The presence of food-borne disease in food systems creates direct and indirect economic impacts. These include the losses caused by the negative effects of disease itself when people are ill or die leading to reduced productivity, loss of income, and human suffering. In animal populations, similar losses occur when animals are ill or die leading to production losses and/or animal welfare issues. To avoid such losses, efforts to prevent, control or eradicate disease can be undertaken but in return also generate economic costs. Economic analyses in this context investigate how resources are allocated to activities and how to balance direct losses against expenditure to reduce the impact of disease.

When considering economic aspects of surveillance, the instant thought is often: “How much does it cost?” In order to estimate the costs of surveillance, all activities related to a programme need to be identified and the associated costs estimated. This should include costs for tests, farm visits and consumables, but also investments in infrastructure such as databases as well as labour costs. Although this may appear to be a relatively straightforward exercise, such costs may be difficult to collect in retrospect. For example, if surveillance tasks are only part of a person’s job, it may be difficult to allocate exact time and therefore labour costs. Also, some activities may be subsidised and costs may therefore not reflect true market value. This is sometimes the case for laboratory diagnostics where tests conducted as part of a large programme are not comparable with market costs. Such differences also impede comparisons between industries and countries with different pricing policies.

However, collection of costs is only the first step. A more interesting question could be: “Is it cost-effective?” This means, are the resources invested such that they provide the effective results. Cost-effectiveness is normally expressed using ratios of cost per effectiveness outcome, i.e. cost in relation to the results of a programme in natural non-monetary units. Therefore, cost-effectiveness can be measured in a range of units, including the “information-cost ratio”. The latter describes how much information can be obtained per invested amount. Cost-effectiveness largely depends on the design of a surveillance programme. There are simple or more complex designs as surveillance systems may consist of one or several components, each with their related performance. The performance of a surveillance activity can be measured as its sensitivity, if the objective is demonstration of the absence of a hazard or to detect cases. It can also be measured as precision if prevalence is estimated or in terms of time to detection, if the main objective is early detection. This indicates that such performance indicators are dependent on the objective of a surveillance programme. The epidemiological performance can then be combined with the costs. For example, it could be calculated how much an increase of the sensitivity of a system by 5% would cost. Sometimes, the target effectiveness is pre-fixed, for example by an international standard or by legislation. Economic concerns then focus on selecting the least-cost option.

Risk-based surveillance has been promoted as a surveillance design with particularly high cost-effectiveness. Over time, it has become clear that the advantages of this design depend on the context in
which it is applied. For example, it is particularly beneficial if applied in a low-prevalence situation where the risk factors for hazard occurrence are well known. This allows targeting of a specific stratum in the population in which the hazard prevalence is expected to be higher. This will impact on the sample size that is required to achieve a defined performance level (e.g. probability of detection). However, the collection of information on risk factors also comes at a cost. Also, samples may be more expensive if they have to be collected from specified individuals or locations. The cost-effectiveness of risk-based surveillance therefore cannot be taken for granted and requires *ex ante* assessment.

The ultimate question to be answered, however, remains the following: "Is it worth it?" Whilst cost-effectiveness of a programme starts to address this question by exploring whether increments in non-monetary effects (e.g. sensitivity) occur, this question is commonly intertwined with the interrogation of whether quantitative benefits can be associated to each unit of cost allocated to the surveillance programme. A commonly used economic tool to assess the increments in benefits per unit of investment is cost-benefit analysis. Unlike cost-effectiveness, it uses monetary units to quantify costs and benefits and it has been often used in animal science and veterinary medicine (Babo Martins and Rushton, 2014).

