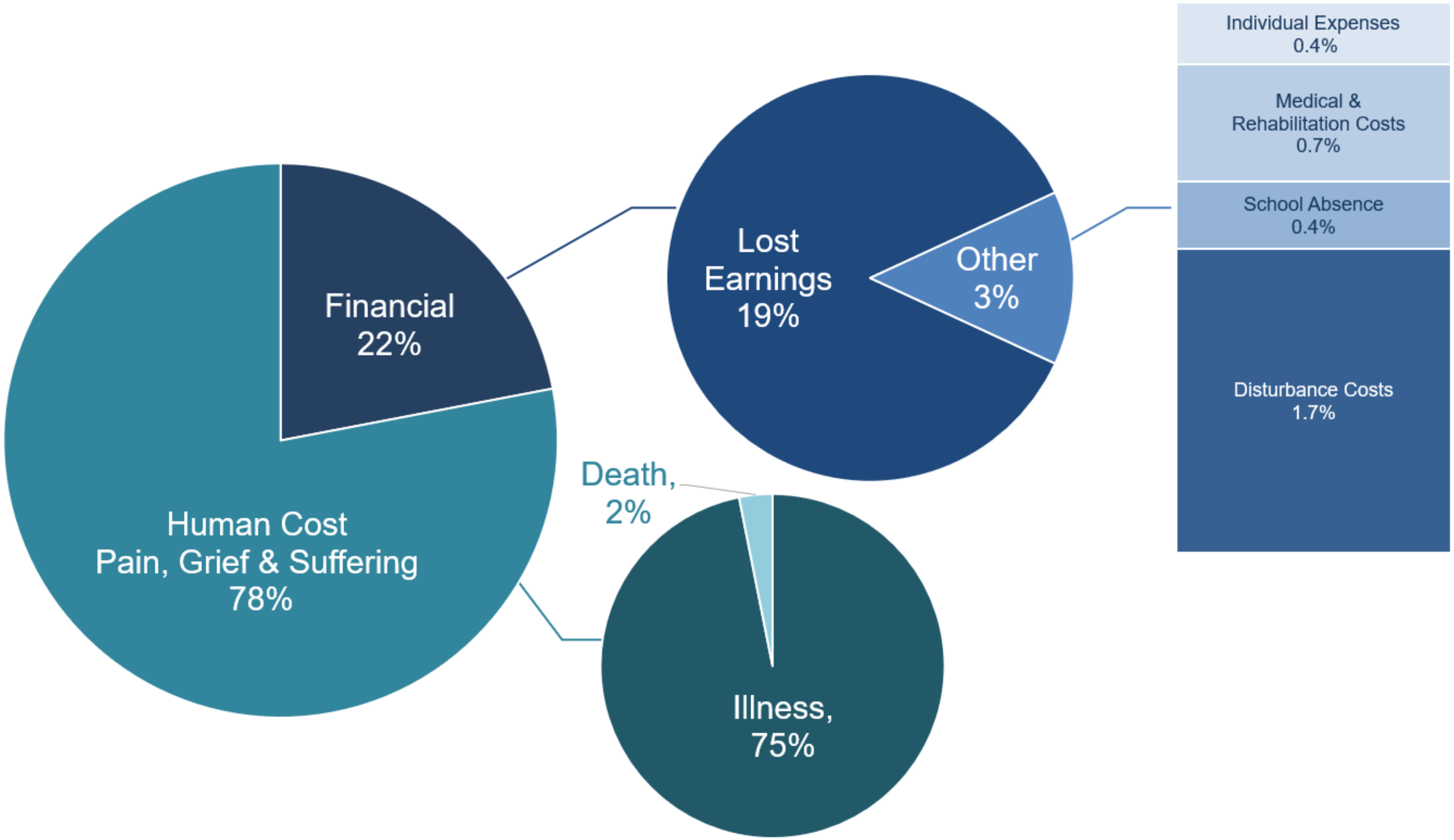


Chart 4: Percentage breakdown of Cost of Illness cost components



3.6 Cost by affected group

Individuals and carers

Individuals and carers are the group bearing the largest cost of FBD in the UK at £8.9bn in 2018. As expected, non-financial human costs (pain, grief and suffering) are entirely borne by the individual sufferer and their family. Financial costs are also predominately borne by individuals and carers, comprising lost earnings from absence due to sickness and individual expenses, for example, over-the-counter medication, travelling expenses and funeral costs. Table 5 presents a breakdown of costs borne by individuals and carers.

Table 5: Breakdown of costs borne by individuals and carers 2018

Cost Component	Cost
Individual expenses	£32.0m
Lost earnings	£1.8bn
Pain, grief and suffering	£7.1bn
Total	**£8.9bn**

Businesses

There are additional costs to businesses associated with production disturbance incurred through absence due to sickness. In an effort to maintain normal output levels, firms will need to invest time and resource into work reorganisation, recruitment and staff training. In 2018, the cost to businesses were estimated at £157.5m, approximately 2% of the total costs of FBD.

Government

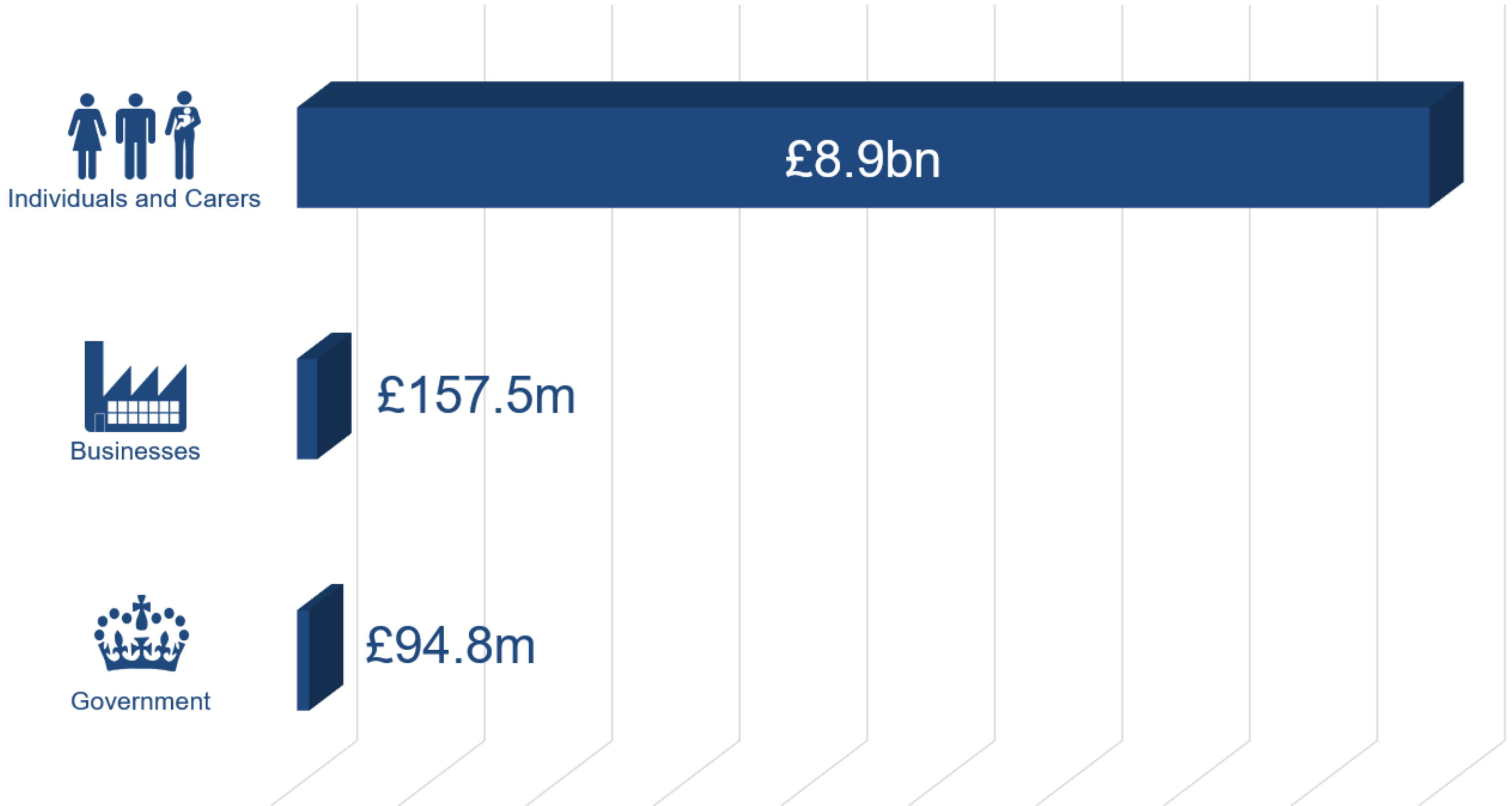
The group bearing the least cost is the government with a total cost of £94.8m (1% of the total cost of FBD) in 2018. These costs stem from NHS resource use (£60.5m per year) and costs associated with absence from school (£34.3m per year). A summary breakdown of costs borne by the government is presented in Table 6.

Table 6: Breakdown of government costs 2018

Cost Component	**Cost**
NHS Resources	£60.5m
Costs associated with absence from school	£34.3m
Total	£94.8m

Chart 5 also shows the total cost of FBD for 2018 borne by affected group.

Chart 5: Cost borne by affected group in 2018

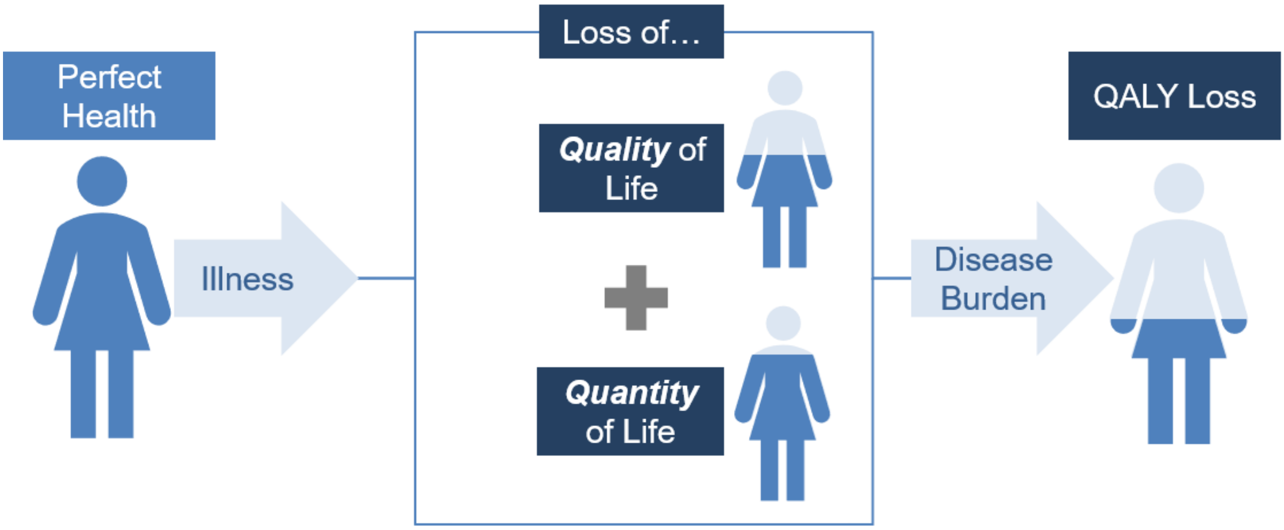


4. Quality adjusted life years (QALYs) – Quantifying non-monetary impact of disease burden

The COI model estimates the monetary impact of FBD including monetised WTP estimates of the pain, grief and suffering burden imposed on society. Yet, the intangible impact associated with the diseases can also be captured using Quality Adjusted Life Year (QALY) measures.

QALYs are a generic measure, which assess the burden of diseases in terms of quality and quantity of life lived. QALYs compare perfect health states with the relevant ill health states and capture the quality of years lost as a result of the illness (see Figure 9).

Figure 9: QALYs – Measure of disease burden



QALYs can be monetized by attributing a constant value of £60,000 per QALY loss. Nevertheless, the FSA's COI model does not use this approach to estimate the non-financial impact of the diseases. Instead. it takes advantage of pathogen-specific estimates that account for the valuation of the health condition associated to the different pathogens.

4.1 Elicitation and use of foodborne disease QALY values

The FSA commissioned research – Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (FSA QALY/WTP Phase

2)[28] – to elicit its own QALY measures for microbiological FBD based on the EuroQol 5-dimension, 3 level health questionnaires (EQ-5D-3L)[29]. QALYs allow the FSA to align with NICE and the NHS in the valuation of interventions to promote generalised health; to compare interventions in diverse areas; and to determine priorities for interventions in FBD by showing the total QALY burden caused by each pathogen as well as the burden caused per case.

For 10 select pathogens (see Table 7), estimates of WTP (discussed in Section 2) and the QALY burden of illness were calculated using the same Markov Transition Models (MTM) [30] to represent: (i) the short term burden of disease – over a single year in which new infections occur, and (ii) the long term burden of disease – in which the total burden of illness associated with those new infections is estimated over 100 years. QALYs lost in future years are discounted at a rate of 3.5% in line with the NICE reference case. By using the same model, inconsistencies in terms of estimated severities are ruled out.

[28] Food Standards Agency (2017). Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2).

[29] The EQ-5D-3L descriptive system comprises the following five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each dimension has 3 levels: no problems, some problems, and extreme problems.

[30] Markov State Transition Models (MTMs) for each pathogen are parameterised to estimate the burden of disease using QALYs. MTMs represent the flow of a defined cohort of people through the various health states which characterise FDB for each of the 10 pathogens. The MTM includes separate states for each pathogen, which are parameterised with values for the transition probabilities between states and the utility losses associated with being in those states relative to being healthy. The values for the transition probabilities and utility losses are identified from a systematic literature review.

