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Integrating epidemiological and economic models to identify the cost of foodborne diseases

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(Article begins on next page)

1 **Title**  
2 **Integrating epidemiological and economic models to identify the cost of food-borne diseases**

3  
4 **Authors**

5 ARAGRANDE Maurizio<sup>a</sup>

6 CANALI Massimo<sup>a</sup>

7  
8 (a) Department of Agricultural and Food Sciences, University of Bologna, via Giuseppe Fanin 50,  
9 40127 Bologna (I)

10  
11 Corresponding author: Maurizio Aragrande, [maurizio.aragrande@unibo.it](mailto:maurizio.aragrande@unibo.it), Department of  
12 Agricultural and Food Sciences, via Giuseppe Fanin 50, 40127 Bologna (I)

13  
14 **Abstract**

15 Despite food technology advancements, food safety policies, and alert systems, food borne diseases  
16 are still a relevant concern for consumers and public health authorities, with great impacts on the  
17 economy and society. The economic evaluation of food-borne diseases is needed to design  
18 appropriate interventions. The first step of this process is the identification of the potential cost of  
19 the disease , which requires a conceptual framework based on system thinking and inter/trans-  
20 disciplinary. This paper proposes a simple method for cost identification of food-borne diseases,  
21 accessible to researchers and practitioners who are not specialist in economics. The method is based  
22 on the assumption that epidemiology and economics should integrate their approaches to analyse  
23 the disease consequences in a wider socio-economic perspective according to a systems view. To  
24 this aim, the authors first focus on the links between epidemiological and economic models, i.e. how  
25 food-born disease outcomes impact on efficient use of economic resources . Then they show how  
26 simple economic models, such as the food-supply chain, can be used to identify a wide range of  
27 consequences determined by the food-born diseases across economic sectors and society.

28  
29 **Keywords:** cost, foodborne diseases, food supply chain, system thinking, interdisciplinarity,

30  
31 **Highlights** (3-5 bullets, 85 caratteri/bullet)

- 32 • Identifying food-born diseases cost needs system thinking and interdisciplinarity  
33 • Epidemic and economic models can be integrated for cost identification  
34 • Food supply chain model can guide to identify cost across sectors and the society

35  
36  
37 **Abbreviations**

38 BOD: burden of disease

39 CBA: cost benefit analysis

40 COI: cost of illness

41 COST: Cooperation for Science and Technology

42 DALY: disability adjusted life years

43 Echin. Gran.: Echinococcus Granulosus

44 EFSA: European Food Safety Agency

45 EFTEC: Economics for the Environment

46 EU: European Union

47 FAO: Food and Agriculture Organization

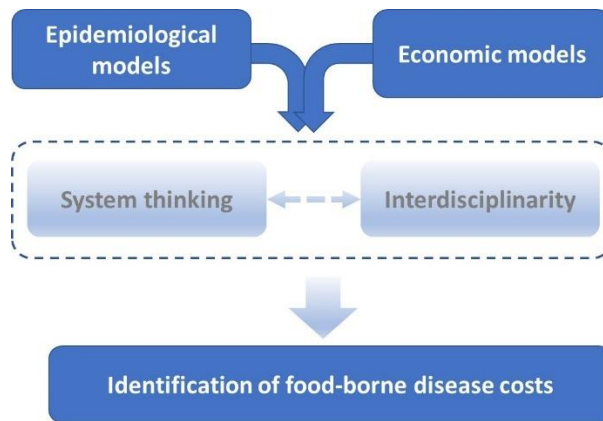
48 FBD(s): foodborne disease(s)

- 49 FBP(s): foodborne parasites
- 50 FSCh(s): food supply chain(s)
- 51 NEOH: Network for the Evaluation of One Health
- 52 OECD: Organization Européenne pour la Coopération et le Development
- 53 OH: One Health
- 54 OIE: (Office Internationale des Epizozies) World Organization for Animal Health
- 55 QALY: quality adjusted life years
- 56 WHO: World Health Organizations
- 57 WTP: willingness to pay

