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Economics of zoonoses surveillance in a "One Health" context: An assessment of *Campylobacter* surveillance in Switzerland

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Running head: Economics of *Campylobacter* surveillance

21 **Summary**

22 Cross-sectorial surveillance and general collaboration between the animal and the public health
23 sectors are increasingly recognized as needed to better manage the impacts of zoonoses. From
24 2009, the Swiss established a *Campylobacter* mitigation system that includes human and poultry
25 surveillance data sharing within a multi-sectorial platform, in a “One Health” approach. The
26 objective of this study was to explore the economics of this cross-sectorial approach, including
27 surveillance and triggered interventions. Costs and benefits of the “One Health” and of the uni-
28 sectorial approach to *Campylobacter* surveillance were identified using an economic assessment
29 framework developed earlier. Cost information of surveillance activities and interventions was
30 gathered and Disability Adjusted Life Years (DALYs) associated to the disease estimated for 2008
31 and 2013. In the first five years of this “One Health” approach to *Campylobacter mitigation*,
32 surveillance contributed with information mainly used to perform risk assessments, monitor
33 trends and shape research efforts on *Campylobacter*. There was an increase in costs associated
34 to the mitigation activities following integration, due to the allocation of additional resources to
35 research and implementation of poultry surveillance. The overall burden of campylobacteriosis
36 increased by 3.4-8.8% to 1751- 2852 DALYs in 2013. In the timing of the analysis, added value
37 associated to this cross-sectorial approach to surveillance of *Campylobacter* in the country was
38 likely generated through non-measurable benefits such intellectual capital and social capital.

39

40 Key results:

- 41 • The information generated by the “One health” approach to surveillance in the period of the
42 study was mainly used to perform cross-sectorial risk assessments and to identify research
43 needs.

- 44
- The implementation of a “One Health” approach to *Campylobacter* to disease mitigation
- 45 activities in the period 2009-2013 in Switzerland had associated increased costs. The main part
- 46 of resources was allocated to commissioned research on *Campylobacter*.
- 47
- Non-measurable benefits such as social and intellectual capital were associated with the multi-
- 48 sectorial approach to *Campylobacter* surveillance in the first five years of this system.
- 49
- The estimated burden of disease in the country was of 1751-2852 DALYs in 2013, an increase
- 50 when compared to 2008.
- 51
- Overall the framework used provided a practical tool to identify and estimate costs and benefits
- 52 associated with surveillance of *Campylobacter* in a “One Health” context.

53

54

55 **Introduction**

56 *Campylobacter* poses an important public health threat, and it is currently identified to be the
57 most important zoonotic infectious agent in Europe [1]. In Switzerland, human
58 campylobacteriosis has been a notifiable disease since 1988 and the most frequently recorded
59 zoonotic infection since 1995. Overall, an increasing trend of the disease in humans has been
60 observed, with a peak of notified cases of 105 reports per 100'000 inhabitants in 2012 [2,3]. Its
61 impact in the country in terms of healthcare costs of laboratory-confirmed campylobacteriosis
62 patients has been recently estimated to be of 8.3 million Euros [4]. There is a distinct two-peak
63 seasonality of reported human cases in the country: a summer peak, likely to be connected to a
64 higher infection rate in poultry flocks, higher frequency of exposure via barbecue activities and
65 travels abroad, and a winter peak mainly related to consumption of chicken meat in the
66 traditional festive dish "*Fondue Chinoise*" [5–7]. The chicken reservoir has been identified as the
67 main source for human campylobacteriosis in Switzerland, with 71% of the human cases
68 attributed to chickens based on the comparison of isolates from humans and animals [8]. In
69 poultry, the prevalence of *Campylobacter* in cloacal swabs ranged from 33% to 38%, from 2010
70 to 2013 [6].

71
72 In response to the observed increasing trend in human campylobacteriosis cases, the animal
73 and the human health authorities enhanced collaborative disease surveillance and intervention
74 efforts with the intention of improving the disease management. A stakeholder group
75 composed by the poultry industry, researchers and public health and animal health national and
76 cantonal authorities – the *Campylobacter* platform – was formed with the aim of exchanging

77 information, coordinating and evaluating control measures, and to identify gaps of knowledge
78 and funding of research [2]. A regular surveillance system in broiler chicken was also
79 implemented. This constituted a shift from the previously instituted system, which was
80 essentially based on the monitoring of human cases.