Table 7: 10 selected foodborne pathogens with elicited WTP and QALY values

Listeria monocytogenes
Giardia
Norovirus
Hepatitis E*
Campylobacter
Salmonella
E. coli O157
Shigella
Cryptosporidium

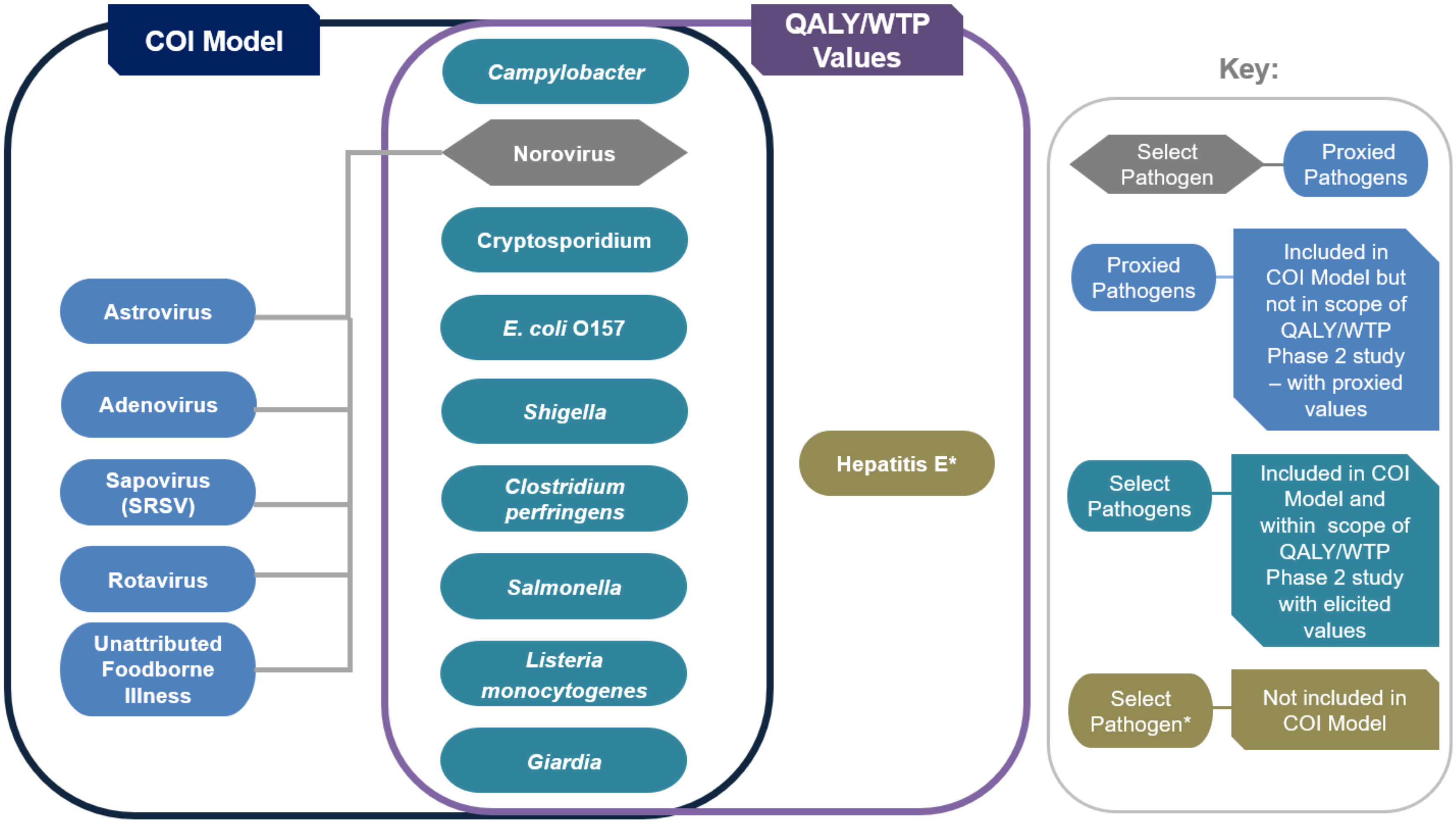
Note:* Hepatitis E is not included in COI Model

As discussed in Section 2, the COI model produces cost estimates for 13 select pathogens plus unattributed foodborne illness. For those pathogens not covered in the *QALY/WTP Phase 2* research (see Figure 10), proxies were developed in collaboration with experts from multi-disciplinary fields[31] using outputs from this research to facilitate the mapping and grouping of pathogens (including unattributed foodborne illness) with similar health states (complications/symptoms and their sequelae). See Appendix C for further details.

For mapping the pathogens with their proxies, their features in terms of severity level, co-morbidities and potential sequalae have been considered. Consistent with other food safety regulatory bodies, norovirus was identified as an appropriate proxy for unattributed foodborne illness including other select pathogens (see Figure 10).

[31] Microbiologists, epidemiologist, clinicians, virologist, health economists, operational researchers.

Figure 10: Select pathogens – QALY / WTP values and proxies



4.2 Foodborne disease QALY estimates

QALY loss per case

The expected QALY loss for a single case of FBD, by pathogen, is shown in Table 8. *Listeria monocytogenes* is the pathogen reflecting the highest QALY loss per case with an expected loss of 4.03 QALYs per case. This was four times the size of the expected burden of *Giardia* which has the second highest burden per case (1.01 QALYs). *Clostridium perfringens* was the least severe pathogen, with an expected QALY loss of 0.004 per case, while *Cryptosporidium* (0.023 QALYs lost per case) and *Shigella.* (0.027 QALYs lost per case) also had low burden of illness per case.

Table 8: QALY loss per case by pathogen

Pathogen	QALY loss per case
Listeria monocytogenes	4.034
Giardia	1.009
Unattributed foodborne illness*	0.673
Norovirus	0.673
Sapovirus (SRSV)*	0.673
Adenovirus*	0.673
Rotavirus*	0.673
Astrovirus*	0.673
Campylobacter	0.260
Salmonella	0.212
E. coli O157	0.060
Shigella	0.027
Cryptosporidium	0.023
Clostridium perfringens	0.004

Note: *Pathogens paired and proxied with norovirus

Total QALY burden

Table 9 presents the estimated total number of QALYs lost, when compared with a healthy population (QALY burden) due to the selected foodborne pathogens in a given year. The pathogens are reported in order of total QALY burden from largest to smallest. The largest burden of illness was attributable to unattributed foodborne illness (940,371 QALYs), norovirus (256,182 QALYs) and *Campylobacter* (72,003 QALYs) whilst E. coli O157 had the lowest burden (25 QALYs).

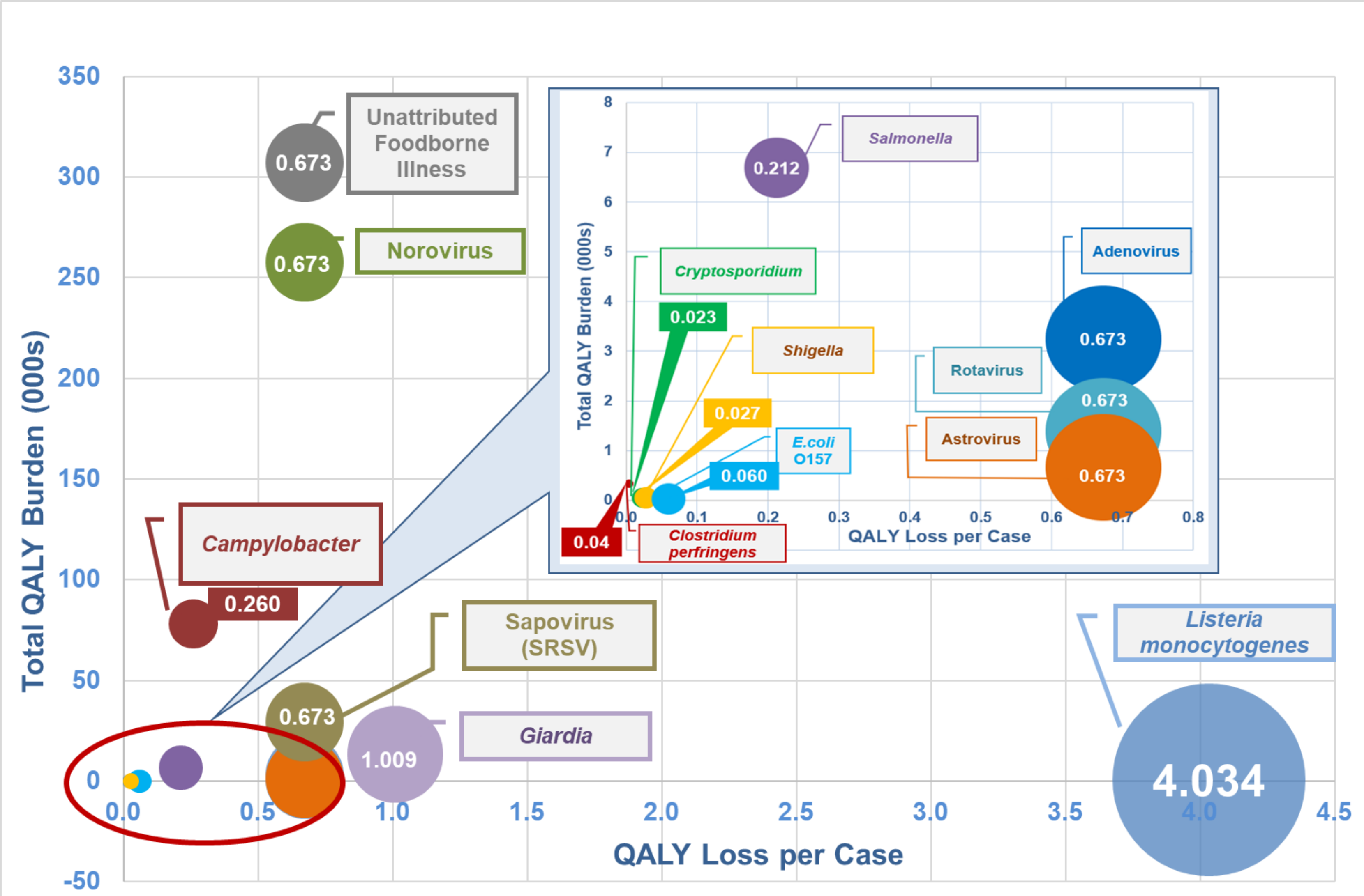
Table 9: Total QALY burden by pathogen

Pathogen	Total QALY burden
Unattributed foodborne illness*	940,371
Norovirus	256,182
Campylobacter	72,003
Sapovirus (SRSV)	29,163
Giardia	11,256
Adenovirus	8,346
Salmonella	6,649
Rotavirus	2,304
Astrovirus	1,709
Listeria monocytogenes	596
Clostridium perfringens	337
Cryptosporidium	40
Shigella	33
E. coli O157	25

Note: *Pathogens paired and proxied with norovirus

Chart 6 shows QALY loss per case and total QALY burden for each of the 13 pathogens plus unattributed foodborne illness.

Chart 6: QALY loss per case and total QALY burden by pathogen



5. Priorities for further research

This section briefly discusses priorities for further FSA research in improving the COI framework in terms of scope, methodology and approach.

5.1 Other food safety related hazards

Food hypersensitivity

Building on the COI framework developed for foodborne illness, the FSA will adopt an analogous approach and methodology to estimating the economic and societal burden of food hypersensitivities. The FSA is now in a position to produce preliminary and partial estimates for hospitalised food hypersensitivity cases including food allergies, food intolerance and coeliac disease.

There are, however, longer-term plans to commission research to address methodological challenges in valuing the financial (direct personal financial costs) and non-financial (pain and suffering reflected by the WTP burden attributed to maintaining a symptom-free state including dietary management, avoidance and the perception of the risks of an adverse reaction.

Chemical and radiological contamination

Currently the FSA does not estimate the economic and societal burden of risks related to chemicals in foods and radiological contamination. However, FSA risk assessors are investigating risk prioritisation tools for chemical and radiological contaminants in food, with the long-term objective of estimating their economic impact. Moreover, the FSA plans to build on previous research, including a feasibility study[32] recommending a contingent valuation approach in which respondents are asked to state their WTP for different FSA activities or outcomes such as maintaining or reducing the current level of contaminants. However, extensive primary research will be needed to understand the impact pathways, symptoms, and affected population to estimate the change in the risk if WTP values to avoid pain, grief and suffering are to be derived.

