THE MONETARY IMPACT OF ZOONOTIC DISEASES ON SOCIETY IN NIGERIA: EVIDENCE FROM FOUR ZOONOSES

1. Introduction

In Nigeria, population growth, urbanization and gains in real per capita income will result in increased consumption of animal source foods. This will provide incentives for livestock producers and other actors along the value chain to rapidly expand and improve their businesses to satisfy the growing consumers’ demand (FAO, 2018a). In a rapidly changing environment, returns on investments are often uncertain: competitive, economic, operational, legal, financial, fiscal, reputational and other risks will affect the profitability of livestock farming. Some livestock farmers and enterprises will succeed, expand and thrive; while others will fail and exit the livestock business altogether.

As livestock is a private business, the key role for the government of Nigeria is to ensure that policies - largely implemented through public investments, laws and regulations - support a smooth and socially desirable transformation of the sector in the coming years. This is easier said than done because livestock, though a private business, also have broader, often negative, impacts on society. For example, grasslands degradation, microbiological water pollution, excess greenhouse gas emissions, animal epidemics and zoonotic diseases, are all consequences of inappropriate livestock farming practices, and reduce societal welfare.

Zoonotic diseases, which jump the animal-human species barrier, are a major threat for society --they can affect entire sectors of the livestock industry and reduce human capital. For example, it is estimated that avian influenza, at its peak, reduced chicken meat production by over one third in China (Huang et al., 2017), and that the 2009 swine flu pandemic, which originated in Mexico, infected over 100 million people with a death toll of about 20 000 (Nathason, 2016). However, given the current zoonotic disease information system, the Federal Ministry of Agriculture & Rural Development and the Federal Ministry of Health in charge of Livestock and Public Health respectively find it challenging to generate accurate estimates of the incidence and prevalence of zoonoses, assess their impact on society, and measure the benefits of programmes and investments for their prevention, management and control (FAO, 2018c). In brief, the Ministries have difficulties in allocating public resources to tackle zoonotic diseases efficiently.

The Africa Sustainable Livestock 2050 initiative (ASL2050), under the guidance of a National Steering Committee comprising representatives of the Federal Ministry of Agriculture & Rural Development, Federal Ministry of Health and Federal Ministry of Environment in charge of Livestock, Public health and Environment respectively have designed and implemented an expert elicitation protocol to assemble information on selected zoonoses and on antimicrobial resistance. The protocol was designed to gather the data needed for measuring the impact of zoonoses on society in monetary terms, thereby providing the government with a key piece of information for allocating taxpayers’ money efficiently in lieu of the fact that three quarters of new infectious diseases emerging in humans have a zoonotic origin and because the anticipated growth of Nigeria will modify the drivers influencing the emergence and re-emergence of zoonotic pathogens, the value of accessing information for measuring the costs and benefits of preventing, managing and controlling zoonoses cannot be overstated.

This brief presents the results of the ASL2050 expert elicitation protocol on zoonotic diseases, as validated by stakeholders. As it was the first time an expert elicitation protocol on zoonotic diseases was implemented in Nigeria and attaching monetary values to some variables rests on numerous assumptions, results are not cast in stone. What matters, however, is that stakeholders have used a One Health
approach to experiment with a new methodology to look at zoonotic diseases—a methodology that they may or may not scale up or replicate—to provide decision-makers with information on how to best allocate admittedly scarce public resources.

2. An expert elicitation protocol for assembling information on zoonoses and AMR

When there is insufficient or unreliable data, or when data is either too costly or physically impossible to gather, expert elicitations are a promising tool to obtain good quality information. They are a scientific consensus methodology to get experts' judgements on the distribution of variables and parameters of interest, including those whose value is either unknown or uncertain. An important feature of expert elicitation is that experts not only provide information on the unmeasured but can also suggest values that differ from those in the scientific literature or from official statistics (the official knowns), for example if they believe some causal linkages are underestimated or some issues underreported. The public sector, but more frequently private parties, have used expert elicitations for a multitude of purposes, such as to investigate the nature and extent of climate change; the cost and performance of alternative energy technologies; and the health impact of air pollution (Morgan, 2014). The World Health Organization has used an expert elicitation to estimate the global burden of foodborne diseases (WHO, 2015).

In Nigeria, the current information system does not provide the government with sufficient information on the incidence, prevalence and impact of zoonoses on society, thereby making it challenging to measure the returns on investments aimed at their prevention, management and control. The Africa Sustainable Livestock 2050 initiative (ASL2050) has therefore designed and implemented an expert elicitation protocol to assemble information on selected zoonoses and antimicrobial resistance. The objective was to gather the data needed to measure the impact of zoonoses on society in monetary terms. It is the collection and dissemination of evidence relating to the economic cost of diseases that, coupled with information about the cost of alternative interventions for disease control and management, should guide decisions in the allocation of taxpayers’ money.

- As it was the first time an expert elicitation protocol on zoonoses was implemented in Nigeria, the protocol focuses on two livestock types, four zoonoses, and antimicrobial resistance. The two livestock types are cattle and poultry, while the four zoonoses are bovine tuberculosis and brucellosis for cattle; and salmonellosis and highly pathogenic avian influenza (HPAI) for poultry (FAO, 2018b, c). These were selected because of their relevance not only for Nigeria but also for other ASL2050 countries implementing the protocol, including other ASL2050 Countries Ethiopia, Burkina Faso, Egypt, Kenya and Uganda, which will facilitate cross-learning.
- For animals and for each zoonosis, the protocol includes questions on the number of cases; number of deaths; number of salvage slaughtered animals; number of culled animals; number of carcasses condemned; productivity loss due to morbidity; and underreporting. Questions were asked by the different cattle and poultry production systems, including dairy intensive, semi-intensive (settled pastoralist), extensive (unsettled pastoralist) systems and poultry extensive, semi-intensive and intensive systems, as defined and quantified by stakeholders using available data and information (FAO, 2018c).
- For humans and for each zoonosis, the protocol includes questions on the number of cases; the average age of the person affected; the number of deaths; and the number of working days lost per case. Questions were asked by different category of people, including livestock keepers, and consumers.
- The protocol did not collect price data, necessary to estimate the monetary values of the cost of any disease. For livestock, we sourced price data for live animals and animal products from the National Bureau for Statistics, stakeholders and experts. For humans, we estimated the yearly value of
statistical life to proxy the willingness to pay (WTP) for a so-called disability-adjusted life year (DALY), which is the amount citizens are willing to pay for ensuring one year of healthy life (box 1). The WTP for a DALY allows the cost associated with mortality and morbidity to be straightforwardly calculated, as detailed in the next section.

• For antimicrobial resistance, the protocol includes four questions: on the proportion of cattle and poultry farms using antibiotics, by production system; on trends on use of antibiotics in cattle and poultry farms, by production system; on trends in antimicrobial resistance in humans; and on experts’ concerns about antimicrobial resistance in humans.