81
82 Such change, from a uni-sectorial to a multi-sectorial approach to *Campylobacter* mitigation, is
83 also in line with an increased recognition at the international level of the need for collaboration
84 between the animal and the public health sectors as a means to improve the management of
85 zoonotic threats. The “One Health” movement is based on the principles that collaborative or
86 integrated efforts across multiple disciplines can result in a decrease of the burden of zoonotic
87 disease and generate a better health status, and that a multi-sectorial approach best captures
88 the interrelationships of health of different species [9,10]. This includes strengthened integrated
89 surveillance systems for zoonotic pathogens and sharing of information, currently seen as key to
90 an effective health system [11–14].

91
92 The need to identify better ways to mitigate the impact of campylobacteriosis has triggered
93 research work into the cost-effectiveness of control options for *Campylobacter* at different
94 levels of the food chain in different countries [15–17]. However, similar to economic
95 assessments of other zoonotic diseases, the focus of these assessments is largely on the
96 economics of disease control, with no specific focus on the costs and benefits of efforts for
97 surveillance or collaborative mitigation activities for *Campylobacter*. Surveillance activities
98 require resource spending that may be significant and information on the extent of expenditure

99 associated to these activities is needed to inform prevention, surveillance and control strategy
100 decisions. Furthermore, from an economics perspective, it is of interest to consider whether
101 overall resources are used more efficiently by integrated, “One Health” surveillance, than by a
102 surveillance system with disconnected, sector-specific components. Such increased efficiency in
103 resource use can be attained either through cost savings and/or by added benefits associated to
104 a reduced impact at a societal level of zoonotic threats [18].

105
106 It has been shown in previous work that the economic assessment of surveillance activities
107 needs to be underpinned by the understanding of how the surveillance activities link to
108 interventions and to the broader mitigation process [19]. An assessment of the overall
109 mitigation approach including surveillance and intervention is therefore needed when exploring
110 the economics of surveillance. In the case of “One Health surveillance”, this extends to the
111 understanding of how surveillance information is used and how it triggers health consequences
112 and benefit streams across different sectors [18].

113
114 In this study, we explored the cross-sectorial costs and benefits associated with the sharing of
115 surveillance information on *Campylobacter* in Switzerland in the period of 2009-2013. The
116 objective is to provide information on the economics of this cross-sectorial approach to
117 *Campylobacter* mitigation and to test the practical implementation of an assessment framework
118 previously developed.

119

120 **Methods**

121

122 **General approach**

123 The “One Health” approach to *Campylobacter* mitigation was considered as the system in place
124 since 2009 to 2013 (in this study). In this period information generated by surveillance activities
125 in the poultry population and in the human population was shared in the *Campylobacter*
126 platform and fed into cross-sectorial policy discussions, triggering public health and animal
127 health targeted interventions. The collaborative nature of the analysis of information generated
128 by the animal and the human surveillance streams in the *Campylobacter* platform fits into the
129 concept of “One Health surveillance”, as currently described [20,21]. This “One Health”
130 approach was compared with the system in place prior to the *Campylobacter* platform
131 establishment, the 5 years-period from 2004 to 2008. The mitigation activities during this period
132 were predominantly public-health-based, with a monitoring system centered on mandatory
133 notification of human cases, triggering public health messaging activities.

134

135 As mentioned before, costs and benefits of surveillance are intrinsically linked to the
136 interventions triggered by the information generated. Taking this into consideration, and to
137 guide our assessment, we applied a framework previously developed [18] to identify
138 surveillance activities across the two sectors, their links to public health and animal health
139 decision making and triggered interventions in the two periods of time. The framework entails
140 an initial step that involves a conceptualization of the links between surveillance and triggered
141 interventions, followed by the identification of costs and benefits and their valuation. An
142 overview of the steps taken in this analysis is provided in Figure 1.

143

7

144 Figure 1. Overview of the steps taken in the economic assessment of *Campylobacter* surveillance in Switzerland in a “One
145 Health” perspective following the conceptual framework used in this study [18].

146
147 Only official surveillance systems and interventions were considered in this assessment and
148 industry-borne costs and benefits were not incorporated in the analysis.

