The annual cost of foodborne illness in Australia by food commodities and pathogens

Final Report

For: Food Standards Australia New Zealand

3 August 2023

Overview of this report

This project is in relation to services to estimate the cost of foodborne illness by food commodity groups and pathogens for Food Standards Australia New Zealand (FSANZ), contract 2022-23/37. The project builds on prior work by the team at the Australian National University (ANU) to estimate the cost of foodborne illness in Australia.

The project milestones are summarised as follows:

1. Scoping meeting.
2. All expert elicitation data provided to ANU.
3. Draft report and R code provided to FSANZ.
4. Final report and model provided to FSANZ.
5. Presentation of results to FSANZ and stakeholders.

This document comprises the Final Report as part of milestone 4.

This report includes a summary of the methods used to estimate the cost of illness (as in prior work), a description of the approach used to combine this model with attribution data, the results of the attribution for six costed pathogens, and for the sum over these pathogens, and a detailed Appendix with all parameters and model assumptions.

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Glossary and acronyms

Acronym	*Descriptor*
ABS	Australian Bureau of Statistics
AIHW	Australian Institute of Health and Welfare
ALOS	Average length of stay
ANU	The Australian National University
AR-DRG	Australian Refined Diagnosis Related Groups
AUD	Australian Dollar
DCE	Discrete choice experiment
ED	Emergency department
FSANZ	Food Standards Australia New Zealand
GBS	Guillain-Barré syndrome
GP	General practitioner
HUS	Haemolytic uraemic syndrome
IBS	Irritable bowel syndrome
MBS	Medicare Benefits Schedule
NGSII	National Gastroenteritis Survey II
NNDSS	National Notifiable Diseases Surveillance System
PBS	Pharmaceutical Benefits Scheme
ReA	Reactive arthritis
STEC	Shiga toxin-producing *Escherichia coli*
UI	Uncertainty interval
VSL	Value of a statistical life
WTP	Willingness to pay

Executive summary

Foodborne disease costs Australia AUD 2.81 billion each year (2023 inflation-adjusted estimate), with high-cost illnesses including campylobacteriosis and its sequelae (annual cost of AUD 420 million), non-typhoidal salmonellosis and its sequelae (AUD 161 million), norovirus (AUD 147 million), and listeriosis (AUD 90 million). Attribution of these costs to food commodity groups is not yet known for Australia, and this evidence could assist in prioritising resources for research, monitoring, surveillance, and standards development.

Expert elicitation is a structured approach to obtaining probabilistic belief statements from experts. An expert elicitation process was carried out for FSANZ, led by Dr Anca Hanea (University of Melbourne), to attribute illness due to eight pathogens (non-typhoidal *Salmonella* species, *Campylobacter* species, *Listeria monocytogenes*, *Toxoplasma gondii*, STEC, *Yersinia* species, *Vibrio* species, and *Bacillus cereus*) to specific foods. The separate food groups included in the elicitation were beef, lamb, pork, poultry, eggs, dairy (milk and cream, fresh uncured cheese, brined cheese, soft-ripened cheese, firm-ripened cheese), finfish, crustaceans, molluscs, fruit, grains and seeds, nuts, vegetables (fungi, leafy vegetables and herbs, root vegetables, sprouts, vine-stalk), and other.

This project combines the attribution proportions from that expert elicitation study with a foodborne disease costing model for Australia to estimate the number of cases and the annual cost associated with fourteen food categories (beef, crustaceans, dairy, eggs, fin fish, fruit, grains and seeds, lamb, molluscs, nuts, pork, poultry, vegetables, and 'other') for the six pathogens from that study that are included in the costing model (non-typhoidal *Salmonella*, *Campylobacter*, *Listeria monocytogenes*, *Toxoplasmosis gondii*, STEC, *Yersinia* enterocolitica), providing costs per food-pathogen pair, and aggregated by pathogen or by food category.

Of the total of AUD 721 million estimated for the six included pathogens, the greatest cost was attributed to poultry (AUD 328 million, with AUD 279 million due to *Campylobacter*). Other food commodities with high costs attributed to them included vegetables (AUD 107 million), dairy (AUD 61 million), beef (AUD 56 million), and pork (AUD 56 million). Vegetables were associated with 26% of the costs due to *Salmonella* and 23% of the costs due to *Listeria monocytogenes*, while beef was associated with 34% of the costs due to STEC and 23% of the costs due to *Toxoplasma gondii*.

These results provide evidence for policy development, while the flexible model framework enables re-estimation of costs over time and in response to interventions. The long-term aim is to maximise the benefits achieved by regulatory interventions by ensuring they are proportionate and appropriately targeted.

Acknowledgements

This work was funded by Food Standards Australia New Zealand (FSANZ) under contract 2022-23/37. The ANU project team consists of Prof Kathryn Glass and Dr Angus McLure, building on a costing project that also involved Prof Emily Lancsar, Prof Martyn Kirk, Dr Siobhan Bourke, and Danielle Cribb. Tables listing model inputs from that costing report are included here in the Appendix to enable replication of all findings.

The expert elicitation was conducted by Dr Anca Hanea (Centre of Excellence for Biosecurity Risk Analysis, University of Melbourne), Snezana Smiljanic (FSANZ) and Ben Daughtry (FSANZ), with the following ten experts completing all rounds of the expert elicitation process: Prof Mark Turner, Dr Alison Turnbull, Dr Thea King, Kate Astridge, Karen Ferres, Stewart Quinn, Henry Tan, Allison McNamara, Stacy Kane, and Dr Helen Withers.

Introduction

Foodborne disease is a significant cause of illness globally and in Australia. Previously, we estimated that foodborne disease and its sequelae costs Australia AUD 2.81 billion each year (90% uncertainty interval 1.90-4.24 billion)[1], including 420 million due to *Campylobacter*, 161 million due to *Salmonella*, 153 million due to non-Shiga-toxin producing pathogenic *Escherichia coli*, and 147 million due to norovirus.

Estimates of the cost of illness help prioritise interventions, including pathogen-specific measures to reduce illness due to contaminated food. Attribution of the disease costs to the foods responsible for illness further helps in this prioritisation process. Attribution of illness costs to food commodity groups had not previously been estimated for Australia.

Expert elicitation is a structured approach to obtaining probabilistic belief statements from experts about unknown quantities or parameters[2–5]. In contrast to mathematical modelling approaches to source attribution, expert elicitation can consider pathways to human infection rather than attributing to animal reservoirs. An expert elicitation process was carried out by FSANZ[6] to attribute foodborne illness to specific foods for eight priority pathogens including six of the ten pathogens included in previous costing work: *Campylobacter*, *Listeria monocytogenes*, non-typhoidal *Salmonella,* Shiga-toxin producing *Escherichia coli* (STEC), *Toxoplasma gondii*, and *Yersinia enterocolitica*.

The objective of this project is to combine attribution estimates from that expert elicitation with the cost of illness model[1]. This enables the estimation of annual cases and the cost of illness by food commodity and by food-pathogen pairs.

Methodology

Model of the cost of foodborne illness

The project builds on prior work[1] which estimated the annual number of cases and cost of illness, circa 2019, due to all causes of gastroenteritis and due to each of the following ten prioritised pathogens:

- *Campylobacter*
- *Listeria monocytogenes*
- Norovirus
- Non-typhoidal *Salmonella*
- *Salmonella enterica* serovar Typhi (*Salmonella* Typhi)
- Shiga toxin-producing *Escherichia coli* (STEC)
- Other pathogenic *Escherichia coli*
- *Shigella*
- *Toxoplasma gondii*
- *Yersinia enterocolitica*

Cost estimates used data on the burden of disease (including illness, hospitalisations, deaths, and sequelae), the financial costs of illness (including direct and indirect costs), the cost of premature mortality, and the non-financial costs of pain and suffering.

The model was developed in R (version 4)[7] using a simulation approach, with uncertainty captured through distributions for model inputs and reported using uncertainty intervals (UIs). The approach used to estimate the burden of disease, model indirect costs, estimate non-financial costs, and source data is described in a prior report[1], and the Appendices from that report are reproduced here in full to provide all parameter inputs and data assumptions.

The model costed deaths using the value of a statistical life (VSL) of AUD 4.9 million, as recommended by the Office of Best Practice Regulation[8]. Financial costs for non-fatal illnesses included both direct costs (healthcare usage, medication costs, and test costs) and indirect costs due to lost productivity. Direct costs were estimated from administrative healthcare data including the Medicare Benefits Schedule (MBS), the Pharmaceutical Benefits Scheme (PBS), and the Australian Refined Diagnosis Related Groups (AR-DRGs) and followed the methods as described in the Australian Government PBS manual of resource items[9]. Lost productivity due to an individual being unwell, or an individual caring for someone else who was unwell was costed using the human capital approach, with the friction cost model used in sensitivity analysis. Assumptions around days of lost paid work are provided in the Appendix.

Non-financial costs were the valuation of avoiding pain and suffering due to foodborne illness. This was estimated using willingness to pay (WTP) values to avoid pain and suffering to the individual for short or long-term foodborne related illnesses based on a FSANZ-commissioned discrete choice experiment (DCE)[10,11]. That DCE included treatment costs and access to sick leave as attributes of the DCE task, with the impacts of each illness described by severity (mild and severe) and duration. The inclusion of attributes around treatment costs and sick leave helped to avoid double counting in the costing model, as lost productivity and direct costs were accounted for elsewhere. WTP estimates and duration of illness by pathogen or illness are provided in the Appendix.

The burden of disease was estimated based on prior work[12], with estimates of incidence, hospitalisations and deaths provided by pathogen and age group (<5, 5–64, and 65+). As in earlier studies[13], estimates of disease burden were also calculated for four sequelae: Guillain Barré syndrome (GBS), haemolytic uraemic syndrome (HUS), irritable bowel syndrome (IBS), and reactive arthritis (ReA). Key multipliers to estimate the burden of disease from surveillance data included the domestically acquired multiplier (to exclude cases acquired outside Australia), the underreporting multiplier (to scale notification data for undetected cases in the community), and the foodborne multiplier (to limit cases to those due to foodborne transmission). Denominator values for rate calculations were drawn from Australian Bureau of Statistics (ABS) population estimates by age group[14].

Estimates of health-care usage were based on data from a national gastroenteritis survey[15], supplemented by hospitalisation data from the Australian Institute of Health and Welfare (AIHW)[16], death data from the ABS, and using prior burden of disease and costing studies[12,17,18]. Sequelae can occur following primary illness with some pathogens as shown in the health outcome trees for each pathogen (see Appendix). Additionally, for some pathogens (listeriosis and toxoplasmosis) and all four sequelae, patients can experience long-term or permanent disability. Owing to a lack of data on the impact of ongoing illness on lost productivity and health care usage, we have not costed this and acknowledge it as a limitation of currently available data.

Estimates of the willingness to pay to avoid pain and suffering were used to value non-financial costs for the four sequelae. Some patients with sequelae will experience ongoing illness over multiple years. As we estimated costs borne in a single year, 2019, we included ongoing illness from sequelae acquired in the five years prior, costed at 2019 rates. Ongoing conditions for listeriosis and toxoplasmosis include long-term neurological sequelae following listeriosis[19], and chorioretinitis resulting from congenital toxoplasmosis[20], primarily in vulnerable groups such as immunocompromised individuals and neonates. Although these conditions were noted in the report on the Australia DCE[10], no willingness to pay to avoid pain and suffering were calculated for these conditions, preventing us from including them in costings.

Our methodology estimated costs, number of cases, deaths, and hospitalisations circa 2019. Though we did not update model inputs to re-estimate burden or costs for the most recent year, we have updated costs for inflation. Using the quarterly all-group CPI rate published by the ABS compounded from baseline (last quarter 2019) to the most recent quarter at the time of the preparation of the report (June 2023), the inflation adjustment was +15.1%.

Model attributing costs to food commodities

To estimate the cost of foodborne illness by food commodity, the costing model described above was augmented with data from a FSANZ expert elicitation to attribute foodborne illness to specific foods for the six of the ten prioritised pathogens included in the costing model: *Campylobacter*, *Listeria monocytogenes*, non-typhoidal *Salmonella*, STEC, *Toxoplasma gondii*, and *Yersinia enterocolitica.* In the expert elicitation study, a group of experts were selected based on their expertise, which included microbiology, food safety, and epidemiology.

The expert elicitation used the IDEA protocol[21] in combination with Cooke's method[22]. Twelve calibration questions were used to evaluate the experts' calibration and the informativeness of their uncertainty bounds, followed by 72 target questions corresponding to pathogen-commodity pairs. In both calibration questions and elicitation questions, experts were asked for a lower bound, an upper bound and a median estimate for each question. Not all pathogens in the costing model were included in the expert elicitation due to survey burden on participants.

The commodities considered in the expert elicitation were:

- Beef
- Crustaceans
- Dairy
- Eggs
- Fin Fish
- Fruit
- Grains and Seeds
- Lamb
- Molluscs
- Nuts
- Pork
- Poultry
- Vegetables

with an additional category for 'other'.

