Economic analysis of Campylobacter control in the Dutch chicken meat chain

M.-J.J. Mangen[1,2], G.A. de Wit[2] and A.H. Havelaar[3]

[1] Wageningen University and Research Center, Agricultural Economics Research Institute, P.O. Box 29703, 2502 LS Den Haag, the Netherlands

[2] National Institute of Public Health and the Environment, Centre for Prevention and Health Services Research, P.O. Box 1, 3720 BA Bilthoven, the Netherlands

[3] National Institute of Public Health and the Environment, Microbiological Laboratory for Health Protection, P.O. Box 1, 3720 BA Bilthoven, the Netherlands

Abstract

The goal of the CARMA project is to advise the Dutch government on the effectiveness and efficiency of measures aimed at reducing campylobacteriosis in the Dutch population. The burden of disease and the corresponding cost-of-illness are estimated, using a series of observational data from epidemiological studies. The disease burden is expressed in Disability Adjusted Live Years (DALYs). The associated costs for the Dutch society, using cost estimates for the year 2000, included direct health-care costs, direct non-health-care costs and productivity losses from missed work. The friction cost method is used to estimate productivity losses. A risk assessment model estimates the reduction in the incidence of Campylobacter infections due to a set of possible interventions in the broiler meat chain. Separately, costs of the intervention under study for all stakeholders in the chicken meat chain will be estimated. For all preventive interventions to be modeled in the CARMA study, the costs of the intervention in the chicken meat chain will be related to (reduced) burden of disease and (reduced) cost-of-illness. This results in a (weighted) cost-effectiveness ratio (CER), expressing the relative efficiency of several policy options to reduce the number of Campylobacter infections.

Keywords: Disease burden; DALYs; cost-of-illness; direct health care costs; direct non-health care costs; productivity losses; friction-cost-method; industry costs; cost-effectiveness; cost-utility; Campylobacter

1. General introduction

Campylobacter infections and sequelae pose an important public health problem in the Netherlands. They result in approximately 80,000 cases of acute gastro-enteritis per year, of which 18,000 see a general practitioner and with a most likely value of 30 fatal cases per year, mainly among elderly. Additionally, each year some 1400 cases of reactive arthritis, 59 cases of Guillain-Barré syndrome and 10 cases of inflammatory bowel disease are associated with a previous Campylobacter infection (Mangen et al., 2004).

The most important reservoirs of campylobacters are found among animals, including farm animals, wild animals and pets. Food products and the environment including the domestic environment undergo continuous contamination from these reservoirs, creating many pathways by which humans can come into contact with Campylobacter (Havelaar, 2002). Chicken meat may be responsible for up to 40% of all human campylobacteriosis cases. Other identified risk factors are the consumption of pork and beef or raw milk, direct contact with animals, contaminated surface water and foreign travel (Havelaar, 2002).

Effective prevention of human campylobacteriosis requires a well-balanced set of measures. To this aim, the CARMA (**CA**mpylobacter **R**isk **M**anagement and **A**ssessment) project has been started in 2001 in the Netherlands. The goal of the CARMA project is to advise on the effectiveness and efficiency of measures aimed at reducing campylobacteriosis in the Dutch population[1]. A risk model will be built for each major route of infection, starting with the consumption of chicken meat. The different components forming the CARMA project are a chicken meat risk model, study of the possible intervention measures in the chicken meat chain[2], autonomous developments, economic analysis, and the societal acceptability of the intervention measures (Bogaardt et al., 2004).

In this paper we will describe the framework for the economic analysis of Campylobacter control

[1] For more details on the CARMA project visit the CARMA website: www.rivm.nl/carma

[2] The term 'chicken meat chain' summarizes all stakeholders in the chain, starting from the farm level to the consumer and including the government, if taking action to control Campylobacter in this chain.

in the Dutch chicken meat chain, as applied within the CARMA project. The economic framework includes: (1) the estimation of Campylobacter associated disease burden (intangible costs such as pain and suffering) and associated costs of illness (section 2); (2) the estimation of the costs of interventions for the chicken meat chain (section 3); and (3) a cost-effectiveness analysis (section 4). Special considerations with respect to the applied economic analysis are discussed in section 5.