149
150 ***Initial framing and identification of cost and benefit items associated to *Campylobacter****
151 ***surveillance***

152 The initial framing for the analysis entailed the conceptualization of the links between the
153 surveillance streams for *Campylobacter* and the triggered interventions across sectors.
154 Information on the type of surveillance activities, integration mechanisms and interventions
155 prompted by the information generated in both the animal and the human health sectors were
156 identified for the “One Health” and uni-sectorial systems, based on discussion with experts
157 involved in the surveillance activities and in the *Campylobacter* platform and literature review
158 [2]. The information was mapped enabling the identification of the costs items and potential
159 benefit streams of the mitigation systems (Figure 2).

160
161 ***Valuing costs and estimating the break-even point***

162 Data used to parameterize the cost estimation model were collected for the two periods in
163 analysis from the Swiss Federal Food Safety and Veterinary Office (FVO) and Federal Office of
164 Public Health (FOPH). Labour costs and expenses accrued by planning and preparation tasks of
165 the surveillance systems, sampling and test costs, including analysis and transport of materials
166 and samples were included where appropriate, as well as labour costs and expenses related to

167 data analysis and interpretation, and information dissemination. Running costs of the
168 *Campylobacter* platform as well as costs associated with interventions that were triggered by
169 surveillance information were also estimated. For the human monitoring system, only labour
170 and expenses associated with the notification of cases upstream from the laboratory diagnosis
171 were considered, as all costs downstream to that point could not be directly allocated to the
172 monitoring system. Intangible costs were not included in the analysis. Table 1 summarizes the
173 inputs considered for the cost estimate.

174
175 Labour costs for scientific and administrative level staff were calculated considering the wage
176 table established by the Swiss Confederation for 2014 and using an average variation of 1.2%
177 [22] to establish the corresponding wages for the years in analysis. A working month of 182.7
178 hours was used as a basis for the calculation of the hourly cost associated with the
179 *Campylobacter* mitigation activities.

180
181 The break-even point for the system, i.e. the point at which cost or expenses and benefits are
182 equal and the system would recover its costs, was calculated in terms of the number of DALYs -
183 the metric used to assess marginal benefits of the system - that would have to be averted. To
184 compare a monetary metric for costs (Swiss Francs [CHF]) with a non-monetary metric, break-
185 even points were calculated using three point estimates of health burden and associated cost-
186 of-illness (converted into CHF, using the yearly average exchange rate of 2013) available in the
187 literature: 8'437 CHF/DALY [23], 61'362 CHF/DALY [24] (considering the average DALY estimate)
188 and 21'534 CHF/DALY [25].

189 **Valuing benefits**

190 From the benefit streams identified (Figure 2), we explored in more detail potential changes in
191 the impact of disease in the human population. The potential benefits of *Campylobacter*
192 mitigation in the poultry population, in terms of direct impact, were not assessed considering
193 the relatively minor role of *Campylobacter* as a pathogen for poultry [26]. Similarly, potential
194 benefits in terms of mitigation of potential indirect impacts (e.g. effects on market access and
195 trade) were not assessed.

196
197 Burden of disease was calculated using DALYs, applying the methodology developed by Murray
198 & Lopez [27] and building upon the model recently used in Denmark for the estimation of the
199 burden of foodborne disease [28]. The estimates of burden for 2013 (5 years after the start of
200 the approach) were compared to the estimated burden of disease in 2008 (the year prior to the
201 implementation of the *Campylobacter* platform).

202
203 Table 2 summarizes the inputs used to parameterize the DALY model. To correct for
204 underdiagnoses and underreporting and estimate the total incidence of disease in the
205 community, multiplication factors of 3.4 [23] and of 9.3 [29] as a best and worst case scenario
206 were used in the two years estimated - 2008 and 2013. Underreporting and underdiagnoses
207 were considered as constant in 2008 and 2013 as there were no changes to the human
208 monitoring system. Health outcomes associated with *Campylobacter* infection considered were
209 gastroenteritis (GE), reactive arthritis (RA), irritable bowel syndrome (IBS), inflammatory bowel
210 disease (IBD) and Guillain-Barre Syndrome (GBS). Data pertaining to these health outcomes

211 were sourced from national data whenever possible and from data available in the literature
212 from elsewhere and recently reviewed in [28]. The disability weights (DW) used were based on
213 the Global burden of disease 2010 study [30]. When the DW for a specific health outcome was
214 not available, a DW from an outcome with similar health effects was used. When DWs for
215 specific health outcomes differentiated between multiple degrees of severity, an overall DW
216 was calculated on the basis of the estimate of the proportion of cases with those severity levels
217 in Switzerland. Life expectancy estimates were obtained from the Swiss population statistics for
218 2013 [31]. Age weighting and discounting were not applied.