The output from the expert elicitation was the proportion of illness attributed to each commodity for each pathogen-commodity pair, with uncertainty expressed by individual experts and variation across experts reflected in a distribution for this proportion. This distribution was constructed by interpolating between expert's percentiles, creating a distribution that is piece-wise linear on the inter-percentile ranges. The calibration questions were used to calculate calibration and informativeness scores, that were used as weights when calculating the aggregated distribution over all experts. These distributions are provided for the six pathogens at the end of the Appendix.

The attribution model combined the attribution proportions from the expert elicitation with estimates of annual cases and costs by age group to provide estimates of cases and costs by age, pathogen, and commodity. For all estimated quantities, the 50% quantile (median) across random simulations was provided as a point estimate, while the 5% and 95% quantiles were provided as uncertainty intervals (UIs). As the quantiles of sums of random numbers are typically not the same as the sums of quantiles of random numbers, the totals of point estimates will be similar but not exactly equal to point estimates of total values. Similarly, totals of upper/lower UIs will not exactly equal upper/lower UIs of totals, with totals typically having narrower UIs than totals of component UIs.

As the elicitation did not provide age-specific attribution proportions and there are no data on the cost of illness by food commodity, we assumed that attribution proportions did not vary with age and that the cost per illness varies by age and pathogen but not by commodity. Attribution proportions were elicited for foodborne disease for all *Yersinia* species however we have assumed that the same attributions are applicable for *Yersinia enterocolitica* specifically. During the expert elicitation process, experts were directed to ensure that the total of their point estimates (median) of attribution summed to 100% for each for each pathogen. However, the procedure for weighting and combining estimates across all experts meant the sum of the aggregated point estimates for a given pathogen could be somewhat greater or less than 100%, ranging from 91% to 107%. This range is less than our typical uncertainty in our estimates of cost. Moreover, this does not impact any estimates of the total number of cases or cost of food-borne disease due to a pathogen, for which we use 100% of previously estimated figures (with costs adjusted for inflation).

Results

In 2019, *Campylobacter*, *Listeria monocytogenes*, non-typhoidal *Salmonella*, STEC, *Toxoplasma gondii*, and *Yersinia enterocolitica* had an estimated combined annual burden of 357,000 cases and a cost of AUD 626 million, inflation-adjusted to AUD 721 million for June 2023. Among the pathogens and food categories considered, poultry was associated with the greatest cost of foodborne illness, with a total cost of AUD 328 million (June 2023). Of this total, AUD 279 million was due to *Campylobacter*, AUD 35.5 million was due to non-typhoidal *Salmonella*, and AUD 2.86 million was due to *L. monocytogenes*. The food category associated with the most cases of foodborne illness circa 2019 was also poultry, with a total burden of 191,000 cases. Of this total, 174,000 cases were due to *Campylobacter*, and 13,200 cases were due to non-typhoidal *Salmonella*.

Table 1: Estimated annual costs for six prioritised pathogens (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	**5–64**	**65+**	**All Ages†**
Beef	32,400 (14,500 - 99,900)	17,200 (7,280 - 62,400)	6,050 (2,770 - 21,300)	55,900 (25,500 - 182,000)
Crustaceans	2,440 (222 - 21,900)	3,170 (316 - 28,200)	1,200 (118 - 10,800)	7,080 (688 - 64,400)
Dairy	30,800 (11,300 - 94,400)	21,700 (8,390 - 65,700)	7,550 (2,990 - 22,700)	60,700 (23,900 - 181,000)
Eggs	16,300 (1,680 - 50,600)	12,500 (1,280 - 37,100)	4,860 (495 - 15,400)	34,000 (3,540 - 101,000)
Finfish	5,250 (1,250 - 25,300)	7,080 (1,360 - 33,400)	2,740 (539 - 13,000)	15,400 (3,330 - 73,500)
Fruit	9,100 (3,170 - 29,000)	9,530 (2,750 - 33,500)	3,700 (1,100 - 12,700)	22,800 (7,390 - 77,100)
Grains and seeds	3,830 (403 - 20,900)	2,550 (161 - 14,200)	1,070 (81.6 - 6,250)	7,530 (690 - 39,600)
Lamb	22,800 (8,280 - 86,000)	11,600 (4,100 - 55,900)	4,020 (1,600 - 19,100)	38,700 (14,600 - 160,000)
Molluscs	2,170 (429 - 21,500)	2,630 (508 - 27,400)	1,000 (192 - 10,400)	5,990 (1,200 - 63,200)
Nuts	1,940 (202 - 13,400)	1,310 (81.7 - 8,010)	547 (41.9 - 3,660)	3,840 (350 - 23,900)
Pork	30,900 (13,200 - 96,000)	17,800 (6,910 - 62,400)	6,510 (2,810 - 21,600)	55,700 (24,100 - 179,000)
Poultry	198,000 (98,000 - 341,000)	99,700 (52,900 - 161,000)	27,800 (14,200 - 47,800)	328,000 (170,000 - 537,000)
Vegetables	54,200 (24,600 - 117,000)	38,100 (17,900 - 79,700)	13,900 (6,530 - 29,000)	107,000 (51,200 - 221,000)
Other	34,900 (6,310 - 102,000)	15,600 (2,390 - 56,400)	4,560 (1,000 - 17,500)	55,600 (10,000 - 176,000)
All Food	404,000 (301,000 - 566,000)	237,000 (190,000 - 304,000)	78,000 (59,300 - 104,000)	721,000 (574,000 - 946,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

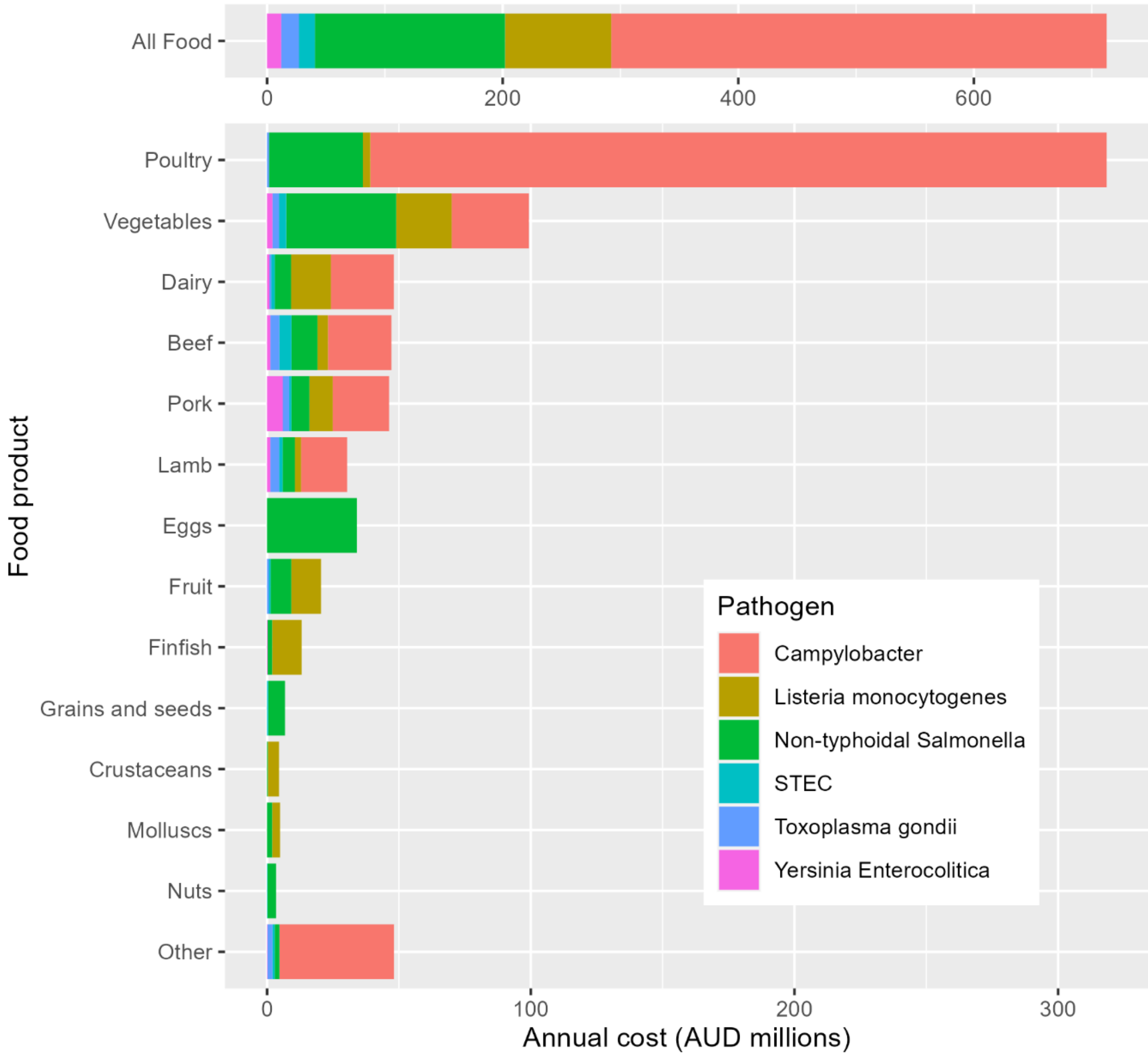

Figure 1 Estimated costs arising from foodborne disease due to six pathogens, attributed to thirteen food commodities and 'other'. For clarity, the total cost for all food has been plotted on a separate horizontal scale. Costs were estimated for 2019 and have been inflation adjusted to June 2023.

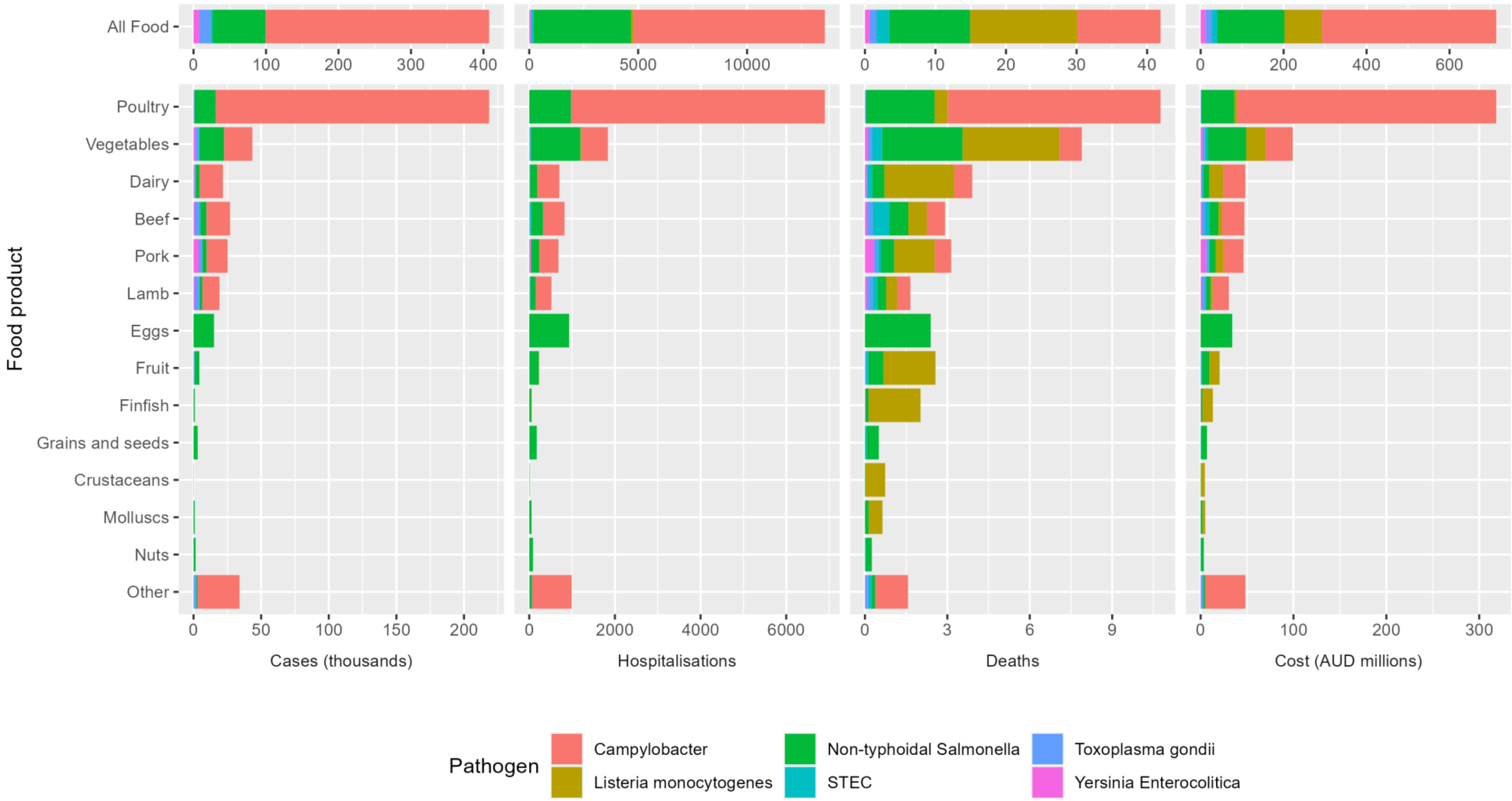

Figure 2 Estimated annual cases, hospitalisations, deaths, and costs arising from foodborne cases for six pathogens, attributed to thirteen food categories and 'other'. For clarity, the total of each outcome has been plotted on a separate horizontal scale. Costs were estimated for 2019 and have been inflation adjusted to June 2023.