2. Estimation of disease burden and cost-of-illness

2.1 Incidence of Campylobacter infections and associated sequelae

To calculate the Campylobacter associated disease burden and cost-of-illness in the Netherlands, information on incidence of Campylobacter-associated gastro-enteritis, reactive arthritis, Guillain-Barré syndrome and Inflammatory Bowel Disease are necessary. Incidence data were obtained from a recent Dutch population study on gastro-enteritis (De Wit et al., 2001a & b) and from Dutch surveillance (Van Pelt et al., 2003), further for GBS from Van Koningsveld (2001), as well as from newly available literature sources (e.g. Hannu et al. and 2002; Helms et al., 2003)[3].

2.2 Disease burden

2.2.1 Valuing health outcome

Health outcome measures might be expressed either in health indices or in monetary measures (Drummond et al., 1997; Krupnick, 2004). Expressing health outcome in monetary measures, means attaching money values to health outcomes[4]. Disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs) are some examples of possible 'health' indices found in the literature (Drumond et al., 1997; Belli et al., 2001). DALYs and QALYs both quantify morbidity or/and mortality outcomes and make them comparable across diseases and possible interventions. While

[3] For more details see Mangen et al. (2004).
[4] Details on monetary measures to valuate health outcome can be found for example in Drummond et al. (1997).

QALYs aggregate the actual health quality over time, DALYs aggregate the loss of health compared to ‘perfect health’. DALYs and QALYs complement each other during a typical course of life, as is demonstrated in figure 1. DALYs are the black part of the rectangle. QALYs are the grey part of the rectangle. The measures do not overlap, but complement each other. The black ‘valleys’ represent acute disease episodes over one’s lifetime. The black space at the far right indicates health loss due to premature death. The downward tapering of the grey QALY zone indicates chronic disease that is continuous until the early end of life.

Figure 1. Graphical illustration of DALY and QALY metrics (Source: Hofstetter and Hammitt, 2002)