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60 **Graphical abstract**

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## 1. Introduction

Food borne diseases (FBDs) include a wide range of diseases which hit human beings in different ways and through different transmission mechanisms (Dorny et al., 2009; EFSA, 2018). They are spread worldwide taking lower or greater importance depending on the specific contexts (Todd 1988; Van DeVenter, 2000, OECD-WHO, 2003; Kaferstein et al., 2007; WHO 2015; Seimenis and Battelli, 2018;). The knowledge of FBD epidemic models and associated costs are key information to conceive health policy strategies to limit effects on population and society (Dewleeschauwuer et al., 2017). Due to the complexity of transmission mechanisms, there are still gaps in the specification of FBDs epidemic models and the quantification of cases and health consequences (Flint et al., 2005; Robertson et al., 2018), and this undermine the evaluation. A large stream of scientific production on FBDs' effects is dedicated to the calculation of the burden of diseases (BOD) which leans on the concept of health losses, usually measured through disability adjusted or quality adjusted life years (respectively DALY and QALY). These are non-monetary measures at individual level that can be aggregated at higher levels (e.g. population layers, social categories, geographical context) with relevant advantages in epidemic studies (WHO, 2015). This method reflects a sectoral approach to the evaluation because it focuses health consequences and do not consider the complexity of effects determined by FBDs in the larger context of the economy and the society. Secondly, from an economic perspective, BOD monetization puts some conceptual and material problems which monetary approaches, such cost of illness (COI), willingness to pay (WTP) and cost benefit analysis (CBA) try to overcome. WTP bypasses the problem of disability monetization by assessing individual propensity to investing money to avoid adverse health outcomes (Roberts, 2007; EFTEC, 2017). COI includes both direct costs (those directly born by public health system and private citizens to implement disease therapies) and indirect costs (e.g. the consequences of the BOD on the economic and emotional status of the patient and the loss of productivity) (Scharff, 2012, Changik, 2014). Social CBA focuses an even wide range of situations which suffer directly and indirectly the consequences of FBDs, i.e. not only the patients and the loss of productivity but also the cost born by the activities linked to the food vehiculating the disease along the food production system (Robertson et al., 2018; Suijkerbuijk et al., 2017). These approaches go beyond the sectoral limitation of the mere disability quantification and extend the evaluation across sectors (health care system, production system). At empirical level, costs arising from FBDs are manifold. They are often categorized according to classification criteria (Carabin et al., 2005; Gadiel 2010; Jansen et al., 2018), extensive meta-analysis of the scientific literature also provides empirical information about the types of cost that researchers include in their evaluation (Buzby and Roberts, 2009; Belaya et al.; 2012, McLinden et al., 2014;), while some works focus evaluation domain usually not considered in the prevailing evaluation literature such transnational perspective, cost of product recall for distributors, sales reduction following food alert, cost of compliance, etc. (OECD-WHO, 2003; Kaferstein, 2007; Ribera et al., 2012, Hussain, 2013).

It's not among the aims of this paper to review the evaluation methods, their pros and cons or their implementation limits, but to first stress that most evaluation studies pay poor attention to how (i.e. according to what conceptual framework) costs are identified or listed. Cost identification is a preliminary step in the evaluation process (Drummond et al., 2015). It logically foreruns cost quantification, of course the most important and expected result of economic evaluation, capturing the greatest attention at scientific and political level. Several reasons stand for focusing cost identification and the way it is performed. Zoonosis determine multiple effects which expand from the individuals to the society according to trans-sectoral pathways. Managing this complexity requires specific conceptual approaches which can capture the whole range of effects occurring in the society, as much as the current scientific knowledge allows for. Reasoning in terms of complexity

113 requires in turn that inter- and trans-disciplinary work-routines are developed among the different  
114 actors (e.g. institutions, researchers, health practitioners and administrators, social bodies). This  
115 approach can lead to the creation of a common expanded knowledge which can be shared and  
116 criticised to increase the effectiveness of the research, the social awareness of the consequences,  
117 and finally support rational decision-making process.

118 The EU funded COST Action “Network for the Evaluation of One Health” (NEOH, COST Action TD  
119 1404) developed a method for the evaluation of One Health initiatives during its mandate (2014-  
120 2018) (<http://neoh.onehealthglobal.net/>). NEOH approach focuses in particular the evaluation of  
121 One Health initiatives in view of assessing the effectiveness of OH approach in comparison with  
122 current traditional approaches to health. It goes through four main elements: (i) defining and  
123 describing the OH initiative and its context (i.e., the system, its boundaries, and the OH initiative as  
124 a subsystem); (ii) assessing expected outcomes based on the theory of change (TOC) of the initiative,  
125 and collecting unexpected outcomes emerging in the context of the initiative; (iii) assessing the “OH-  
126 ness”, i.e., the implementation of operations and infrastructure contributing to the OH initiative; (iv)  
127 comparing the degree of “OH-ness” and the outcomes produced (Rüegg et al, 2018). Beside the  
128 specific aim mentioned above, NEOH approach combines in a coherent framework a set of  
129 conceptual tools (namely system approach, inter- and transdisciplinary, theory of change) which  
130 allow tackling complexity of health problems in their context. These tools can be applied to build up  
131 a framework for the identification of FBDs cost which reflects the complexity of FBDs effects across  
132 the society, according a cross-sectoral systemic view and in line with OH concept.