Table 2: Estimated annual number of cases circa 2019 for six prioritised pathogens (90% uncertainty intervals)

	<5	5–64	65+	All Ages[†]
Beef	19,400 (7,480 - 60,100)	4,330 (1,450 - 15,100)	3,880 (1,630 - 13,400)	27,600 (10,800 - 88,600)
Crustaceans	86.6 (3 - 2,770)	29.7 (2.68 - 632)	33 (1.05 - 1,060)	149 (7.94 - 4,470)
Dairy	15,600 (3,930 - 53,300)	4,000 (888 - 13,700)	2,980 (843 - 12,200)	22,600 (5,750 - 79,500)
Eggs	7,910 (800 - 26,500)	1,790 (181 - 6,000)	3,030 (307 - 10,100)	12,700 (1,290 - 42,600)
Finfish	604 (87.4 - 5,550)	157 (30.8 - 1,460)	206 (26.1 - 1,600)	967 (146 - 8,640)
Fruit	2,780 (704 - 12,400)	504 (93.3 - 1,990)	932 (201 - 3,880)	4,220 (1,020 - 18,100)
Grains and seeds	1,710 (115 - 10,600)	393 (28.1 - 2,410)	634 (33.6 - 4,040)	2,740 (178 - 17,000)
Lamb	14,700 (4,590 - 51,500)	3,110 (765 - 12,300)	2,890 (1,010 - 12,100)	20,800 (6,540 - 76,600)
Molluscs	462 (3.86 - 3,110)	108 (4.11 - 708)	177 (1.41 - 1,190)	746 (9.93 - 5,010)
Nuts	878 (58.9 - 6,070)	201 (14.4 - 1,390)	324 (17.5 - 2,290)	1,400 (91.2 - 9,730)
Pork	17,800 (6,550 - 57,000)	4,240 (1,360 - 14,400)	3,580 (1,460 - 12,900)	25,700 (9,530 - 84,400)
Poultry	133,000 (62,700 - 238,000)	36,800 (17,100 - 66,400)	21,100 (10,300 - 36,700)	191,000 (90,400 - 341,000)
Vegetables	28,300 (10,600 - 67,200)	6,700 (2,240 - 16,700)	6,800 (2,520 - 16,600)	41,900 (15,600 - 100,000)
Other	23,900 (4,120 - 67,400)	6,140 (702 - 17,900)	3,860 (892 - 13,100)	33,900 (5,830 - 97,600)
All Food	247,000 (169,000 - 367,000)	64,300 (42,900 - 98,100)	46,000 (32,600 - 65,300)	357,000 (245,000 - 529,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

Campylobacter

The total annual cost of campylobacteriosis and its sequelae was estimated to be AUD 420 million (inflation-adjusted to 2023), arising from 264,000 cases of foodborne campylobacteriosis, with an associated 5,640 hospitalisations and 4 deaths each year. We also estimated 19,800 cases and 598 hospitalisations each year due to reactive arthritis following foodborne campylobacteriosis, 23,200 cases and 2,300 hospitalisations each year due to IBS following campylobacteriosis, and 98 hospitalised cases and 8 deaths each year due to GBS following campylobacteriosis. Poultry was the leading source (66%) with a total annual cost of AUD 280 million arising from 174,000 cases of initial illness, 28,000 cases of sequel illness, 5,920 hospitalisations, and eight deaths. The next three most frequent sources were other (10%), vegetables (7%), and beef (6%).

Table 3: Estimated annual cost for *Campylobacter* (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	15,100 (2,580 - 61,600)	6,970 (1,230 - 28,100)	1,780 (300 - 7,420)	24,000 (4,190 - 94,100)
Crustaceans	0*	0*	0*	0*
Dairy	14,900 (1,170 - 53,500)	6,970 (548 - 24,600)	1,750 (138 - 6,420)	23,900 (1,880 - 81,200)
Eggs	0*	0*	0*	0*
Finfish	0*	0*	0*	0*
Fruit	0*	0*	0*	0*
Grains and seeds	0*	0*	0*	0*
Lamb	11,000 (537 - 46,500)	5,090 (250 - 21,000)	1,290 (63.1 - 5,560)	17,500 (859 - 70,300)
Molluscs	0*	0*	0*	0*
Nuts	0*	0*	0*	0*
Pork	13,500 (1,170 - 56,200)	6,220 (547 - 25,300)	1,580 (137 - 6,740)	21,400 (1,880 - 85,800)
Poultry	175,000 (79,500 - 316,000)	81,200 (39,100 - 137,000)	20,500 (9,070 - 37,800)	279,000 (133,000 - 480,000)
Vegetables	18,300 (1,410 - 59,500)	8,520 (659 - 26,900)	2,140 (165 - 7,060)	29,300 (2,260 - 90,300)
Other	27,000 (11.6 - 79,400)	12,700 (5.44 - 36,100)	3,160 (1.41 - 9,540)	43,400 (17.9 - 122,000)
All Food	265,000 (170,000 - 423,000)	122,000 (85,800 - 182,000)	31,200 (19,300 - 50,800)	420,000 (288,000 - 637,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

* No cases were deemed to be attributable to this source.

Listeria monocytogenes

Listeria monocytogenes resulted in an annual cost of approximately AUD 90 million (inflation-adjusted to 2023), arising from 101 cases (all assumed to be hospitalised) and 15 deaths. Vegetables were the leading source (23%) with a total annual cost of AUD 21 million arising from 22 cases of illness (assumed hospitalised) and four deaths. The next three most frequent sources were dairy (17%), fruit (12%), and finfish (12%).

Table 4: Estimated annual cost for *Listeria monocytogenes* (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	1,170 (40.1 - 5,580)	2,020 (69.4 - 9,280)	759 (26.6 - 3,810)	3,990 (135 - 16,500)
Crustaceans	1,250 (57.9 - 6,170)	2,150 (99.5 - 10,300)	810 (37.5 - 4,200)	4,230 (198 - 18,500)
Dairy	4,430 (1,050 - 14,900)	7,590 (1,820 - 25,000)	2,860 (639 - 9,930)	15,100 (3,920 - 46,400)
Eggs	0*	0*	0*	0*
Finfish	3,300 (355 - 13,100)	5,670 (614 - 22,100)	2,130 (223 - 8,830)	11,200 (1,260 - 40,700)
Fruit	3,160 (299 - 8,880)	5,480 (520 - 14,800)	2,010 (192 - 6,040)	11,200 (1,060 - 26,400)
Grains and seeds	0*	0*	0*	0*
Lamb	695 (23.3 - 3,380)	1,190 (39.7 - 5,610)	448 (15 - 2,320)	2,360 (77.3 - 9,760)
Molluscs	861 (40 - 3,300)	1,490 (68.3 - 5,490)	550 (26 - 2,270)	3,000 (137 - 9,560)
Nuts	0*	0*	0*	0*
Pork	2,540 (71.4 - 9,200)	4,370 (124 - 15,300)	1,630 (47.4 - 6,250)	8,800 (239 - 27,900)
Poultry	858 (13.3 - 5,170)	1,460 (22.4 - 8,620)	560 (8.77 - 3,540)	2,860 (43.2 - 15,400)
Vegetables	6,000 (1,840 - 14,300)	10,300 (3,210 - 24,000)	3,840 (1,130 - 9,680)	21,000 (7,020 - 43,600)
Other	0*	0*	0*	0*
All Food	26,300 (16,100 - 41,000)	45,200 (28,600 - 67,900)	17,000 (9,550 - 28,400)	90,200 (67,500 - 118,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

* No cases were deemed to be attributable to this source.

Non-typhoidal *Salmonella*

Non-typhoidal *Salmonella* resulted in an annual cost of approximately AUD 160 million (inflation-adjusted to 2023), arising from 61,600 cases of initial illness, 11,100 cases of sequel illness (reactive arthritis or irritable bowel syndrome), 4,460 hospitalisations, and eleven deaths. Vegetables were the leading source (26%) with a total annual cost of AUD 42 million arising from 15,300 cases of initial illness, 2,630 cases of sequel illness, 1,150 hospitalisations, and three deaths. The next three most frequent sources were poultry (22%), eggs (21%), and beef (6%).

Table 6: Estimated annual cost for non-typhoidal *Salmonella* (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	4,700 (784 - 17,500)	3,600 (611 - 12,300)	1,400 (231 - 5,420)	9,830 (1,690 - 33,700)
Crustaceans	159 (0.00163 - 5,150)	116 (0.00112 - 3,490)	48.7 (0.000505 - 1,600)	313 (0.00299 - 9,630)
Dairy	3,030 (94.6 - 20,800)	2,290 (72.5 - 14,900)	914 (28.5 - 6,440)	6,200 (195 - 40,400)
Eggs	16,300 (1,680 - 50,600)	12,500 (1,280 - 37,100)	4,860 (495 - 15,400)	34,000 (3,540 - 101,000)
Finfish	809 (1.42 - 4,960)	611 (1.02 - 3,370)	242 (0.432 - 1,560)	1,670 (2.73 - 9,210)
Fruit	3,780 (321 - 15,300)	2,890 (248 - 10,900)	1,130 (94.8 - 4,760)	7,880 (676 - 29,400)
Grains and seeds	3,130 (58.5 - 19,700)	2,360 (44.4 - 14,000)	943 (17.8 - 6,110)	6,400 (119 - 38,100)
Lamb	2,270 (348 - 12,800)	1,710 (272 - 8,980)	683 (102 - 3,950)	4,650 (753 - 24,500)
Molluscs	932 (1.6 - 5,730)	705 (1.14 - 3,930)	279 (0.469 - 1,770)	1,920 (3.36 - 10,800)
Nuts	1,560 (32.4 - 11,000)	1,170 (24.3 - 7,740)	471 (9.73 - 3,400)	3,190 (65.7 - 21,000)
Pork	3,290 (377 - 16,000)	2,490 (290 - 11,200)	991 (112 - 4,950)	6,790 (800 - 30,800)
Poultry	16,900 (2,510 - 48,300)	13,000 (1,960 - 35,100)	5,030 (743 - 14,800)	35,500 (5,420 - 95,300)
Vegetables	19,700 (2,650 - 50,700)	15,200 (2,070 - 36,800)	5,860 (780 - 15,500)	41,700 (5,670 - 99,600)
Other	896 (2.9 - 6,250)	678 (2.12 - 4,430)	270 (0.876 - 1,970)	1,840 (5.71 - 11,900)
All Food	77,400 (50,600 - 123,000)	59,700 (40,900 - 85,800)	23,200 (14,500 - 38,200)	161,000 (117,000 - 231,000)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

Shiga-toxin producing *Escherichia coli* (STEC)

STEC resulted in an annual cost of approximately AUD 13 million AUD (inflation-adjusted to 2023), arising from 2,630 cases of initial illness, 78 cases of sequel illness (haemolytic uremic syndrome), 112 hospitalisations, and two deaths. Beef was the leading source (34%) with a total annual cost of AUD 4.6 million arising from 864 cases of initial illness, 25 cases of sequel illness, 38 hospitalisations, and one death. The next three most frequent sources were vegetables (20%), dairy (10%), and lamb (9%).

Table 9: Estimated annual cost for STEC (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	3,170 (569 - 8,050)	703 (114 - 2,270)	462 (73.9 - 1,540)	4,640 (848 - 10,800)
Crustaceans	0*	0*	0*	0*
Dairy	903 (41 - 4,880)	210 (9.15 - 1,310)	138 (5.95 - 875)	1,280 (58.9 - 6,640)
Eggs	0*	0*	0*	0*
Finfish	0*	0*	0*	0*
Fruit	429 (57.3 - 1,760)	96.1 (11.8 - 506)	63.2 (7.67 - 340)	622 (84.8 - 2,320)
Grains and seeds	287 (19.4 - 1,470)	64.9 (4.19 - 424)	42.7 (2.78 - 286)	413 (28.3 - 1,940)
Lamb	887 (62.1 - 4,590)	205 (13.6 - 1,250)	135 (8.79 - 839)	1,260 (90.2 - 6,250)
Molluscs	0*	0*	0*	0*
Nuts	139 (2.17 - 824)	31.6 (0.541 - 250)	20.7 (0.348 - 167)	200 (3.03 - 1,090)
Pork	590 (27.1 - 3,360)	137 (6.01 - 917)	89.9 (4.02 - 623)	840 (38.8 - 4,530)
Poultry	0*	0*	0*	0*
Vegetables	1,900 (373 - 6,870)	435 (73.3 - 1,880)	286 (47.3 - 1,260)	2,710 (564 - 9,410)
Other	611 (101 - 2,880)	140 (20.1 - 795)	92.3 (13 - 536)	873 (152 - 3,830)
All Food	9,370 (5,230 - 16,200)	2,150 (891 - 4,960)	1,410 (570 - 3,380)	13,400 (8,360 - 21,100)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

* No cases were deemed to be attributable to this source.

