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HPAI HIGHLY PATHOGENIC AVIAN INFLUENZA
PRO-POOR HPAI RISK REDUCTION

Approach for Evaluating the Impact of HPAI Control Options

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Africa/Indonesia Region Report No. 7

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Preface

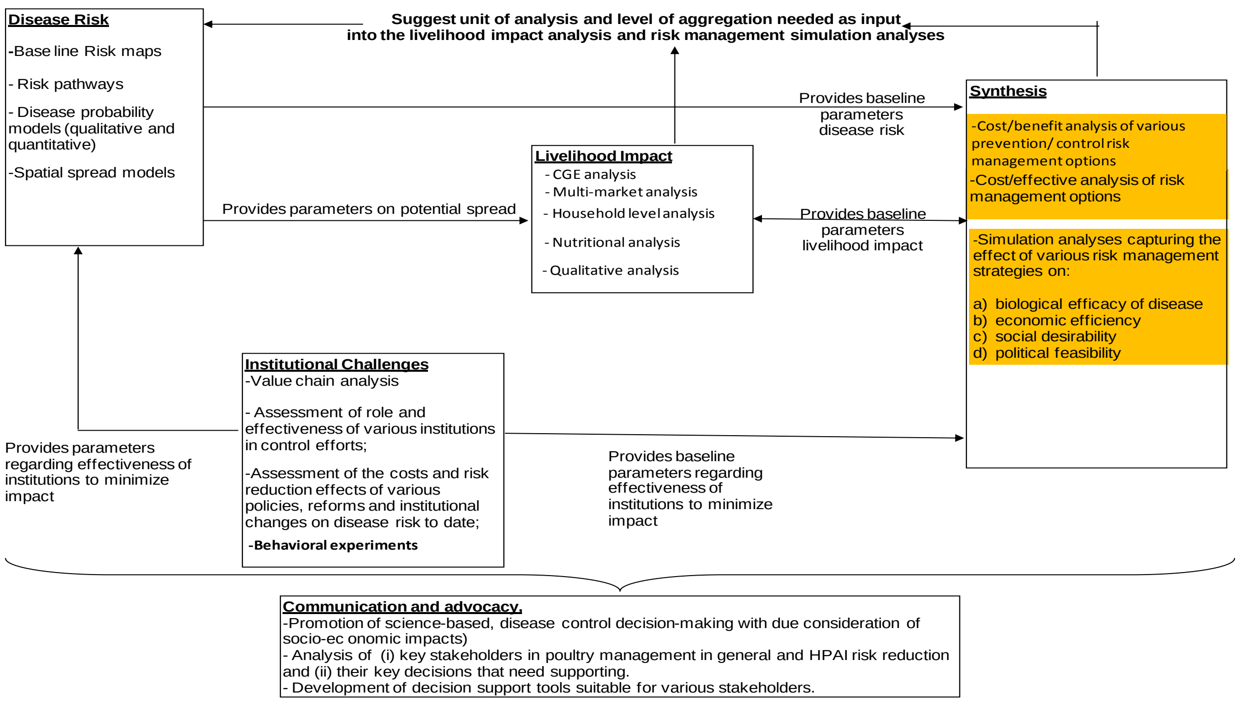
Since its re-emergence, HPAI H5N1 has attracted considerable public and media attention because the viruses involved have been shown to be capable of producing fatal disease in humans. While there is fear that the virus may mutate into a strain capable of sustained human-to-human transmission, the greatest impact to date has been on the highly diverse poultry industries in affected countries. In response to this, HPAI control measures have so far focused on implementing prevention and eradication measures in poultry populations, with more than 175 million birds culled in Southeast Asia alone.

Until now, significantly less emphasis has been placed on assessing the efficacy of risk reduction measures, including their effects on the livelihoods of smallholder farmers and their families. In order to improve local and global capacity for evidence-based decision making on the control of HPAI (and other diseases with epidemic potential), which inevitably has major social and economic impacts, the UK Department for International Development (DFID) has agreed to fund a collaborative, multidisciplinary HPAI research project for Southeast Asia and Africa.