133 The aim of this paper is to provide elements and suggestions about the possibility to fill the gap,  
134 which apparently exists in the current literature, concerning the methods to identify FBDs costs. In  
135 this paper we focus in particular the role of system thinking and interdisciplinarity in the  
136 identification of disease effects of FBDs, providing a simple way to identify disease consequences  
137 and costs. A key step on this way is to show how different disciplinary domains, namely epidemiology  
138 and economics, can work together by integrating epidemic models and economic models. First, we  
139 will briefly recall the basic concepts forming the conceptual background (§ 2); then we will focus on  
140 how they can work together in view of the objective of this paper (§ 3); finally we will draw  
141 conclusions and consideration about the utility of the effectiveness of the proposed method.  
142

## 143 **2. Materials and methods**

144 Given the aim of this paper, materials and methods are basically of conceptual nature and they  
145 concern system thinking and inter-/trans-disciplinarity, and the meaning of epidemic and economic  
146 models, focusing in particular the food supply chain (FSCh) model.

### 147 **2.1. System thinking and inter-/trans-disciplinarity**

148 System thinking and inter-disciplinarity are increasingly used to solve complex problems (including  
149 health related ones) where traditional approaches, based on linear causation, mono- or multi-  
150 disciplinarity, fail or show limits in problem understanding and problem solving. Systems thinking  
151 covers a wide range of concepts and theories (Hofkirchner and Schafranek, 2011). Adopting a  
152 system view or approach implies that we examine a problem as part of a wider context, where it  
153 represents an element connected with other elements by complex, dynamic relationships. At the  
154 operational level, this approach is increasingly applied to health and related issues and policies (de  
155 Savigny and Taghreed, 2009; Anderson, 2016; Hitziger et al, 2018;). According to Meadows (2008)  
156 a system is “A set of elements or parts that is coherently organized and interconnected in a pattern  
157 or structure that produces a characteristic set of behaviors, often classified as its function or  
158 purpose.”. The definition suggests that a system can be articulated in units of different nature,

159 connected with each other by different kind of interactions (direct and indirect causation, feedbacks  
160 or loops, of different sign and intensity). Partitions (sub-systems) may appear within a wider system,  
161 showing a relative homogeneity or similarity in relation to the effect they produce or the role they  
162 play in the general framework. The identification of system limits is a crucial aspect for system  
163 thinking to be effective, avoiding undue expansion of the system. Limits may arise from objective  
164 scientific criteria or practical consideration thus they may subjective as they depend from the  
165 observer's interpretation of the reality, but should not be considered arbitrary.

166 Inter- and trans-disciplinarity are functional to system thinking, as system complexity cross the  
167 boundaries of scientific disciplines, sectors or institutional competencies. Differently from mono-  
168 and even multi-disciplinarity, interdisciplinarity *"involves the integration of perspectives, concepts,*  
169 *theories, and methods to address a common challenge"* (Rüegg et al., 2018), while trans-disciplinarity  
170 goes beyond the boundaries of academic knowledge by involving institutions, communities and  
171 social parties in the building up of new knowledge. Implementing inter-/trans-disciplinarity needs  
172 participative practices and teamwork organization as well as specific methods to elicit and  
173 synthesize across multiple point of views. These are quantitative and qualitative methods well  
174 rooted in team or project management and decision support (i.e. stakeholder analysis, multicriteria  
175 analysis, Delphi technique, and similar). Also, simple tools can be conceived to ease interdisciplinary  
176 team working in the day-by-day routine (Aragrande and Canali, 2015).