Toxoplasma gondii

The total cost of illness due to toxoplasmosis was estimated at AUD 15 million per year (inflation-adjusted to 2023), arising from 15,500 cases of foodborne illness, 35 hospitalisations, and one death. Beef was the leading source (23%) with a total annual cost of AUD 3.5 million arising from 3,380 cases of illness, and eight hospitalisations. The next three most frequent sources were lamb (23%), vegetables (17%), and pork (16%).

Table 11: Estimated annual cost for T*oxoplasma gondii* (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	2,480 (458 - 7,890)	592 (95.7 - 2,320)	277 (45.5 - 1,030)	3,450 (657 - 10,700)
Crustaceans	0*	0*	0*	0*
Dairy	507 (8.58 - 2,310)	121 (2.21 - 739)	57 (1.01 - 318)	707 (11.7 - 3,130)
Eggs	0*	0*	0*	0*
Finfish	0*	0*	0*	0*
Fruit	503 (69.8 - 1,710)	117 (15.2 - 566)	55.5 (7.1 - 242)	705 (98.9 - 2,270)
Grains and seeds	0*	0*	0*	0*
Lamb	2,440 (204 - 7,970)	572 (46.6 - 2,350)	270 (21.7 - 1,040)	3,410 (287 - 10,800)
Molluscs	0*	0*	0*	0*
Nuts	0*	0*	0*	0*
Pork	1,770 (167 - 5,680)	411 (37.5 - 1,700)	195 (17.6 - 744)	2,480 (236 - 7,650)
Poultry	546 (92.3 - 1,990)	129 (19.4 - 636)	60.6 (9.3 - 275)	764 (133 - 2,630)
Vegetables	1,800 (121 - 6,600)	427 (27.8 - 1,920)	200 (13 - 856)	2,510 (170 - 8,920)
Other	1,310 (117 - 5,380)	316 (26.1 - 1,580)	148 (12.4 - 701)	1,830 (164 - 7,260)
All Food	10,900 (6,250 - 17,000)	2,560 (1,140 - 5,830)	1,230 (537 - 2,450)	15,100 (9,350 - 22,400)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

* No cases were deemed to be attributable to this source.

Yersinia enterocolitica

The total cost of illness due to yersiniosis was estimated at AUD 12 million per year (inflation-adjusted to 2023), arising from 7,170 cases of initial foodborne illness, 820 cases of sequel illness (reactive arthritis), 63 hospitalisations, and one death. Pork was the leading source (50%) with a total annual cost of AUD 6 million arising from 3,510 cases of initial illness, 377 cases of sequel illness, and 32 hospitalisations. The next three most frequent sources were vegetables (17%), beef (10%), and lamb (10%).

Table 12: Estimated annual cost for *Yersinia enterocolitica* (90% uncertainty intervals). Costs are thousands of AUD, estimated for 2019 and inflation adjusted to June 2023.

	<5	5–64	65+	All Ages†
Beef	867 (40.9 - 3,690)	169 (7.97 - 901)	150 (7.16 - 742)	1,220 (57.6 - 5,090)
Crustaceans	0*	0*	0*	0*
Dairy	664 (29 - 3,240)	131 (5.69 - 798)	116 (5.05 - 650)	933 (41 - 4,500)
Eggs	0*	0*	0*	0*
Finfish	184 (0.127 - 1,140)	36.5 (0.0359 - 315)	32.3 (0.0271 - 250)	258 (0.177 - 1,570)
Fruit	0*	0*	0*	0*
Grains and seeds	0*	0*	0*	0*
Lamb	863 (43.2 - 3,640)	168 (8.47 - 891)	150 (7.46 - 732)	1,210 (60.6 - 5,020)
Molluscs	0*	0*	0*	0*
Nuts	0*	0*	0*	0*
Pork	4,210 (847 - 9,350)	789 (151 - 2,440)	712 (137 - 1,940)	5,950 (1,220 - 12,900)
Poultry	0*	0*	0*	0*
Vegetables	1,440 (83.4 - 5,580)	281 (16.1 - 1,340)	249 (14.2 - 1,100)	2,030 (118 - 7,720)
Other	125 (0.133 - 9,110)	33.5 (0.0346 - 2,090)	26.5 (0.0284 - 1,740)	171 (0.186 - 12,600)
All Food	8,540 (4,870 - 14,400)	1,630 (766 - 4,100)	1,470 (712 - 3,190)	12,000 (7,070 - 19,700)

† Totals reflect the median of model simulations, so may not equal the sum of individual columns or rows, and uncertainty intervals (UIs) of totals will typically be narrower than the sum of the component UIs.

* No cases were deemed to be attributable to this source.

Conclusions

Foodborne disease costs Australia AUD 2.44 annually (circa 2019, inflation adjusted to 2.81 billion in 2023), with *Campylobacter*, norovirus, other pathogenic *Escherichia coli*, and non-typhoidal *Salmonella* all estimated to cost Australians over AUD 100 million each year[1]. An expert elicitation process was carried out by FSANZ to obtain estimates of the proportion of foodborne illness that can be attributed to specific foods for prioritised foodborne pathogens. This project combined these expert elicitation proportions with the costing model to calculate the cost associated with foodborne illness for fourteen food commodities and six pathogens.

Of the total AUD 721 million (2023 dollars) associated with the six included pathogens, the greatest cost (AUD 328 million) was associated with poultry, followed by vegetables (AUD 107 million), dairy (AUD 61 million), beef (AUD 56 million) and pork (AUD 56 million). *Campylobacter* had the highest total cost and contributed AUD 279 million to the costs associated with poultry. The high cost associated with vegetables was largely due to *Salmonella* (26% of costs), *Campylobacter* (7% of costs), and *L monocytogenes* (23% of costs). Beef was the leading source associated with both STEC and *T. gondii*, while pork was the leading source associated with *Y. enterocolitica*.

A relatively high cost (AUD 56 million) could not be attributed to any of the fourteen food commodities, primarily due to 10% of campylobacter cases being attributed to 'other' in the expert elicitation. Consideration of potential additional food sources may be helpful in controlling *Campylobacter*, the pathogen with the greatest estimated annual cost in Australia.

The costing model includes four additional pathogens (norovirus, other pathogenic *E. coli*, *Salmonella* Typhi, and *Shigella*) that were not considered in the expert elicitation, due to the burden on participants and challenges associated with defining cases and transmission routes for these pathogens. Norovirus and other pathogenic *E. coli* are both estimated to cost Australians over AUD 100 million each year, so further work in this space may be of value. The flexibility of the costing tool enables costs to be updated if further studies are conducted to include these pathogens.

The costing model provides strategic information that enables interventions to be targeted at specific produce and pathogens and so maximise the benefits achieved by regulatory intervention.

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Appendix

This Appendix reproduces much of the Appendix of the prior report1, to enable replication of the model findings, together with tables summarising additional data used in these calculations.

Pathogen and illness-specific health-care usage assumptions

The following tables summarise multipliers and data sources for gastroenteritis due to all causes and for each pathogen and sequelae, in line with Kirk *et al.* and Ford *et al.*[12,13]. The definitions of each multiplier and model parameter are as follows:

Term	*Definition*
Bacterial multiplier	Proportion of sequelae due to the associated pathogen
Correction factor	Adjustment when data does not include all states
Domestically acquired multiplier	Proportion of cases, hospitalisations and deaths acquired in Australia
ED proportion	Proportion of cases that visit the emergency department
Foodborne multiplier	Proportion of cases, hospitalisations and deaths acquired from food
Gastroenteritis multiplier	Proportion of Australians experiencing gastroenteritis
GP proportion	Proportion of cases that attend general practice
Hospitalisation code	International Classification of Diseases 10-AM code
Mortality code	International Classification of Diseases 10 code
Ongoing illness proportion	Proportion of cases that experience ongoing illness
Percent hospitalisations principal	Percent of all hospitalisations where the diagnosis is coded as the principal reason for admission
Sequelae multiplier	Proportion of cases of the associated pathogen that lead to this sequela
Under-diagnosis multiplier	Adjustment for requirement for laboratory testing to confirm hospitalisations and deaths
Under-reporting multiplier	Adjustment for under-notification of incident cases

Gastroenteritis due to all causes

*Model input**	*Source or Distribution*	*Ref*
Gastroenteritis multiplier†	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	15
Foodborne multiplier	Pert (2.5%=0.13, median=0.25, 97.5%=0.42)	12
GP proportion	Pert (2.5%=0.156, median=0.196,97.5%=0.234)	15
ED proportion	Pert (2.5%=0.025, median=0.044,97.5%=0.074)	15
Hospitalisation codes	A01.0, A02.0-A02.9, A03.0-A03.9, A04.0, A04.1, A04.3-A04.6, A05.0, A05.2-A05.4, A07.1, A07.2, A08.0-A08.2, A08.5, A09.0, A09.9	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	71%	12
Mortality codes	A01.0, A02, A03, A04.0, A04.1, A04.3-A04.6, A04.8, A04.9, A05.0, A05.2-A05.4, A05.8, A05.9, A07.1, A07.2, A07.8, A07.9, A08.0-A08.4, A08.5, A09	12

* No under-reporting multiplier or domestically acquired multiplier as incidence based on community surveillance where all cases were locally acquired. † Yearly probability of gastroenteritis due to any cause.

Campylobacter

Model input	*Source or Distribution*	*Ref*
Notifications	NNDSS data	23
Domestically acquired multiplier	Pert (min=0.91, mode=0.97, max=0.99)	12
Under-reporting multiplier	Lognormal (mean=10.45, sd=2.98)	24
Foodborne multiplier	Pert (5%=0.62, median=0.77, 95%=0.89)	2
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A04.5: Campylobacter enteritis	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	79%	12
Mortality code	A04.5: *Campylobacter enteritis*	12

Listeria monocytogenes

*Model input**	*Source or Distribution*	*Ref*
Notifications	NNDSS data	23
Domestically acquired multiplier	Assumed 100%	12
Under-reporting multiplier	Pert (5%=1, median=2, 95%=3)	12
Foodborne multiplier	Pert (min=0.9, mode=0.98, max=1)	2
GP visits per incident case	Pert (min=1, mode=2, max=3)	18
Specialist visits per incident case	Pert (min=1, mode=2, max=3)	18
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Mortality code	A32: Listeriosis	12
Ongoing illness proportion (congenital)	Pert (2.5%=0.034, median= 0.066, 97.5%=0.104)	19
Ongoing illness proportion (non-congenital)	Pert (2.5%=0.012, median=0.042, 97.5%=0.074)	19

* All incident cases assumed to be hospitalised and all hospitalised cases assumed to visit ED before admission

Non-typhoidal Salmonella

Model input	*Source or Distribution*	*Ref*
Notifications	NNDSS data	23
Domestically acquired multiplier	Pert (min=0.7, mode=0.85, max=0.95)	12
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	23
Foodborne multiplier	Pert (5%=0.53, median=0.72, 95%=0.86)	2
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5%=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A02.0-A02.9: Salmonellosis	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	77%	12
Mortality code	A02: other *Salmonella* infections	12

Norovirus

Model input*	***Source or Distribution***	***Ref***
Gastroenteritis multiplier†	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	15
Pathogen fraction multiplier	Pert (2.5%=0.0772, median=0.0982, 97.5%=0.1226)	25
Foodborne multiplier	Pert (5%=0.05, median=0.18, 95%=0.35)	2
GP proportion	Pert (2.5%=0.156, median=0.196,97.5%=0.234)	15
ED proportion	Pert (2.5%=0.025, median=0.044,97.5%=0.074)	15
Hospitalisation code	A08.1: Acute gastroenteropathy due to Norwalk agent	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	37%	12
Mortality code	A08.1: Acute gastroenteropathy due to Norwalk agent	12

* No under-reporting multiplier or domestically acquired multiplier as based on community surveillance where all cases were locally acquired. † Yearly probability of gastroenteritis due to any cause.