<table>
<thead>
<tr>
<th>Box 1. The willingness to pay for a disability-adjusted life year</th>
</tr>
</thead>
<tbody>
<tr>
<td>To estimate the social cost of the disease, we estimate the Disability-Adjusted Life Years (DALY), a method used by the World Health Organization (WHO) to quantify the burden of disease from mortality and morbidity(^1). One DALY can be interpreted as one year of healthy life lost. It is a health gap measure that combines both time lost due to premature mortality and the time spent in sickness. For each disease, a disability weight is attached to the DALY, which measures the severity of a disease during sickness.</td>
</tr>
</tbody>
</table>

We calculate the willingness to pay of a DALY to arrive at its value in monetary terms. We start from the yearly value of a statistical life calculated for the United States. The value of a statistical life has been calculated at USD 9.5 million by the US Department of Human and Health Services and at USD 9.6 million by the US Department of Transportation (DOT, 2016), and is used to value the reduction of fatalities and injuries. To translate the latter into a yearly value, we use the OECD’s discounting approach (Quinet et al., 2013):

\[
VSL = \sum_{t=0}^{T} VSLY \times (1 + \delta)^{(-t)}
\]

where VSL is the value of statistical life, VSLY the yearly value, \(t\) is a discrete variable going from the present (0) to the expected end of the individual’s life (T) and \(\delta\) is the discount rate. Using a discount rate of 3 percent (ERG, 2014) and the expected life span of 79 years (World Bank, 2017), we calculate around 400 000 USD as a yearly value of a statistical life in the US, that will represent society’s willingness to pay for a healthy year of life or for a DALY. To translate this value in the Nigerian context, we use the benefit transfer methodology presented in Hammit and Robinson (2011), which takes into account the differences in real GDP per capita, as measured in purchasing power parity (PPP) and the elasticity of the willingness to pay for risk reduction with respect to income:

\[
VSLY_{Country} = VSLY_{US} \times \left( \frac{\text{GDP per capita in PPP}_{Country}}{\text{GDP per capita in PPP}_{US}} \right)^{\text{elasticity}}
\]

We used a snowball sampling approach to identify the experts to interview, with representatives of the ASL2050 Steering Committee suggesting names of renowned national experts, including two animal health and two human health experts for each zoonotic disease. We then asked these experts to recommend additional experts to interview, and so on. When this snowball approach got occasionally interrupted, the ASL2050 National Focal points retook the expert unveiling process. The final sample comprised 41 experts, including 30 animal health experts and 11 human health experts. The sample is biased towards animal health experts, as there are few human doctors with expertise in the selected zoonotic diseases. However, animal health experts were often in a position to respond to human health questions as, being specialised in zoonotic diseases, they typically operate at the interface between animal

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and human health. We conducted the interview in October and November 2017, analysed the data and validated the results with stakeholders in April 2018.

3. Livestock and public health monetary impact calculation: methodology

The monetary impact of the priority zoonotic diseases on society is determined as the sum of the losses in value (USD) due to morbidity and mortality in infected animals and humans over the period of one year.

\[
\text{Livestock and Public Health USD Impact} = \text{Value of animals lost} + \text{Value of production decrease in infected animals} + \text{Social cost of mortality in humans} + \text{Social cost of morbidity in humans}
\]

The methodology used to calculate the value of the different variables in the equations is briefly discussed below both for animals and humans. Detailed explanation and data sources are described in the Annexes.

3.1 Cattle

In cattle systems, an infected animal will either die, be salvage slaughtered or survive but suffer from reduced productivity during the disease. Both the value of the animals lost as well as the decreased production should be estimated to calculate the total loss due to occurrence of a disease in animals. Figure 1 depicts a flowchart that highlights the different cattle-related variables the protocol data estimates, including the value of animals lost due to the disease (in red) and the value of production lost in survivors (in dark orange). The cost of treating sick animals is not accounted for as data on farmers’ expenses on veterinary goods and services by disease are not available, because the share of farmers with access to animal health services is usually small, and because their spending on veterinary services is typically negligible (CAHI, 20115; MAAIF, 2016). The value of animals lost is calculated as the sum of:

- the number of animal deaths multiplied by the farm-gate price of an adult animal;
- the number of carcasses fully condemned multiplied by the farm-gate price of an adult animal;
- the number of unborn calves, due to fertility reduction in survivors, multiplied by the farm-gate price of a young animal.

The value of production decrease in survivors is calculated as the sum of:

- the number of carcasses partially or not condemned animals multiplied by discounted farm-gate price of an adult animal that was obtained at a stakeholder consultation;
- The number of lost lactation periods – which is equal to the number of unborn calves, or the number of cows infected by the disease and affected by fertility loss – multiplied by the average litre per lactation and by the market price of one litre of milk;
- The number of cows infected by the disease and not affected by fertility loss, multiplied by the average reduction in milk production in litres and by the market price of one lit. of milk;
- The number of survivors multiplied by the average dressed weight lost and by the market price of one kg of beef.
3.2 Poultry

In poultry systems, birds affected by a disease may die, be culled or salvage slaughtered, or suffer from a decrease in egg production. In the context of the calculation, the number of animals culled refers to the animals slaughtered by the authorities for control of the specific disease during the reference period. For some diseases the whole flock might be slaughtered or culled as a precaution, therefore salvage slaughtered and culled birds might also include non-infected birds. In addition, while no sale happens after culling, in the case of salvage slaughter the birds can still be consumed, though they presumably have not reached their full slaughter weight. Figure 2 depicts a flowchart that highlights the different poultry-related variables the protocol data estimates, including the value of animals lost due to the disease (in red) and the value of production decrease in survivors (in dark orange). The cost of treating sick birds is not accounted for as data on farmers’ expenses on veterinary goods and services by disease are not available, because the share of farmers with access to animal health services is usually small, and because their spending on veterinary services is typically negligible. The value of birds lost is calculated as the sum of:

- the number of birds killed by the disease multiplied by the farm-gate price for a live chicken;
- the number of culled birds multiplied by the farm-gate price of a live chicken;
- the number of salvage slaughtered birds multiplied by the discounted farm-gate price for a live chicken;

The value of production decrease in surviving hens is calculated as:

- The number of surviving hens multiplied by the average reduction in the number of eggs produced and by the egg market price.

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2 Discount rates were obtained via stakeholder consultation.
3.3 Humans

Zoonoses are transmitted from animals to humans through direct and indirect contact, vectors and food consumption. Different categories of people, therefore, face different risks of contracting zoonotic diseases. To estimate the impact of morbidity and mortality of zoonoses in humans, we have split the population at risk in three broad groups: (i) non-livestock keepers & non consumers of animal source foods; (ii) non-livestock keepers & consumers of animal source foods; (iii) livestock keepers & consumers of animal source foods.

Figure 3 depicts a flowchart that highlights the different human-related variables the protocol data estimates, including the number of infected people, as well as survivors and deaths, by category of people. We assume there are no infections among the non-livestock keepers & non-consumers of animal source foods.

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3 Occupations at higher risk of infection include veterinarians, culling personnel, slaughterhouse workers and all those in direct contact with live animals and animal material. It is however not possible to obtain good information on the number of such workers, let alone knowing how many of them are already included in the other two categories. We assume thus that the majority are already living in a livestock keeping households or are consumers of animal source foods.
Figure 3. Human related variables in the USD loss calculation

The economic cost of the zoonotic disease is calculated as the sum of:

- The total number of survivors multiplied by the average number of working days lost (proxy for duration of the disease) and the DALY weight measuring the severity of the disease\(^4\) and by the society’s willingness to pay for one day of healthy life.
- The total number of deaths multiplied by the average number of years of life lost – given by the difference between life expectancy and average age at infection – and society’s willingness to pay for one year of healthy life.