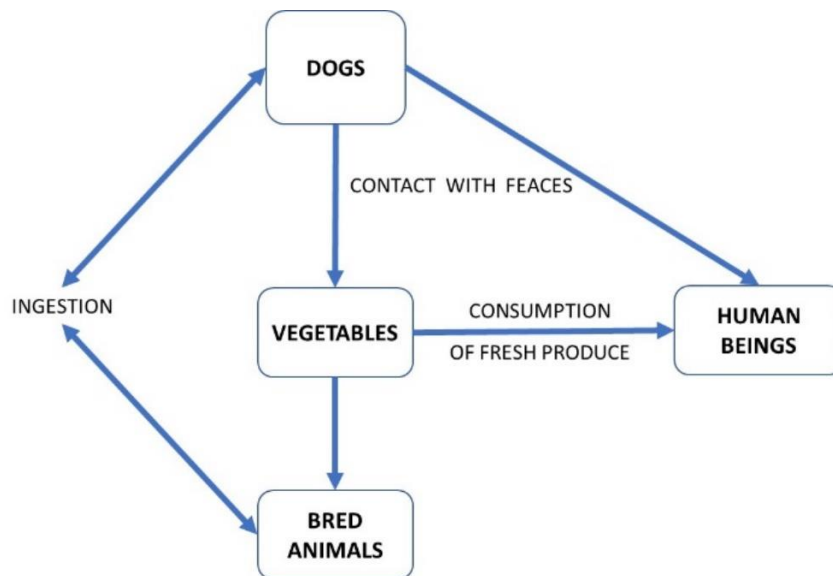
## 177 **2.2. Epidemiological models**

178 According to Hethcote (1989) *"an epidemiological model uses a microscopic description (the role of*  
179 *an infectious individual) to predict the macroscopic behavior of disease spread through a*  
180 *population"*. According to Keeling and Ames (2007) mainstream disease models basically *"describes*  
181 *the number of individuals (or proportion of the population) that are susceptible to, infected with*  
182 *and recovered from a particular diseases"*, making reference to the *"foundations of almost all of*  
183 *mathematical epidemiology: the susceptible-infectious-recovered (SIR) model."*. Though an  
184 equivalent definition doesn't exist on the veterinary side, in this context an epidemiological model  
185 has been defined as a *"mathematical and/or logical representations of the epidemiology of disease*  
186 *transmission and its associated processes ... among animals, and/or among groups of animals, in*  
187 *time and/or space"* (Willeberg et al, 2011). Because of their quantitative nature, epidemiological  
188 models lend to simulation and find their most useful application in the management of health crises  
189 and to test the effectiveness of possible intervention strategies (Dubé et al, 2007), given that  
190 *"Experiments with infectious disease spread in human populations are often impossible, unethical*  
191 *or expensive"* (Hethcote, 1989). The above-mentioned definitions allow for the assumption that an  
192 epidemiological model can be considered a system in itself, where units and subsystem of different  
193 nature and dimension show specific behaviours (of biological or social nature) and interact  
194 according to complex relationships (transmission mechanisms), determining effects at different  
195 levels and in different contexts (e.g. human or animal diseases, the environment, the economic  
196 sectors). Often epidemiological models are described graphically to outline complex relationships  
197 and effects (Figure 1). This approach is well grounded in epidemiology (Joffe et al, 2012; EFSA, 2018)  
198 and in many applications of the systems theory ( Anderson and Johnson, 1997; Meadows, 2008;)  
199 not only as an alternative to wording but as a tool to ease and improve understanding.

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**Figure 1 - Elementary epidemiological model of Echinococcus Granulosus**  
 The figure is a simplified and generic representation of the epidemiologic model of Echinococcus Granulosus (*Echin. Gran.*) where the white boxes are the intermediate and final hosts, and the blue lines the ways of transmissions.

### 2.3. Economic models

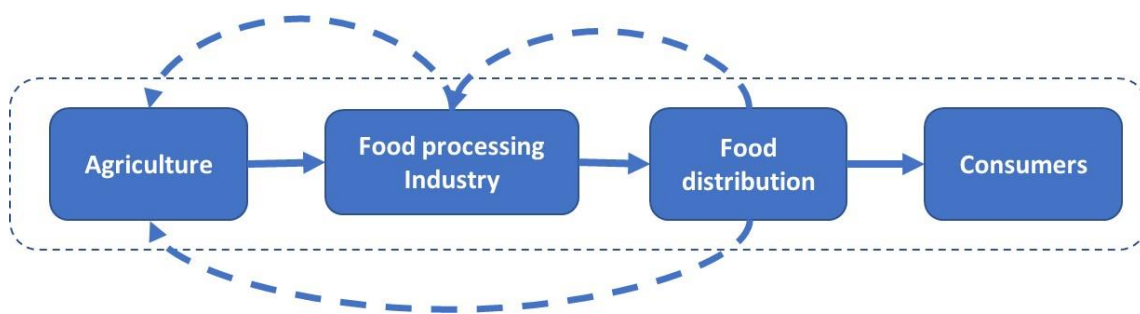
An economic model is a conceptual tool to represent economic phenomena, i.e. how relevant economic variables interact to produce economic effects. A cartesian diagram of the market, where demand and supply functions are represented in relation to price and quantity, well represents the basic idea of an economic model. In its simplicity, this model (as well as many others in economics) allows to explain and predict the result of economic behaviour (e.g. consumer and producer behaviour in reaction to price variation) on the basis of the assumption (at the core of the economic science) that resources (i.e. anything can be used to create some kind of utility for the individuals and the society) are scarce. Resource scarcity implies that a rational choice is needed to allocate them among alternative uses to get the maximum utility; and that when a resource is allocated in a use, the utility it could produce in an alternative use is lost (the so-called opportunity cost, which is at the core of the common concept of cost in economics) (Canali et al, 2018). When resources are destroyed or their ability to create utility is limited, resource efficiency (i.e. the amount of utility a resource can create) is lost; this loss is a cost for the individuals and the society. In economic terms, diseases are events which reduces the efficiency of resources (human beings and animals) to some extent. Said in other words, pathologies alter the health status of humans and animals and affect their efficiency in the creation of economic utility, causing welfare losses, or costs, that are the object of the economic evaluations. The same way, human actions to prevent, contain or eliminate diseases also imply the decision about the allocation of limited (usually monetary) resources, determining private and public costs. The economic evaluation assesses the cost of the diseases and supports the decisions making of individuals, businesses and/or public administrations about the health measures to undertake for reducing disease impacts and social costs. Efficiency losses of resources can be assumed as the functional and conceptual link between epidemiology and human and animal health economics (Howe, 1988). A wide list of costs can be identified depending on the type of pathogen, the transmission mechanisms and the social and economic behaviour: e.g. costs of medical and hospital cares, hours of work lost by affected humans and their relatives involved in patient care, costs of veterinary treatment for companion and farm animals and related additional work for farmers, livestock losses and related costs for carcass disposal, losses of values along the