Salmonella Typhi

Model input*	***Source or Distribution***	***Ref***
Notifications	NNDSS data	23
Domestically acquired multiplier	Pert (min=0.02, mode=0.11, max=0.25)	12
Under-reporting multiplier	Pert (2.5%=1, median=2, 97.5%=3)	12
Foodborne multiplier	Pert (min=0.02, mode=0.75, max=0.97)	2
GP visits per incident case	Pert (min=1, mode=2, max=3)	26
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	93%	12
Mortality code	A01: Typhoid and paratyphoid fevers	12

* All incident cases assumed to be hospitalised and all hospitalised cases assumed to visit ED before admission

Shigella

Model input	***Source or Distribution***	***Ref***
Notifications	NNDSS data	23
Domestically acquired multiplier	Pert (min=0.45, mode=0.7, max=0.84)	12
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	23
Foodborne multiplier	Pert (5%=0.05, median=0.12, 95%=0.23)	2
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A03.0-A03.9: Shigellosis	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	76%	12
Mortality code	A03: Shigellosis	12

Shiga toxin-producing Escherichia coli

Model input	***Source or Distribution***	***Ref***
Notifications	State-level surveillance data	12
Domestically acquired multiplier	Pert (min=0.93, mode=0.99, max=1)	12
Under-reporting multiplier	Lognormal (mean=8.83, sd=3.7)	23
Foodborne multiplier	Pert (5%=0.32, median=0.56, 95%=0.82)	2
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A04.3: Enterohemorrhagic *E. coli* infection	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	59%	12
Mortality code	A04.3: Enterohemorrhagic *E. coli* infection	12

Other pathogenic Escherichia coli

Model input*	***Source or Distribution***	***Ref***
Gastroenteritis multiplier	Pert (2.5%=0.64, median=0.74, 97.5%=0.84)	15
Pathogen fraction multiplier†	Pert (2.5%=0.0525, median=0.074, 97.5%=0.0914)	25
Foodborne multiplier	Pert (5%=0.08, median=0.23, 95%=0.55)	2
GP proportion	Pert (2.5%=0.241, median=0.367, 97.5=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A04.0: Enteropathogenic *E. coli* infection; A04.1: Enterotoxigenic *E. coli* infection; A04.2: Enteroinvasive *E. coli* infection A04.4: Other intestinal *E. coli* infection	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	59%	12
Mortality code	A04.0: Enteropathogenic *E. coli* infection; A04.1: Enterotoxigenic *E. coli* infection; A04.2: Enteroinvasive *E. coli* infection A04.4: Other intestinal *E. coli* infection	12

* No under-reporting multiplier or domestically acquired multiplier as based on community surveillance where all cases were locally acquired. † Yearly probability of gastroenteritis due to any cause.

Toxoplasma gondii

Model input	***Source or Distribution***	***Ref***
Illness	Seroprevalence data	27
Domestically acquired multiplier	Pert (min=0.7, mode=0.85, max=0.95)	12
Proportion symptomatic	Pert (min=0.11, mode=0.15, max=0.21)	12
Foodborne multiplier	Pert (min=0.04, mode=0.31, max=0.74)	12
GP proportion	Pert (min=0, mode=0.2, max=0.4)	18
ED proportion	Assumed no ED visits	18
Specialist visits per hospitalisation	Pert (min=1, median=2, max=3)	18
Hospitalisation code	B58.0-B58.9: Toxoplasmosis	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	39%	12
Mortality code	B58: Toxoplasmosis	12
Ongoing illness	Pert (2.5%=0.003, median=0.005, 97.5%=0.007)	26

Yersinia enterocolitica

Model input	***Source or Distribution***	***Ref***
Notifications	State-level surveillance data	12
Domestically acquired multiplier	Pert (min=0.8, mode=0.9, max=1)	12
Under-reporting multiplier	Lognormal (mean=7.44, sd=2.38)	23
Foodborne multiplier	Pert (min=0.28, mode=0.84, max=0.94)	12
GP proportion	Pert (2.5%=0.241, median=0.367,97.5%=0.501)	15
ED proportion	Pert (2.5%=0.06, median=0.124, 97.5%=0.228)	15
Hospitalisation code	A04.6: Enteritis due to *Yersinia enterocolitica*	16
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	64%	12
Mortality code	A04.6: Enteritis due to *Yersinia enterocolitica*	12

Guillain-Barré syndrome

Model input*	***Source or Distribution***	***Ref***
Sequelae multiplier	Pert (min=0.000192, mode=0.000304, max=0.000945)	13
Domestically acquired multiplier	Pert (min=0.91, mode=0.97, max=0.99)	13
Bacterial multiplier	Pert (min=0.048, mode=0.31, max=0.717)	13
Foodborne multiplier†	Pert (2.5%=0.1, median=0.25, 97.5%=0.43)	12
GP visits per incident case	Pert (2.5%=3.56, median=3.6, 97.5%=3.66)	26
ED proportion	Assumed no ED visits	18
Specialist visits per incident case	Pert (2.5%=2.5, median=3, 97.5%=3.5)	18
Physiotherapy visits per incident case	Pert (2.5%=5.5, median=6, 97.5%=6.5)	18
Underdiagnosis multiplier‡	Pert (min=1, mode=2, max=3)	12
Mortality code	G61.0: Guillain-Barré syndrome	12
Ongoing illness proportion (<5)	Pert (2.5%=0.065, median=0.075, 97.5%=0.085)	28
Ongoing illness proportion (5-64)	Pert (2.5%=0.14, median=0.16, 97.5%=0.18)	28
Ongoing illness proportion (65+)	Pert (2.5%=0.47, median=0.49, 97.5%=0.50)	28

* All incident cases are assumed to be hospitalised, and no additional ED visit costed; † Includes bacterial multiplier and applied to deaths only as only foodborne *Campylobacter* cases included in estimates of incidence and hospitalisation; ‡ Deaths only.

Haemolytic uraemic syndrome

Model input*	***Source or Distribution***	***Ref***
Sequelae multiplier	Pert (2.5%=0.017, median=0.03, 97.5%=0.051)	13
Domestically acquired multiplier	Pert (min=0.93, mode=0.99, max=1)	12
Bacterial multiplier	Pert (min=0.3, mode=0.608, max=0.852)	13
Foodborne multiplier†	Pert (2.5%=0.17, median=0.33, 97.5%=0.53)	12
GP visits per incident case	Pert (2.5%=1, median=3, 97.5%=5)	26
ED proportion	Assumed no ED visits	18
Underdiagnosis multiplier‡	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	30%	12
Mortality code	D59.3: Hemolytic-uremic syndrome	12
Ongoing illness proportion	Pert (2.5%=0.08, median=0.16, 97.5%=0.277)	29

* All incident cases are assumed to be hospitalised, and no additional ED visit costed; † Includes bacterial multiplier and applied to deaths only as only foodborne STEC cases included in estimates of incidence and hospitalisation; ‡ Deaths only.

Irritable bowel syndrome

Model input	***Source or Distribution***	***Ref***
Sequelae multiplier (all prior illnesses†)	Pert (2.5%=0.072, median=0.088, 97.5%=0.104)	13
Domestically acquired multiplier	Pert (5%=0.88, median=0.91, 95%=0.94)	13
Foodborne multiplier*	Pert (2.5%=0.068, median=0.13, 97.5%=0.33)	12
GP visits per incident case	Pert (2.5%=4.27, median=4.5, 97.5%=4.73)	26
ED proportion	Assumed no ED visits	26
Specialist visits per incident case	Pert (2.5%=0.286, median=0.3, 97.5%=0.315)	30
Hospitalisation code	K58.0: Irritable bowel with diarrhea; K58.9: Irritable bowel without diarrhea	12
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	69%	12
Mortality code	K58: Irritable bowel syndrome	12
Ongoing illness proportion	Pert (2.5%=0.218, median=0.429, 97.5%=0.66)	31

* Includes bacterial multiplier and applied to deaths and hospitalisations only as only foodborne cases included in estimates of incidence. †IBS is a possible sequela for *Campylobacter, Salmonella* and *Shigella*.

Reactive arthritis

Model input	***Source or Distribution***	***Ref***
Sequelae multiplier (*Campylobacter*)	Pert (min=0.028, mode=0.07, max=0.16)	13
Sequelae multiplier (*Salmonella*)	Pert (min=0, mode= 0.085, max=0.26)	13
Sequelae multiplier (*Shigella*)	Pert (min=0.012, mode=0.097, max=0.098)	13
Sequelae multiplier (*Y. enterocolictica*)	Pert (min=0, mode=0.12, max=0.231)	13
Domestically acquired multiplier	Pert (5%=0.86, median=0.91, 95%=0.95)	13
Bacterial multiplier	Pert (min=0.5, median=0.66, max=0.947)	13
Foodborne multiplier*	Pert (5%=0.36, median=0.48, max=0.61)	12
GP visits per incident case	Pert (2.5%=0.66, median=0.8, 97.5%=0.89)	26
ED proportion	Assumed no ED visits	26
Specialist visits per case per year	Pert (2.5%=0.223, median=0.24, 97.5%=0.258)	32
Hospitalisation code	M02.1: Postdysenteric arthropathy, multiple sites; M02.3: Reiter's disease, multiple sites; M02.8: Other reactive arthropathies, multiple sites; M03.2: Other postinfectious arthropathies in diseases classified elsewhere, multiple sites	12
Underdiagnosis multiplier	Pert (min=1, mode=2, max=3)	12
Percent hospitalisations principal	50%	12
Mortality code	M02.1: Postdysenteric arthropathy; M02.8: Other reactive arthropathies	12
Ongoing illness proportion	Pert (2.5%=0.23, median=0.5, 97.5%=0.77)	30,31

* Includes bacterial multiplier and applied to deaths and hospitalisations only as only foodborne cases included in estimates of incidence.

Pathogen and illness-specific medication usage assumptions

Gastroenteritis due to all causes and Norovirus

Medication*†	***Age group***	***Distribution***
Antidiarrhoeal	0–4	Pert (2.5%=0.012, mode=0.062, 97.5%=0.27)
	5–64	Pert (2.5%=0.107, median=0.145, 97.5%=0.193)
	65+	Pert (2.5%=0.232, median=0.349, 97.5%=0.489)
Painkillers	0–4	Pert (2.5%=0.29, median=0.38, 97.5%=0.47)
	5–64	Pert (2.5%=0.13, median=0.178, 97.5%=0.238)
	65+	Pert (2.5%=0.014, median=0.053,97.5%=0.186)
Anti-nausea	0–4	Pert (2.5%=0.008, median=0.04, 97.5%=0.187)
	5–64	Pert (2.5%=0.04, mode=0.065, 97.5%=0.104)
	65+	Pert (2.5%=0.035, median=0.106, 97.5%=0.279)
Anti-cramps	0–4	none
	5–64	Pert (2.5%=0.012, median=0.028, 97.5%=0.063)
	65+	Pert (2.5%=0.0002, median=0.001, 97.5%=0.004)
Antibiotics	0–4	Pert (2.5%=0.008, median=0.04, 97.5%=0.187)
	5–64	Pert (2.5%=0.006, median=0.014, 97.5%=0.035)
	65+	Pert (min=0, median=0.051, 97.5%=0.104)

* All estimates from the NGSII15; † Medication proportions applied to incident cases.

Bacterial pathogens causing gastroenteritis

Medication†*	***Age group***	***Distribution***
Antidiarrhoeal	0–4	Pert (min=0.0025, mode=0.003, max=0.3)
	5–64	Pert (2.5%=0.166, median=0.286, 97.5%=0.439)
	65+	Pert (min=0.094, median=0.653, max=0.906)
Painkillers	0–4	Pert (2.5%=0.12, median=0.38, 97.5%=0.65)
	5–64	Pert (2.5%=0.127, median=0.242, 97.5%=0.385)
	65+	Pert (2.5%=0.051, median=0.307, 97.5%=0.708)
Anti-nausea	0–4	Pert (min=0.0025, mode=0.003, max=0.305)
	5–64	Pert (2.5%=0.042, median=0.12, 97.5%=0.237)
	65+	Pert (2.5%=0.051, median=0.307, 97.5%=0.708)
Anti-cramps	0–4	none
	5–64	Pert (min=0.028, mode=0.077, max=0.204)
	65+	Pert (2.5%=0.051, median=0.277, 97.5%=0.708)
Antibiotics (*Shigella*)	0–4	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
	5–64	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
	65+	Pert (2.5%=0.25, median=0.37, 97.5%=0.50)
Antibiotics (all other bacterial pathogens)	0–4	Pert (2.5%= 0.005, median=0.082, 97.5%=0.305)
	5–64	Pert (2.5%= 0.016, median=0.067, 97.5%=0.169)
	65+	Pert (min=0, median=0.051, 97.5%=0.104)

* All estimates from the NGSII15, weighted by disease severity; † Medication proportions applied to incident cases, assuming all cases of *Shigella* who visit a GP receive antibiotics.

Listeria monocytogenes

Medication*	***Age group***	***Assumption***	***Ref***
Antibiotics	All	All surviving cases receive 4 weeks amoxicillin	18

* Medication proportions applied to incident cases.

Toxoplasma gondii

Medication*	***Age group***	***Assumption***	***Ref***
Antibiotics	All	All cases receive 4 weeks high-dose medication	18

* Medication proportions applied to cases that visit a GP.

Irritable bowel syndrome

Medication‡	***Age group***	***Assumption***	***Ref***
Any medication†	All	Pert (5%=0.385, median=0.4, 95%=0.416)	*

* Where information sources were not available, we obtained expert opinion from clinical advisor Philip Haywood; † Includes Anti-diarrhoeal medication, Anti-depressants, Anti-spasmodic medication, Anti-cramp medication, and anti-constipation medication; ‡ Medication proportions applied to incident cases.