As described above, the costs are relatively easy to collect. However, the benefits may be more difficult to identify. Surveillance is conducted to provide information that is used for decision making in the context of animal or public health. If the information is not used in this way or no decisions are taken, surveillance has almost no value. This indicates that the benefits of surveillance cannot be assessed in isolation, but need to be considered in combination with the related interventions. A model for such economic assessments has been proposed by Häslers and colleagues (2011). Benefits of disease mitigation – now consisting of both surveillance and intervention – may be direct or indirect, tangible or intangible. A direct benefit would be increased productivity if a certain disease is absent. An indirect benefit would be that farmers’ income is increased and therefore they can afford better schooling for their children. A tangible benefit could be the access to a specific export market that requires freedom from a specific hazard. But there could also be intangible benefits, for example, peace of mind for the chief veterinary officer. Tangible or direct benefits are usually easier to translate into monetary units. In contrast, the valuation of intangible, indirect or temporary benefits is complex and consequently often not addressed in current economic assessments of animal health and food safety programmes.

The challenges of assessing benefits of surveillance become particularly obvious when surveillance systems are subject to evaluation. Evaluation is increasingly applied to assure that surveillance is achieving its objective. As long as the latter are defined in terms of effectiveness, this can be relatively straightforward. However, if efficiency or over-all value should be quantified, this can become quite challenging. Also, good practice is not yet fully established in this area although some first guidance is provided, for example through the RISKSUR project (www.fp7-risksur.eu).

All statements made so far are true for any surveillance, regardless of whether the main focus is on animal or public health. However, when surveillance is conducted in the context of food safety, benefits are expected also on the public health side. For some hazards, there may be animal health benefits too (e.g. brucellosis), but for some, these may be limited (e.g. *Salmonella* in pigs). Therefore, economic assessment of surveillance of such hazards needs to include costs as well as benefits incurred across animal and human populations, thus adding substantial complexity.

We propose a framework that supports the mapping of cost and benefit streams of surveillance in a situation covering more than one population. The core concept is that surveillance will trigger certain activities (interventions) in either or both populations with the objective of risk mitigation. The benefits of these actions are then identified through the links established between surveillance and interventions, and – if possible – these are valued. This framework is currently being tested in the context of case examples, and our first experience revealed interesting results. For example, we hypothesise that a substantial proportion of surveillance conducted in animal populations for the benefit of public health has mainly intermediate or intangible benefits. This set of benefits is generated when surveillance data is used to, for example, inform risk assessments, identify gaps on surveillance systems, shape research agendas, or aid in outbreak investigation exercises, all of which contribute with knowledge that, whilst not triggering immediate actions of disease mitigation, can be used in future interventions. This stream of intangible benefits is linked to the value of knowledge in itself - intellectual capital - to the generation of social capital, and to the value of peace of mind (Babo Martins et al, submitted). As these are very difficult to value, the assumption, from a rational resource-use point of view, is that they are valuable enough for the user of the information (e.g. policy makers, risk assessors) to justify the current surveillance efforts and the resources allocated. The framework has not yet been applied to pig-related hazards, but to Campylobacter in chicken and West Nile virus. Results from these case examples will be presented and discussed.

It is expected that evaluation – including economic evaluation – will become a routine activity in most disease mitigation programmes. This will also include food-borne risks. It is therefore recommended that stakeholder in the food industry develop technical competencies including not only epidemiology and risk assessment, but also surveillance and economics.

Suggestions for additional reading:

- Howe, K.S., Häslers, B., Stark, K.D., 2013. Economic principles for resource allocation decisions at national level to mitigate the effects of disease in farm animal populations. Epidemiology and Infection 141, 91-101

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• Häslér, B., Howe, K.S., Stärk, K.D.C., 2011. Conceptualising the technical relationship of animal disease surveillance
to intervention and mitigation as a basis for economic analysis. BMC Health Serv. Res. 11, 225. doi:10.1186/1472-
6963-11-225
• Howe, K.S., Häslér, B., Stark, K.D., 2013. Economic principles for resource allocation decisions at national level to
mitigate the effects of disease in farm animal populations. Epidemiology and Infection 141, 91-101.
surveillance in the field of veterinary medicine and veterinary public health: review of current approaches. BMC

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Control strategies to mitigate foodborne pathogens