4. Livestock and public health monetary impact calculation: results

4.1. Data validation

We validated the collected data through a three-step process. First, we generated summary statistics for the key variables and reviewed them with members of the ASL2050 Steering Committee. Second, for those variables whose values were implausible, we consulted relevant literature. Finally, we presented the summary statistics and literature review at a workshop involving protocol respondents and other stakeholders to arrive at consensus on measures of central tendency. Table 1 presents the reference population, prevalence and fatality rate data that were ultimately used to calculate the impact of the selected zoonoses on society.

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\(^4\) A DALY weight measures the severity of a disease and can take values from 0 to 1, zero meaning completely healthy and 1 meaning death. DALY weights by disease are provided by the WHO Global Burden of Disease
| Table 1. Key protocol-variables underpinning the USD loss calculation |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                | Cattle          |                 |                 |                 |                 |                 |
|                                | Intensive       | Semi-Intensive  | Extensive       | TOTAL           | Livestock keepers | Consumers       |
| Brucellosis (2016)             |                 |                 |                 |                 |                 |                 |
| Total population               | 203 548         | 3 089 804       | 15 111 309      | 18 404 661      | 28 166 411       | 100 375 574     |
| Prevalence (cases/tot. population) | 8.00%           | 12.00%          | 15.00%          | 14.00%          | 0.12%            | 0.14%           |
| Fatality rate (deaths/cases)   | 0.00%           | 0.00%           | 0.00%           | 0.00%           | 0.9%             | 2.0%            |
|                                |                 |                 |                 |                 |                 |                 |
| Bovine Tuberculosis (2016)     |                 |                 |                 |                 |                 |                 |
| Total population               | 203 548         | 3 089 804       | 15 111 309      | 18 404 661      | 28 166 411       | 100 375 574     |
| Prevalence (cases/tot. population) | 10.5%           | 10.5%           | 10.7%           | 10.7%           | 0.111%           | 0.300%          |
| Fatality rate (deaths/cases)   | 2.50%           | 4.00%           | 5.00%           | 4.81%           | 10.00%           | 10.00%          |
|                                |                 |                 |                 |                 |                 |                 |
| Highly Pathogenic Avian Influenza (2010-2016) |                 |                 |                 |                 |                 |                 |
| Total population               | 38 365 391      | 58 367 529      | 83 340 089      | 180 073 009     | 63 634 993       | 27 407 441      |
| Prevalence (cases/tot. population) | 10.14%          | 10.14%          | 0.24%           | 2.27%           | 0.000%           | 0.000%          |
| Fatality rate (deaths/cases)   | 10%             | 10%             | 10%             | 10%             | 0.000%           | 0.000%          |
|                                |                 |                 |                 |                 |                 |                 |
| Salmonellosis (2016)           |                 |                 |                 |                 |                 |                 |
| Total population               | 38 365 391      | 58 367 529      | 83 340 089      | 180 073 009     | 63 634 993       | 27 407 441      |
| Prevalence (cases/tot. population) | 20.00%          | 22.00%          | 15.00%          | 18.33%          | 0.375%           | 0.500%          |
| Fatality rate (deaths/cases)   | 40.00%          | 40.00%          | 25.00%          | 34.32%          | 0.320%           | 0.320%          |

5 To avoid double-counting, here we include only consumers that do not keep livestock.
6 Intensive and semi-intensive systems have been discussed together for HPAI.
4.2. Results

4.2.1. Brucellosis

Brucellosis in Cattle

Brucellosis is a highly infectious, chronic disease caused by the Brucella bacteria. It is not a killer disease, with the main symptoms in cattle being repetitive abortions. The prevalence rate of the disease in cattle was estimated at 14 percent overall in Nigeria, with highest occurrence in the extensive systems (15 percent), with no any death associated to it. Table 2 shows the value of animals lost (including the value of unborn calves) and the value of production lost due to Brucellosis in cattle by production system. The loss was calculated using the variables described in Table 1. The biggest loss is encountered in extensive systems, amounting up to 1 billion USD PPP, out of which 95 percent came from forgone production value. The high amount of losses in extensive systems is due to both the high prevalence rate (15 percent) and the large cattle population (15 million cattle). In all three production systems, the value of total forgone production loss contributes 95.9 percent of the total, while 4.1 percent is the value of unborn calves due to fertility loss (Figure 4). The overall loss in animal production due to Brucellosis is estimated at 1.37 billion USD PPP, which is equivalent to 7.77 percent of the livestock GDP and 0.13 percent of the national GDP.

Table 2. Cases of brucellosis and estimates of its economic cost by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated number of cases</strong></td>
<td>16 284</td>
<td>370 776</td>
<td>2 266 696</td>
<td>2 653 757</td>
</tr>
<tr>
<td><strong>Value of animals lost (USD PPP)</strong></td>
<td>79 160</td>
<td>3 357 720</td>
<td>53 127 504</td>
<td>56 564 385</td>
</tr>
<tr>
<td><strong>Value of forgone production (USD PPP)</strong></td>
<td>55 716 987</td>
<td>309 947 692</td>
<td>948 906 611</td>
<td>1 314 571 290</td>
</tr>
<tr>
<td><strong>Total loss in animals (USD PPP)</strong></td>
<td>55 796 147</td>
<td>313 305 413</td>
<td>1 002 034 115</td>
<td>1 371 135 674</td>
</tr>
<tr>
<td><strong>Loss as a % of livestock GDP</strong></td>
<td>0.32%</td>
<td>1.78%</td>
<td>5.68%</td>
<td>7.77%</td>
</tr>
<tr>
<td><strong>Loss as a % of national GDP</strong></td>
<td>0.01%</td>
<td>0.03%</td>
<td>0.09%</td>
<td>0.13%</td>
</tr>
</tbody>
</table>

Figure 4. Cattle production systems: value of production loss and animal lost (%) due to brucellosis

As explained above, the high share of total losses (94 percent) of the extensive system can be largely explained by the large share in total cattle population (82 percent of animals belong to this production system). To eliminate differences coming from the size of population, we show the losses per case and as a percentage of the price of a healthy live animal in Table 3. The loss per case can be higher than the price of a live cattle if the average value of production loss per head (unborn calves, milk production loss, meat production loss) is higher than the average value of an animal. In some cases, also non infected animals are lost, when the producer decides to salvage slaughter animals as precaution.

As opposed to total losses, the loss per case due to brucellosis is highest in the intensive production system, amounting to 3 446 USD PPP, while that of semi-intensive and extensive productions are 845 and 442 USD PPP, respectively. Minimal losses are associated to animal mortality because of the nature
of the disease. The loss per case as a percentage of the farm-gate price of a healthy animal is 54 percent in intensive systems, 32 percent per cent in semi-intensive system and 28 percent in extensive systems.