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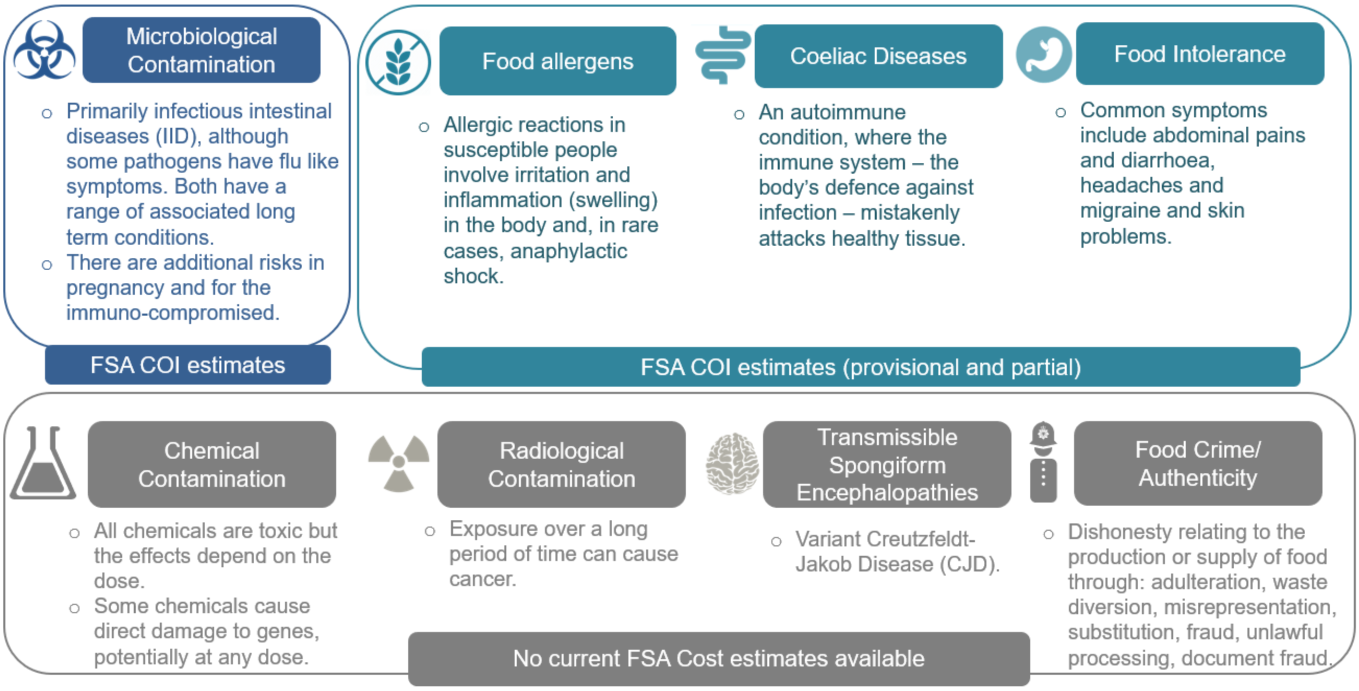
[32] Food Standards Agency (2013). Consumer Willingness to Pay for Food Safety Health Outcomes. www.food.gov.uk/sites/default/files/media/document/868-1-1610_20131219_FSA_WTP_Final_Report_v3_Clean_Version.pdf

Food crime and food authenticity

The FSA has recently commissioned research as part of an initial phase of a programme of work that will conduct a comprehensive review of existing methods and techniques for evaluating the economic impact of food crime to society and to develop a conceptual framework based on these findings. This framework will seek to capture the full range of impacts that food crime has on society, which will be used to provide a robust methodology for future assessment of the cost of food crime.

Together, FBD, food hypersensitivities, chemicals and radiological contamination, food crime and food authenticity all form a significant proportion of food safety related hazards that are of concern to the FSA (Figure 11).

Figure 11: Food safety related hazards



5.2 Refining the COI model for foodborne illness

Loss of earnings

Loss of earnings creates the next highest impact on COI after WTP. Nevertheless, the current COI model only considers the burden of health-related productivity loss due to sick-leave – "absenteeism" - hence further research is needed in understanding the impact of reduced performance while at work due to illness – "presenteeism" - including the impact of employment status (full-time, part-time, self-employed, fixed term, permanent).

Demographics and socioeconomics

The COI model only presents a national average of the burden and cost of illness. The FSA is looking to mirror research currently being undertaken by FSS, with a view to better understand the burden and costs across the UK population by demographics and socioeconomics. This will enable the FSA to identify potential key population groups (by age and socioeconomic group) facing the highest burden in terms of loss of earnings, individual expenses, medical costs and costs to businesses through production disturbance; where reductions in the number of FBD cases would potentially have the greatest impact on the costs incurred by society.

Value of a life year (VOLY)

As discussed in Sections 1, 2 and 4, the FSA commissioned primary research to elicit QALY and WTP values for microbiological foodborne disease. The FSA is aware that different approaches and valuations are applied in different policy contexts and across UK government appraisals.[33]

The HM Treasury ‘Green Book’ guidance sets out different approaches to valuing life and health impacts[34], while maintaining flexibilities in the valuation approach used; choices between valuing changes to the risk of a statistically prevented fatality, value of a life year (VOLY) and QALYs all depend on the extent to which the risk appraised entails loss of longevity, quality of life or both. The current VOLY primarily used by UK Government departments and agencies, and which forms the basis of the Department for Transport ‘Value of a Prevented Fatality’ (VPF), is derived from studies including – *On the*

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[33] Wolff, J., & Orr, S. (2009). Cross-Sector Weighting and Valuing of QALYs and VPFs. A Report for the Inter-Departmental Group for Valuation of Life and Health. www.ucl.ac.uk/health-humanities/docs/IGVLH.pdf

[34] HM Treasury (2018). The Green Book. Central Government Guidance on Appraisal and Evaluation. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

Contingent Valuation of Safety and the Safety of Contingent Valuation: Part 2 — The CV / SG " Chained " Approach [35].

The FSA is part of a Project Group Consortium[36], which is seeking to commission new primary research to update the VOLY and WTP for a QALY. This could then be used by UK government Departments and Agencies in a way that is consistent across government appraisals, reflecting the same underlying preferences over health and safety.

[35] Carthy, T., Chilton, S., Covey, J., Hopkins, L., Jones-lee, M., Graham;, L., Spencer, A. (1999). On the Contingent Valuation of Safety and the Safety of Contingent Valuation: Part 2 — The CV / SG " Chained " Approach. Journal of Risk and Uncertainty, 17(3), 187–213. http://doi.org/10.1023/A:1007782800868

[36] Department for Environment, Food and Rural Affairs, Department of Health and Social Care, Department for Transport, the Food Standards Agency, Food Standards Scotland, the Health and Safety Executive, and the Home Office.

6. Conclusion

The estimation of the cost of foodborne illness is an ongoing area for research for food safety regulators around the world. There are still significant gaps in the underlying data and several assumptions are required to fill these gaps. In turn, this increases the uncertainty and the degree of comparability. Nevertheless, for the FSA, this COI work represents a major milestone. For the first time, we have a robust methodology to estimate the annual burden to society for the overall prevalence of foodborne illness among the UK population.

All the major foodborne pathogens included in the COI model causes similar symptoms, mostly lasting a few days and occasionally resulting in complications and long-lasting health outcomes. Estimates of the burden of illness reflect difference in prevalence and severity, hence they allow a comparison of burden across illness with differing symptoms and health outcomes. As such, the COI analysis provides decision-makers with a perspective on the magnitude of the societal burden of a particular disease or condition and can support the prioritisation of policy interventions.

In particular, robust and reliable cost of illness estimates allow the FSA to enhance its ability to assess the cost effectiveness of food safety policy interventions, improve impact assessments analysis, appraisals and evaluation. It can identify the burden by the main cost bearers, namely: individuals and carers, businesses and government. However, there are limitations with its application: for example, the COI model only presents a UK average of the burden and cost of illness, hence it is not possible to identify country-level costs of foodborne illness; nor can it be used to estimate spill-over effect from foodborne outbreaks (e.g. local authority enforcement) or identify vulnerable groups facing a greater disease burden. Most importantly, costs of illness cannot be the only metric guiding the decision-making process in a prioritisation exercise: for example, the effectiveness and cost of the policy interventions in reducing the burden, alongside the cost and concerns about the distribution of health and policy impacts and other relevant legitimate factors, are all very important inputs to policy decision making.

Regular cost updates on the burden of foodborne illness by the main pathogen can now be provided, based on up-to-date estimates for foodborne disease cases in the UK, when these become available. It is recommended that the assumptions and methodology underpinning the model be reviewed and revised every three or five years, to ensure it incorporates the latest developments in this research area using the most up-to-date data sources that become available overtime.

In addition to the COI estimates, QALY metrics are now also available for the main foodborne pathogens, and these measure the burden of diseases on individuals in terms of quality and quantity of life lived for a given pathogen. While the COI model does not include monetised figures of QALY losses, they are complementary to the COI estimates both allowing comparison of the burden of diseases with diverse outcomes on a common scale. By integrating these two estimates and measures, we now have enhanced evidence supporting risk-based approaches to setting food safety policy.

In terms of future steps, the scope of further research is predicated on understanding the burden and costs across different demographics and socioeconomic groups within the UK population. This would enable the FSA to identify key vulnerable groups (by age or socio-economic group) facing the highest burden, for example in terms loss of earnings, individual expenses and medical costs; where reductions in the number of FBD cases could potentially have the greatest impact on the costs incurred by society

Building on the work presented here on foodborne disease, a further programme of work estimating the burden of other food safety related hazards in the UK is underway, namely the COI for food hypersensitivities and the cost of food crime and food authenticity.

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Appendix A: Data and assumptions

Table A1.0: Medical costs

Cost component	Data source	Description	Assumptions and limitations
GP visits	Personal Social Service Research Unit (PSSRU) 2017/18. https://kar.kent.ac.uk/70995/1/Unit%20Costs%202018%20-%20FINAL%20with%20bookmarks%20and%20covers%20%282%29.pdf	Unit cost per GP visit	One GP visit per case was assumed. This assumption is based on interviews with GPs. Prior to hospitalisation it is assumed that the individual would have consulted with their GP. We use PSSRU costs data for England as a proxy to scale up cost to the NHS at a UK level. We assume the severity of cases and outcome of FBD is the same for Wales, Scotland and Northern Ireland, hence assuming transferability of the cost vector
GP Home visits		GP cost per hour of General Medical Service (GMS) activity	Costs comprise of time spent by GP i.e. hourly rate (£) of a GP multiplied by duration of home visit. It is assumed that 5% of all GP presentation cases receive a home visit. Overheads such as transportation and administration costs have not been fully accounted for.
	The National Institute for Health and Care Excellence (NICE) Guideline www.nice.org.uk/guida	Durations of home visit of home visit including travel time.	

Cost component	Data source	Description	Assumptions and limitations
GP Home visit	nce/ng94/documents/draft-guideline-6		
	Integrate Study funded by the Department of Health and Welcome Trust: www.integrateproject.org.uk Ratios of GP resource use - Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2).	The ratio of GP home visits per patient	
Follow-up calls	Hospital Episode Statistics (HES) data by NHS England. (Private access)	Dependent population derived and elicited from the hospitalised age profile. Individuals of aged 0-16 and 65+ are defined as dependent population.	Only dependent population are assumed to receive a follow-up call from the GP after consultation. This assumption is based on interviews with GPs. However, the actual use of follow-up calls is highly dependent on surgeries and GPs. Population profiles, used to derive the dependent population, were calculated using pathogenic specific HES data are applied in the context of GP and hospital visits. In a non-medical context,

Cost component	Data source	Description	Assumptions and limitations
Follow-up calls	NHS Reference Cost - - https://improvement.nhs.uk/resources/reference-costs/#rc1718	Cost of phone call and phone triage	population profiles calculated using general population age profile (data from ONS) are applied.
Prescription	PSSRU	Prescription cost per GP consultation	To avoid double counting, out-of-pocket (OOP) prescription costs to the individual are deducted from NHS prescription cost and counted as a separate cost component – a direct cost for patients. It is assumed that all individuals presenting to a GP are prescribed some form of medication. The number of prescriptions dispensed are likely to vary by surgery and pathogen.
Laboratory	Report of The Study of Infectious Intestinal Disease in England (IID1 Study (2000))	Stool test rate	The rate of prescribed test is assumed to be the same across all pathogens. IID1 is the best available data source we have on stool test rate. The study was conducted in 1994.
	NHS Reference Cost	Costs of microbiology laboratory test	

Table A1.1: Medical costs

Cost component	**Data source**	**Description**	**Assumptions and limitations**
Telephone calls	Integrate Study	No. of times speaking with GP on phone	The rate of telephone calls is flat across pathogens (this applies approximately to 77% of GP visits). The rate of telephone triage cost by doctor is applied to capture a higher bound cost. The telephone triage can be conducted by different healthcare professionals – the GP rate (£) here thus captures the higher bound.
	NHS Reference Cost	Cost of telephone calls and phone triage in GPs by doctors.	
NHS 111 consultation	NHS Reference Costs	Cost of NHS 111 call	Assume 7% presenting to their GP use 111. Call usage is pathogen specific.
	Integrate Study	Rate of patients dialling 111	
Hospitalization costs – inpatient/ outpatient/ A&E	Hospital Episode Statistics	Proportion of hospitalised cases using different admission method i.e. proportion of elective and non-elective patients, A&E patients and outpatients	The proportions of A&E patients and outpatients were elicited from the admission methods. This is a lower bound as the non-admitted A&E visitors and outpatients are not considered.

Hospitalization costs – inpatient/ outpatient/ A&E		Age profile of the hospitalized cases Proportion of FBD cases with a duration-of-illness of more than 21 days Inpatient data breakdown, i.e. elective and non-elective admissions	We use pathogen specific proportion of inpatient, outpatient and A&E cases with generic hospital unit cost vectors.
	NHS reference costs	Gastroenteritis related cost vectors were identified and synthesized from NHS reference cost. Unit costs of elective inpatient, non-elective long stay, non-elective short stay and outpatient were calculated	

Table A2.0: Personal expenses

Cost component	Data source	Description	Assumptions and limitations
Transportation cost – visit to GP	National Institute for Health Research (NIHR)	Transportation cost to GP surgery	Unit transport costs assumed to be uniform across the population.
OOP prescription	Kings fund report and Self-care forum	Prescription charge - %	For England only – 40% of the population are not exempt from prescription charges. Exemption rate could be higher due to cases being skewed to individuals entitled to free prescription due to age profile. To avoid double counting, out-of-pocket (OOP) prescription costs to the individual are deducted from NHS prescription cost and counted as a separate cost component – a direct cost for patients. Divergence between UK countries not considered.
Hospital transportation Cost	National Institute for Health Research (NIHR)	Transportation cost to hospital	Unit transport costs assumed to be uniform across the population.
Over-the-counter medication	The Pharmaceutical Journal	Gastrointestinal Medication	It is assumed that 80% of individuals not visiting the GP use over-the-counter medication. The rate of self-care is not gastroenteritis specific but related to minor ailments in general.
	Self-care forum	Usage rate of Over-the-counter medication	

Cost component	Data source	Description	Assumptions and limitations
Over-the-counter medication			Cost are not pathogen specific. The rate of self-care is not gastroenteritis specific but related to minor ailments in general.
Funeral cost per fatality	Royal London Funeral Cost Index	Funeral cost per a fatality	This is a present value cost rather than a current year cost because it represents the cost of bringing forward the funeral due to an FBD related fatality.