Reactive arthritis

Medication†	***Age group***	***Assumption***	***Ref***
Antibiotics	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
NSAID	All	Pert (5%=0.528, median=0.762, 95%=0.918)	33
Eye drops	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
Prednisone	All	Pert (5%=0.001, median=0.019, 95%=0.099)	18
Inter-articular glucocorticoid	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
DMARD	All	Pert (5%=0.012, median=0.095, 95%=0.304)	33

* Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; † Medication proportions applied to cases that visit a GP.

Pathogen and illness-specific testing assumptions

Gastroenteritis due to all causes, other pathogenic E. coli and Norovirus

Test*†	***Age group***	***Distribution***
Stool culture	All	Pert (5%=0.016, median=0.031, 95%=0.057)

* All estimates from the NGSII15; † Test proportions applied to incident cases.

Bacterial pathogens causing gastroenteritis modelled using the surveillance approach

Test*	***Assumption***
Stool culture	All notifications have a stool culture

* *Campylobacter*, *Salmonella, Shigella,* STEC (population adjusted), *Yersinia enterocolitica* (population adjusted)

Listeria monocytogenes

Test*	***Age group***	***Assumption***	***Ref***
FBC	All	All surviving cases undergo this test	18
ESR	All	All surviving cases undergo this test	18

* Test proportions applied to incident cases. FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate

Toxoplasma gondii

Test*	***Age group***	***Assumption***	***Ref***
FBC	All	All cases that visit a GP undergo this test	26
ESR	All	All cases that visit a GP undergo this test	26

* Test proportions applied to cases that visit a GP. FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate

Irritable bowel syndrome

Test†	*Age group*	*Distribution*	*Ref*
Stool culture	All	Pert (min=0.667, mode=1, max=1)	*
Full blood count (FBC)	All	Pert (min=0.667, mode=1, max=1)	*
ESR	All	Pert (min=0.667, mode=1, max=1)	*
Liver function test	All	Pert (min=0.667, mode=1, max=1)	*
C-reactive protein	All	Pert (min=0.667, mode=1, max=1)	*
Coeliac screening	All	Pert (min=0.667, mode=1, max=1)	*
Radiology	All	Pert (5%=0.652, median=0.667, 95%=0.681)	*
Ultrasound	All	Pert (5%=0.484, median=0.5, 95%=0.516)	*
Endoscopy and biopsy	0–4	Not done	*
	5–64	Pert (5%=0.05, median=0.1, 95%=0.15)	*
	65+	Pert (5%=0.15, median=0.2, 95%=0.25)	*

* Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; † Test proportions applied to incident cases.

Reactive arthritis

Test †	***Age group***	***Distribution***	***Ref***
Stool culture	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
Serology	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
Urine test	All	Pert (5%=0.097, median=0.132, 95%=0.174)	*
C-reactive protein and Urate	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
FBC	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
ESR	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
EUC	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
ANA	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
Rheumatoid factor	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
Renal function	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*
Blood HLA-B27	All	Pert (5%=0.16, median=0.2, 95%=0.244)	18
X-ray	All	Pert (5%=0.012, median=0.095, 95%=0.304)	*
Ultrasound	All	Pert (5%=0.017, median=0.034, 95%=0.062)	*
MRI	All	Pert (5%=0.002, median=0.01, 95%=0.03)	*
Joint aspiration	All	Pert (5%=0.16, median=0.2, 95%=0.244)	*

FBC= Full Blood Count; ESR=Erythrocyte Sedimentation Rate; EUC= Electrolytes, urea, creatinine; ANA= Antinuclear Antibody; * Where information sources were not available, we obtained opinions from clinical advisor Philip Haywood; † Test proportions applied to cases that visit a GP.

Hospitalisation codes for pathogens and illnesses

*Pathogen or illness**	*AR-DRG code and description*	*ALOS (days)*	*Cost ($)*
Guillain-Barré syndrome (ALOS 10.1)	B06A: Procedures for Cerebral Palsy, Muscular Dystrophy and Neuropathy, Major Complexity	12.0	28,927
Pathogens causing gastroenteritis ages 65+	G67A Oesophagitis and Gastroenteritis, Major Complexity	3.5	6,155
Pathogens causing gastroenteritis ages <65; Irritable bowel Syndrome	G67B Oesophagitis and Gastroenteritis, Minor Complexity	1.3	1,961
Reactive arthritis (ALOS 3.0)	I66B Inflammatory Musculoskeletal Disorders, Minor Complexity	3.3	6,364
Haemolytic uraemic syndrome (ALOS 1.8)	L02B Operative Insertion of Peritoneal Catheter for Dialysis, Minor Complexity	1.4	6,065
Listeriosis (ALOS 13.8)	*50% T01A Infectious and Parasitic Diseases W GIs, Major Complexity*	*23.1*	*50,828*
	50% T01B Infectious and Parasitic Diseases W Gis, Intermediate Complexity	*9.7*	*18,592*
	Average	16.4	34,710
Toxoplasmosis (ALOS 25.9)	T01A Infectious and Parasitic Diseases W Gis, Major Complexity	23.1	50,828
***S.* Typhi (ALOS 5.3)**	*50% T64B Other Infectious and Parasitic Diseases, Intermediate complexity*	*7.7*	*12,233*
	50% T64C Other Infectious and Parasitic Diseases, Minor complexity	*3.3*	*5,199*
	Average	5.5	8,716

* For single pathogen or illness categories, the ALOS for 2018–19 corresponding to that ICD10-AM code is provided in brackets for comparison.

Days of paid work lost

Pathogen or Illness	Non-hospitalised cases						Hospitalised cases					
	Days lost by the case			Days lost by a carer			Days lost by the case			Days lost by a carer		
Age group	**< 5**	**5 – 64**	**65+**	**< 5**	**5 – 64**	**65+**	**< 5**	**5 – 64**	**65+**	**< 5**	**5 – 64**	**65+**
Total infectious gastroenteritis	0	0.73	0.1	0.61	0.18	0.39	0	1.5	0.5	1.6	0.5	1.0
Bacteria												
Campylobacter spp.	0	0.73	0.1	0.61	0.18	0.39	0	2.0	0.6	1.7	0.7	1.3
Listeria monocytogenes	all cases assumed hospitalised						0	6.9	1.6	8.5	2.6	3.0
Non-typhoidal *Salmonella*	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.8	2.1	0.8	1.6
Shigella spp.	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.5	2.2	0.8	1.2
Shiga toxin-producing *Escherichia coli*	0	0.73	0.1	0.61	0.18	0.39	0	2.3	0.5	2.0	0.8	1.2
Other pathogenic *Escherichia coli*	0	0.73	0.1	0.61	0.18	0.39	0	2.1	1.1	2.6	0.7	2.1
Salmonella Typhi	all cases assumed hospitalised						0	3.2	1.1	3.3	1.2	2.1
Yersinia enterocolitica	0	0.73	0.1	0.61	0.18	0.39	0	1.9	0.7	2.1	0.7	1.5
Protozoa												
Toxoplasma gondii	0	0.73	0.1	0.61	0.18	0.39	0	16.6	1.0	1.2	6.4	2.0
Viruses												
Norovirus	0	0.73	0.1	0.61	0.18	0.39	0	2.1	0.8	1.9	0.7	1.6

Sequelae	Days lost by the case			Days lost by a carer		
Age group	**< 5**	**5 – 64**	**65+**	**< 5**	**5 – 64**	**65+**
Guillain-Barré syndrome	0	43.1	9.6	51.4	17.1	17.1
Haemolytic uraemic syndrome	0	11.0	2.5	13.1	4.4	4.4
Irritable bowel syndrome	0	2.4	0.5	2.9	1.0	1.0
Reactive arthritis	0	4.8	1.1	5.7	1.9	1.9

Willingness to pay to avoid pain and suffering

Pathogen or Illness	Non-hospitalised cases		Hospitalised cases	
	Daily WTP to avoid pain and suffering (95% CI) †	Mean Duration††	Daily WTP to avoid pain and suffering (95% CI)	Mean Duration††
Total infectious gastroenteritis	Mild GI illness: $11 ($9, $12)	3 days	Severe GI illness: $23 ($22, $24)	5.3 days
Bacteria				
Campylobacter spp.	Severe GI illness: $23 ($22, $24)	6 days	Severe GI illness: $23 ($22, $24)	9.5 days
Listeria monocytogenes	all cases assumed hospitalised		Severe flu-like illness: $19 ($17, $20)	34.7 days
Non-typhoidal *Salmonella*	Severe GI illness: $23 ($22, $24)	6 days	Severe GI illness: $23 ($22, $24)	9.8 days
Shigella spp.	Severe GI illness: $23 ($22, $24)	6 days	Severe GI illness: $23 ($22, $24)	9.3 days
Shiga toxin-producing *Escherichia coli*	Severe GI illness: $23 ($22, $24)	6 days	Severe GI illness: $23 ($22, $24)	9.5 days
Other pathogenic *Escherichia coli*	Mild GI illness: $11 ($9, $12)	3 days	Severe GI illness: $23 ($22, $24)	8.6 days
Salmonella Typhi	all cases assumed hospitalised		Severe GI illness: $23 ($22, $24)	26.4 days
Yersinia enterocolitica	Severe GI illness: $23 ($22, $24)	6 days	Severe GI illness: $23 ($22, $24)	9.4 days
Protozoa				
Toxoplasma gondii	Mild flu-like illness: $8 ($6, $10)	7 days	Severe flu-like illness: $19 ($17, $20)	42.9 days
Viruses				
Norovirus	Mild GI illness: $11 ($9, $12)	2 days	Severe GI illness: $23 ($22, $24)	5.7 days

†Values from CHERE report[10]. †† Mean duration of illness for acute non-hospitalised cases from prior report[34]; duration of illness for acute hospitalised cases assumed to be ALOS in hospital in 2018/2019 plus duration of illness of non-hospitalised cases for pathogens causing gastroenteritis, and based on Abelson[18] for listeriosis, toxoplasmosis and *S*. Typhi. GI = Gastrointestinal Illness.

Sequelae	Yearly WTP † to avoid pain and suffering for primary phase of illness (95% CI)	Proportion with ongoing illness†† (95% Confidence Interval)	Yearly WTP † to avoid pain and suffering for ongoing illness (95%CI)	Duration of ongoing illness
Guillain-Barré syndrome	Severe GBS: $1,371 ($1,291, $1,426)	age <5: 7.5% (6.5–8.5) age 5–64: 16% (14–18) age 65+: 49% (47–50)	Mild GBS: $762 ($625, $862)	5 years
Haemolytic uraemic syndrome	Severe HUS: $1,620 ($1,595, $1,637)	16% (8%–27.7%)	Mild HUS: $901 ($778, $993)	5 years
Irritable bowel syndrome	70%: Mild IBS: $344 ($124, $506) 30%: Severe IBS: $964 ($755, $1,100)	42.9% (21.8%–66.0%)	Mild IBS: $344 ($124, $506)	5 years
Reactive arthritis	80%: Mild ReA: $605 ($461, $714) 20%: Severe ReA: $1,166 ($1,060, $1,241)	41% (29–54) of those with severe primary illness	Mild ReA: $605 ($461, $714)	5 years

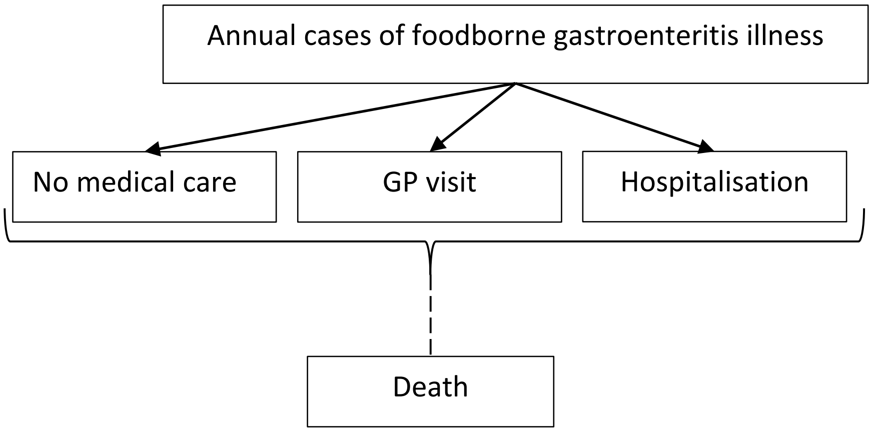
†Willingness to pay values from CHERE report[10]. †† Defined as permanent disability for GBS[28], permanent disability due to chronic renal failure for HUS[29], and ongoing symptoms at 12 months for IBS and ReA[31,32,35].

Health outcome trees

We present the health outcome trees previously reported34 that illustrate the disease states by pathogen. Note that these trees do not represent an individual patient's journey, but capture states associated with health costs.