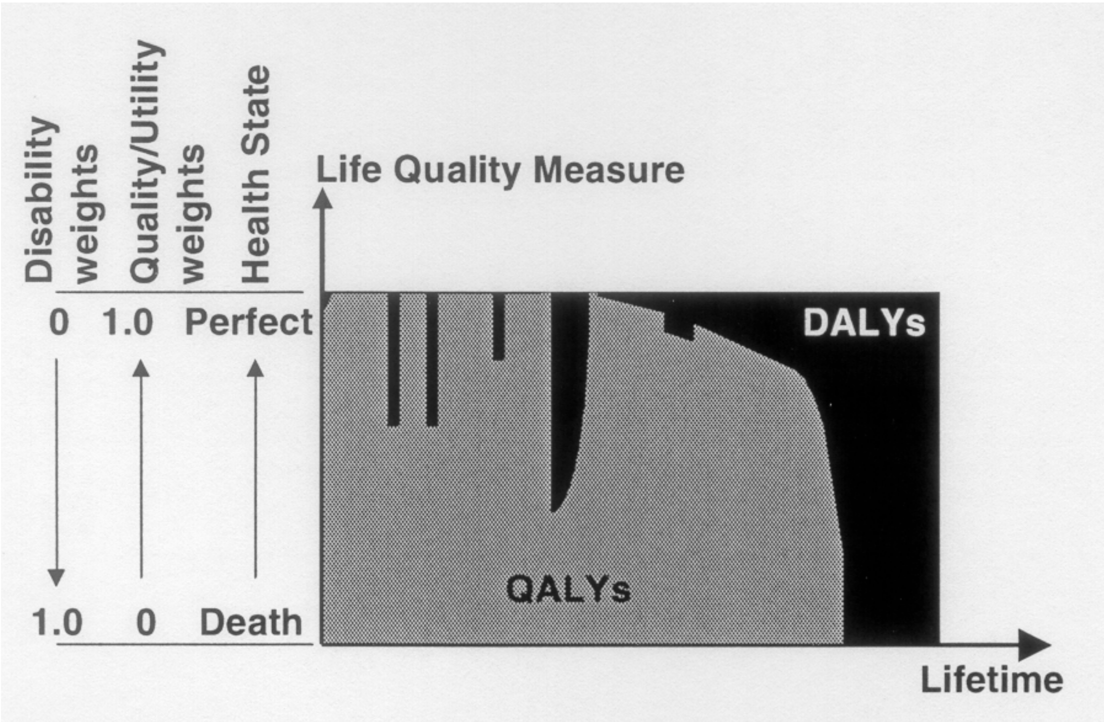

Figure 1 illustrates the difference in reference point for DALYs and QALYs. Any effective intervention to reduce the number of Campylobacter infections should result in either a reduction in DALYs associated with infection or a gain in QALYs. Note that QALYs and DALYs use different scales on the vertical axis. In the QALY approach, health-related quality of life is expressed in a number between 1 and 0, where 1 corresponds with perfect health and 0 with death. Compared to the quality weights used for QALY calculations, disability weights are anchored in the opposite way. Here, 0 refers to perfect health, while 1 refers to death.

2.2.2 Disability-adjusted life years

In the CARMA study we opt to measure the health outcome in health indices, whereby choosing the DALY methodology. The DALY methodology is commonly used by the WHO to evaluate public health priorities, as is it also in the Netherlands.

The concept of DALYs aggregates the loss of health compared to 'perfect' health, whereby combining morbidity and mortality into one single unit. The DALY methodology adds up the sum of years of life lost (YLL) and years lived with disability (YLD):

$$\text{DALY} = \text{YLL} + \text{YLD}$$

YLL is the number of years of life lost due to early mortality. YLL is calculated by accumulation over all fatal cases and all diseases of the expected individual life span (e) at the age of death. Thus:

Mortality burden: $YLL = \sum d \times e$ (life years per year)

where:	Incidence of death	d (cases per year)
	Expected life span at the age of death	e (years)

The first step in the DALY approach is to specify life expectancy. Within the CARMA study we use standard Dutch life expectancy for age and sex for the year 2000 as reported by Statistics Netherlands (for details see Appendix 6 of Havelaar et al. (2003)).

YLD is the number of years lived with disability. YLD is calculated by accumulation over all cases and all diseases of the product of the duration of the illness (t) and the disability weight (w). Thus:

Disability burden: $YLD = \sum N \times t \times \frac{w}{365}$ (healthy life years per year)

where:	Incidence of illness	N (cases per year)
	Duration of symptom	t (days)
	Disability weight	W

Each health effect is weighed for its severity, with death as the most severe outcome (weight 1) and perfect health as the best outcome (weight 0). For each specific health effect, the disability weight (w) is then multiplied by the duration (t) of this specific health effect, and by the number of people affected by the particular outcome. The estimated burden of disease, attributable to one agent, is obtained by adding up all the health outcomes caused by this agent (Murray & Acharya, 1997).

The estimated number of DALYs with regard to the different illnesses associated with Campylobacter infection is presented both discounted at a rate of 4% and not discounted. Applying a discount rate is generally used to account for the fact that health today is valued higher than health in the future, and for the fact that there is uncertainty about future possibilities to 'better' treat diseases.

2.2.3 Disability weights

The DALY methodology requires quantification of the value of different disease states relative to full health. Disability weights to use in DALY calculations have so far been based on descriptions of (different stages of) specific diseases presented to panels of experts, i.e. health care workers and medical doctors, and thus reflect the values of a limited part of the general population.

The Dutch disability weights were derived from medical doctors (Stouthard et al., 2000). In the Netherlands, DALYs have been used in a descriptive sense, to compare the burden of disease relative to each other (Van Oers, 2002). Within the CARMA project only Dutch disability weights were used. The disability weights used for IBD and ReA were based on Stouthard et al. (1997), whereby for ReA we had to fall back on rheumatic arthritis disability weights. The GE and GBS disability weights were mainly based on Havelaar et al. (2000a, b)[5, 6]. Both are Dutch studies, whereby the second study followed the protocol described by the first (Stouthard et al., 1997).