219
220 Total years of life lost to disability (YLD), to mortality (YLL), and overall DALYs for the years in
221 analysis were calculated by applying a stochastic model using the DALY Calculator interface
222 developed in R [38]. In addition to the estimate of best and worst case scenarios to explore the
223 uncertainty resulting from data limitations in the incidence of *Campylobacteriosis*, sensitivity
224 analysis using a linear regression-based analysis was conducted in the same software to explore
225 the contribution of each stochastic variable in model input parameters to the overall
226 uncertainty of the end result.

227
228 **Results**

229 From 2009 to 2013, the information generated by surveillance in the animal population and by
230 human cases monitoring shared in the *Campylobacter* platform, triggered activities concerning
231 biosecurity messaging in poultry farms and public health messaging on hygienic measures for
232 chicken meat handling and prevention of cross-contamination. Integration of surveillance

233 information was also used to perform cross-sectorial risk assessments and to identify gaps in
234 the knowledge base for *Campylobacter* infection in the country and research needs. The links
235 between information generated by the animal health sector and triggered interventions in the
236 public health sector through the integration of this information in a “One Health” approach are
237 represented in Figure 2.

238

239 Figure 2. Conceptual representation of the links between *Campylobacter* surveillance and triggered activities across the public
240 health and the animal health sectors and the benefit streams generated, in 2009-2013.

241

242 Through its links to public health messaging, surveillance of *Campylobacter* in poultry and
243 integration of information has the potential to generate a reduction in the direct and indirect
244 impact of the disease in the human population, namely on the burden of disease or cost-of-
245 illness. Equally, through its links to biosecurity messaging at farm level, it has the potential to
246 reduce the direct and indirect impact of disease in the animal population, ultimately
247 contributing to a reduction in human infection.

248

249 Intermediate or intangible benefits were identified, related to enhanced knowledge,
250 performance of risk assessments and triggering of research, such as intellectual capital, and to
251 social capital, generated through the intrinsic value of multi-sectorial collaboration and
252 networking.

253

254 The overall mitigation activities surrounding *Campylobacter* in Switzerland in the period 2009-
255 2013 had an associated cost of approximately 1.85 million CHF, corresponding to a yearly

256 average expenditure of approximately 370'000 CHF. This figure does not include mitigation
257 costs borne by industry as these were not available but known to be >0. The overall marginal
258 cost of such an enhanced effort was of 1.2 million CHF (over 5 years) in relationship with the 5-
259 year period 2004-2008 when the activities were mainly public-health based. Almost half (48%)
260 of the total expenditure in 2009-2013 was absorbed by commissioned research on
261 *Campylobacter* in Switzerland, followed by the surveillance and monitoring activities in poultry
262 and humans respectively. Table 3 shows the cost analysis results by system component for the
263 “One Health” approach.

264
265 The average total burden of disease of campylobacteriosis was estimated to be 1751 (95%
266 Confidence Interval (CI): 1478, 2069) to 2852 (95% CI: 2520, 3227) DALYs in 2013, in the best
267 and worst case scenarios respectively. This represents a 3.4-8.8% increase since 2008 when the
268 estimated burden of disease was of 1609 (95% CI: 1330, 1947) DALYs to 2756 (95% CI: 2412,
269 3140) (undiscounted). From the total results, 746-802 to 820-942 of the DALYs were related to
270 GE in 2008 and in 2013, respectively, with the remaining burden allocated to the disease
271 sequelae. The total DALYs correspond to 20.19-34.59 and to 21.96-35.08 DALYs/100'000
272 inhabitants in 2008 and 2013 respectively. Table 4 shows these results in more detail.

273
274 The “One Health” mitigation approach would recover its costs if 6 to 43.8 DALYs were averted
275 per year, depending on the cost-of-illness to DALY match estimate used in the break-even point
276 calculations.

277

278 Figure 3 summarizes the results of the cost analysis and burden calculation by showing the
279 evolution of costs per activity in the 10 years of the analysis and the campylobacteriosis burden
280 estimate from 2008 to 2013.

281

282 Figure 3. Costs of *Campylobacter* mitigation activities in Switzerland per activity undertaken, from 2004 to 2013 (CHF) and
283 estimates of overall campylobacteriosis burden of disease (DALYs) for 2008 and 2013 (best and worst case scenarios for
284 estimated true incidence).