Table 3. Estimates of value lost per case of brucellosis by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of animals lost per case (USD PPP)</td>
<td>5</td>
<td>9</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Value of production lost per case (USD PPP)</td>
<td>3 422</td>
<td>836</td>
<td>419</td>
<td>495</td>
</tr>
<tr>
<td>TOTAL loss per case (USD PPP)</td>
<td>3 426</td>
<td>845</td>
<td>442</td>
<td>517</td>
</tr>
<tr>
<td>Loss per case as a percentage of the farm-gate price of a healthy animal</td>
<td>54%</td>
<td>32%</td>
<td>28%</td>
<td></td>
</tr>
</tbody>
</table>

Brucellosis in Human Beings

As described above, the social cost of the disease is estimated as the sum of the cost of mortality and cost of morbidity. We estimate the impact of the disease for two sub-groups: cattle keepers, who are in contact with the animals and are potentially consuming beef, milk and other cattle products, and individuals who are not cattle keepers but might be infected through consumption of infected food products. Results for brucellosis are shown in Table 4 for the two groups, both in aggregate and per case. In 2016 in Nigeria 3 044 people died of brucellosis, on average at age 26. According to the World Bank, the expected life span of an individual is 53 years in the country, meaning we account for 3 044 deaths times 27 (53-26) years lost all together.

To put these numbers in context, Table 4 also shows the results as a percentage of GDP. This comparison should be regarded with caution: the GDP is an annual value, whereas mortality costs include the individual’s future years remaining up to the expected end of his/her life. The total social cost of the 13 283 DALYs caused by Brucellosis infections in livestock keepers is estimated at 168 million USD PPP, that is 0.02 percent of the national GDP. For consumers, 66 553 DALYs were estimated (note that there are more than 3 times as many cattle consumers as keepers), at a loss of 845 million USD PPP, roughly 0.08 percent of the national GDP. The cost estimation was based on the average willingness of people to pay for a healthy life in Nigeria at a cost of 12 700 USD PPP per person. Figure 5 shows the share of the total social cost of livestock workers (16.60 percent) and for consumers (83.40 percent).

Table 4. Estimates of the annual public health costs of brucellosis in Nigeria

<table>
<thead>
<tr>
<th></th>
<th>Livestock keepers</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of life lost due to mortality (YLL)</td>
<td>11 484</td>
<td>62 977</td>
</tr>
<tr>
<td>Years lost due to morbidity (YLD)</td>
<td>1 755</td>
<td>3 576</td>
</tr>
<tr>
<td>DALYs (YLL + YLD)</td>
<td>13 238</td>
<td>66 553</td>
</tr>
<tr>
<td>Willingness to pay for 1 year of healthy life (USD PPP)</td>
<td>12 700</td>
<td>12 700</td>
</tr>
<tr>
<td>Total social cost (USD PPP)</td>
<td>168 128 526</td>
<td>845 222 470</td>
</tr>
<tr>
<td>Social cost as a % of national GDP</td>
<td>0.02%</td>
<td>0.08%</td>
</tr>
</tbody>
</table>

1 The average price of a healthy animal varies across production systems.
Cost of Brucellosis in animals and humans in 2016

Figure 6 below depicts the share of losses due to brucellosis infection in animals (58 percent) and humans (42 percent), suggesting that the disease had a significant impact on both.

Table 5 compares the cost of brucellosis in animals and livestock keepers by production system. Consumers could not be included as the data did not allow to associate them to the different production systems. In all systems, costs are higher among animals than humans and the largest share of costs are in the extensive dairy production system.

### Table 5. Brucellosis: Animal and human related losses (livestock keepers) by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals (USD PPP)</td>
<td>55 796 147</td>
<td>313 305 413</td>
<td>1 002 034 115</td>
<td>1 371 135 674</td>
</tr>
<tr>
<td>Livestock keepers (USD PPP)</td>
<td>31 967</td>
<td>2 958 974</td>
<td>165 137 585</td>
<td>168 128 526</td>
</tr>
</tbody>
</table>

4.2.2. Bovine TB

**Bovine tuberculosis** (bTB) is a chronic infectious disease in animals and humans caused by *Mycobacterium bovis* (*M. bovis*) of the *M. tuberculosis* complex. The economic impacts of bTB in livestock are related to production losses, e.g. reduced milk yield, weight loss, impaired draught power; and the cost of surveillance and control programs, e.g. complete or partial condemnation of carcasses, animal culls and trade restrictions. Table 6 shows the value of losses due to infection in cattle, amounting up to 1.8 billion USD PPP, that is 9.97 percent of the livestock value added and 0.61 percent of the national GDP. The bulk of the losses (1.3 billion USD PPP) occur in the extensive production system, where the majority of the cattle population are kept. Total loss in animals in the semi-intensive system is about 356 million USD PPP (121.6 million due to animals lost and 234.3 million associated to forgone production). It is about 48 million USD PPP (10.2 million due to animals lost and 37.8 million associated to forgone production) in intensive production systems.
Table 6. Cases of bovine TB and estimates of its economic cost by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated number of cases</td>
<td>21 373</td>
<td>324 429</td>
<td>1 616 910</td>
<td>1 962 712</td>
</tr>
<tr>
<td>Value of animals lost (USD PPP)</td>
<td>10 187 635</td>
<td>121 577 539</td>
<td>526 686 092</td>
<td>658 451 266</td>
</tr>
<tr>
<td>Value of forgone production (USD PPP)</td>
<td>37 841 694</td>
<td>234 333 481</td>
<td>829 239 550</td>
<td>1 101 414 725</td>
</tr>
<tr>
<td>Total loss in animals (USD PPP)</td>
<td>48 029 329</td>
<td>355 911 020</td>
<td>1 355 925 642</td>
<td>1 759 865 991</td>
</tr>
<tr>
<td>Loss as a % of livestock GDP</td>
<td>0.27%</td>
<td>2.02%</td>
<td>7.69%</td>
<td>9.97%</td>
</tr>
<tr>
<td>Loss as a % of national GDP</td>
<td>0.00%</td>
<td>0.03%</td>
<td>0.12%</td>
<td>0.16%</td>
</tr>
</tbody>
</table>

Table 7 shows the same estimates by case and as a percentage of the price of a live animal. The total cost of loss per case is the highest in intensive systems, at 2 247 USD PPP, that is about 35 percent of the value of a healthy animal in this production system. In semi-intensive systems the loss per case is 1 097 USD PPP, that is 41 percent of the average price of a healthy animal in this system. In the extensive systems losses amounted up to 839 USD PPP, that is 53 percent of the price of an average animal in this system. Note that the price of a live animal differs by production system because of the different breeds farmers keep.

Table 7. Estimates of value lost per case of bovine TB by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of animals lost per case (USD PPP)</td>
<td>477</td>
<td>375</td>
<td>326</td>
<td>335</td>
</tr>
<tr>
<td>Value of production lost per case (USD PPP)</td>
<td>1 771</td>
<td>722</td>
<td>513</td>
<td>561</td>
</tr>
<tr>
<td>TOTAL loss per case (USD PPP)</td>
<td>2 247</td>
<td>1 097</td>
<td>839</td>
<td>897</td>
</tr>
<tr>
<td>Loss per case as a percentage of the farm-gate price of a healthy animal</td>
<td>35%</td>
<td>41%</td>
<td>53%</td>
<td></td>
</tr>
</tbody>
</table>

Bovine TB in Human Beings

Table 8 shows estimates of the cost of bovine tuberculosis in human beings in Nigeria. The estimated total public health costs of the disease among livestock keepers and consumers are 1 234 million USD PPP and 6 625 million USD PPP, respectively. This amounts to nearly 8 billion USD PPP, which is 0.7 percent of total national GDP. As noted above, this comparison has to be interpreted with caution as GDP is an annual value, whereas estimates of human losses account also for the value of the future years of life lost.