237 food supply chain, for example due to food alert (Aragrande and Canali, 2017), animal welfare losses  
238 ( Vetter et al., 2014; Gibson and Jackson, 2017), costs of disease monitoring and surveillance. As  
239 mentioned above, cost listing is usually made apparently without a conceptual framework that  
240 could provide health operators (researchers of different academic domains, health administrators,  
241 health institutions) with general guidelines to identify diseases consequences and cost before (or  
242 independently) from their quantification and evaluation. While quantification and evaluation  
243 require disciplinary and technical competences, the mere identification of consequences would  
244 benefit from the close cooperation among different disciplines in a comprehensive inter-disciplinary  
245 framework. The identification of the economic consequences of any disease may be operated by  
246 integrating the epidemiology of the disease (the epidemiological model) and the economic functions  
247 of the impacted entities (the economic model).

248 Among the many economic models, the food supply chain model (FSCh) may prove effective for the  
249 aim of this paper. The FSCh identifies the series of technical steps leading from raw material to  
250 product(s) across economic sectors (agriculture, processing, distribution). It's graphical  
251 representation is usually linear but it can include side complementary activities of the production  
252 system which develop around a product. More recent applications of the FSCh model in agro-food  
253 economics (Malassis and Gherzi, 1996) focus the complex relationships occurring along the food  
254 supply chain which determine its structure, functioning and socio-economic performances (i.e.  
255 production capacity, competitiveness, distributional effects, job creation, etc.). In this sense a FSCh  
256 (Figure 2) may be seen as a sub-system, nested in the wider context (the agro-food system, the  
257 socio-economic system), made of actors controlling technological units (blue boxes, corresponding  
258 to economic sectors), linked each other by commercial flows of goods (straight lines), where some  
259 actors may influence the behaviour of other actors by way of economic, normative and social  
260 relationships (dashed lines). This also allows for inter-disciplinary perspective of the analysis, making  
261 FSCh model a very flexible tool lending to systemic and inter-disciplinary contamination which may  
262 provide useful elements to understand disease transmission and to identify consequences in a wider  
263 context, especially in the case of FBPs and FBDs. In the next section we develop an exercise to show  
264 how this can be done.

265



266

267 **Figure 2 – Elementary representation of a food supply chain**

268 The figure represents an elementary FSCh. The classic partition of the economic system is made of  
269 sectors (e.g. agriculture, industry, services), while the FSCh concept gathers together the activities  
270 of each sector which participate to a same aim (food production) and the consumers (dashed line  
271 box) and outlines possible feedback and relationships among sectors (dashed lines) beyond the  
272 typical product flow among sectors regulated by classical market relationships (full lines), in line  
273 with the system approach.