285

286 In addition to the impact of the estimated true incidence input parameter showed above, the
287 sensitivity analysis indicated that, from the stochastic inputs to the model, changes in the
288 duration of symptoms of GE had the highest impact on the model outcome. One standard
289 deviation change in duration of GE symptoms would lead to a difference of 34.2 DALYs in the
290 overall DALY estimate.

291

292 **Discussion**

293 We assessed the costs and benefits associated with *Campylobacter* surveillance in Switzerland
294 from a “One Health” perspective.

295

296 Our results suggest that, in the first five years of the system, the level of the expenditure
297 increased with a cross-sectorial approach to surveillance and intervention for *Campylobacter* in
298 the country, particularly in research funding and surveillance activities in poultry. In the period
299 of this work, integrated surveillance information contributed mainly to the assessment of
300 trends, to perform risk assessments and to inform discussion on gaps and information needs

301 regarding *Campylobacter* in the country, thus contributing to the shaping of research efforts
302 and strengthening of the knowledge base regarding the disease. Consequently, in these initial
303 five years, the nature of benefits was intangible, including the generation of intellectual capital.
304 The latter relates to the intangible value (information, intellectual property, experience) in the
305 knowledge and relationships of employees, management staff, and other stakeholders of a
306 company or institution, that can be used, in the future, to generate wealth. In the public sector
307 context, measurement of intellectual capital and knowledge assets has been carried out by
308 universities and research funding institutions [39].

309
310 Such intellectual capital created by surveillance can later generate measurable value when it is
311 translated into control measures that mitigate the impact of the disease. In fact, from 2014, the
312 *Campylobacter* mitigation system in Switzerland shifted from a main focus on assessment and
313 knowledge-generation to the implementation of interventions targeting the food chain. New
314 national regulations in place from January 2014 require that poultry liver from *Campylobacter*-
315 positive herds can only be sold frozen and that pre-packed fresh poultry meat and meat
316 preparations should be labeled with information on the need to thoroughly cook the products
317 before consumption and on hygiene rules [6].

318
319 The timing of our analysis is therefore particularly relevant for the benefits assessment. A time
320 delay between initiating research and implementing interventions with possible health effects
321 can be expected. Furthermore, it can be expected that the power of an integrated surveillance
322 system increases with time as information is gathered and trends and sources are more

323 accurately identified. This has been shown with other integrated surveillance approaches such
324 as the Danish Integrated Antimicrobial Resistance Monitoring Programme [40]

325
326 The estimated burden of disease increased from 1609-2756 in 2008 to 1751-2852 DALYs in
327 2013. The increase of overall burden of disease in Switzerland of 96 to 142 DALYs from 2008 to
328 2013 reflects not only an increase in overall incidence of disease, but also a shift in the age
329 structure of cases, with a steady increase of case reports among the elderly aged above 65,
330 where the *Campylobacter* associated mortality rate is higher, from 49/100'000 inhabitants in
331 2004 to 100/100'000 in 2013 [6]. Simultaneously, an increase in chicken meat consumption
332 from 10.88 to 11.42 kg per capita has been observed in the country over the same period
333 (Proviande data). Such increase needs to also be interpreted considering that in the period of
334 this analysis there was no direct control interventions implemented in the food chain, and
335 therefore a direct health effect and measurable benefit of surveillance in this timeframe would
336 not be expected. Additional economic analysis further in time could allow understanding if
337 measurable benefits are generated by the intervention measures implemented from 2014
338 described above. Such benefits could be quantified by assessing the effect of the interventions
339 and by comparing it with baseline scenarios as described in studies estimating the cost-
340 effectiveness of interventions targeting *Campylobacter* along the food chain (reviewed in [23]).
341 Increasing the timeframe would allow to capture possible measurable health effects and to
342 estimate cost-effectiveness of the "One Health" when compared to uni-sectorial approaches.

343

344 The break-even point analysis for the “One Health” approach suggests that a return on
345 investment can be achieved with a small reduction in cases reported. Although this information
346 provides a perspective on how intervention costs can be recouped, it does not provide evidence
347 on how this system compares in terms of costs per DALY avoided with other mitigation system
348 designs. For *Campylobacter* in particular, a reduction in cases does not seem to be easily
349 achievable [41] as shown by the increasing trends on disease incidence until 2012 in most
350 countries facing this challenge. Interventions in the poultry meat production chain, such as
351 biosecurity alone, have limited effect and the most effective interventions such as freezing are
352 costly and face consumer acceptance constraints [41].