Table 8. Estimates of the annual public health costs of bovine TB in Nigeria

<table>
<thead>
<tr>
<th></th>
<th>Livestock keepers</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of life lost due to mortality (YLL)</td>
<td>95 786</td>
<td>514 295</td>
</tr>
<tr>
<td>Years lost due to morbidity (YLD)</td>
<td>1 439</td>
<td>7 414</td>
</tr>
<tr>
<td>DALYs (YLL + YLD)</td>
<td>97 225</td>
<td>521 709</td>
</tr>
<tr>
<td>Willingness to pay for 1 year of healthy life (USD PPP)</td>
<td>12 700</td>
<td>12 700</td>
</tr>
<tr>
<td>Total social cost (USD PPP)</td>
<td>1 234 758 331</td>
<td>6 625 707 772</td>
</tr>
<tr>
<td>Social cost as a % of national GDP</td>
<td>0.11%</td>
<td>0.61%</td>
</tr>
</tbody>
</table>
Cost of Bovine TB in animals and humans in 2016

The total costs estimated due to Bovine TB add up to 9.6 billion USD PPP, that is roughly 0.88 percent of the national GDP. A very high part of this amount (82 percent) is coming from human infections. According to the expert elicitation, there were nearly 2 million cases of Bovine TB in cattle and 300 thousand cases of Bovine TB in humans.

Table 9 splits the value of bovine TB losses in animals and humans (livestock keepers) by production system. Without considering consumers, the total accrued loss in animals (1.76 billion USD PPP) is higher than the loss among humans (1.2 billion USD PPP). Losses are highest in extensive production systems for both animals (1.4 billion USD PPP) and humans (1.1 billion USD PPP). In semi-intensive systems animal losses amount to 355.9 million USD PPP and human losses to 124.6 million USD PPP. Losses for both animals and humans are the lowest in intensive production systems.

Table 9. Bovine TB: value of animal and human (livestock keepers) loss by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals (USD PPP)</td>
<td>48 029 329</td>
<td>355 911 020</td>
<td>1 355 925 642</td>
<td>1 759 865 991</td>
</tr>
<tr>
<td>Livestock keepers (USD PPP)</td>
<td>4 225 521</td>
<td>124 580 104</td>
<td>1 105 952 707</td>
<td>1 234 758 331</td>
</tr>
</tbody>
</table>

4.2.3. Highly Pathogenic Avian Influenza (HPAI)

**HPAI in poultry**

Highly pathogenic avian influenza (HPAI) viruses cause severe illness in poultry, often resulting in the death of the entire flock. Common clinical signs various systemic, respiratory and/or neurological symptoms such as depression, oedema and cyanosis of the un-feathered skin, diarrhoea, ecchymosis on the shanks and feet, and coughing, but no signs are pathognomonic. Sometimes the first sign of infection is sudden death (ASL 2050, 2018). Table 10 shows number of cases of HPAI and estimates of its economic cost by production system for the outbreaks between 2014 and 2016. The total loss for HPAI is about 10.6 million USD PPP from direct death and 96 million USD PPP from culling, adding up to about 0.6 percent of the livestock value added and 0.01 percent of the country’s national GDP. Almost all loss (103 out of 106 million USD PPP) is accounted by the impact of the disease in intensive production systems.

---

8 Note that here culling refers to the slaughter of the birds by Nigerian authorities.
Table 10. Cases of HPAI and estimates of its economic cost by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated number of cases</strong></td>
<td>3 891 000</td>
<td>200 000</td>
<td>4 091 000</td>
</tr>
<tr>
<td><strong>Value of animals lost (USD PPP)</strong></td>
<td>10 348 404</td>
<td>319 149</td>
<td>10 667 553</td>
</tr>
<tr>
<td><strong>Value of forgone production (USD PPP)</strong></td>
<td>93 135 638</td>
<td>2 872 340</td>
<td>96 007 979</td>
</tr>
<tr>
<td><strong>Total loss in animals (USD PPP)</strong></td>
<td>103 484 043</td>
<td>3 191 489</td>
<td>106 675 532</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loss as a % of livestock GDP</th>
<th>Intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.59%</td>
<td>0.02%</td>
<td>0.60%</td>
</tr>
<tr>
<td>Loss as a % of national GDP</td>
<td>0.01%</td>
<td>0.00%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

Table 11 presents estimates of the value lost per case of HPAI from the various production systems. Since all birds either died or were culled, the total loss per case is equal to the total price of a healthy animal. We have to emphasis that figures are in USD Purchasing Power Parity, using the conversion rate of the World Bank for 2016 at 94 Naira equaling one US dollar. The prices used for evaluating the losses were 2 500 Naira for layers and broilers and 1 500 Naira for local birds.

Table 11. Estimates of value lost per case of HPAI by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Value of animals lost per case (USD PPP)</strong></td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Value of production lost per case (USD PPP)</strong></td>
<td>24</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td><strong>TOTAL loss per case (USD PPP)</strong></td>
<td>27</td>
<td>16</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loss per case as a percentage of the farm-gate price of a healthy animal</th>
<th>Intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HPAI in Human Beings

Human infections with HPAI virus are rare and usually occur after prolonged close contact with infected poultry. They result in severe illness, pneumonia, respiratory failure and death. There have been no cases of HPAI in humans in Nigeria since 2010.

4.2.4. Salmonellosis

Salmonellosis in Poultry

Salmonellosis is a foodborne zoonotic disease caused by the Salmonella bacteria. It is transmitted from both animals to humans and vice versa. Clinical signs in animals are diarrhoea, fever and vomiting, but infection is often asymptomatic. Diagnosis is based on clinical signs and isolation of the pathogen from the faeces, blood or tissues of affected animals (ASL 2050, 2018). Table 11 shows cases of Salmonellosis and estimates of its economic cost by production system. The intensive production system records the largest loss in production due to salmonellosis, estimated at 145.4 million USD PPP (82 million USD PPP poultry loss and 63 million USD PPP forgone production), followed by extensive production system with total loss amounting to 139.6 million USD PPP (50 million USD PPP poultry loss and 90 million USD PPP forgone production). The total loss in semi-intensive management is estimated at 110.7 million USD PPP (82 million USD PPP value of birds lost and 28 million USD PPP production loss). The total loss from salmonellosis for the three production systems is 395.6 million USD PPP, that is 2.24 percent of the livestock GDP and 0.4 percent of the national GDP.
Table 12. Cases of Salmonellosis and estimates of its economic cost by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated number of cases</strong></td>
<td>7 673 078</td>
<td>12 840 856</td>
<td>12 501 013</td>
<td>33 014 948</td>
</tr>
<tr>
<td><strong>Value of animals lost (USD PPP)</strong></td>
<td>81 628 491</td>
<td>81 962 913</td>
<td>49 871 064</td>
<td>213 462 468</td>
</tr>
<tr>
<td>Value of forgone production (USD PPP)</td>
<td>63 721 241</td>
<td>28 687 020</td>
<td>89 767 915</td>
<td>182 176 176</td>
</tr>
<tr>
<td><strong>Total loss in animals (USD PPP)</strong></td>
<td>145 349 733</td>
<td>110 649 933</td>
<td>139 638 979</td>
<td>395 638 644</td>
</tr>
<tr>
<td><strong>Loss as a % of livestock GDP</strong></td>
<td>0.82%</td>
<td>0.63%</td>
<td>0.79%</td>
<td>2.24%</td>
</tr>
<tr>
<td><strong>Loss as a % of national GDP</strong></td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.01%</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

Table 13 presents the value of salmonellosis loss per case. In intensive and extensive poultry systems, the average loss per case is around 70 percent of the value of a healthy bird, while in semi-intensive production systems is about 54 percent. The USD PPP loss per case is the highest (19 USD) in intensive production system followed by the extensive (USD 11) and semi-intensive (USD 9) systems. The average loss per case across all production systems is 12 USD PPP.