Table A3.0: Lost Earnings, Disturbance Cost, School Absence

Cost component	Data source	Description	Assumptions and limitations
Loss of earnings to individual/ sufferer	IID1 study - Report of The Study of Infectious Intestinal Disease in England (IID1 study (2000))	Duration of FBD	The model assumes the individual is absent from work during the entire episode of foodborne illness. It is also assumed that the individual would not receive any statutory sick pay to compensate the salary loss due to the short length of illness – typically lasting a few days. The length of the disease depends on use of healthcare services. Individuals not visiting the GP are assumed to be ill for up to 7 days. Lost earnings were adjusted by working population. The proportion of the working population was
	Health & Safety Executive’s (HSE) - Cost to Britain (CTB)	Methodology on computing and estimating loss of earnings due to temporary absence derived from the CtB model.	
	Hospital Episode Statistics (HES)	Length of the disease for more than 21 days	

Cost component	Data source	Description	Assumptions and limitations
		Population distribution – proportion of working population visiting the GP	assumed to be different between cases visiting the GP and not visiting the GP. The underlying rationale for this assumption relates to those visiting the GP i.e. the tendency for those individuals to be more vulnerable. Population distribution derived from HES data. The lack of data on individual's socioeconomic characteristics does not allow the model to disentangle lost earnings across the society spectrum. Estimates are based on average weekly pay gross.
	ONS	Population distribution – proportion of working population not visiting GP	
	Annual Survey for Hours & Earnings (ASHE)	Weekly pay gross	

Table A3.1: Lost earnings, disturbance cost, school absence

Cost component	Data source	Description	Assumptions and limitations
Loss of earnings to carers	Methodology and data sources as per individual/ sufferer	Methodology and data sources as per individual/ sufferer	It is assumed that only the dependent population needs a carer. The dependent population was defined by age profile; i.e. individuals below 16 years old and those above 65.
Disturbance Costs to employer	ONS	Hourly pay - Gross	No permanent replacement is required due to the short length of the disease. Any readjustment of the workload is done internally, and hence it exclusively captures the

Cost component	Data source	Description	Assumptions and limitations
			resultant incremental costs per unit of production due to administrative burden.
Under 16 school absenteeism	Institute of Fiscal Studies (IFS)	Cost and number of pupils	The model only estimates cost of school absence up to the age of 16 years, hence representing a lower bound cost estimate. As the larger part majority of school costs is are fixed (housing, personnel and materials) a child missing school does not result in actual savings

Table A4.0: Human cost

Cost component	Data source	Description	Assumptions and limitations
Pain & suffering moderate/ severe (WTP)	Estimating Quality Adjusted Life Years and Willingness to Pay Values for Microbiological Foodborne Disease (Phase 2)	Pathogen specific Willingness to Pay values	The severity distribution of the disease is assumed to be comparable to FDEM – model driving the number of cases assessed in the model. For those pathogens not covered in the QALY/WTP Phase 2 research, proxies were developed in collaboration with experts from multi-disciplinary fields using outputs from Markov Transmission

Cost component	Data source	Description	Assumptions and limitations
Pain & suffering moderate/ severe (WTP)			Models (MTMs) to facilitate the mapping and grouping of pathogens (including unattributed foodborne illness) with similar health states (complications/symptoms and their sequelae)
Fatalities – human costs (WTP)	Department for Transport	Human Cost – fatalities	WTP values for fatalities encompass the intrinsic cost of life enjoyment (excepting consumption of goods and services) up to standard life expectancy. No context specific values
Fatalities – loss of consumption	Department for Transport's (DfT's) value of a prevented fatality (VPF) study Transport Analysis Guidance (TAG) Data Book	Methodology as per HSE guidance and CtB model	Loss consumption is captured by estimating 80% of lost gross output an approach consistent with HSE's CtB model. .
	ASHE	Mean salary	

Appendix B: Methodology: Monetary valuation of pain, grief and suffering (human cost) for foodborne disease in the UK

B1.0 Willingness to pay

This section explores in further detail the methodology underpinning the QALY WTP Phase 2 work, and how it feeds into the COI model.

Willingness to Pay is the monetary measure of the value of obtaining a gain in the provision of a good or service or avoiding a loss. For the cost of illness, WTP was used to estimate the non-financial burden of foodborne diseases – the pain, grief & suffering. A stated preference survey was designed to elicit the value to avoid the short-term and long-term health conditions associated with a select group of foodborne pathogens; ranging from diarrhoea or vomiting to sequalae's such as IBS.

Individuals taking part in the study (over 4,000 observations) were presented with a questionnaire and were asked to choose between a set of similar health states related to intestinal infectious diseases. To build the different options, and so to derive WTP estimates, two approaches were used:

- Vignettes, which described the states using medical definition of symptoms.
- EuroQol – 5 Dimension – 3 Level (EQ-5D-3L), which describe the states using the approach's definitions of: five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) and three levels of severity (no problems/some or moderate problems/extreme problems).

While the WTP derived from vignettes where used to specify Markov Transition model health states[37], which consider the number of people passing through each disease state over a year, the EQ-5D-3L provided estimates for the burden of the disease by attributing

[37] A cohort model that present the population travelling through different states in a given period. A probability is associated with moving from each state to a new state, and the cases also present the probability of remaining in the same state. In order to quantify the outcomes, each state has an associate WTP that is aggregated at the end.

a published monetary value per QALY[38]. The values used in the COI model were those derived from vignette valuations, an approach that allows direct valuation of the outcome of interest.

WTP (monetised) values derived from the EQ-5D-3L approach produced significantly higher estimates (by a factor of 2.9) compared to monetary values based on vignettes. The differential in total burden was largely due to the difference in the monetary value assigned to long term sequalae, and their relative weight driven by the total number of cases. The cost of illness model opts for a more conservative valuation of the pain, grief and suffering associated with FBD, by using values derived from the vignettes approach.

The risk of double counting was considered and rigorously tested for before including any WTP values in the COI model. Two potential sources of double counting were considered:

- Whether individuals' factor in loss of income, workdays lost, medical expenses, extra childcare expenses etc. in their WTP valuations – the QALY WTP Phase 2 study reports the proportion of WTP that is due to the cost of workdays lost to be very small and possibly to be isolated from the key results. The likelihood of the presence of embedding (part-whole bias) was tested; participants were able to think about pain and suffering in isolation i.e. separating out loss of income, workdays lost, medical expenses, etc from their valuation. When the survey was run and the results assessed using a conditional logit model, a variable capturing the interaction between time and potential loss of earnings was included in the model specification. The interaction term was significant, which is in line with the economic theory, but the magnitude was marginal compare to the size of the other coefficients.[39]

The vignette WTP study does not provide a value for death. The study focused on certain outcomes instead of risks of any given ill health state occurring. Therefore, the survey did not ask respondents about their WTP to avoid their certain death. Hence, WTP values in

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[38] QALYs were derived using the same Markov Transition model, introducing health state utility values instead of WTP. Once the QALY loss were computed those were multiplied by the monetary value derived from the answers to the EQ-5D-3L questionnaire.

[39] Table 15 and Table L1 in the original report QALY phase 2.

the COI model only consider comorbidities and not fatalities. The valuation of fatalities continues to be based on valuations estimated as part of the Department for Transport's (DfT) value of a prevented fatality (VPF) study, which is discussed below.

B.2.0 Value of a statistical life

The COI model uses WTP valuations of a small reduction in the risk of death derived from the DfT's VPF. The DfT study used stated preference techniques to elicit individual WTP and WTA for the prevention of a fatality in a road traffic accident. The following elements comprise the VPF estimate:

1. Loss of output – this is calculated as the present value of the expected loss of earnings plus any non-wage payments (national insurance contributions etc) paid by the employer. This includes the present value of the consumption of goods and services that are lost as a result of injury accidents (assumed to be 80% of lost gross output).
2. Ambulance costs and the costs of hospital treatments.
3. Human costs, based on WTP values which encompass pain, grief and suffering to the individual, family and friends and for fatalities, the intrinsic cost of life enjoyment (excepting consumption of goods and services) up to standard life expectancy. Since 1993 values have been uprated using '1+ (% increase in nominal GDP per capita/100)'.

Note that because the COI model estimates 1) and 2) for FBD specifically, the FSA uses only the third element from the VPF study, adjusted as per Health and Safety Executive guidance on valuing the human cost of illness.

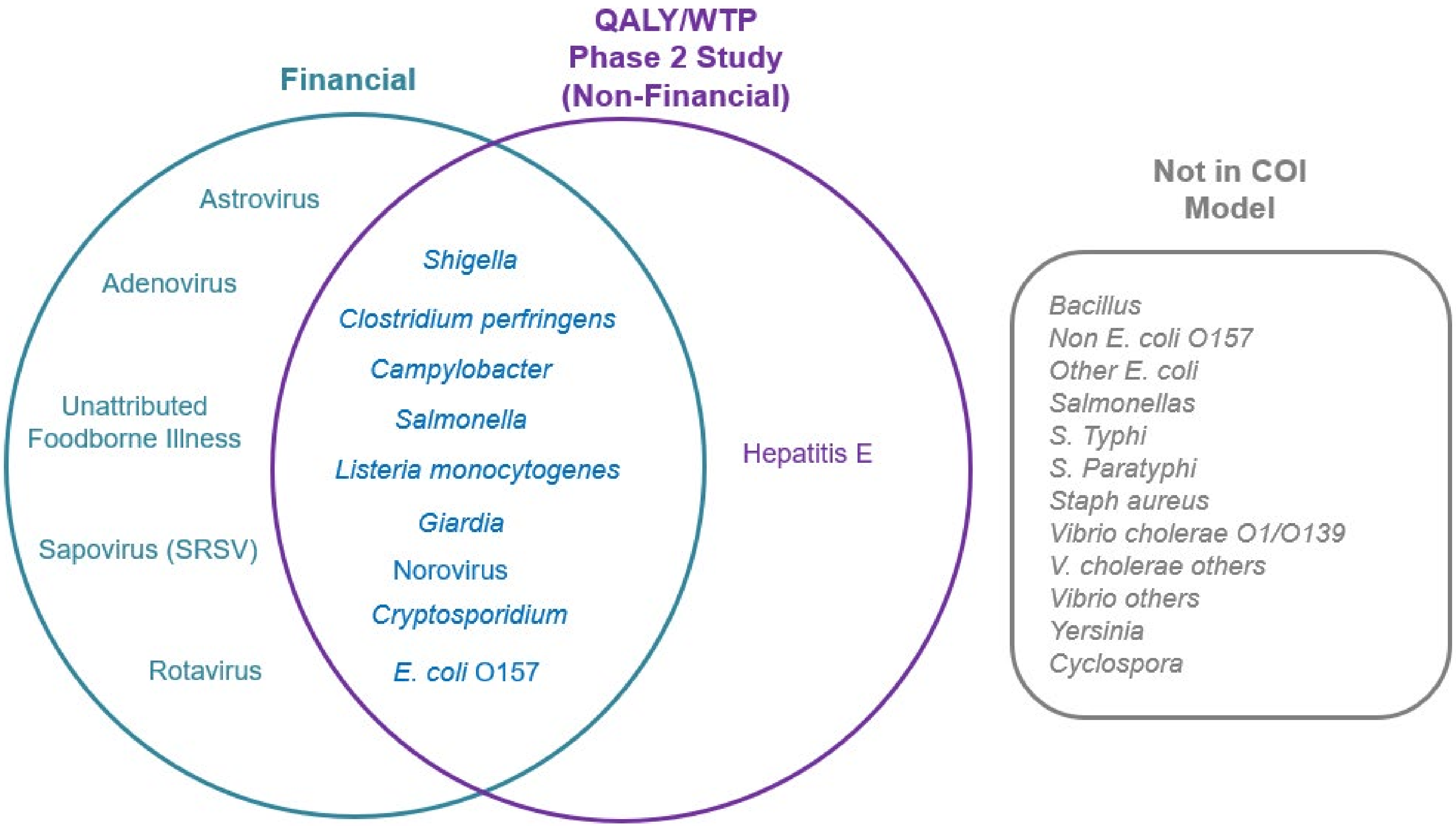
Appendix C: Methodology and approach for estimating the burden of unattributed foodborne illness cases for foodborne disease

For the first time we are now able to estimate the societal burden attributable to unattributed foodborne illness cases for FBD in the UK. The rationale for including unattributed foodborne illness stems from the need to get an overall FBD cost burden figure, therefore including gastroenteritis episodes for which it is not possible to identify the pathogen causing the disease.

In order to calculate the cost of illness for unattributed foodborne illness cases, Norovirus was used as a proxy for identifying relevant cost vectors and prices for estimating the financial (direct and indirect costs) burden for these cases; an approach consistent with the USDA and FSANZ approach. For the non-financial (WTP and QALY estimates) component, the FSA ran a workshop with an expert panel including members from the Advisory Committee on the Microbiological Safety of Food (ACMSF)[40], to develop proxies using existing outputs from the *QALY and WTP FBD Phase 2 study*. Drawing on expert opinion, knowledge and experience, the FSA was able to map and pair 10 pathogens (some of which are not included in the COI model) plus unattributed foodborne illness to the 10 select pathogens modelled in the Phase 2 study (see Figure C1).