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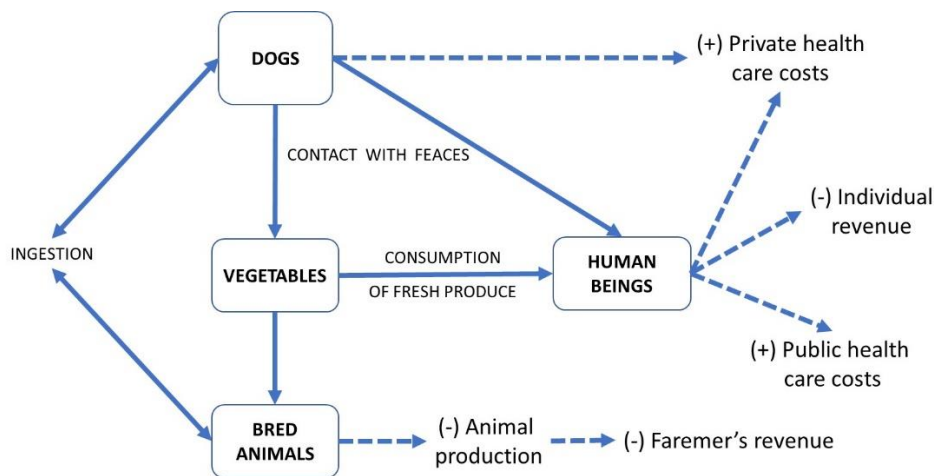
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### 3. Result



276 In this section we propose an exercise of cost identification based on the conceptual tools described  
 277 in the former section. We will refer to the case *Ech. Gran.* described in Figure 1 and we will apply  
 278 simple reasoning to show how epidemiological and economic models can work together to the aim.  
 279 For sake of exemplification we will also take some freedom or assumptions in the identification of  
 280 the possible scenarios determined by the parasite. The starting point of the exercise may be  
 281 subjective, determined by the individual understanding or by the disciplinary background of the  
 282 observer. Looking at Figure 1, and considering that economics deal with the use of resources, a good  
 283 starting point is the identification of the resources outlined in the figure, namely human beings,  
 284 production and companion animals, fresh produce. The specific health outcomes of *Ech. Gran.*  
 285 suggest that human beings may lose to some extent the ability to work which means lost working  
 286 days and revenue, and bear private health care cost to re-establish from the disease. Depending on  
 287 the local health care system, public health care cost may also increase. *Ech. Gran.* in bred animals  
 288 may result in production losses (in this case, liver or carcasses condemnation) which ends in reduced  
 289 meat sales and revenue losses for the farmers. Fresh produce may vehiculate *Ech. Gran.* especially  
 290 to human being through the ingestion of contaminated materials like salads, fruits and even fruit  
 291 juice (EFSA, 2018) not subject to health treatment. Differently from meat, fresh produce doesn't  
 292 undergo systematic controls by health authority, in a way that contaminated fresh produce directly  
 293 enter the food chain (increasing the exposition and the risk for consumers) but do not generate  
 294 immediate losses for the farmers. Pets generally do not show symptoms of *Ec. Gran.* and are not  
 295 meant to produce marketable goods (just utilities for their owners). Assuming, as a mere fictional  
 296 scenario, that they suffer some health consequence, their owners might be willing to spend money  
 297 for care, thus increasing private health care cost (Figure 3).

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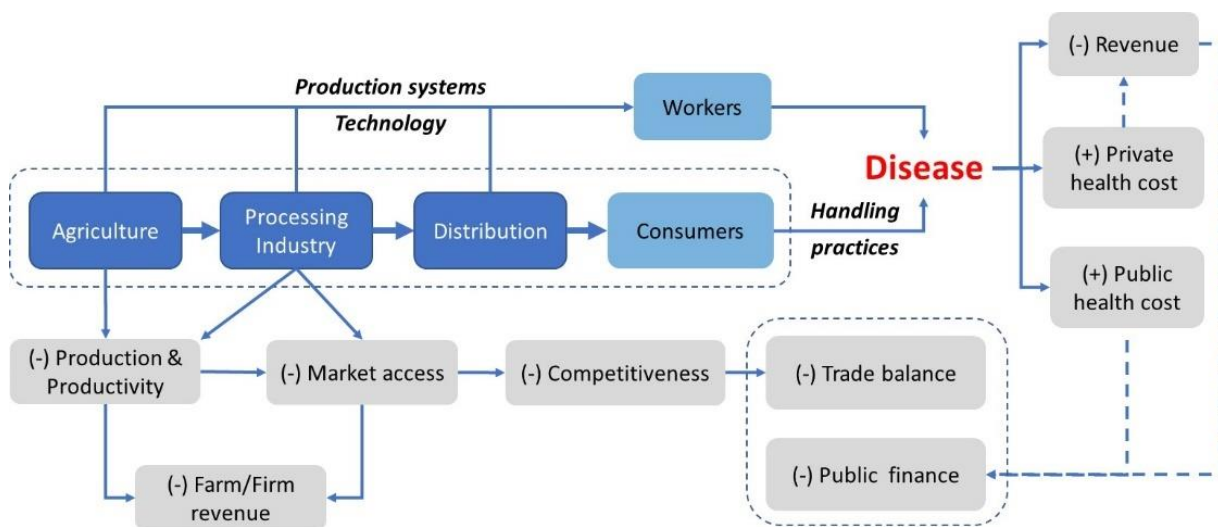
300 **Figure 3 – Economic outcomes of *Ech. Gran.***  
 301 In this figure we consider that the basic biological units of the epidemiological model (or system)  
 302 represented in Figure 1 are economic resources. As resources they have an economic value and a  
 303 role for the economy (or the economic system) which is altered by the disease. This translates  
 304 directly in productivity losses or in expenses in view of re-establishing the original productivity of  
 305 the resource, as outlined by the dashed lines