Table 12. Estimates of value lost per case of Salmonellosis by poultry production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of animals lost per case (USD PPP)</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Value of production lost per case (USD PPP)</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td><strong>TOTAL loss per case (USD PPP)</strong></td>
<td>19</td>
<td>9</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td><strong>Loss per case as a percentage of the farm-gate price of a healthy animal</strong></td>
<td>71%</td>
<td>54%</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>

Salmonellosis in Human Beings

Salmonellosis is a foodborne zoonotic disease caused by the *Salmonella* bacteria. The symptoms in humans include acute abdominal pain, diarrhoea, nausea, fever, and sometimes vomiting. Table 14 presents estimates of losses due to salmonellosis in humans. The total losses due to infections in livestock keepers is estimated at about 363.8 million USD PPP, while loss due to infections in consumers is about 158.8 million USD PPP. They amount to 0.03 and 0.01 of the national GDP, respectively.

Table 13. Estimates of the public health costs of Salmonellosis in Nigeria

<table>
<thead>
<tr>
<th></th>
<th>Livestock keepers</th>
<th>Consumers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of life lost due to mortality (YLL)</td>
<td>28 192</td>
<td>12 269</td>
</tr>
<tr>
<td>Years lost due to morbidity (YLD)</td>
<td>456</td>
<td>236</td>
</tr>
<tr>
<td>DALYs (YLL + YLD)</td>
<td>28 648</td>
<td>12 505</td>
</tr>
<tr>
<td>Willingness to pay for 1 year of healthy life (USD PPP)</td>
<td>12 700</td>
<td>12 700</td>
</tr>
<tr>
<td><strong>Total social cost (USD PPP)</strong></td>
<td><strong>363 824 392</strong></td>
<td><strong>158 808 764</strong></td>
</tr>
<tr>
<td><strong>Social cost as a % of national GDP</strong></td>
<td><strong>0.03%</strong></td>
<td><strong>0.01%</strong></td>
</tr>
</tbody>
</table>
Cost of Salmonellosis in animals and humans

Figure 8 presents the share (%) of the value loss due to salmonellosis infections in animals and humans. The former accounts for 57 percent of the total loss and the latter for 43 percent.

Table 15 shows the value of animal and human loss (livestock keepers) due to Salmonellosis by production system. The former amounts to 395.6 million USD PPP while the latter to 363.8 million USD PPP. Losses in animals are relatively equally distributed across the three poultry production systems (145, 111 and 140 million USD PPP), while losses in humans are significantly higher in extensive systems (323 million out of the 363 million USD PPP in total) than in the others.

Table 15. Salmonellosis: value of animal and human losses (livestock keepers) by production system

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Semi-intensive</th>
<th>Extensive</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals (USD PPP)</td>
<td>145 349 733</td>
<td>110 649 933</td>
<td>139 638 979</td>
<td>395 638 644</td>
</tr>
<tr>
<td>Livestock keepers (USD PPP)</td>
<td>2 251 544</td>
<td>38 277 652</td>
<td>323 295 195</td>
<td>363 824 392</td>
</tr>
</tbody>
</table>

4.3 Discussion

We compare in this section estimates of disease prevalence and economic losses with those available in the literature. Consider, however, that most of the literature relies on data from small samples of animals / humans and often measure seroprevalence, while our objective is to generate nationally representative statistics for animals and humans that showed symptoms of the diseases, thereby having a clear negative impact on society. Therefore, we expect our estimates to be lower than those presented in the literature.

Available studies on brucellosis show a wide range of prevalence rates in cattle, ranging from 3.1 to 15.9 percent in intensive systems and from 3.9 to 45.1 percent in extensive systems (Akinseye et al. 2016; Mai et al., 2012; Maurice et al. 2013 and ICONZ, 2013). The results of the expert elicitation protocol (8 and 15 percent prevalence rate in intensive and extensive production systems respectively) are within these ranges. The only available study on brucellosis in semi-intensive systems reports a prevalence rate of 22 percent for systems in Northern Nigeria (Mai et al., 2012). This is higher than the 12 percent estimated through expert elicitation protocol data. This difference, as explained above, could be however explained by the different purpose of the expert elicitation, which aimed at generating national estimates of brucellosis prevalence.

There is one study that estimated the prevalence of brucellosis in humans. Relying upon a sample of 224 abattoir workers in Abuja, it estimates a seroprevalence of 24.1% (Aworth et al., 2011). The expert elicitation protocol data generates an estimate of 0.12 and 0.5 percent of brucellosis prevalence in livestock keepers and consumers, respectively. It is difficult to make any assessment of the quality of these estimates based on one only study targeting abattoir workers.

---

9 The data does not allow to associate consumers to the different production systems.
Two studies investigate the monetary impact of Brucellosis in Nigeria. They date 1979 and 1984 respectively. Magaji (1984) estimated the economic losses due to reduced fertility at 19.91 million USD and those due to reduced milk production at 124.5 million USD, amounting in total to 0.6 percent of the country GDP. Esuruoso (1979) estimated the economic losses due brucellosis for the Nigerian livestock industry at 218.57 million USD per annum, that is about to 1.3 percent of the country GDP. Expert elicitation data generates an estimated monetary loss due to brucellosis in cattle equals to about 0.6 percent of the country GDP, which is consistent with the available literature.

Table 16. Monetary losses due to Brucellosis in animal production: literature vs expert elicitation protocol

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total loss in animal production, million NGN (current)</td>
<td>141</td>
<td>129</td>
<td>128 886</td>
</tr>
<tr>
<td>GDP, million NGN (current)</td>
<td>42 912</td>
<td>64 326</td>
<td>102 575 418</td>
</tr>
<tr>
<td>Agriculture value added (% of GDP)</td>
<td>26%</td>
<td>36%</td>
<td>21%</td>
</tr>
<tr>
<td>Loss as a % of GDP</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Loss as a % of AG GDP</td>
<td>1.3%</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

The prevalence rate for Bovine Tuberculosis (BTb) in cattle as estimated using expert elicitation protocol data - 10.7 percent – is within estimated ranges in the literature: 1.25 percent (Cadmus et al., 2010), 1.78 percent (Oluwasile et al., 2013), 4.3 percent (Cadmus et al., 2008), 3.19- 5.16 percent (Aliyu et al., 2009), 14 percent (Abubakar et al., 2011) and 21.4 percent (Okeke et al., 2014).