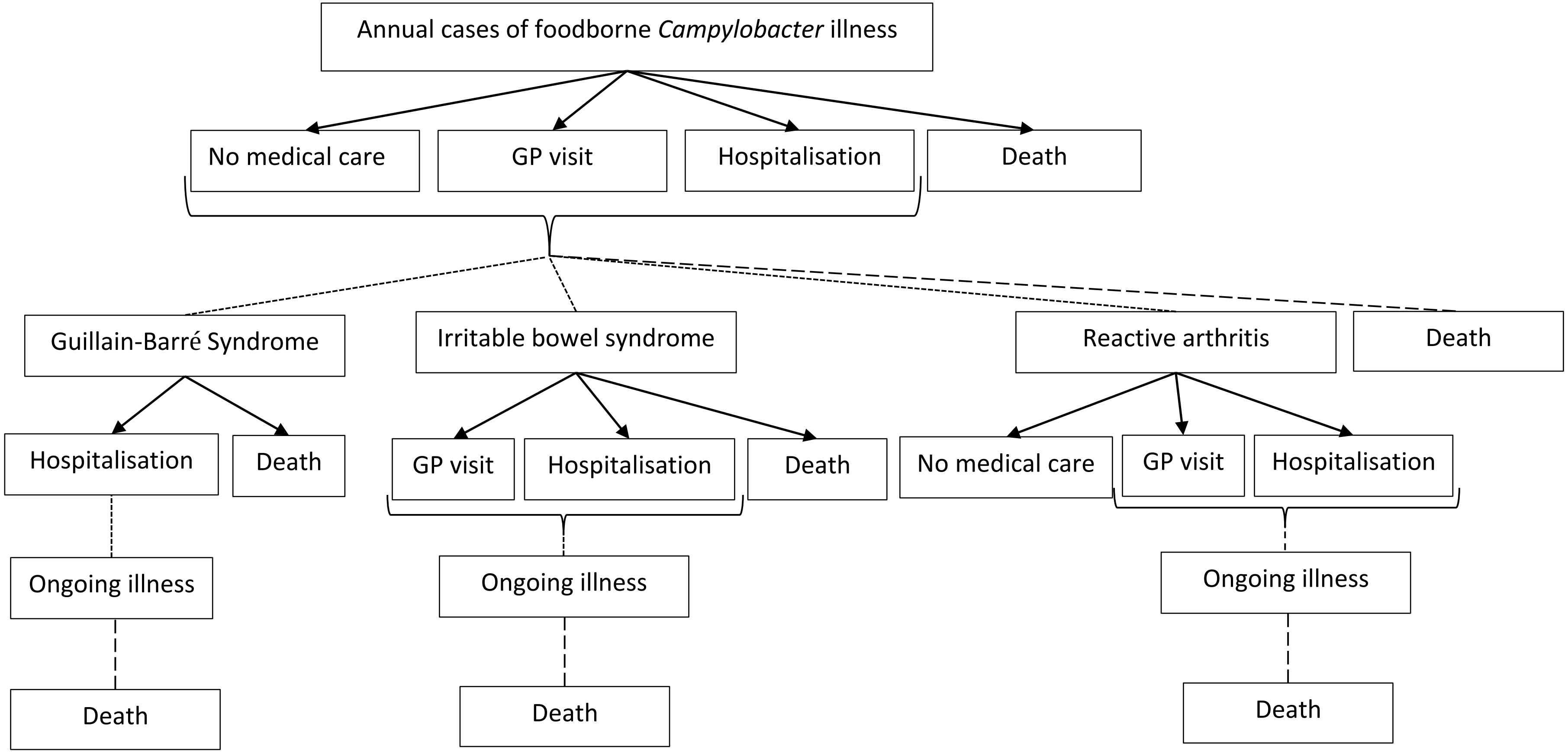
Gastroenteritis

Figure A1: Health outcome tree for gastroenteritis due to all causes; dashed lines indicate that death may follow the preceding states



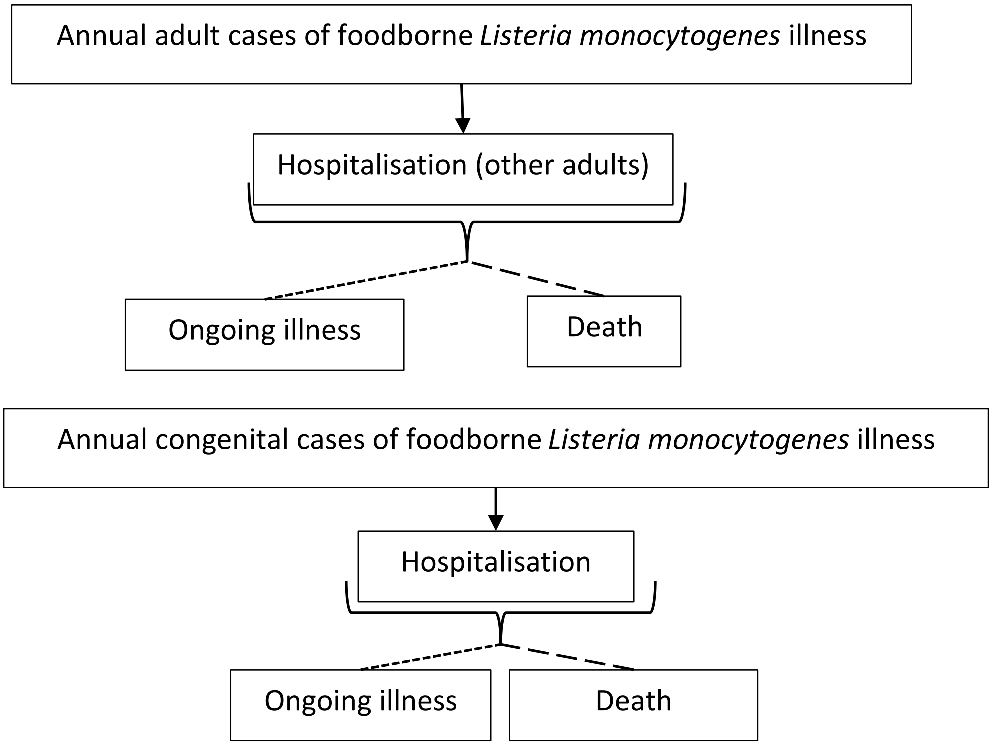
Campylobacter

Figure A2: Health outcome tree for *Campylobacter* spp.; dotted lines indicate the potential for these sequelae to follow acute illness, and for ongoing illness to result from sequelae, while dashed lines indicate that death may follow the preceding state.



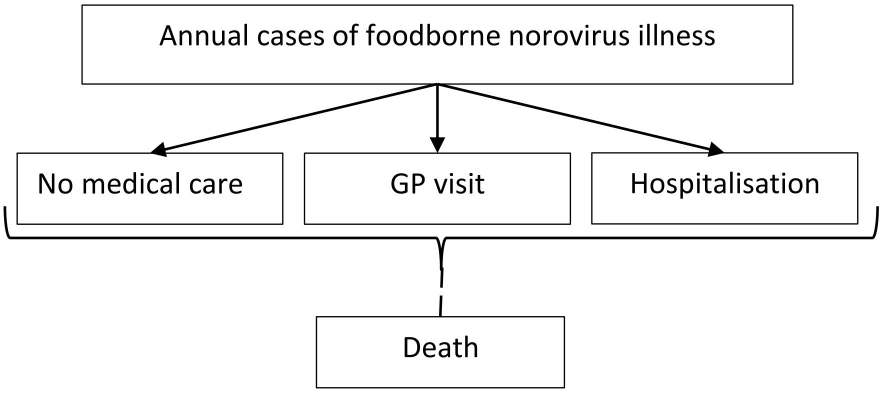
Listeria monocytogenes

Figure A3: Health outcome tree for *Listeria monocytogenes*; dotted lines indicate potential for ongoing illness following hospitalisation, while dashed lines indicate that death may follow hospitalisation.



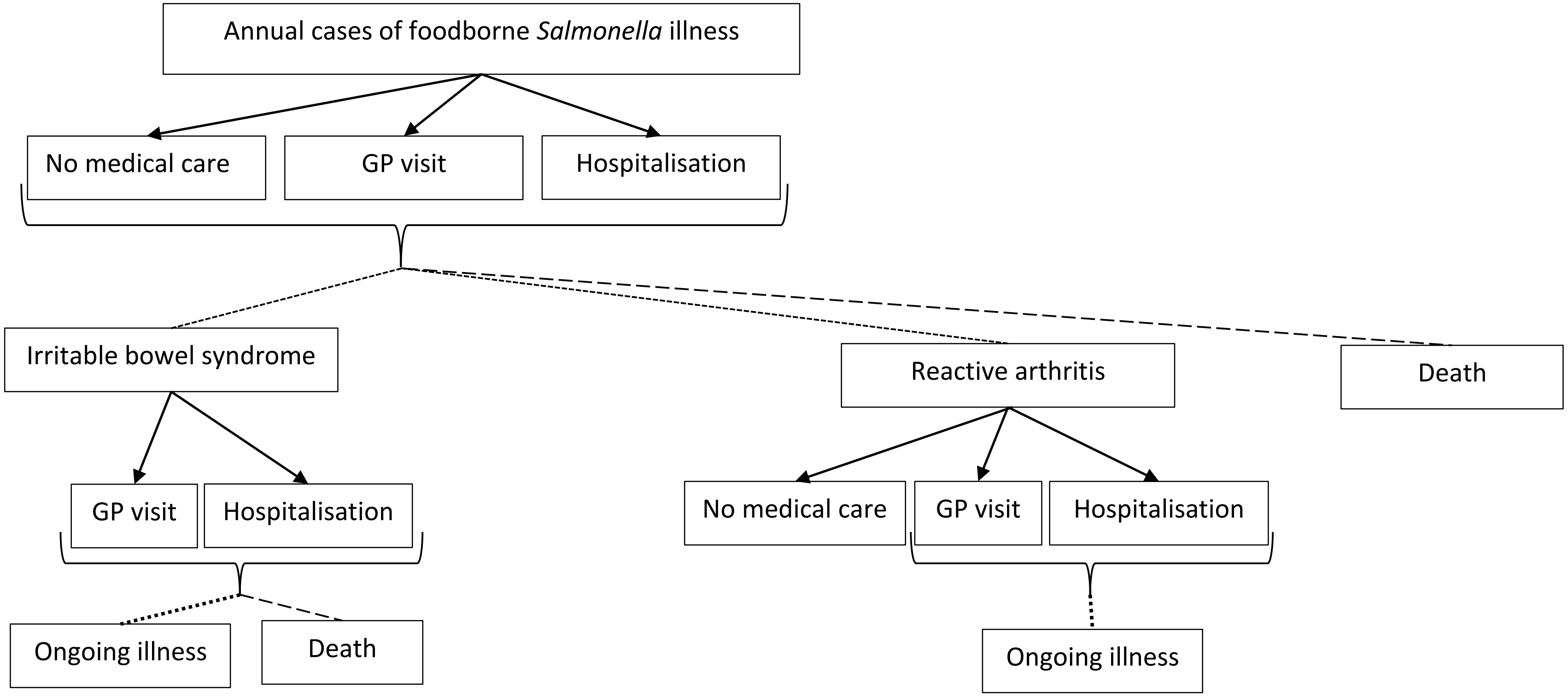
Norovirus

Figure A4: Health outcome tree for norovirus; dashed lines indicate that death may follow the preceding states.



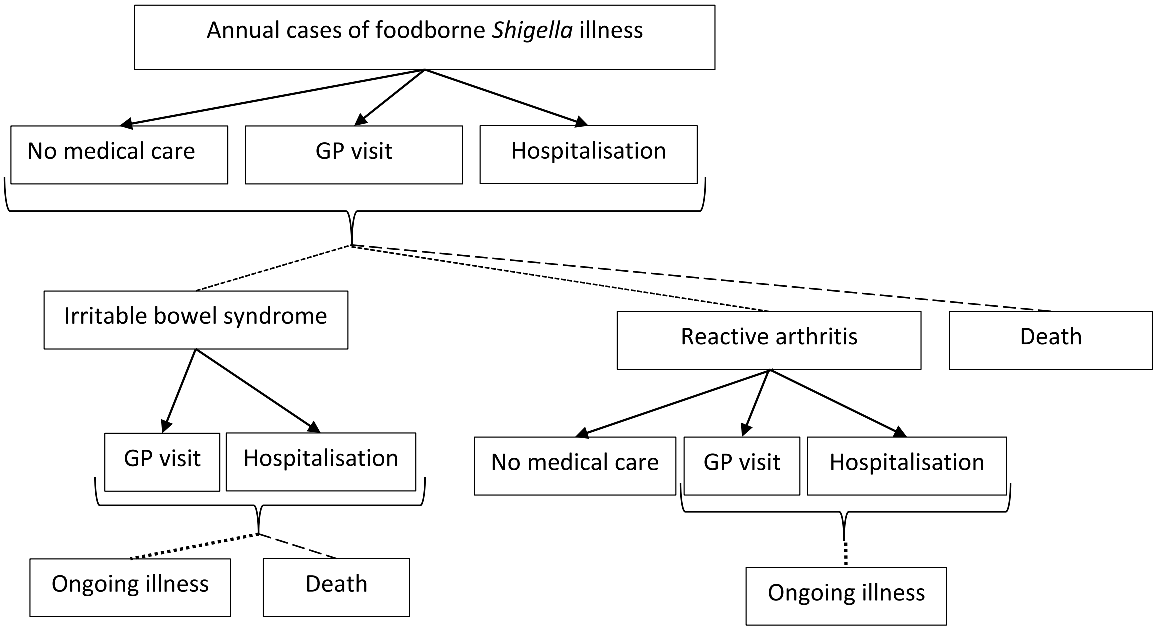
Non-typhoidal *Salmonella*

Figure A5: Health outcome tree for *Salmonella*; dotted lines indicate potential sequelae following acute illness, and potential ongoing illness following GP consultation or hospitalisation for a sequela, while dashed lines indicate that death may follow the preceding state.