306

307 The figure can be further elaborated expanding the range of relationships from the individual or  
 308 sectoral perspective (the micro-economic and sectoral dimension of the economic system, figured  
 309 by private consumers, agricultural sector, health sector) to the wide inter-sectoral and macro-  
 310 economic dimension (i.e. identifying the relationship between the sub-system and other sub-system

311 and the wider system). Just to exemplify, should health consequences of *Ech. Gran.* acquire a  
 312 relevant epidemic dimension and/or the damages acquire a sectoral dimension, macro-economic  
 313 effects could become important: reduction of tax revenue, public budget limit, loss of competitiveness,  
 314 trade balance deficit should be considered. This scenario is a fictional hypothesis and doesn't pertain  
 315 current *Ech. Gran.* epidemiology but often occurs in disease outbreaks of major relevance when  
 316 food alert and food occur. In those cases consumer's behaviour may change dramatically  
 317 determining reversed effects backward along the FSCh with unexpected distributional effects in the  
 318 economy and the society (Elci, 2006; James, 2006; Otte et al., 2006; FAO, 2016; Ramos et al, 2016;).

319 The reasoning above shows how the relevant units of an epidemiologic model (or system) involved  
 320 in the transmission mechanism meet units and categories of the economic system allowing for a  
 321 first identification of units or actors which suffer economic losses, and the kind of cost they may  
 322 incur. A further structuration of the exercise in cost identification can be performed adopting the  
 323 FSCh model and its expansion. Figure 4 synthesizes the result of the exercise.



324

325 **Figure 4 - Cost identification of FBDs based on FSCh model**

326 This figure builds on the diagrams of Figure 2 and 3 to identify the wide range of effects and costs  
 327 associated to the disease. Elements of the epidemiologic models are outlined in relation to  
 328 production technology and consumer's handling practices. Secondly, grey boxes outline the  
 329 economic mechanisms leading to sector and social costs in the wider economic system.

330

331 FBPs models show how parasites arising somewhere in human activities may affect different types  
 332 of food and reach human beings. Following the FSCh steps parasites pass through the processing  
 333 industry and the food distribution system and reach the consumer level. From a FSCh perspective,  
 334 meat and fresh produce depict different cases because of the different processing technologies they  
 335 go through and the different consumption habits of consumers (salads are washed but not cooked;  
 336 industrial washing systems may not be effective on the parasites, depending on the technology and  
 337 the biosecurity practices, etc.). Further, not only consumers but also FSCh workers might be exposed  
 338 to disease risk. Regulation on controls along the FSCh differs between the two FSCh. The above-  
 339 mentioned situations indicate that the same parasite can create different distributional effects of  
 340 economic relevance, i.e. who bear what kind of cost along the two FSCh and inside the same FSCh.

341 The lower side of the diagram focuses the effects born by the supply chain sectors. Depending on  
 342 the effects of the diseases on production animals, both farmers and meat processing industry (e.g.  
 343 slaughter-houses) may suffer production and productivity losses which determine lower market

344 access and profit losses. Fresh produce processors may be less exposed to this effect in the short  
345 run, but they may suffer the same effects later on, in case of a demand reduction following food  
346 scare. This consideration suggests another perspective for cost identification as distributional  
347 effects and related costs may change over time (immediate, short, medium or long period) and in  
348 relation to FSCh actors to food alert.