The specific purpose of the project is to aid decision makers in developing evidence-based, pro-poor HPAI control measures at national and international levels. These control measures should not only be cost-effective and efficient in reducing disease risk, but also protect and enhance livelihoods, particularly those of smallholder producers in developing countries, who are and will remain the majority of livestock producers in these countries for some time to come.

To facilitate the development of evidence based pro-poor HPAI control measures the project is designed so that there are five work streams: disease risk, livelihood impact, institutional mechanisms, risk communication, and synthesis analysis. Project teams are allocating and collecting various types of data from study countries and employing novel methodologies from several disciplines within each of these work streams. So that efforts aren't duplicated and the outputs of one type of analysis feeds into another the methodologies in each work stream will be applied in a cohesive framework to gain complementarities between them based on uniformity of baselines and assumptions so that policy makers can have consistent policy recommendations. The figure below is the methodological framework used to depict how five work stream outputs fit together. This brief details how the outputs of the various work streams are linked to the synthesis analysis which is highlighted in the methodological framework below.

Methodological Framework



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Disclaimer

The views expressed in this report are those of the author(s) and are not necessarily endorsed by or representative of IFPRI, or of the cosponsoring or supporting organizations. This report is intended for discussion. It has not yet undergone editing.

More information

For more information about the project please refer to www.hpai-research.net.

1. Introduction

In a perfectly competitive market, the outputs of the goods and services of the economy and the set of prices for these outputs are determined in the marketplace in accordance with consumers' preferences and incomes, as well as producers' minimization of cost for a given output. In this market, the outcome is efficient and social welfare is maximized. When it comes to disease control there are often situations in which the conditions required to achieve the market-efficient outcome are not present due to market failures. Under such situations governments may choose to intervene to correct the market failure. Due to stochastic forces it is not always clear how to intervene optimally.

Uncertainty involved in disease spread, control, and adoption of control measures decision makers are increasingly using analysis based on probability theory to aid them in making informed decisions regarding regulatory actions to prevent (or reduce) the incidence of disease. Risk analysis, a probability-based analytical approach, typically consists of hazard identification, risk assessment, risk management, and risk communication. Risk assessment involves the evaluation of the likelihood of entry, establishment, and spread of disease identified as the hazard as well as the biological and economic consequences of the disease. Risk management involves evaluation of how to best mitigate the risk and to determine the cost to society of the action. Risk communication involves identifying ways to interact with the public as stakeholders and inform them of risk findings so that their decisions can be adequately informed. Typically, approaches tend to be generic and do not specifically focus on the impact of risk reduction measures on the poor per se and the effectiveness of the institutions to implement the control measures.

Within the DfID funded Pro-Poor HPAI project we are using a modified risk analysis approach, which is the risk analysis plus a number of other outputs so that decision makers are fully aware of the potential impact of control measures on the poor. The project focuses on the outputs from 5 work streams: disease risk, livelihood impacts, institutional mechanisms, risk communication, and the synthesis analysis. The hazard identification and risk assessment components of the traditional approach are done under the disease risk work stream of the DfID project. The economic consequences of the disease (part of the traditional risk assessment) takes place in the livelihood impact work and synthesis analysis work stream of the DfID project. The livelihood impact work stream estimates the direct and indirect consequences of the disease in terms of the macro-economic and household impacts, while the synthesis analysis looks at the economic impact of the cost and benefits of disease control including operating expenses and compensation. The evaluation of risk management options within the traditional approach is done under the synthesis analysis work stream integrating the outputs of all the work streams in a series of simulations to identify optimal pro-poor control strategies of the DfID project. The institutional mechanism work stream is an addition to the traditional risk analysis approach, but provides a more complete understanding of the role of actors along the value chain as well as the effectiveness of institutions in place to implement control measure and the effectiveness of that effort on reducing the risk of disease. In addition under the institutional mechanisms behavioral experiments are done to better understand what economic factors driving individual’s choice to alter behavior associated with disease control.