353
354 Some limitations to our estimates can be considered. The cost analysis and results for marginal
355 cost increase associated to the cross-sectorial mitigation efforts for *Campylobacter* in this study
356 focused on official surveillance programmes and interventions reliant on public spending. Yet, in
357 addition to the official surveillance and control activities, the poultry industry has also been
358 carrying out mitigation activities to tackle *Campylobacter* at *pre-harvest* and *post-harvest* levels.
359 Since our estimates do not account for the costs of such activities, our results are likely an
360 underestimation of the societal efforts in terms of expenditure in *Campylobacter* surveillance
361 and mitigation. In the same way, we did not exhaustively assess all benefit streams potentially
362 linked to surveillance integration. Fluctuations in terms of consumption and production due to
363 trade at the country level and potential alleviation effects on changes in consumer perception
364 and loss of sales could have implications in the overall benefits assessment from a societal
365 perspective. Benefits could therefore also be undervalued in this study.

366

367 Our DALY estimates of 21.98-35 DALYs/100'000 inhabitants in 2013 are in agreement with
368 results recently observed elsewhere in Europe. For other countries, the most recent estimates
369 point to a burden of campylobacteriosis of 19.8 DALYs/100'000 in the Netherlands [33] and of
370 28.4 DALYs/100'000 in Denmark [28]. However, the burden of disease estimation in this study
371 was limited by the fact that many parameters in the DALY model relied on assumptions and
372 data sourced from literature of studies developed elsewhere. Particularly, the underreporting
373 factor used to estimate the true incidence of *Campylobacter* associated disease in the human
374 population may be influential. In our estimation, we used a multiplier factor available in the
375 literature for Switzerland [23] as a best case scenario. That value was calculated using relative
376 risks to Swedish travelers as a proxy for relative incidence in local residents. There are many
377 caveats surrounding such calculations, namely underdiagnoses of travel-related cases, late
378 expression of symptoms and inability to attribute cases to countries, absence of information on
379 the nature and duration of travel and immunity in the resident population [42]. Preferably, the
380 construction of national disease surveillance pyramids should be informed by country-specific
381 information collected as part of multiplier studies [42] and involving data such as care seeking
382 behavior, probabilities of stool sample submission, positive laboratorial results reporting and
383 testing for a specific pathogen and the sensitivity of the laboratory tests [28]. Since multiplier
384 studies are not available for Switzerland, and the reported factor was inferior to all other recent
385 estimates of multiplier factors in Europe (reviewed in [28]), we also used a multiplier factor
386 calculated for the United Kingdom to model a worst case scenario. Similarly, the use of a
387 multiplier factor from another country can be disputed as differences in health care systems

388 may lead to bias [42]. The reliance on scenarios and data sourced from studies conducted
389 elsewhere, suggests that the human cases monitoring system based upon case reporting was
390 not generating sufficient information to be able to determine more accurately the burden of
391 disease in the country. Future burden of disease or cost-of-illness estimations would greatly
392 benefit from information on the parameters that seem impact the model results most, notably
393 human incidence and prevalence data.

394
395 Gains in information and knowledge have been recognized as benefits from One Health
396 approaches [43,44]. However, the lack of ability to measure the final outputs in tangible
397 indicators means that it is infrequent to have such benefits incorporated into economic
398 assessments. The same situation is observable in overall economic assessment of disease
399 control [45]. We believe that to accurately understand the added value of “One Health” and
400 surveillance integration for decision making, the assessment of these assets needs to be an
401 integral part of the analysis. This is particularly relevant for the surveillance systems that are at a
402 similar maturity stage, i.e. mainly informing assessment and producing knowledge, as the
403 *Campylobacter* mitigation system in Switzerland in the period 2009-2013. Further work on the
404 importance of these intangible assets generated by surveillance integration would enrich our
405 understanding of the economic aspects of zoonoses surveillance and policy making.