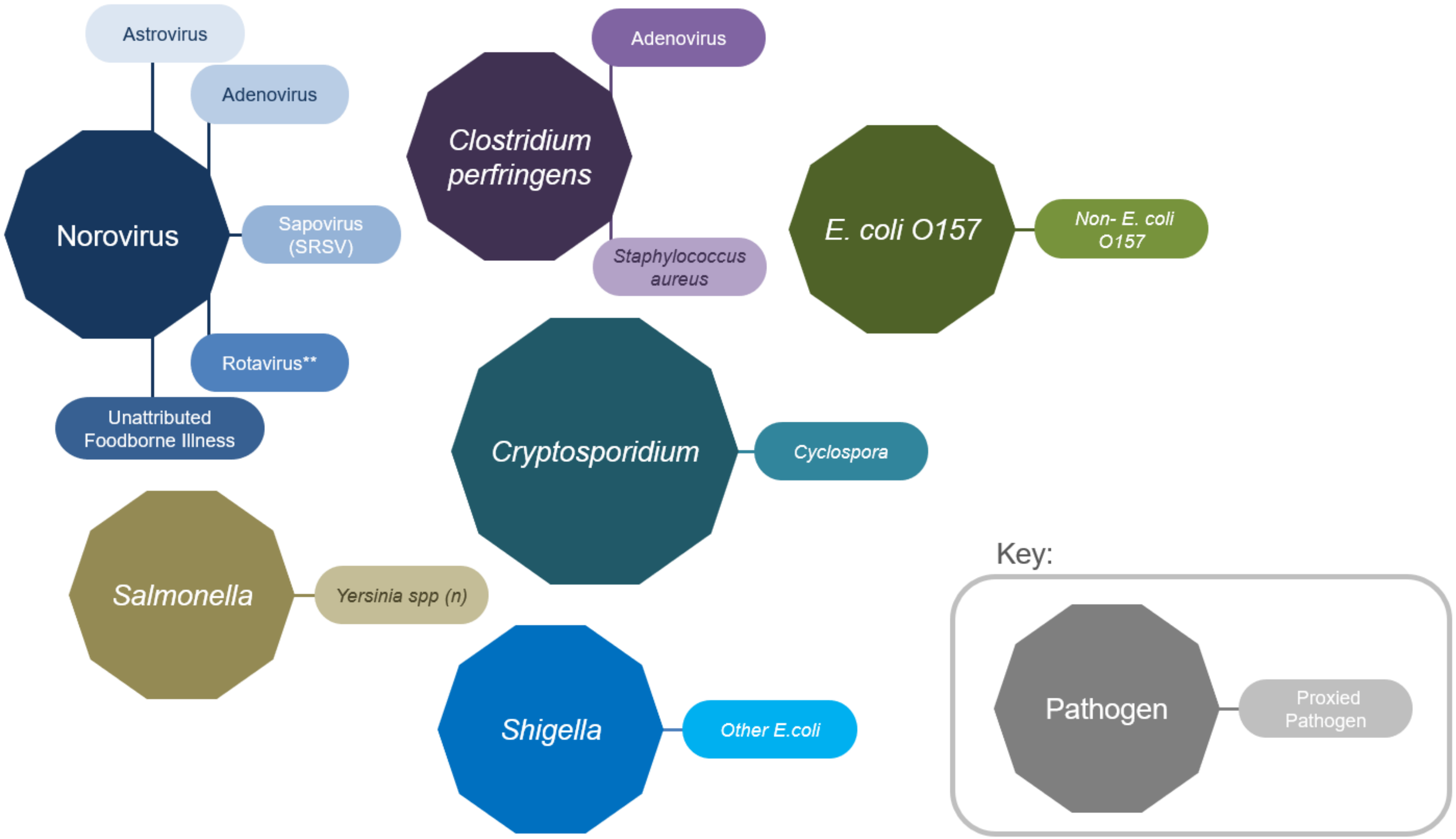
[40] The workshop was organised and facilitated by the FSA Analytics Unit - Economics Branch and was used as a forum for eliciting expert opinion, views, knowledge and experience - drawing from multi-disciplinary fields (microbiologists, epidemiologist, clinicians, virologist, health economists, operational researchers).

Figure C1: Pathogens with and without QALY and WTP Values



Proxies were constructed by grouping and pairing pathogens with similar health states in terms severity level, co-morbidities complications, symptoms and their sequelae derived from decision-analytic model structures developed for the 10 select pathogens as part of the Phase 2 study. Figure C2 presents a summary of those pathogens that have been paired and proxied.