The overall goal of the synthesis analysis is to help national governments and international organizations to be prepared to make informed decisions should need arise (in countries that have not had HPAI) and to limit the spread of HPAI (in countries that have had HPAI), while minimizing the impact on different socio-economic groups, particularly the poor. Most analysis regarding HPAI to date have looked at either the risk of HPAI or the impact (see Beach 2007, Burgos and Burgos, 2007, Goutard et al, 2006, Carver, 2003, Pfeiffer, 2007, Curry 2006, etc) have taken a disciplinary approach (economic, veterinarian, epidemiology, or sociological). Though these analyses are insightful in their own right, singularly they do not provide all the answers to the questions decision makers have regarding how to optimally intervene to correct market failures.

Currently the types of questions that policy makers seeking to combat HPAI are faced with include:

- What are the pathways by which HPAI can spread to poultry in each study country, and what is the likelihood that it will spread by each identified pathway?
- Where are the critical control points for mitigation of HPAI risk in each study country, given the over-arching objective of averting a global human pandemic?
- What is the epidemiological impact of various control and prevention strategies in each study country, and what are the economic costs and benefits associated with each strategy at each identified control point?
- What would be the impact if there were no intervention to control for HPAI?
- How are the costs and benefits of various control and prevention strategies distributed among different segments of the population in each study country, with particular emphasis on the poor?
- What are the cost-effective control strategies or bio-security measures that are most likely to be implemented (i.e. adopted) by the poor in each study country?
- What are the institutions and incentive mechanisms that would enable or impede adoption of control and prevention strategies that are both effective and pro-poor in each study country, and how can these be facilitated by interaction with international institutions?
- What type of decision and communication processes need to be in place in each country to ensure that research findings are incorporated into the policies and plans for HPAI control and prevention?
- What are the similarities and differences among various control and prevention strategies, and institutions and incentive mechanisms for different countries in terms of their epidemiological and economic situation?

An analysis that enables decision makers to understand the risk-risk tradeoffs associated with one action versus another, such as culling all potentially infected animals versus nutritional impact on different segments of the population, provides a more complete picture of the impact of their potential actions. With this in mind the synthesis work stream has been designed to use the outputs of other work streams to conduct cost benefit and cost effectiveness analysis of control options to evaluate the effects of HPAI control strategies on biological efficacy, economic efficiency, social desirability and political will. Cost-benefit analysis (CBA) is a tool commonly used by decision makers to systematically estimate all the benefits and all the costs of associated with a contemplated course of action in comparison with alternative courses of actions. According to Arrow, et al. (1997), the role of CBA in environment, health, and safety regulations is to inform the allocation of scare resources to be put the greatest social good. However in not all cases is the monetary costs what is most important to decision makers. Cost-effectiveness analysis (CEA) is a tool commonly used to evaluate the return of an intervention when it is impractical to consider the monetary value of the benefit by the alternative under consideration. When it comes to disease risk reduction decision makers are also interested in the effectiveness of the measures in terms of risk reduction. The distribution of costs among socio-economic groups may differ from the distribution of benefits. A bio-economic simulation modeling approach described below will be used to measure the changes in outcomes from alternative HPAI control strategies on these four work streams with particular attention to the underserved populations.