The WHO Tuberculosis Report found 407,000 new cases of tuberculosis (all types) in humans in 2016 in Nigeria, which corresponds to a rate of 0.2 percent of the total population (WHO, 2017). Ofukwu (2006) investigated the epidemiology of zoonotic tuberculosis in Benue state and found a prevalence rate of 6 percent. The results of the expert elicitation protocol are between these findings, estimating 0.1 and 0.3 percent prevalence rate of BTb in livestock keepers and consumers, respectively.

The expert elicitation protocol generated estimates of BTb losses in animals at about 1.8 billion USD PPP or 10 percent of the livestock value added and 0.16 percent of the national GDP. The literature comprises two studies that estimate losses only in selected abattoirs: 1.7 USD million in Maiduguri main abattoir (Kwaghe et al., 2015); 3.3 USD million in Ibadan at the Bodija abattoir (Adedipe, 2014). Such a high figure for individual abattoirs suggest that the expert elicitation protocol estimates are plausible.

Expert elicitation protocol data on HPAI fatality rate are consistent with official statistics, as they result in about 4.1 million cases for the period 2015-2017. The expert elicitation protocol data estimate the monetary loss due to HPAI at about 106 million USD PPP, equivalent to 0.59 percent of the livestock GDP and 0.01 percent of the national GDP. These estimates, amounting to about 10 billion Naira, are in line with the total economic loss due to HPAI calculated by Kwaghe et al. (2017), that is 9.7 billion Naira.

The expert elicitation protocol data generate an estimated prevalence of Salmonellosis in extensive poultry systems of 15 percent. This is in line with the available literature: 8.5 percent (Abdoulaye, 2012) and 15 percent (Salihu et al., 2014). For in intensive poultry systems, expert elicitation protocol data suggest an estimated prevalence of salmonellosis of 20 percent, which is slightly higher than the 14.1 percent reported by Fagbamila et al. (2017).

---


12 Proxied by share of 1981, the closest datapoint available
As to humans, data elicited from experts generate a prevalence rate of 0.38 among livestock keepers and 0.5 percent among consumers. Fashea et al. (2010) found a sero-prevalence rate of 4 percent in a sample of 991 people 2004 and 2005; Oluyege and Bola (2014) found a 12 percent prevalence rate of non-typhoidal Salmonella among 150 HIV/AIDS patients in Eliti state. Estimates from the literature are, as expected higher, because they refer to seroprevalence.

We were unable to find any published paper estimating the economic cost of Salmonellosis in Nigeria. Data from the expert elicitation protocol, suggesting the disease generates a total economic loss of about 395.6 million USD PPP, that is 2.24 percent of the livestock GDP and 0.04 percent of the national GDP, allows thus a first estimate of the economic cost of Salmonellosis for Nigeria.

5. Conclusion

A comprehensive assessment of the economic and social impact of zoonotic diseases on society is challenging both because of lack of a standard methodology and insufficient data. This report presents a first evaluation of the economic costs of four zoonotic diseases for the Nigeria society.

In the next decades, Nigeria development will lead to a transformation of the livestock sector, leading to novel interaction between animals, humans and wildlife, and novel and different risks of zoonotic disease emergence and spread. Within this context, it is imperative that policy-makers be in a position to assess the impact of zoonoses on society to take informed decisions. This paper presented an expert elicitation protocol to gather data to quantify in monetary terms the impact of zoonotic diseases in Nigeria and its implementation on brucellosis and bovine tuberculosis in cattle and HPAI and salmonellosis in poultry. Nigerian livestock stakeholders may wish to consider refining the expert elicitation protocol and expanding it to other zoonotic diseases for improved information base for decision making.

October 2018. This report has been written by Emmanuel Odunze (Federal Ministry of Agriculture and Rural Development), Orsolya Mikecz (FAO Animal Production and Health Division), Ugo Pica-Ciamarra (FAO Animal Production and Health Division) and Hiver Boussini (FAO Nigeria). We thank all the human and animal health experts who generously shared their knowledge and experiences. ASL2050 is a USAID-funded policy initiative that is implemented under the umbrella of the FAO Emerging Pandemic Threat Program.
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APPENDIX

A1. DATA SOURCES

- **Protocol data**: After a thorough review of available literature and data, the ASL2050 team designed an Expert Elicitation Protocol to gather the information needed to calculate the economic and public health impact of the priority diseases in project countries. More than 250 experts were interviewed in the six countries. The questions were asked in relative terms (i.e. per 1,000 cattle, per 100,000 consumers etc.) and were converted to national numbers using information from the production system briefs (animal population), number of livestock keepers (household surveys) and number of consumers (World Bank Consumption Database).

- **Household survey data**: Nationally representative household survey data implemented by the countries’ National Statistical Offices allow the number of households keeping livestock to be determined.

- **World Bank Consumption Database**: The World Bank Consumption Database provides information on the share of households consuming cattle and poultry products.

- **Global Livestock Environmental Assessment Model (GLEAM)**: GLEAM is a GIS\(^{13}\) framework that simulates the bio-physical processes and activities along livestock supply chains under a life cycle assessment approach. The aim of GLEAM is to quantify production and use of natural resources in the livestock sector and to identify environmental impacts of livestock in order to contribute to the assessment of adaptation and mitigation scenarios to move towards a more sustainable livestock sector.

A2. EQUATIONS

We determine the economic and public health impact in monetary terms, as a sum of the value of animals lost due to the diseases, the loss from salvage slaughtering and culling, the loss from production decrease and the social cost of human mortality and morbidity. The following sections describe the calculations and the sources of data for these components.

\[
\text{Economic and Public Health impact (USD)} = \\
\text{Value of animals lost (I)} + \\
\text{Loss from salvage slaughter and culling (II)} + \\
\text{Loss from production decrease (III)} + \\
\text{Social cost of human mortality (IV.1)} + \\
\text{Social cost of human morbidity (IV.2)}
\]

**Value of animals lost**

The value of animals lost comprises three main components: the value of the animals that died due to the disease, the value of animals whose carcass had to be condemned and the value of calves who were not born due to fertility decrease caused by the disease:

\[
\text{Value of animals lost} = \\
\text{Number of animals that died due to disease (I.1)} * \\
\text{Animal farmgate price (I.2)}
\]

\(^{13}\) Geographic Information System
Only for cattle:

\[
\text{Number of carcasses condemned (I.3)} \\
\times \text{Animal farmgate price (I.2)} \\
+ \text{Number of unborn calves (I.5)} \\
\times \text{Calf farmgate price (I.6)}
\]

I.1 **Number of animals that died due to the disease**: The number of animals that died due to the disease was asked in the protocol per 1,000 animals for Brucellosis, Bovine TB, Anthrax and Salmonellosis and per 1,000,000 birds for HPAI.

I.2 **Adult animal farmgate price**: To attach a monetary value to the number of animals lost, country data on the adult animal farmgate price was used.

I.3 **Number of carcasses condemned**: The number of carcasses condemned was asked in relative terms (see I.1) for cattle related diseases.