[5] A detailed description of the disability weights used for the estimation of Campylobacter associated disease burden is given in Mangen et al. (2004).

[6] Results and further details of the estimated disease burden as applied in the CARMA study can be found in Mangen et al. (2004).

2.3 Cost-of-illness

According to Hay & Hay (1992), two different approaches are available to estimate costs of disease: the prevalence based approach and the incidence based approach. In the prevalence approach, illness costs are defined as 'the stream of health care costs accruing to all patients alive during a specific time period' (e.g., the annual disease costs for all IBD patients alive in 2000), taking into account the proportion of patients in each disease state during the specified time period. 'Under the incidence approach, the costs of disease are defined as the present discounted expected sum of current and future costs accruing to all incident cases of disease in a specific time period' (e.g., the IBD incidence cohort of 2000), taking into account lifetime probabilities of transition to each disease state (Hay & Hay, 1992). Both methods produce the same results when aggregated across all patients and time periods.

In order to estimate the costs associated with Campylobacter infections and sequelae, we used the incidence approach in this study. The available data for IBD, however, forced us to opt for a *kind* of prevalence approach. In a first step we defined the annual incidence of Campylobacter-associated IBD cases, whereby determining for each IBD case individually the patient's life expectancy. Further we calculated for each patient the costs related to the diagnosis of the illness. (*All steps in accordance with the incidence approach)*. However, for direct health care costs, direct non-health care costs, and for indirect non-health care costs made during the patient's life-time, we had to use 'average' cost-of-illness, considering the proportion of patients in each disease state during that specific time period.

The intangible costs such as pain and suffering of the patient due to illness or years lost due to premature death is expressed within the DALY estimates of the CARMA study. Following the guidelines of Oostenbrink et al. (2000), we estimate the cost-of-illness associated with Campylobacter infections and its sequelae for Dutch society as a whole. In our cost-of-illness study, we measure direct medical costs; direct non-medical costs and indirect non-health care costs, using Dutch cost estimates for the year 2000. In accordance with Dutch guidelines for costing research (Oostenbrink et al. (2000)), this study does not consider 'potential' indirect health care costs (the future costs of health care in life years gained through current medical intervention).

The direct health care costs included such costs as doctor consultations (specialists and generalists), hospitalization, drugs, rehabilitation and other medical services. Travel costs of patients and any co-payments by patients for costs such as informal care, if applicable, were considered as direct non-health care costs. Indirect non-health care costs, which are defined as the value of production lost to society due to disease may occur as a consequence of: a) temporary absence from work; b) disability; and c) premature mortality. Following Dutch guidelines, we only estimated the productivity losses that occur due to sickness leave of sick people, and, if information was available also on third persons taking care of patients (the friction cost-method).

Studies that estimate indirect non-health care costs often use the human capital approach. The human capital approach estimates the value of *potential* lost production (or the potential lost income) as a consequence of disease. In the case of permanent disability or premature death at a specific age the total productivity value (or income) from that age until the age of retirement is counted as productivity losses. But according to Koopmanschap et al. (1995), the real production losses for society are smaller. The human capital method is based on neoclassical labor theory, using assumptions that are unrealistic given the contemporary European labor market. ‘The aim of the friction cost approach is to adjust the human capital estimates of productivity costs for the compensations that are likely to occur as a result of a labor market that does not adhere to neoclassical theory’ (Sculpher, 2001). A comparison of estimates from both methods is demonstrated in box 1.