Figure C2: Proxied pathogens



Appendix D: Cost breakdown by pathogen 2018

Chart D1 - Norovirus

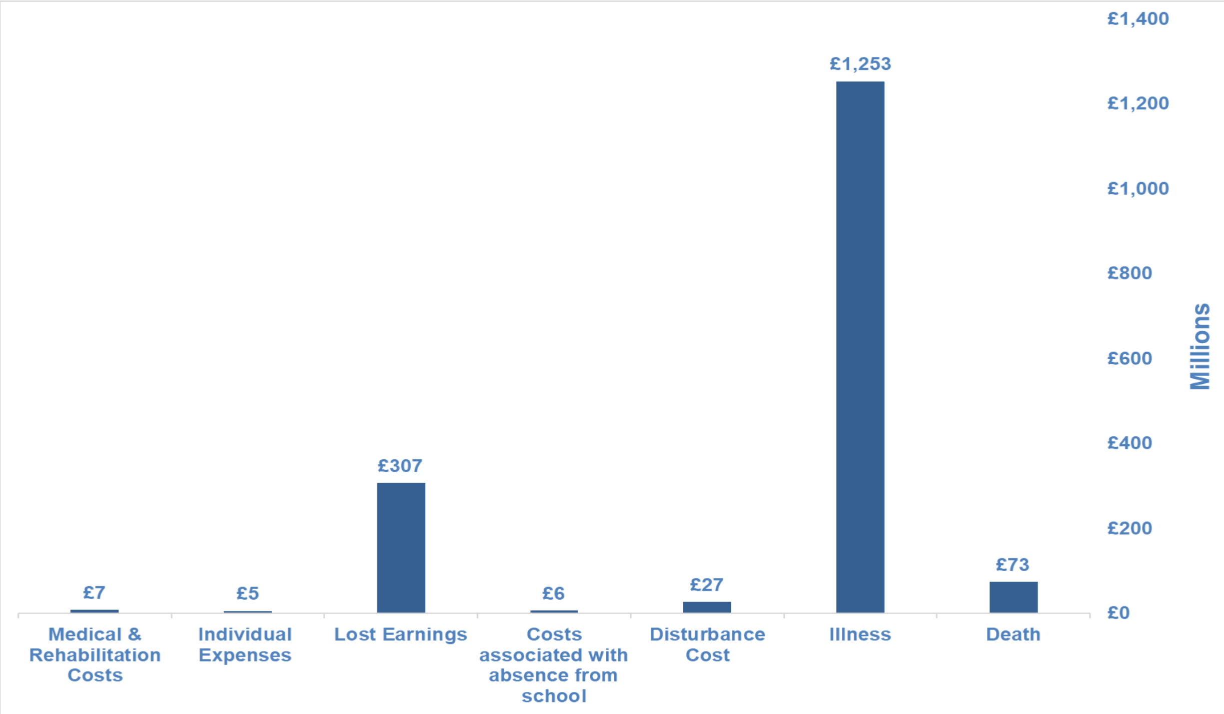


Chart D2 - Campylobacter

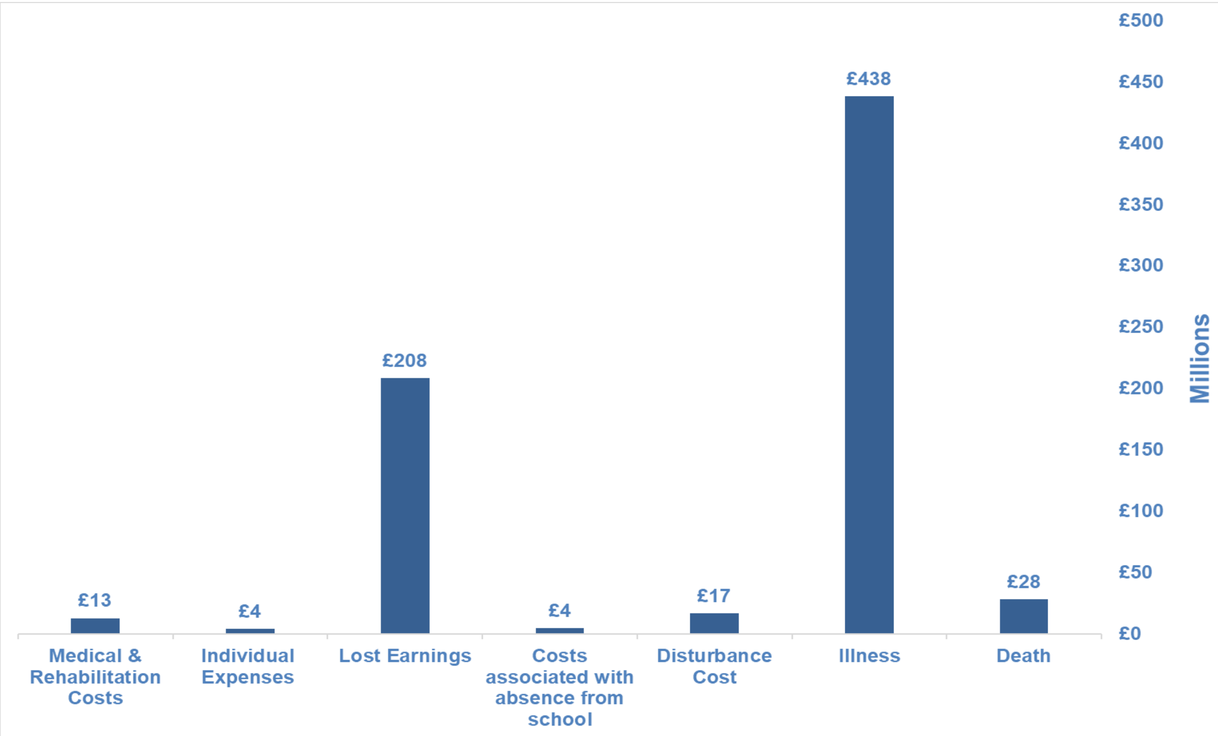


Chart D3 - Salmonella

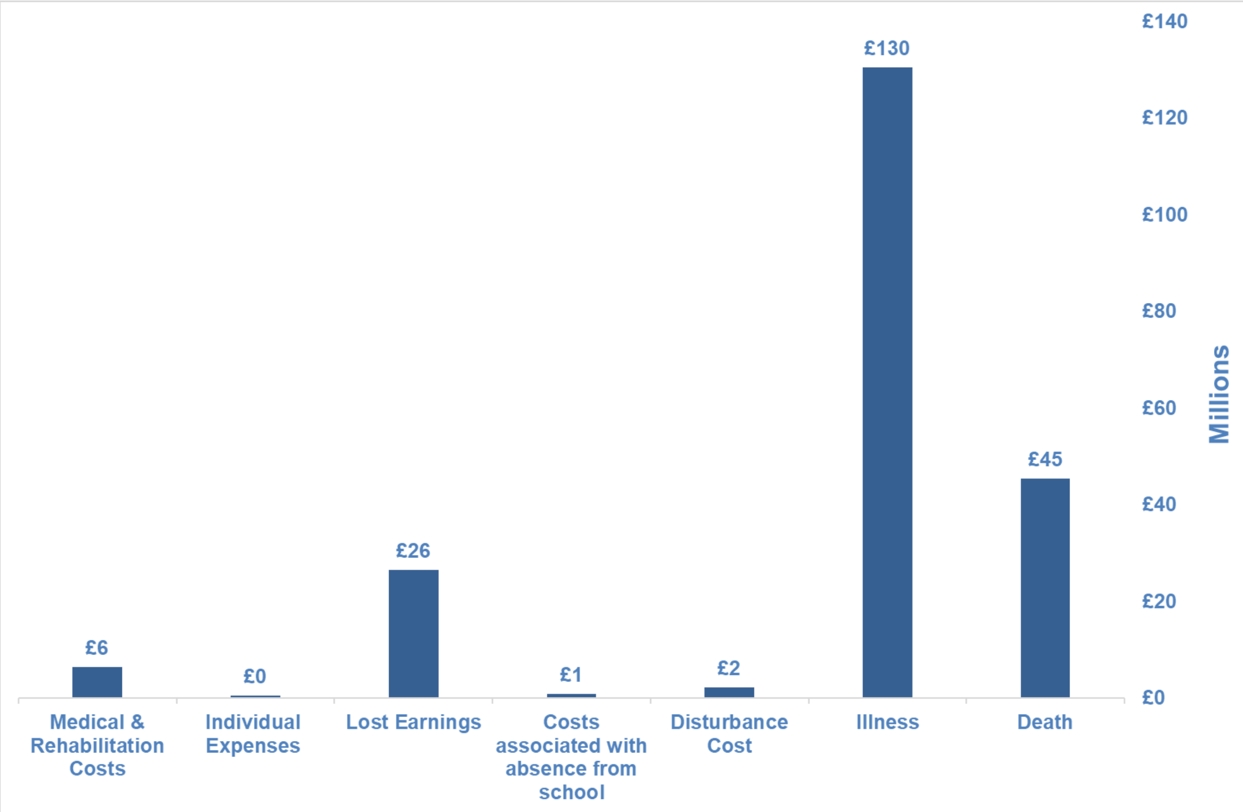


Chart D4 - Sapovirus

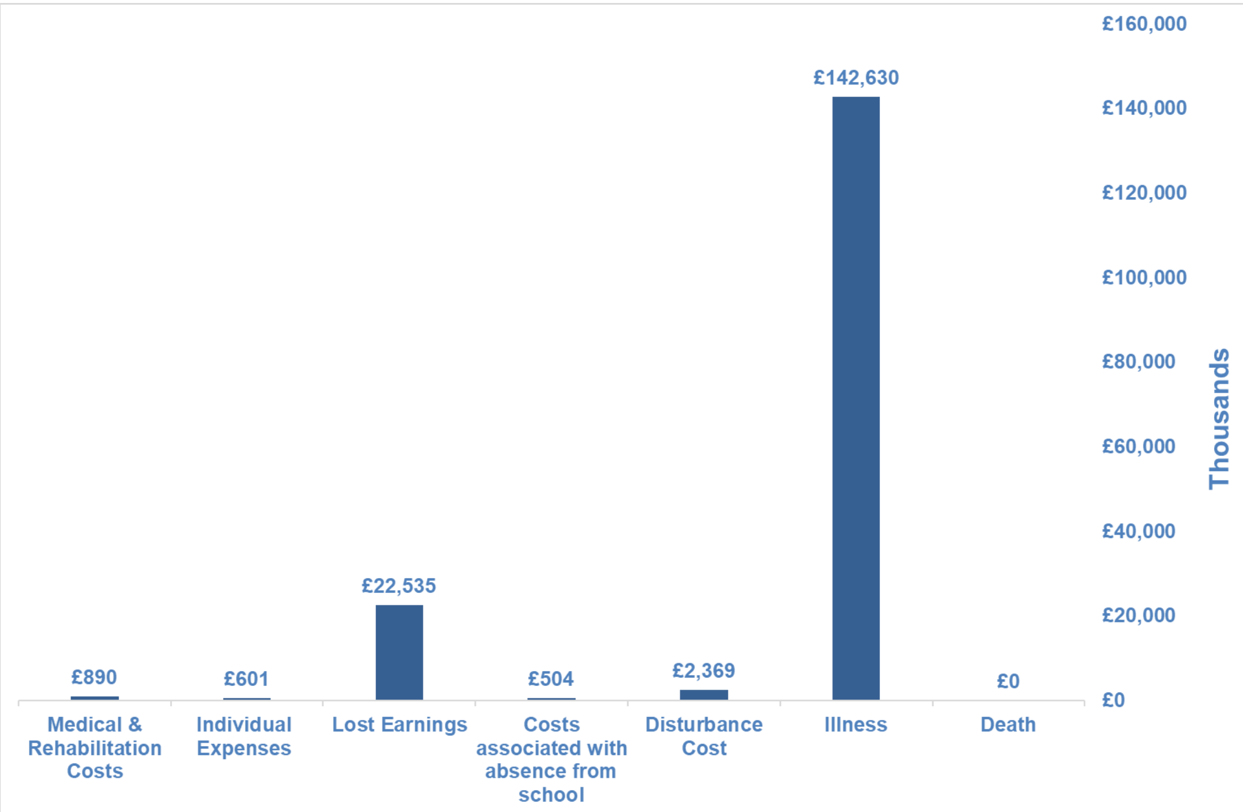


Chart D5 - Clostridium perfringens

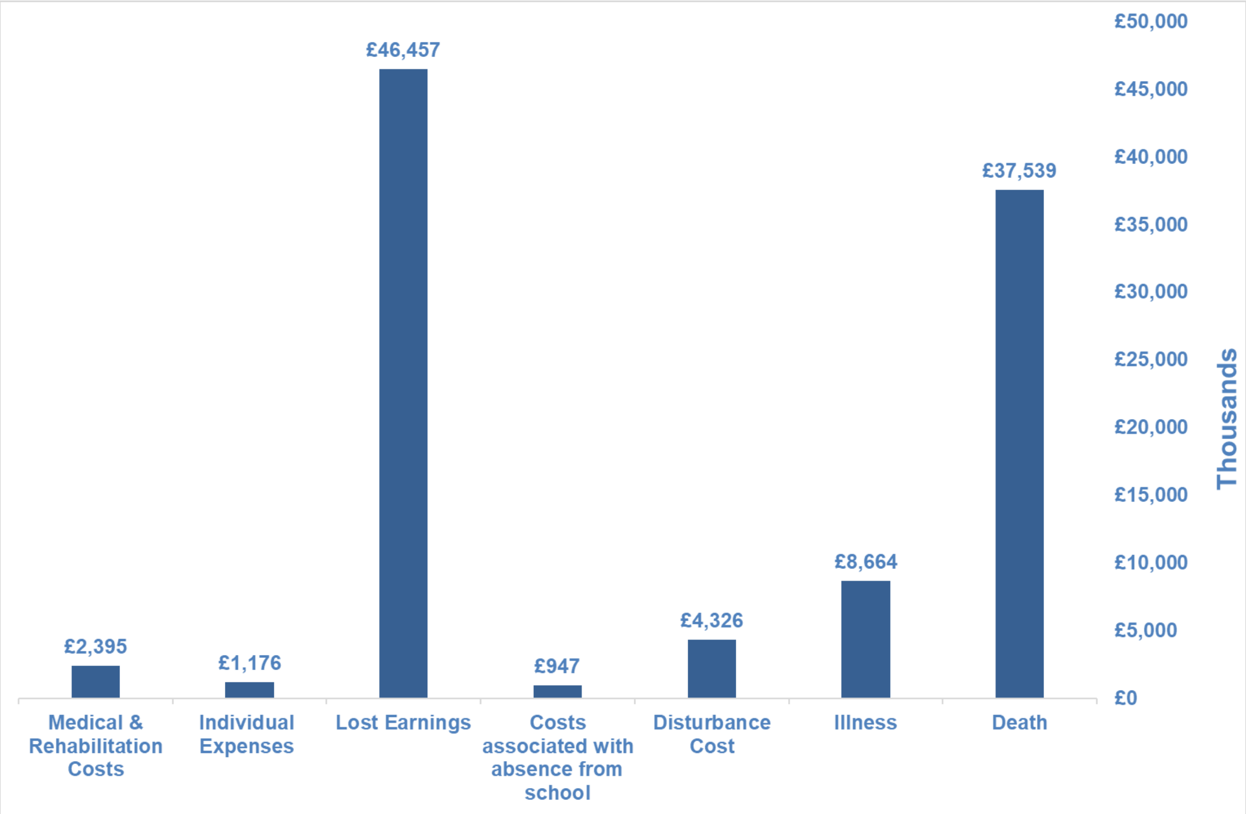


Chart D6 - Giardia

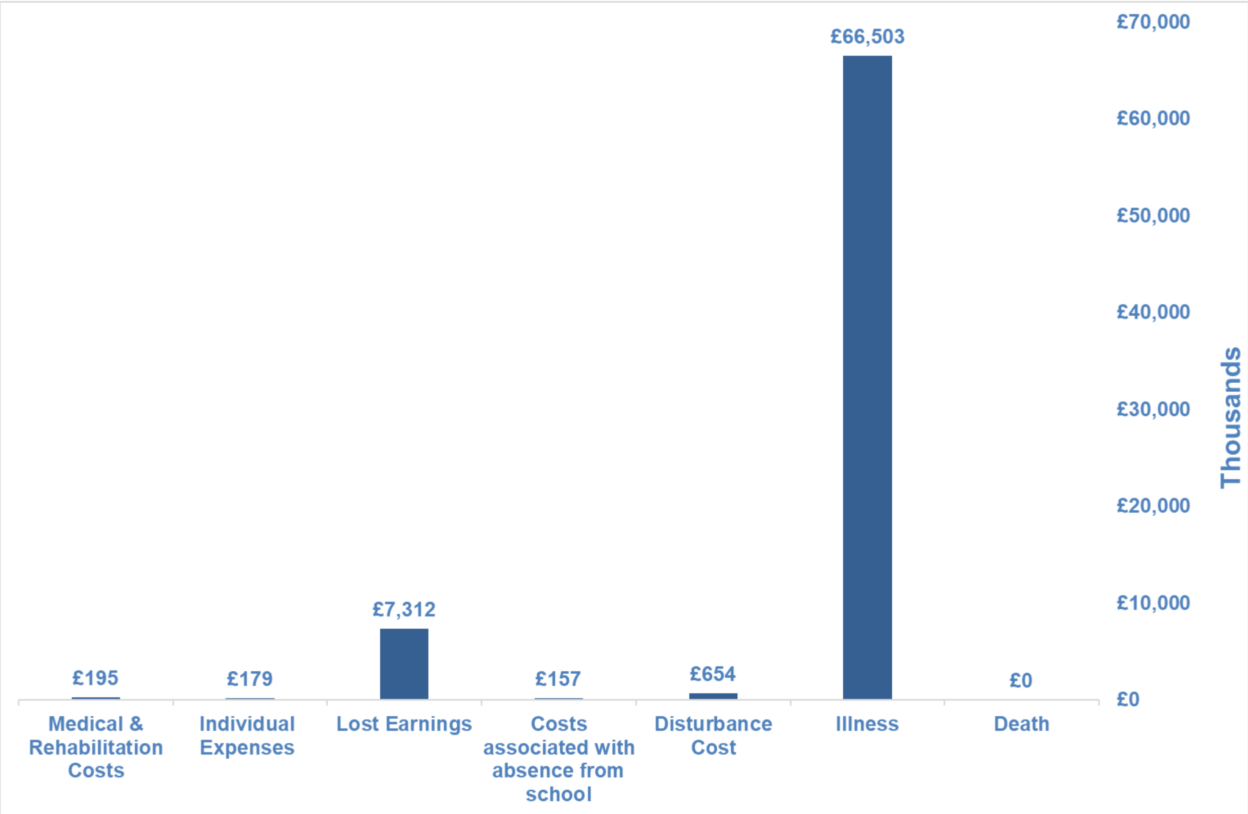


Chart D7 - Adenovirus

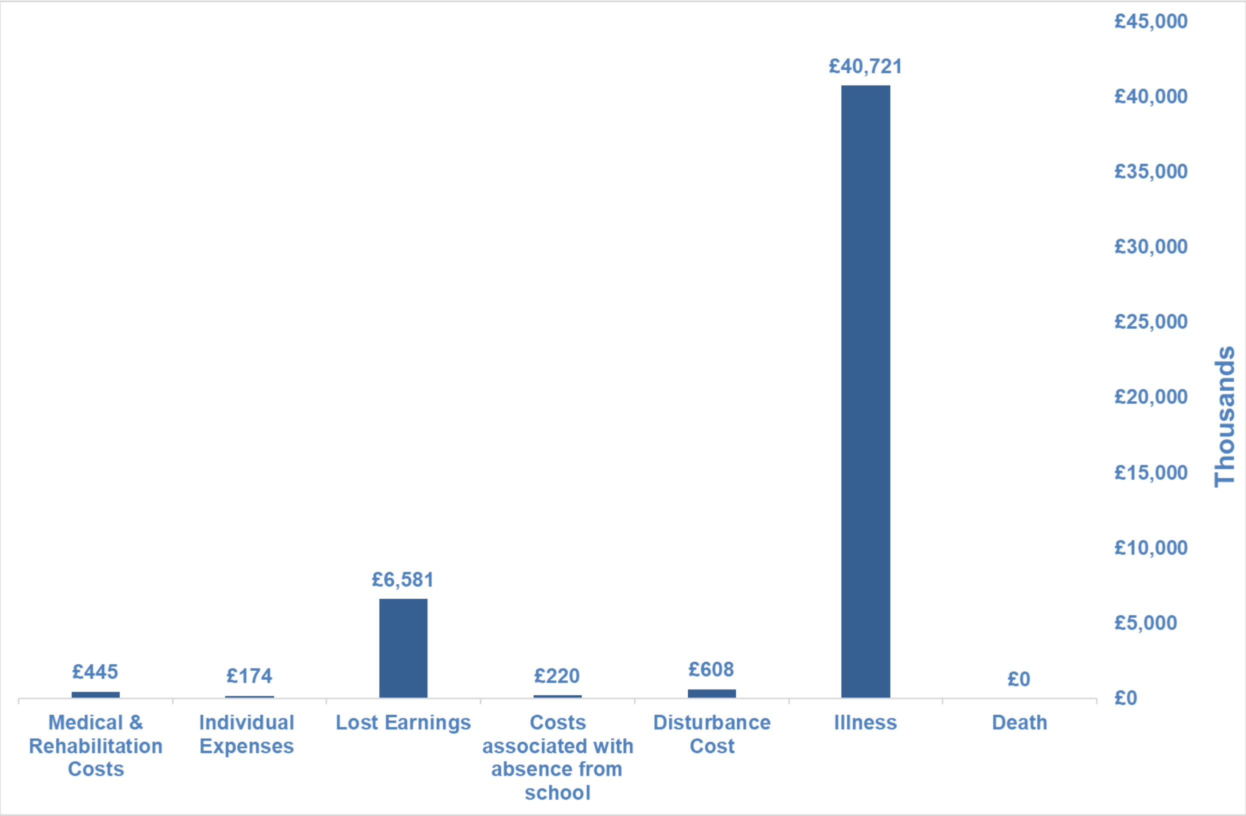


Chart D8 – Listeria monocytogenes

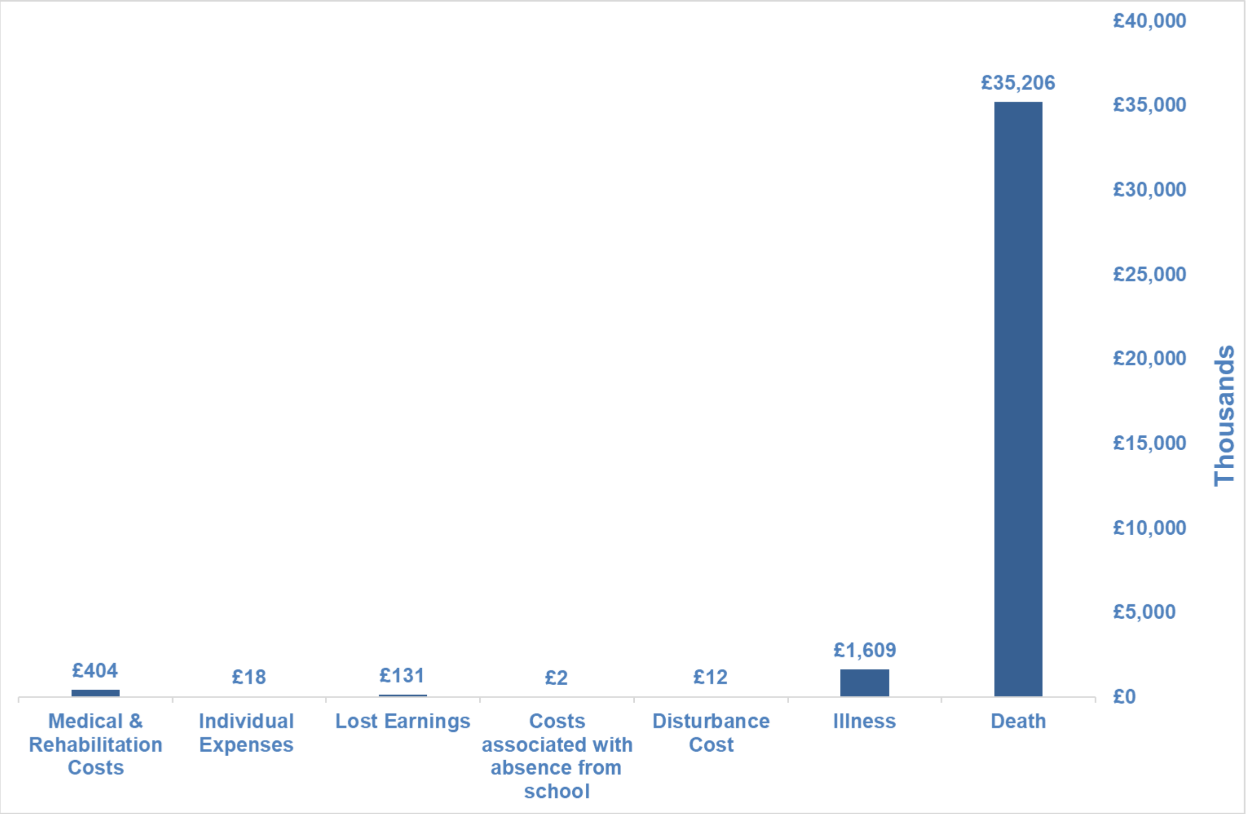


Chart D9 - Shigella

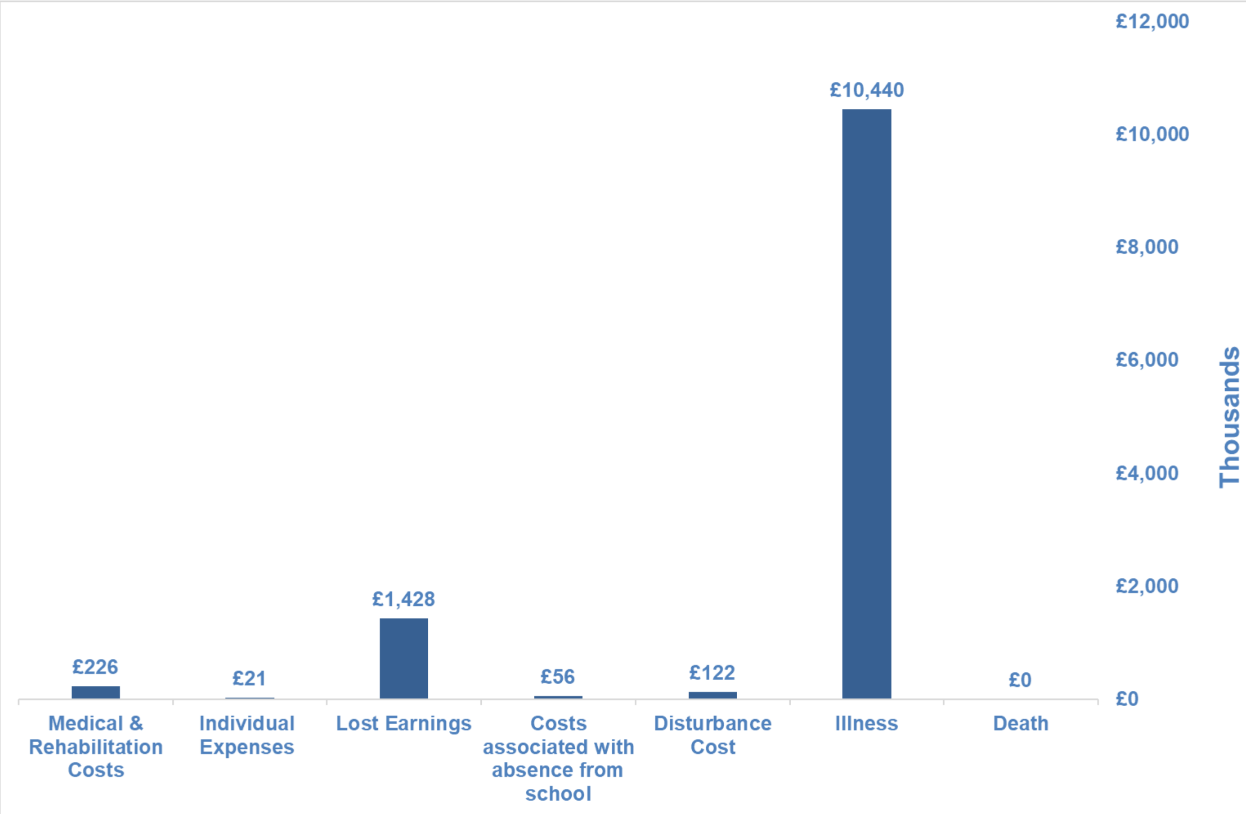


Chart D10 - Astrovirus

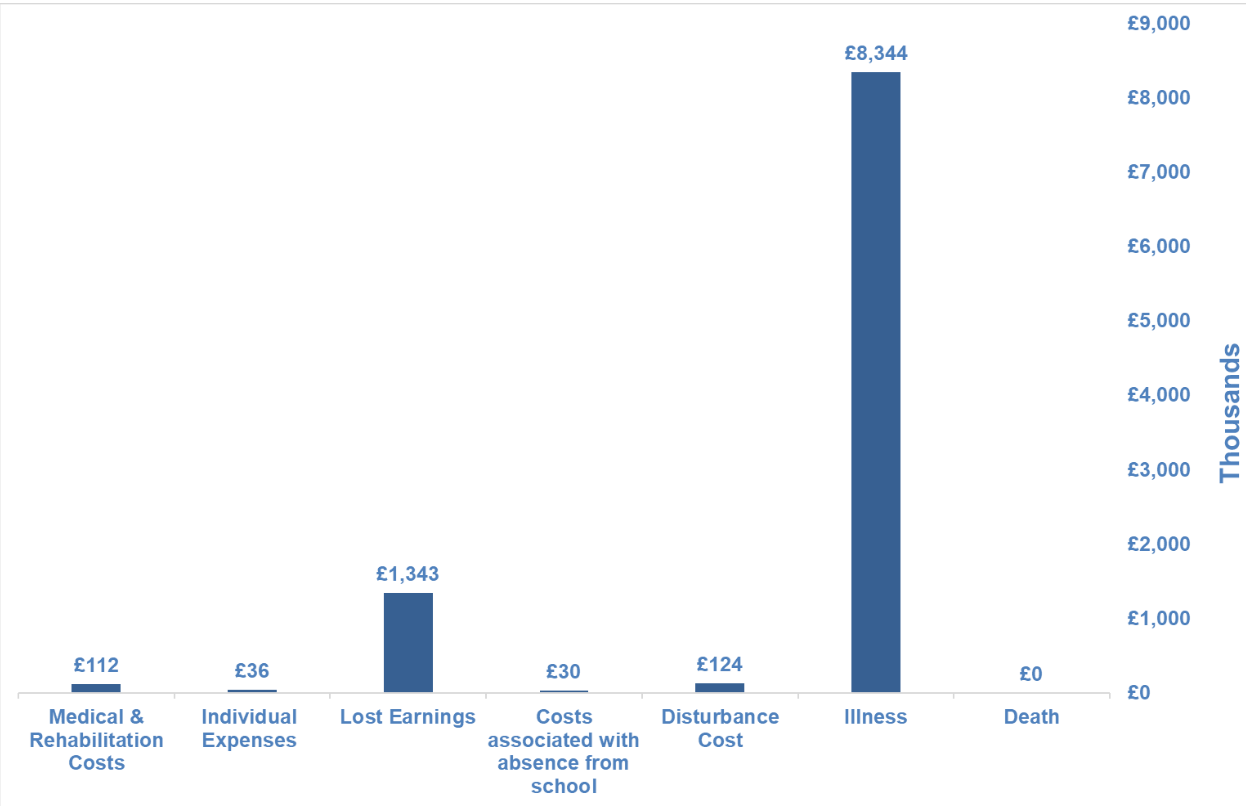


Chart D11 - Rotavirus

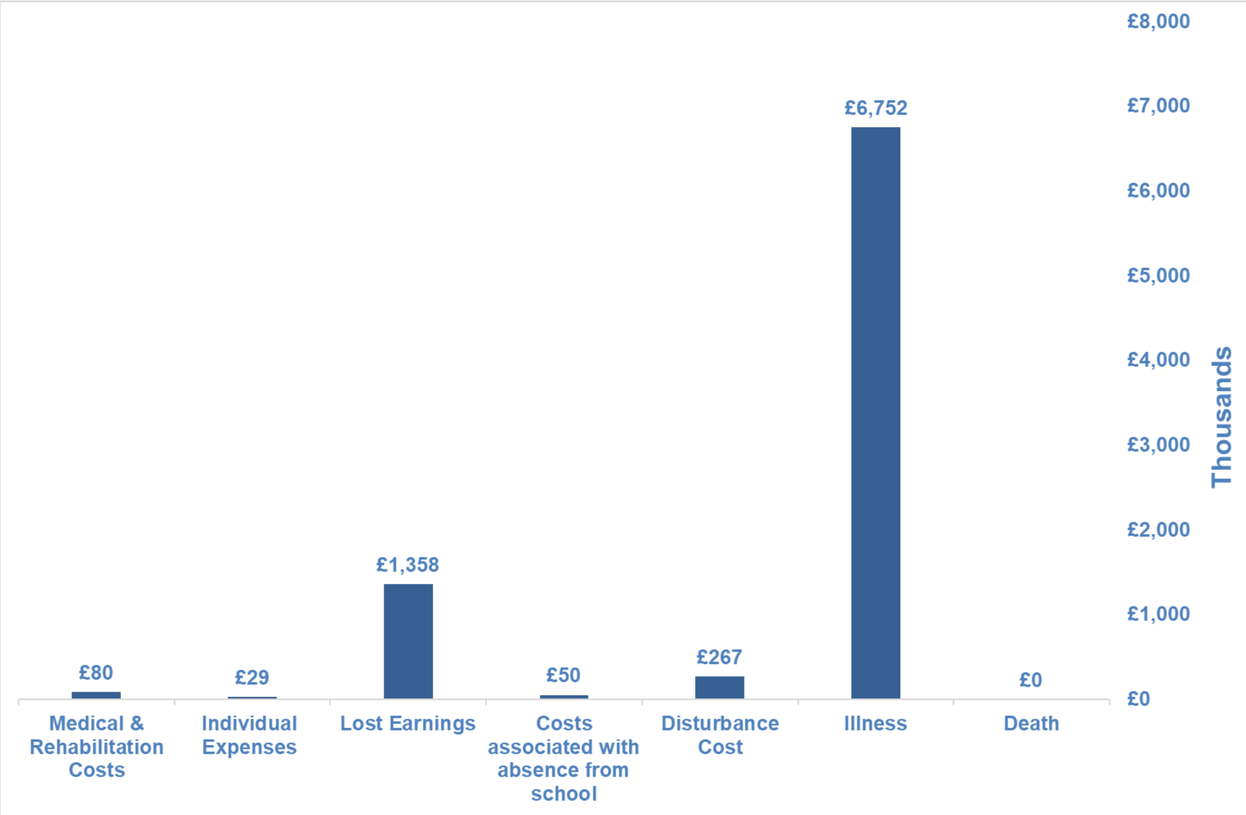


Chart D12 - E. coli O157

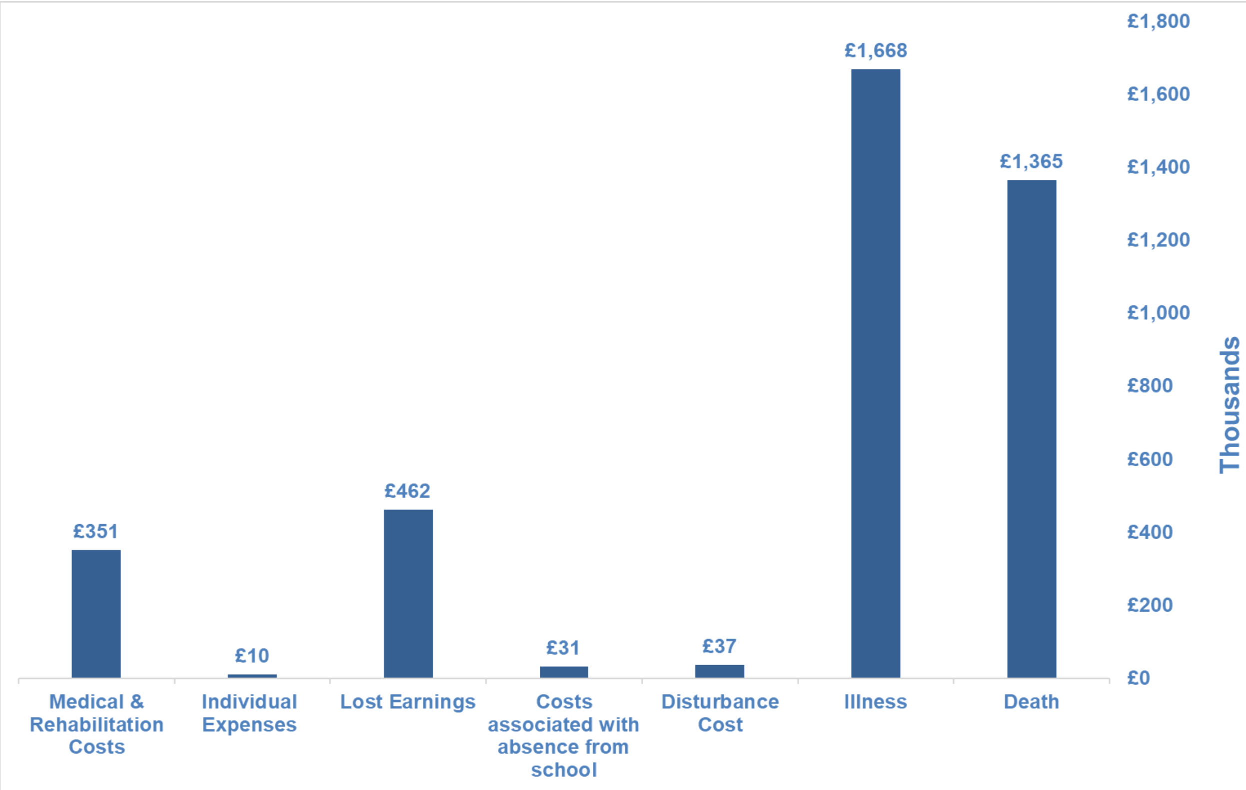


Chart D13 - Cryptosporidium

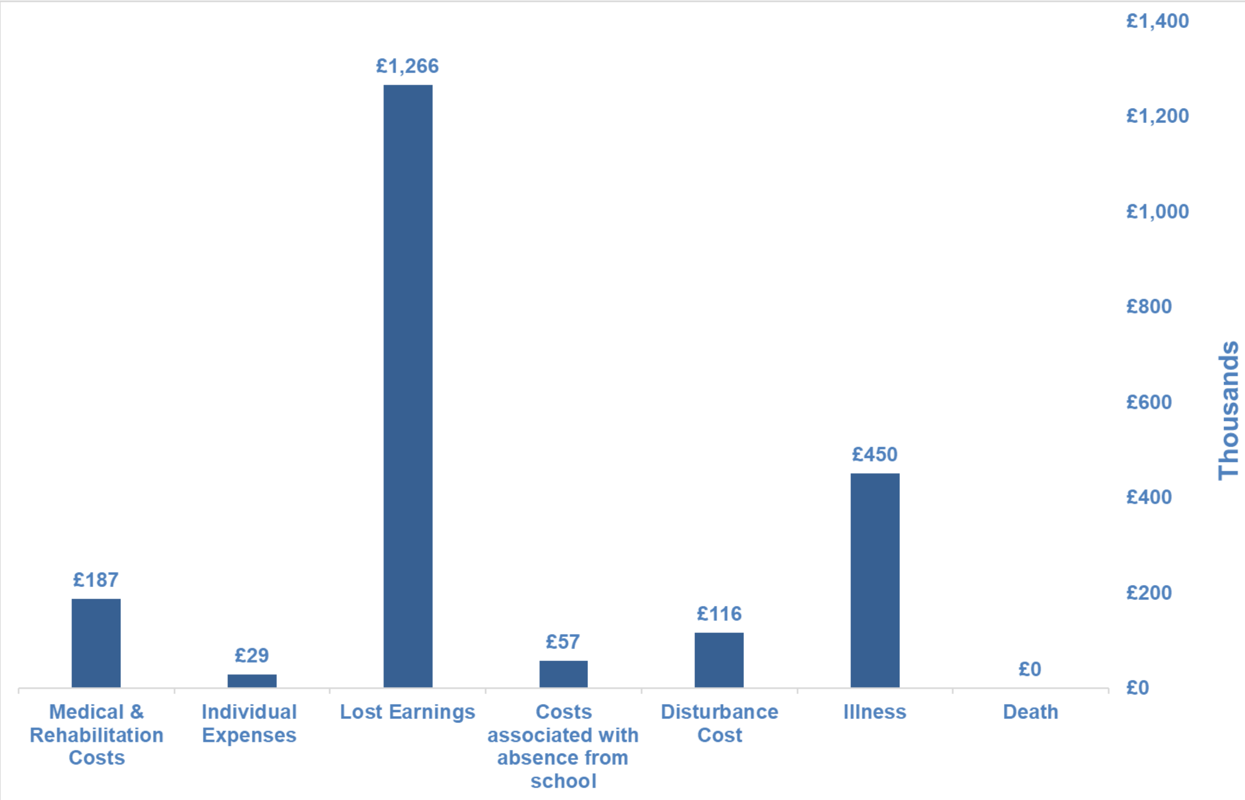
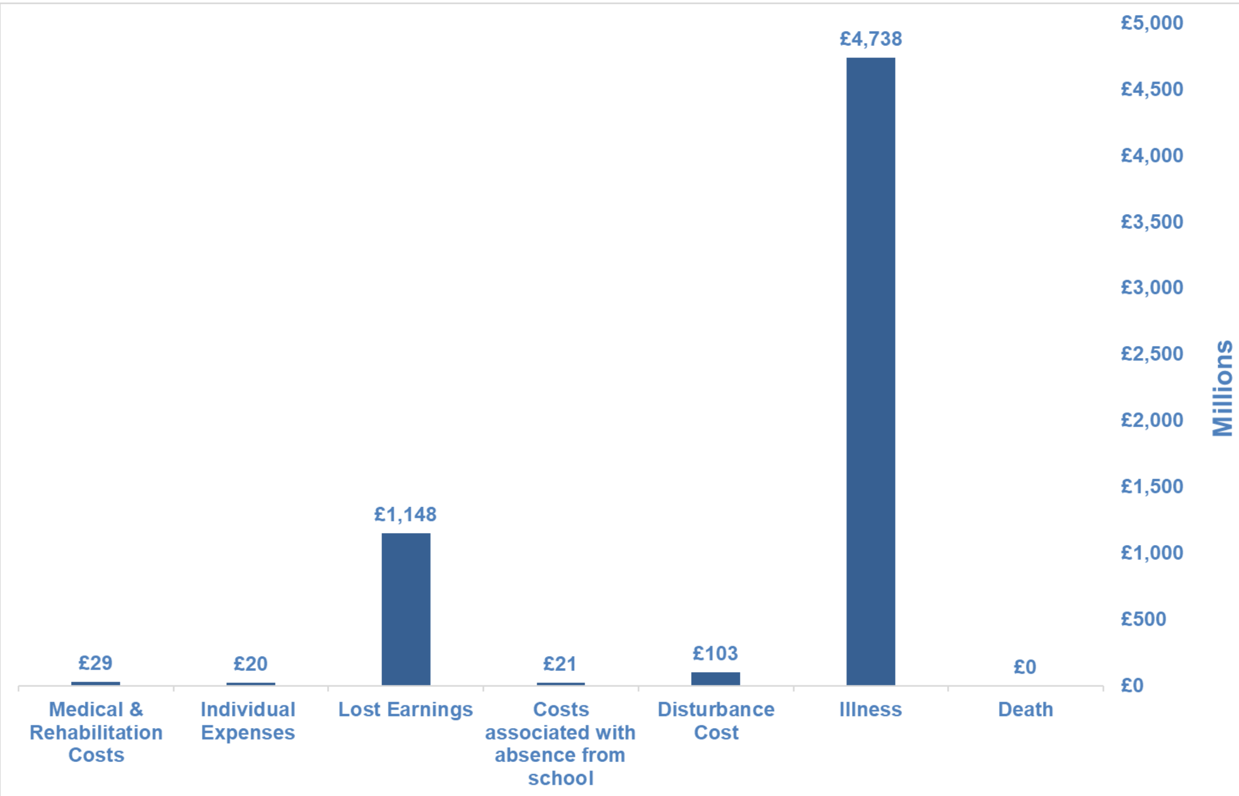


Chart D14 - Unattributed foodborne illness



Appendix E: Cost Estimates of UK Foodborne Disease in 2018 With 95% Credible Intervals

Table E1. Cost Estimates of UK Foodborne Disease in 2018 £(Millions) – Medical Costs, Individual Costs, Lost Earnings, School Absence…

Pathogen	Medical Costs			Individual Costs			Lost Earnings			School Absence		
	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI
Bacteria												
Campylobacter	£12.77	£5.15	£26.24	£4.14	£1.75	£7.94	£208.35	£85.74	£374.85	£4.41	£1.85	£8.33
Clostridium perfringens	£2.40	£0.91	£6.42	£1.18	£0.43	£3.23	£46.46	£17.19	£118.70	£0.95	£0.35	£2.51
E.coli O157	£0.35	£0.23	£0.47	£0.01	£0.01	£0.01	£0.46	£0.23	£0.48	£0.03	£0.02	£0.04
Listeria monocytogenes	£0.40	£0.37	£0.42	£0.02	£0.02	£0.02	£0.13	£0.10	£0.12	£0.00	£0.00	£0.00
Salmonella	£6.32	£1.55	£27.39	£0.49	£0.10	£2.31	£26.48	£5.54	£101.94	£0.76	£0.20	£2.78
Shigella	£0.23	£0.01	£0.86	£0.02	£0.00	£0.06	£1.43	£0.08	£3.78	£0.06	£0.00	£0.16
Parasites												