I.4 **Number of unborn calves**: The protocol gathered information on the fertility loss in percentages due to cattle related diseases. To estimate the number of unborn calves, we determined the number of calves that were likely to be born among the infected animals in the given year by calculating the number of survivors as the difference between cases and deaths available from the protocol and multiplying this with the share of adult cows and the calving rate that is available by production system in GLEAM. Then we applied the fertility loss in percentages to the number of calves that were to be born among survivors:

\[
\text{Number of unborn calves (I.4)} = \text{Number of survivors (Protocol: cases-deaths)} \times \text{Share of adult cows (GLEAM)} \times \text{Calving rate (GLEAM)} \times \text{Fertility loss (Protocol)}
\]

(II) **Salvage slaughter and culling**

a) **Cattle**

Carcasses (or parts thereof) may be condemned after culling (or salvage slaughter), therefore we must subtract the number of carcasses condemned to avoid double counting. The loss due to culling or salvage slaughtering one animal is determined as the difference in the sales value of a healthy adult and the salvage value. The salvage value of an animal has been calculated using a discount rate on the full price, given by experts consulted during the validation of the protocol data.

\[
\text{Loss from salvage slaughter and culling (cattle)} = (\text{Number of salvage slaughter} + \text{Number of animals culled} - \text{Number of carcasses condemned}) \times (\text{Animal farmgate price (I.2)} - \text{Salvage value (II.2)})
\]

II.1 **Number of salvage slaughter, animals culled and carcasses condemned**: available from protocol data, in relative terms (per 1,000 cattle) and converted to absolute numbers using cattle population data from the countries’ Production Systems Spotlights.
II.2 ‘Salvage value’ of culls/salvage slaughter: A discounted price of an animal culled (or salvage slaughtered), estimated using the discount rate given by experts consulted at the validation of Protocol results.

b) Poultry:

For poultry, some producers decide to slaughter and consume the animal a disease is suspected. The animal will likely have a lower weight and therefore we suggest using a discount rate of 50% when calculating the total value. The producer may cull the entire flock, such that the number of deaths + salvage slaughters + culls may be more than cases. Where the number of deaths + salvage slaughters + culls surpass the number of cases, we assume total loss of all the cases plus the additional animals that were slaughtered/culled but not sick. Where there the number of survivors is obtainable, then we calculate the productivity loss. There is no production from poultry being culled, therefore there we account the total value of the animals as a loss.

\[
\text{Loss from salvage slaughter and culling (poultry)} = \\
\left(\text{Number of salvage slaughter (Protocol)} \times \right. \\
\left. \text{Price of live animal (Country data, FAOSTAT)} \times \right. \\
\left. (1 - \text{Discount rate due to disease (50%)})) + \right. \\
\left. \text{Number of culls (Protocol)} \times \right. \\
\left. \text{Price of live animal (of same age as culls) (Country data, FAOSTAT)} \right)
\]

(III.) Loss from production decrease

a) Cattle: The animals infected but not dead suffer a decrease in productivity, notably weight loss, milk production decrease and fertility loss. To evaluate the economic impact of a disease we estimate the value of total decrease in production:

\[
\text{Loss of production decrease (cattle)} = \\
\text{Loss of meat production (III.1)} + \\
\text{Loss of milk production (III.2)}
\]

(III.1) Loss of meat production

\[
\text{Loss of meat production} = \\
\text{Number of survivors (cases-deaths, Protocol)} \times \\
\text{Weight loss in kilograms per head (Protocol)} \times \\
\text{Dressing percentage (GLEAM)} \times \\
\text{Price of beef per kg (Country data, FAOSTAT)}
\]

(III.2) Loss of milk production
Loss of milk production

= Loss from foregone lactation period (III.2.1) 
  + Loss from milk productivity decrease (III.2.2)

III.2.1 Loss from forgone lactation period:

Loss from foregone lactation period

= Number of unborn calves (see I.5 above) 
  * 
  Average litres per lactation (Country data by production system)

III.2.2 Loss from milk productivity decrease:

Loss from productivity decrease

= Number of cows affected by productivity decrease (II.2.1) 
  * 
  Milk loss in litres per lactation period (Protocol)

II.2.1 Number of cows affected by productivity decrease: The number of cows affected by productivity loss are those survivors who were likely to have a calf and were not affected by the fertility loss (i.e. they had a calf):

Number of survivors (cases-deaths from Protocol) 
  * 
  Share of adult cows (GLEAM) 
  * 
  Calving rate (GLEAM) 
  * 
  (1-Fertility loss) (Protocol)

b) Poultry

(III.3) Loss from eggs lost in survivors:

Loss from eggs lost in survivors

= Number of survivors (cases-deaths from Protocol) 
  * 
  Percentage of eggs lost in survivors (Protocol) 
  * 
  Number of eggs per hen in one year (Country data) 
  * 
  Farmgate price of eggs (Country data, FAOSTAT)

IV. Social cost of disease

Social cost of disease

= DALY (IV.1) 
  *
Willingness to pay for a DALY (IV.2)

Variables:

**Number of livestock keepers by production system:** We estimate the number of people at risk of contracting one of the zoonotic diseases through direct contact with animals. We use household survey data (LSMS and DHS) to estimate the number of people living in households keeping cattle and poultry. We assume that the distribution of livestock keepers among production systems is the same as the distribution of the number of farms among production systems. We use the animal population per production system and the average herd size to estimate the number of farms per production system.

**Number of consumers who are not livestock keepers:** In cases where people can be affected by the disease through consumption, we need to calculate the number of consumers but to avoid double-counting, we do not include livestock keepers. We determine the number of non-livestock keepers using household survey information described above. We use the share of households reporting consumption of cattle and poultry products using the Global Consumption Database of the World Bank.14

**VI.1 DALY**
Disability adjusted life years (DALYs) are calculated as the sum of the years of life lost due to premature mortality in the population and the equivalent “healthy” years lost due to disability during the sickness of survivors.

\[
\text{DALY} = \left( \text{Number of deaths (Protocol)} \times (\text{Average life expectancy (World Bank)} - \text{Average age of infection (Protocol)}) + \text{Number of survivors (Protocol)} \times \text{Duration of disease (Protocol)} \right) \times \text{DALY weight (WHO)}
\]

**IV.2 Willingness to pay for a DALY**
To attach a monetary value to a DALY, we need to determine the willingness to pay for a healthy year of life, i.e. the WTP to avoid a DALY. We use the value of statistical life calculated by the US Department of Transport, and translate it into a yearly value using the expected life span and a discount rate, following the methodology of the OECD. Then we translate this value into country context using a benefit transfer methodology. This methodology takes into account the differences in GDP per capita and the elasticity of the willingness to pay for a healthy life (i.e. how WTP changes as income grows).

\[
\text{Willingness to pay for a healthy life year} = \left( \frac{\text{Willingness to pay for a healthy life year in the United States (PPP) (see below)}}{\frac{\text{GDP per capita in PPP of country}}{\text{GDP per capita in PPP of US}}} \right)^{\text{elasticity}}
\]

\[
\text{Willingness to pay for a healthy life in the United States (PPP)} = \frac{\text{Value of Statistical Life (US Department of Transport)}}{\sum_{t=0}^{T}(1+\text{discount rate})^t}
\]