In the CARMA study we follow Dutch guidelines and apply the friction cost method to estimate the production losses. In the friction cost method, production losses are only considered for the period needed to replace a sick, invalid or dead worker, the ‘friction period’. The friction cost method places a zero value on persons outside the labor market, such as children 15 and younger and retirees 65 and older. The friction cost method takes explicitly into account the economic processes whereby a sick, invalid or dead person can and will be replaced after a period of adaptation (Koopmanschap & van Ineveld, 1992). The length of the friction period depends on the situation of the labor market. A high unemployment rate generally allows fast replacement of a sick, invalid or dead person, whereas in the case of a low unemployment rate, on average more time is needed. Because the Dutch unemployment rate in 2000 was comparable to the one in 1998, we assume for the year 2000 a friction period of 123 days similar to the one estimated by Oostenbrink et al. (2000) for the year 1998.

Box 1. Comparing the human capital and friction cost methods

Koopmanschap et al. (1995) compared the estimated productivity losses from illness in the Netherlands by all causes, using both methods. The friction costs amounts to 2.1 per cent of net national income compared to 18 per cent for the human capital approach. The value of production losses due to ill-health according to the friction cost approach was only 12 per cent that of the human capital approach. 'The huge difference compared to the friction costs is due to the cost of disability and mortality, which are assumed to cause production losses in the long term. Costs of disability are very large, because the average duration of disability in the Netherlands is 15 years' (Koopmanschap et al., (1995).

Productivity costs from illness in the Netherlands: a comparison of human capital and friction cost estimates (billions of Dutch guilders)[a]

Cost category	Friction costs 1988	Human capital costs
Absence from work	9.2	23.8
Disability	0.15	49.1
Mortality	0.15	8.0
Total	9. 5	80.9

a) Extracted from Koopmanschap et al. (1995)

Apart from various Dutch studies that use the friction cost method to estimate the productivity losses, there are also non-Dutch studies available in the literature, for example Goeree et al. (1999), Lopez-Bastida et al. (2003) and Marcotte & Wilcox-Gök (2001). These latter studies estimated the productivity costs, using the human-capital and the friction-cost methods.

The formulas for cost-of-illness are in basic notation:

Direct health care costs: $$DHC = \sum_i m_i \times p_i \times c_i$$

Where: Cases using medical service i — m_i; for i = 1 to n

# of medical service i/case — p_i; for i = 1 to n

Cost/medical service i — c_i; for i = 1 to n

Direct non-health care costs: $$DNHC = \sum_j r_j \times q_j \times c_j$$

Where: Cases using non-medical service j — r_j; for j = 1 to n

# of non-medical services j/case — q_j; for j = 1 to n

Cost /non-medical service j — c_j for j = 1 to n

Indirect non-health care costs: $$INHC = s \times u \times v$$

Where: Cases of sickness leave — s (cases per year)

Duration of sickness leave — u (days); maximum 123 days per episode

Wage costs per day — v (age dependent)

Results are presented in the CARMA project both discounted at a rate of 4% and undiscounted.

3. Estimation of intervention costs in the chicken meat chain

3.1 Industry costs

An essential step within the CARMA project is the analysis of various intervention measures to reduce Campylobacter in the chicken meat chain. These various intervention measures are applied on different levels within the chicken meat chain. These levels are:

- The chicken producers, including all levels from the pedigree (elite) flocks until the commercial broiler chick flock;
- The transport industry;
- The slaughter and processing industry;
- The wholesalers and retailers;
- And the final consumer.

In most cases, the affected level is also the primary affected stakeholder who has to invest the additional industry costs triggered by the intervention measure taken. In the case of the final consumer however, public funds or chicken meat chain funds might have to be raised to pay for e.g. educational measures to teach the final consumer a “safer” food handling.