406
407 Overall, the framework used as the basis for economic assessment allowed the identification of
408 cross-sectorial cost items and benefits streams, associated to *Campylobacter* in Switzerland in
409 the period in analysis, through the conceptualization of its links to intervention. By providing

410 information on the economics of cross-sectorial surveillance of *Campylobacter* as well as the
411 tools for this assessment, the results of this work can be directly applicable and can inform
412 planning of effective and efficient future surveillance programmes for zoonoses. Such
413 assessments require an understanding of how information generated by surveillance is part of
414 the zoonoses mitigation process, and availability of data on costs of activities conducted and on
415 the impacts of such activities in terms of intangible and tangible benefits. The latter set of
416 benefits can only be accurately assessed if adequate surveillance information allows capturing
417 changes in disease dynamics in the populations.

418

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423

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427

428 **Declaration of interest**

429 None.

430

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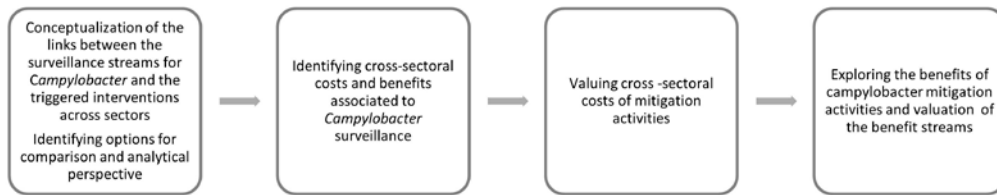
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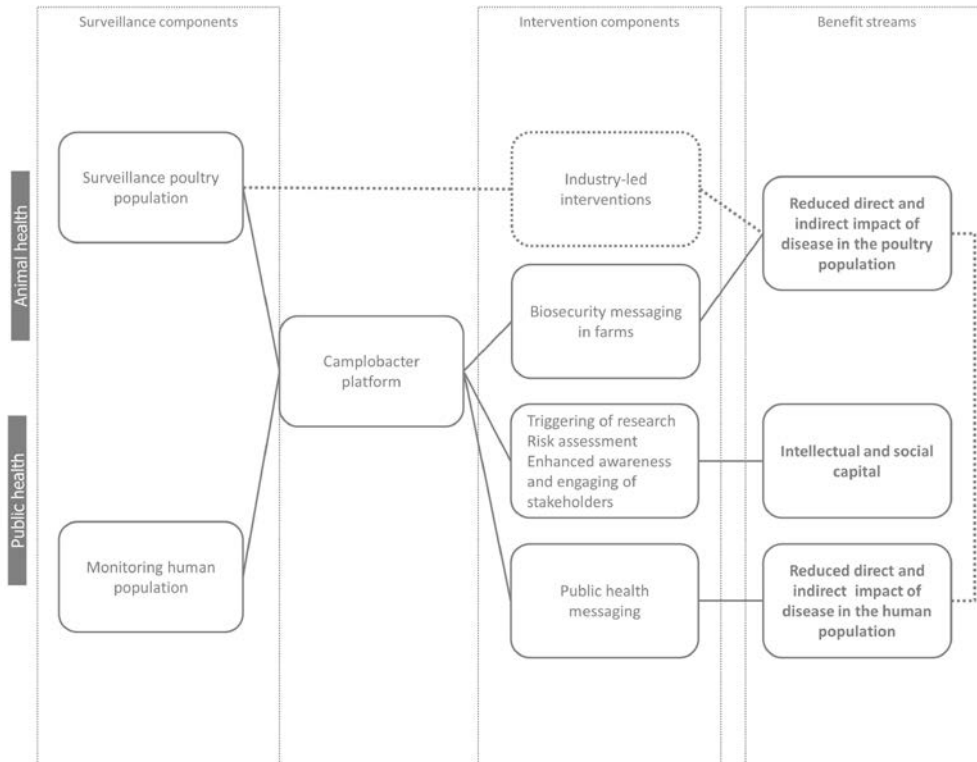
562 **Figure 1**



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565 **Figure 2**



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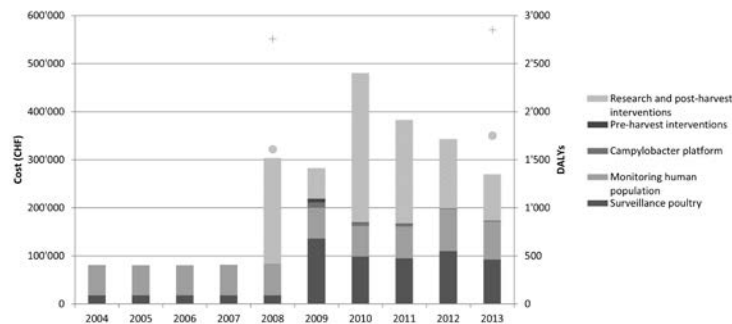
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 574 **Figure 3**
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581 Table 1. Inputs considered for the cost analysis per system component