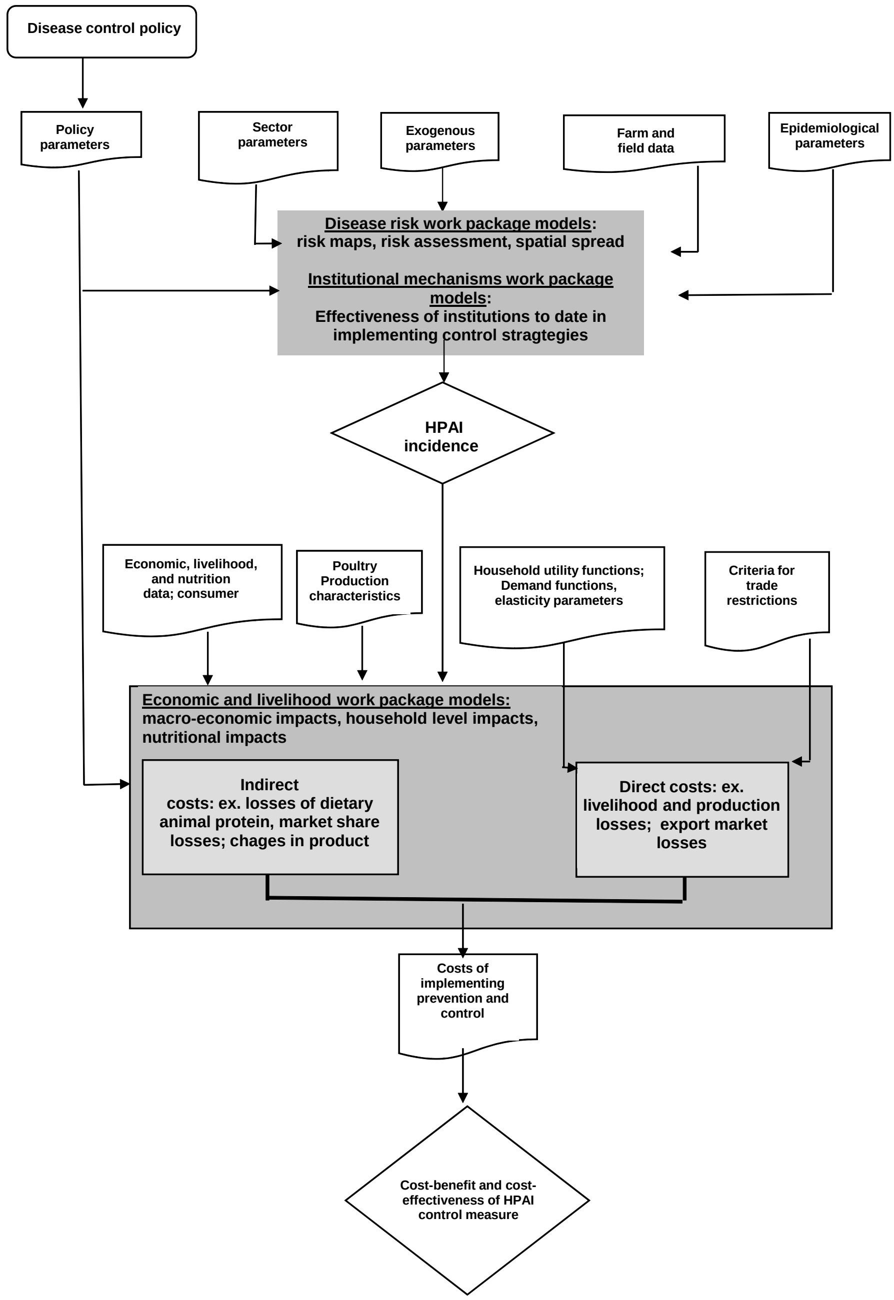
This brief proceeds by discussing a) the role of the synthesis analysis and the steps that will take place under this work stream, b) a modeling approaches that will be used for the cost benefit analysis (CBA), cost effective analysis (CEA), building of decision/event trees, and simulation of a bio-economic model, c) data needs for conducting the CBA and CEA, d) the types of policy scenarios for which simulations are proposed, and e) a methodological framework depicting how the outputs of each of the work streams are linked.