Given our priorities, we will therefore estimate the additional costs that are related to the various intervention measures under study. A list of the costs that might arise for the poultry production chain by the application of the intervention measures under study is summarized in table 1. Some of these intervention measures might require only a single, but expensive investment, e.g. capital investments in a slaughterhouse. Capital investments are by definition long-lasting assets, which involve high financial costs. These costs remain unchanged in total for a given time period despite possible changes in the related level of total activity or volume (Horngren et al., 2000). Once a long-lasting asset is purchased or constructed, it is often difficult or costly to change, alter, or reverse a capital investment decision (Kay and Edwards, 1994). These investment costs will be depreciated following standard accounting principles. For other intervention measures, costs recur with each application (e.g. soap and disinfection materials, when cleaning and disinfecting a stable before repopulating with the following flock). These latter costs change mostly in relation to the total applied volume or activity (Horngren et al., 2000). Consequently, not all costs will occur at the same time, and also ‘benefits’ might be realized at different moments in the future. In order to be able to compare the different intervention measures under study, we will calculate the net present value for each of them and then compare average annual costs and benefits of the different intervention measures. In this study a discounting rate of 4% will be used, according to the Dutch recommendation for public sector investment (Oostenbrink et al., 2000). However, for sensitivity reasons, we will also estimate the costs, using a 2% and a 6% discounting rate respectively.

Table 1. Costs to be included in an economic evaluation on intervention measures to reduce Campylobacter in the poultry production chain.

Cost category	**Affected**
Industry costs [1)]	
Direct costs related to animal production [2)]	Reduced number of cycles per year (additional time to disinfect stable between two flocks) Reduced number of chicken birds per cycle (no thinning out)
Direct costs related to control costs for pathogens at all links in the food chain[2)]	Altered and new farm practices (bio-security measures, disinfection / sterilization, phage therapy, etc) New slaughterhouse procedures (logistic slaughtering, carcass sterilizing, etc) New processing procedures (pathogen test, logistic processing, decontamination, products development, etc)
Direct costs related to outbreaks[3)]	
Regulatory and public costs for controlling Camppylobacter [4)]	
	Monitor pathogen in the food chain Information campaign

[1)] A more complete list of industry costs can be found in Buzby et al. (1996). Within this table we will consider only costs that are appropriated for the intervention measures under study.

[2)] But apart of 'direct costs' related to intervention measures to reduce Campylobacter in the chicken meat chain, there might be also 'indirect benefits', such as: better control of other foodborne pathogens; better management systems and control of whole production process; etc. However, these later benefits are hard to quantify and are therefore in first instance not considered in the CARMA project.

[3)] According to Buzby et al. (1996) 'direct costs related to an outbreak' are also a part of societal costs of foodborne illness. However, most human Campylobacter infection that are related to chicken meat, are sporadic cases. Therefore, we will not consider them in our economic evaluation.

[4)] According to Buzby et al. (1996) regulatory and public health chain costs is another cost category of the societal costs of foodborne illness. However, some of these costs falls in the category of 'public health' costs and are therefore considered in the cost-of-illness study (section 2). Whereas the other public costs are more closely related to the chain itself and might have to be even financed by the chain itself. Within this list we will consider only the latter one. A more complete list on regulatory and public health chain costs can be found in Buzby et al. (1996).

3.2 Underlying assumption

When estimating the industry costs we will make the assumption that the Dutch chicken meat supply as well as the Dutch demand for Dutch chicken meat will be equal to that of the year 2000, our base year. This is an oversimplification and it assumes that none of the intervention measures under study would affect a) the Dutch supply of chicken meat, b) the Dutch domestic consumer demand of chicken meat and c) the export position of the Dutch broiler industry.