Cryptosporidium	£0.19	£0.03	£0.98	£0.03	£0.00	£0.17	£1.27	£0.20	£6.73	£0.06	£0.01	£0.25
Giardia	£0.20	£0.03	£1.27	£0.18	£0.03	£0.89	£7.31	£1.11	£38.23	£0.16	£0.02	£0.84
Virus												
Adenovirus	£0.44	£0.10	£1.45	£0.17	£0.04	£0.45	£6.58	£1.61	£18.08	£0.22	£0.05	£0.61
Astrovirus	£0.11	£0.01	£0.77	£0.04	£0.01	£0.12	£1.34	£0.30	£4.12	£0.03	£0.01	£0.09
Norovirus**	£7.24	N/A	N/A	£5.29	N/A	N/A	£306.72	N/A	N/A	£5.74	N/A	N/A
Rotavirus	£0.08	£0.02	£0.25	£0.03	£0.01	£0.08	£1.36	£0.34	£3.72	£0.05	£0.01	£0.14
Sapovirus (SRSV)	£0.89	£0.52	£1.50	£0.60	£0.40	£0.89	£22.53	£14.93	£33.47	£0.50	£0.33	£0.75
Total FBD*	**£31.6**	**£8.9**	**£68.0**	**£12.2**	**£2.8**	**£16.2**	**£630.4**	**£127.4**	**£704.2**	**£13.0**	**£2.9**	**£16.5**
Unattributed Foodborne Illness (UFI)	£28.87	£18.21	£44.28	£19.85	£14.36	£27.24	£1,148.40	£922.15	£1,235.55	£21.35	£20.79	£27.37
Total FBD including UFI*	**£60.5**	**£27.1**	**£112.3**	**£32.0**	**£17.2**	**£43.4**	**£1,778.8**	**£1,049.5**	**£1,939.8**	**£34.3**	**£23.7**	**£43.9**

Notes: *The reported total number of cases for FBD is the result of the simulation based on median estimates of overall cases. It is a different figure from the sum-up of the reported number of cases across pathogens, which was used to calculate the cost per case.
**Credible intervals for norovirus were not possible for cases due to the modelling approach. This does not mean that there is no uncertainty in these estimates. There were a number of parameters used in the NoVAS study which, while based on the best science currently available, were acknowledged to have uncertain values. Sensitivity analysis undertaken as part of the study showed that changes to the values of these parameters could make big differences to the overall estimates.

Table E2. Cost Estimates of UK Foodborne Disease in 2018 £(Millions) – Disturbance Costs, Deaths and Illness

Pathogen	Disturbance Cost to Businesses			Deaths			Illness		
	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI	Median	Lower 95% CI	Upper 95% CI
Bacteria									