Mitigation system component	Inputs considered for cost calculation
Surveillance programme in poultry	Working time involved in sample size calculation and sampling plan, planning of activities, sampling, data analysis, report writing, and dissemination activities; expenses with transport of sampling material, tests, shipment of samples and translation.
Monitoring programme of cases in humans	Working time involved in data management, analysis and dissemination.
Campylobacter platform	Working time involved in preparation and participation in meetings, and post-meeting activities including reporting of outcomes; expenses with transport costs.
Pre-harvest interventions	Working time on leaflets development and dissemination activities; expenses with printing.
Post-harvest interventions and research funding	Working time and expenses on commissioned research and public health messaging activities.

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586 Table 2. Inputs parameters for DALYs calculation and data sources

Parameter	Input	Source
Incidence of human campylobacteriosis	Reported cases per year and per age group (2004-2013)	FOPH
Underdiagnoses and underreporting factor	3.4 and 9.3	[23,29]
Health outcomes	Estimated true incidence	FOPH & multiplying factors
	Mortality. Calculated based on excess mortality risk for laboratory-confirmed cases (0.9). This multiplier was applied to age-specific mortality risk by all causes (Statistics Netherlands' data used as surrogate)	[32,33]
GE*		
	Calculated based on:	[33]
	- Probability of having RA for a GE patient visiting a GP (RiskBeta (46;565)),	
RA**	- Probability of a patient with RA seeking care for (RiskBeta (10;37)),	
	- Probability of hospitalization for RA patients who visit a GP (RiskBeta (2;45))	
IBS [‡]	Pert (7.2; 8.8; 10.4)	[34]
IBD [#]	Calculated based on the age specific risk of IBD and the excess risk IBD	[33]
GBS [^]	Beta(60;29,942) Mortality: RiskPert (0.01;0.02;0.05)	[35]
Duration of illness (years)	GE (diarrhea)	Pert (0.007;0.02;0.09)
	RA	0.608219178
	IBS	5
	IBD	Life-long
	GBS	Life-long
Disability weight		Mild: 0.061
		Moderate: 0.202
	GE (diarrhea)	Severe: 0.281
		Overall: 0.1049555
	RA	0.21
	IBS	0.042
	IBD	0.26
	GBS	0.445
Life expectancy	Men: 80.5 / Women: 84.8 /Average: 82.65	Swiss statistics
Onset of disease and average age at death	Average age of the population group	
Hospitalization	14.5%	[5]

587 *GE: gastroenteritis; **RA: reactive arthritis; ‡IBS: irritable bowel syndrome; #IBD: irritable bowel disease; ^GBS: Guillian-Barré syndrome.

589 Table 3. Estimated cumulative cost of the “One Health” mitigation system per component, in the period
590 2009-2013 (in CHF)

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Mitigation system component	Estimated cost in CHF, 2009-2013
Surveillance programme in poultry	531'000
Monitoring programme of cases in humans	358'570
Campylobacter platform	66'700
Pre-harvest interventions	8'340
Post-harvest interventions and research funding	884'900

602 Table 4. Estimated total DALYs, YLD and YLL associated with campylobacteriosis in Switzerland in 2008
 603 and 2013 in two scenarios of estimated total incidence (BCS: best case scenario; WCS: worst case
 604 scenario). The results are expressed in mean and 95%CI

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		2008	2013
Reported cases		7384	7473
Estimated total cases	BCS	27906 (27534,28281)	28442 (28064, 28828)
	WCS	75516 (74889,76137)	76470 (75838, 77090)
Estimated deaths	BCS	50 (37,65)	64 (49,80)
	WCS	49 (36,73)	64 (49,80)
DALY total	BCS	1609 (1330, 1947)	1751 (1478, 2069)
	WCS	2756 (2412,3140)	2852 (2520, 3227)
DALY/case	BCS	0.057	0.061
	WCS	0.036	0.037
DALY /100,000	BCS	20.32	21.98
	WCS	34.59	35.08
YLD	BCS	926 (774,1102)	990 (842,1163)
	WCS	2071 (1844,2335)	2075 (1842,2339)
YLL	BCS	678 (451,970)	757 (540,1031)
	WCS	681 (437,972)	781 (549,1058)

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