4. Cost-effectiveness analysis

The objective of the CARMA project is to analyze different intervention strategies that might result in a reduction of the number of human campylobacteriosis in the Netherlands. Given this objective, the economic setting should then allow us to judge the success of the intervention, in terms of its impact on health status (Belli et al., 2001). Several forms of economic evaluation of health programs are available. Drummond et al. (1997) provide a framework for such analyses. Four major types of full economic evaluation studies (as opposed to partial economic evaluation) are available: cost-minimization analysis, cost-effectiveness analysis, cost-utility analysis and cost-benefit analysis. With a cost-minimization analysis, equal effectiveness of all programs under review is required, and the cheapest program is thus considered the most attractive. This type of analysis is e.g. useful in the comparison of two alternative drugs that have the same effect. In the current study, different strategies to reduce human campylobacteriosis obviously have different effects, so cost-minimization analysis would not be the best research design. A less used form of economic evaluation research in human health economics is cost-benefit analysis, although it is considered as the 'gold standard' in other economic fields. Its aim is to express all costs and all effects in monetary terms. One of the major problems in this type of research is the valuation of effects. What is the monetary value of an improvement in quality or length of life? Within CARMA, these problems are not addressed and therefore, cost-benefit analysis is not the research design of choice. Cost-effectiveness analysis (CEA) is a form of full economic evaluation, where both costs and health consequences of alternatives strategies are examined. In cost-effectiveness analysis, costs are related to a single, common effect that may differ in magnitude between the alternative programs (Drummond et al., 1997). The results of such comparisons may be stated either in terms of cost per unit of effect, or in terms of effects per unit of cost. A special form of CEA is cost-utility analysis (CUA) (Drummond et al., 1997), some also call this form a weighted cost-effectiveness analysis (Belli et al., 2001). Here, the aim is to link net cost of an intervention to the combined effects of the intervention on mortality and morbidity, e.g. QALYs, DALYs. Within the CARMA project, the economic evaluation of interventions to reduce campylobacteriosis will be performed both as a cost-effectiveness and as a cost-utility analysis.

From the extensive listing of cost categories that are relevant from a health economist perspective (section 2) and cost categories relevant for the chicken meat chain (section 3), it is instantly clear that campylobacteriosis crosses the traditional borders of economic evaluation studies within one sector of society, e.g. health care. It is to be expected that most costs will be made in the food production chain, while health care (reduced costs of treatments for human campylobacteriosis), employers (reduced days lost paid work) and society at large (reduced intangible costs) benefit from these investments.

Traditionally, the societal perspective is the principal perspective to choose in economic evaluation. From a societal perspective, investments/interventions are worth doing, when the society as a whole is better off, than when doing nothing. This means that all costs and benefits to society have to be included in the analysis, irrespective of the payer of costs or receiver of benefits. The central question is whether society at large would benefit from the implementation of these interventions. In a following step, decision-makers would then have to apply/develop measures in order to stimulate and compensate the ‘losers’ and assure their participation. However, this last step is beyond the scope of the CARMA project. In the case of Campylobacter reduction, interventions will be evaluated from the perspective of (different players in) the chicken meat chain and from the societal perspective separately. Policy makers may then choose the perspective that is most relevant to them. Such disaggregated information is also essential to improve the acceptance of interventions under study.

5. Special considerations with respect to the applied economic analysis

As many necessary data are lacking, uncertainty analysis will be an important aspect of the work. However, for some interventions only sensitivity analyses will be possible.

The Dutch poultry meat production is an open system with considerable import and export of both live broiler chickens and broiler meat. This implies that measures taken to reduce the contamination with Campylobacter of Dutch broiler flocks or poultry meat slaughtered and processed in the Netherlands will not only have a positive effect on the health risks of consumers in the Netherlands, but also in countries that import Dutch products. On the other hand, a part of the meat consumed by Dutch consumers is not domestically produced, and consequently will not offer additional health protection if measures are only implemented in the Netherlands. When applying our cost-effectiveness analysis we will take these different trade flows into consideration.

As already explained, we assumed that none of the intervention measures under study would affect a) the Dutch supply of chicken meat, b) the Dutch domestic consumer demand of chicken meat and c) the export position of the Dutch broiler industry. In reality, however, the chicken meat chain is strongly vertically integrated and there is also high competitiveness between countries in this sector (Bondt and Van Horne, 2002). Most of the intervention measures under study however, will involve additional costs without a direct benefit for the investor. In order to survive, Dutch chicken meat producers and Dutch processing plants specialized in chicken might be forced to spill their additional production costs through to the final consumer. A higher product price for Dutch chicken meat, however, might have different effects on consumer demand and as such on the long-term supply of Dutch chicken and chicken meat. However, the current economic analysis is not adequate to quantify these effects. Other economic models, e.g. general equilibrium models, might be better prepared to do so. But, this will be behind the scope of the current CARMA project.

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