349 Side effects of a shortening of domestic production can lead to supplier substitution (i.e. food  
350 processors and food distributors might change food supplier) and/or product substitution (in case  
351 of food alert, consumers might decide to change product category to satisfy their needs of meat or  
352 fresh produce), paradoxically determining positive effects to competing producers or to the  
353 economic sectors producing substitute products. Through different ways, the competitiveness of the  
354 FSCh at some geographical dimension would be reduced. Depending on the epidemiological  
355 dimension of foodborne disease, typical macro-economic variables could be affected: lower  
356 domestic production translates into higher import to satisfy the domestic demand (trade  
357 imbalance), while at the same time increased public health cost may demand more public funding  
358 to the detriment of alternative public expenditures. Given the usual dimension of FBDs, the latter  
359 scenario is to be considered merely fictional, but local effects might be relevant. Economic effects  
360 also have a spatial dimension

#### 361 **4. Concluding remarks**

362 Methods for the identification of disease effects are a relevant preliminary step of evaluation which  
363 usually receive poor attention from the researchers in favour of the quantitative assessment  
364 through monetary and non-monetary metrics. In this paper we provided some reflection on this gap  
365 and forwarded some suggestion to outline the relevance of this activity. In particular we tried to  
366 show that interdisciplinary work and system thinking can be easily implemented by integrating  
367 epidemic models and simple, well rooted economic models, such food supply chain, a concept  
368 widely used and referred to (implicitly or explicitly) by scientists and researchers from different  
369 disciplinary domains but usually not included in a general comprehensive framework to assess  
370 disease effects and related costs.

371 In FBDs, food consumption is the ending point of various activities occurring at different points in  
372 time and space, across different biological systems, the environment and the socio-economic  
373 system. This makes difficult to understand the complexity FBP and FBDs for both epidemiology and  
374 economics when an evaluation task must be performed. Using the food-supply-chain model as the  
375 analytical unit for the evaluation of FBD effects may ease the task for a scientists, administrators,  
376 practitioners who are not specialist in economics but would like to embed their specific knowledge  
377 in a wider (system) context. From an operational perspective, the exercise we developed led to the  
378 identification of the distributional effects of a FBD in different directions (i.e. sub-systems). We  
379 reasoned about the way FBD may hit consumers, in relation to their consumption habits and food  
380 handling practices; economic sectors (agricultural production, industrial processing, food  
381 distribution) depending on production systems and processing technologies; social categories  
382 depending on their position along the food supply chain (consumers of different type of food, and  
383 FSCh workers). Other considerations concerned the way relevant elements of the epidemiological  
384 disease (i.e. fresh produce vs meat) can start different series of economic effects depending on food  
385 practices and technologies and institutional settings (e.g. the type of controls imposed by the public  
386 health system on different type of food). Finally, we suggested that disease effects and costs can be  
387 distributed along the timeline (by including possible reactions of consumers and producers to food  
388 alert), the space (potential effects of supplier substitution in geographically defined markets) and  
389 within the food supply system (product substitution that could paradoxically benefits some  
390 producers during the food scare).

391 The other face of the medal is the difficulty of integrating conceptual models from different  
392 academic disciplines and institutions, an aspect which call into question the inter-disciplinary and  
393 trans-disciplinary and the way different knowledges can be coordinated. In practice, team working  
394 is probably the frontline of interdisciplinarity (Aragrande and Canali 2015). Simple tools of team  
395 management do exist and can be easily implemented, but this requires some investment (usually  
396 time and organization) to be evaluated in a cost-benefit perspective (how much understanding and  
397 problem solving can improve against the above-mentioned investment?). The increasing trend  
398 toward One Health approach to health problems may provide some indication and motivation in  
399 this sense.

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#### 582 **Auhtors' biography**

583 **Maurizio Aragrande** is associate professor at the Bologna University where he teaches Agro-food  
584 economics and Agricultural policy (Veterinary Faculty). He also teaches Political economy at the  
585 University of Modena, Faculty of law. Research concerns the economics of the agro-food system, animal  
586 product supply chains, animal health economics and policy measures evaluation. He collaborated with  
587 FAO to built up a system, interdisciplinary approach to study urban food distribution systems in Wester  
588 Africa; developed evaluation studies for the European Commission and the European Parliament; and is  
589 currently involved in national and international evaluation studies on animal health policies and One  
590 Health.

591

592 **Massimo Canali** is senior researcher at the University of Bologna, where he teaches agricultural  
593 economics and policy, environmental economics and economic geography. His research is mainly  
594 concerned with sustainable development of agriculture and food systems by focusing on animal and  
595 environmental health economics and One-Health. He has a large experience of international research  
596 and development projects and is presently involved in economic evaluations related to the control of  
597 animal and zoonotic diseases in Italy and is Work Package Leader in the European H2020-project  
598 ROADMAP for a more prudent use of antimicrobials in livestock farming.