Campylobacter	£16.82	£7.17	£31.83	£28.05	£10.69	£70.57	£438.11	£186.03	£836.06
Clostridium perfringens	£4.33	£1.66	£8.73	£37.54	£1.50	£222.44	£8.66	£3.27	£22.94
E.coli O157	£0.04	£0.02	£0.05	£1.36	£1.36	£1.35	£1.67	£1.08	£2.24
Listeria monocytogenes	£0.01	£0.01	£0.01	£35.21	£32.50	£38.49	£1.61	£1.45	£1.69
Salmonella	£2.16	£0.58	£8.69	£45.36	£9.62	£204.15	£130.46	£27.99	£607.50
Shigella	£0.12	£0.01	£0.37	£0.00	£0.00	£1.28	£10.44	£0.70	£31.77
Parasites									
Cryptosporidium	£0.12	£0.02	£0.64	£0.00	£0.00	£3.85	£0.45	£0.07	£2.65
Giardia	£0.65	£0.10	£3.50	£0.00	£0.00	£1.28	£66.50	£10.29	£359.92
Virus									
Adenovirus	£0.61	£0.15	£1.70	£0.00	£0.00	£2.57	£40.72	£10.09	£113.37
Astrovirus	£0.12	£0.03	£0.39	£0.00	£0.00	£0.00	£8.34	£1.87	£26.14
Norovirus**	£26.82	N/A	N/A	£73.44	N/A	N/A	£1,252.91	N/A	N/A
Rotavirus	£0.27	£0.07	£0.73	£0.00	£0.00	£0.00	£6.75	£1.69	£18.54
Sapovirus (SRSV)	£2.37	£1.57	£3.52	£0.00	£0.00	£0.00	£142.63	£94.61	£211.57
Total FBD*	**£54.4**	**£11.4**	**£60.2**	**£221.0**	**£55.7**	**£546.0**	**£2,109.3**	**£339.2**	**£2,234.4**
Unattributed Foodborne Illness (UFI)	£103.02	£73.97	£142.31	£0.00	£0.00	£0.00	£4,738.41	£3,421.81	£6,512.06
Total FBD including UFI*	**£157.5**	**£85.4**	**£202.5**	**£221.0**	**£55.7**	**£546.0**	**£6,847.7**	**£3,761.0**	**£8,746.4**

Notes: *The reported total number of cases for FBD is the result of the simulation based on median estimates of overall cases. It is a different figure from the sum-up of the reported number of cases across pathogens, which was used to calculate the cost per case.

**Credible intervals for norovirus were not possible for cases due to the modelling approach. This does not mean that there is no uncertainty in these estimates. There were a number of parameters used in the NoVAS study which, while based on the best science currently available, were acknowledged to have uncertain values. Sensitivity analysis undertaken as part of the study showed that changes to the values of these parameters could make big differences to the overall estimates.