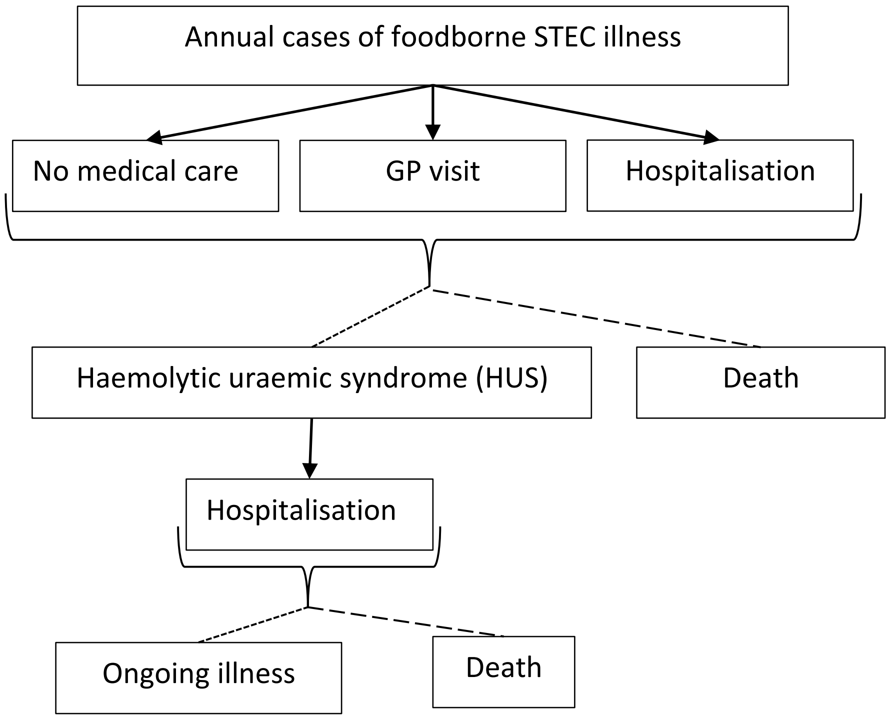
Shigella

Figure A6: Health outcome tree for *Shigella* spp.; dotted lines indicate potential sequelae following acute illness, and ongoing illness following GP visit or hospitalisation for reactive arthritis, while dashed lines indicate that death may follow the preceding state.



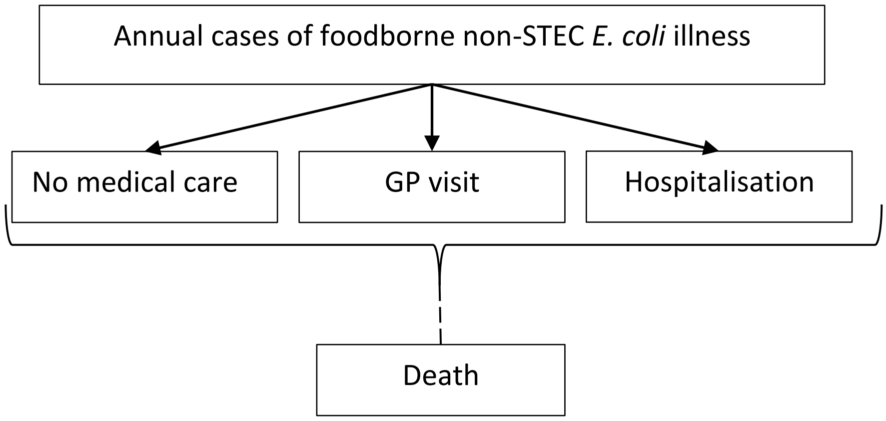
STEC

Figure A7: Health outcome tree for Shiga toxin-producing Escherichia coli (STEC); dotted lines indicate potential sequelae of haemolytic uraemic syndrome (HUS) following acute illness and potential ongoing illness following hospitalisation for HUS, while dashed lines indicate that death may follow the preceding states.



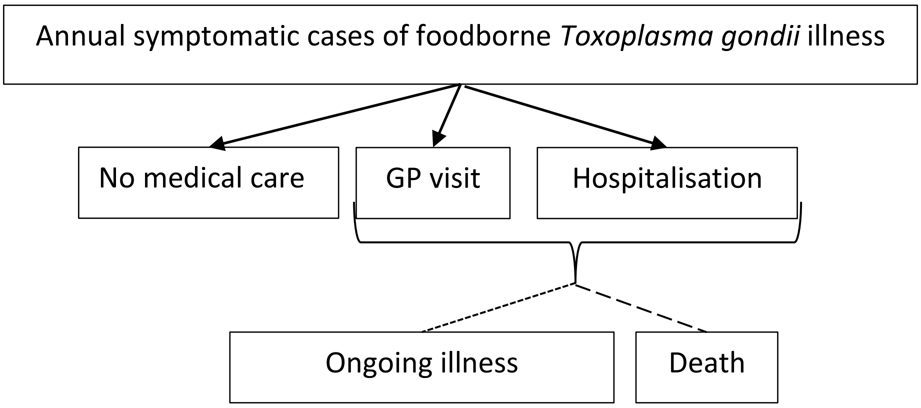
Other pathogenic *E. coli*

Figure A8: Health outcome tree for other (non-STEC) pathogenic E. coli; dashed lines indicate that death may follow the preceding states.



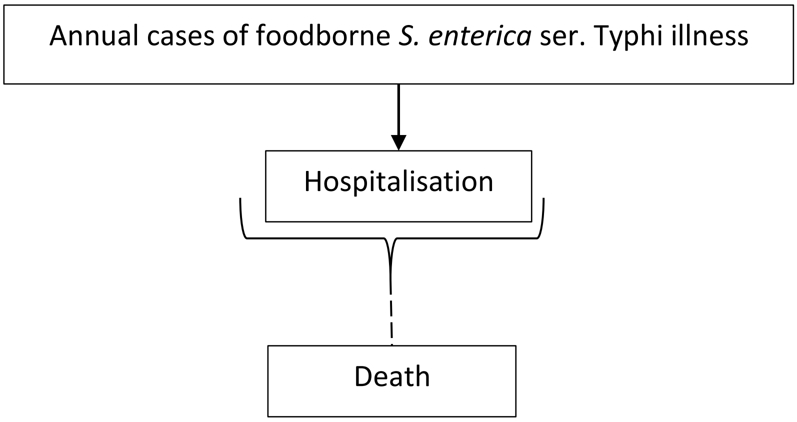
Toxoplasma gondii

Figure A9: Health outcome trees for Toxoplasma gondii; dotted lines indicate the potential for ongoing illness to follow health care; dashed lines indicate that death may follow the preceding states.



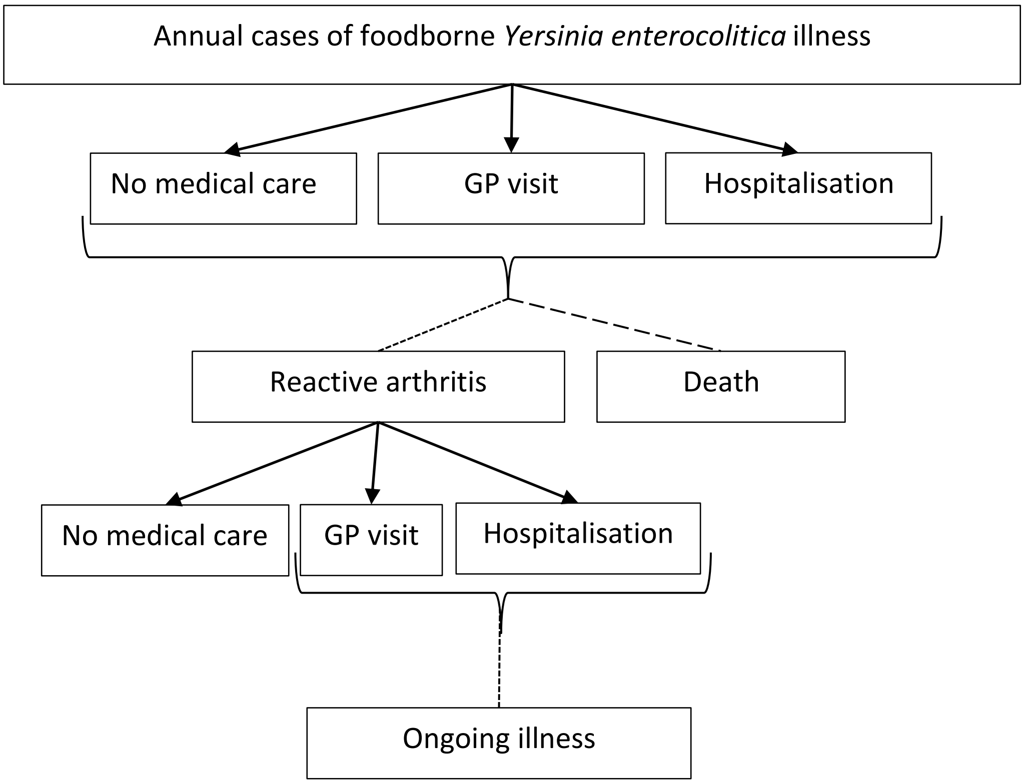
Salmonella Typhi

Figure A10: Health outcome tree for *S.* Typhi; dashed lines indicate that death may follow hospitalisation. All incident cases are assumed to be hospitalized.



Yersinia enterocolitica

Figure A11: Health outcome tree for Yersinia enterocolitica; dotted lines indicate potential sequelae following acute illness, and potential for ongoing illness to follow health care for reactive arthritis, while dashed lines indicate that death may follow the preceding states.



Attribution proportions by pathogen

The attribution proportions aggregated across experts were modelled using a step-wise uniform distributions defined by their 0%, 5%, 50%, 95% and 100% quantiles, with constant probability density between each of these quantiles. The two extreme quantiles were assumed fixed to 0% and 100% attribution respectively for all product/pathogen pairs, but the medians (50% quantiles) and 90% intervals (5% and 95% quantiles) are summarised in the table below.

Median (90% interval) for aggregated estimates of attribution percentages (%)

	Campylobacter	*Listeria monocytogenes*	Non-typhoidal *Salmonella*	STEC	*Toxoplasma gondii*	*Yersinia Enterocolitica*
Beef	5 (1 - 15)	4 (0 - 15)	6 (1 - 14)	36 (7 - 63)	22 (5 - 58)	10 (0 - 30)
Crustaceans	0*	5 (0 - 16)	0*	0*	0*	0*
Dairy	6 (0 - 13)	16 (5 - 43)	3 (0 - 18)	9 (0 - 38)	5 (0 - 15)	7 (0 - 27)
Eggs	0*	0*	21 (2 - 51)	0*	0*	0*
Finfish	0*	12 (1 - 38)	1 (0 - 4)	0*	0*	2 (0 - 8)
Fruit	0*	13 (1 - 23)	5 (0 - 13)	5 (1 - 11)	5 (1 - 10)	0*
Grains and seeds	0*	0*	4 (0 - 17)	3 (0 - 9)	0*	0*
Lamb	4 (0 - 11)	3 (0 - 8)	3 (0 - 11)	9 (1 - 35)	22 (2 - 59)	10 (0 - 30)
Molluscs	0*	3 (0 - 8)	1 (0 - 4)	0*	0*	0*
Nuts	0*	0*	2 (0 - 9)	1 (0 - 5)	0*	0*
Pork	5 (0 - 14)	10 (0 - 25)	4 (1 - 14)	6 (0 - 24)	17 (2 - 39)	54 (12 - 82)
Poultry	69 (40 - 89)	3 (0 - 14)	22 (4 - 47)	0*	5 (1 - 12)	0*
Vegetables	7 (1 - 14)	24 (9 - 39)	26 (4 - 49)	19 (5 - 56)	16 (1 - 47)	16 (1 - 49)
Other	11 (0 - 20)	0*	1 (0 - 5)	6 (1 - 20)	12 (1 - 38)	1 (0 - 95)
Total†	107	91	98	93	103	100

* No cases were deemed to be associated with this source/pathogen pair.

† Totals are of point estimates (medians) for each food commodity and therefore are not guaranteed to sum to 100 after estimates from experts are weighted and aggregated. Estimates of the cost associated with 'All food' in this report use 100% of costs and do not use the total across food commodities.

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