2. Role of the Synthesis Analysis

The purpose behind the synthesis analysis is to provide an analytical framework that captures the biological efficacy, economic efficiency, social desirability, and political feasibility of available intervention options and their appropriateness to country policies and programs. The synthesis will provide decision makers with an understanding of how to select amongst a number of options how to best correct for market failures. The outputs under this umbrella include a framework for decision makers to assess various preventive/control risk management options being considered in terms of (1) a CBA of various control options being considered, (2) a CEA of these control options in terms of risk reduction, and (3) interplay between impact on livelihoods and adoption of control measures. The synthesis will employ outputs from all the work streams to produce a decision tool that can be used to simulate the spatial distribution of effects from HPAI and its control.

Following the method of Breukers, et al (2008) shown in figure 1, and adapted to the specifics of HPAI project and the study countries, a bio-economic simulation modeling approach will be formulated to assess the changes in outcomes from alternative disease management options on disease risk and livelihoods. This approach links the disease risk models outputs which simulate the propagation of disease through the supply chain with an economic and livelihood consequences model to create a cost-effectiveness trade-off curve that can inform policy decisions. The approach will be tailored to the data collected as well as estimates, and to the features of the poultry value chain.

Figure 1: Bio-economic model illustrating how the components are related.



In Tiongco brief; adapted from (Breukers, et al, 2008)

Given a variety of stochastic forces can alter the outcome of mitigations, the synthesis analysis will include a series of outputs based on simulations showing decision makers the trade-offs that they would face as they try to balance the effect of various risk management strategies on biological efficacy of disease, economic efficiency, social desirability, and political feasibility while recognizing that the effectiveness of any strategy will be dictated by level of adoption. The goal of these simulations is to provide decision makers the likely performance of different strategies in terms of key decisions parameters (origin and length of outbreak, spatial spread outbreak, cost of outbreak, effectiveness of response and control measures). It should be noted that since a complete census of poultry producers is not the focus of this project we will be using existing data sets, and in a selected set of countries, sampling and aggregation will be used to describe the spatial distribution of poultry producers. Each sub-regional unit of aggregation will include producers of different groups based on socio-economic and production type classification.

In order to create the bio-economic model, the disease risk work stream will need to supply spatially explicit event trees (one for each country) that will be used to compute the probability that a producer in a certain class (specified by its type, size, biosecurity regime, and proximity to other producers, etc.) and at a particular location will transition from a state of no infection to a state of infection. It will need to provide parameters such as number of premises infected, duration of the outbreak, the number of animals culled in addition to other control options implemented. Control measures applied at different critical points along the supply chain will change these probabilities, reducing the overall disease risk. The spatial aspect is captured by the fact that using a control measure in one region will affect the incidence, and possibly the spread, of disease in another neighboring region. The model will produce distribution for each of these parameters to reflect the range of potential outcomes for an outbreak or continual outbreaks.

The economic and livelihoods impact work stream will quantify the degree to which poultry production factors into the livelihoods of the poor, as small producers and labor for larger producers, and as consumers of poultry products. HPAI will affect producers' ability to earn income from poultry processing. The simulation based on the disease risk work stream outputs will be used to generate scenarios that will feed into the economic and livelihood impact work stream. These scenarios, or shocks, to the economy will have effects on productivity and income at both the household level and the larger economy. At the household level these shocks will be modeled using partial equilibrium models capturing the impact on livelihoods at the household level. As partial equilibrium models cannot adequately capture the impact to the larger economy multi-market approaches and CGE approaches where warranted will also be used.

The institutional mechanism work stream aims to identify the effectiveness, and how it can be improved, of the actors involved in the poultry supply chain, both public and private sector. The effectiveness of institutions bears directly on the effectiveness of control measures, especially regarding implementation, adoption, monitoring and enforcement. Thus the institutional mechanism in play in a specific country factor into the effectiveness of the control measures to reduce HPAI at critical control points, and hence the overall effectiveness of the disease management strategy.

The synthesis integrates the above outputs into the large bio-economic model. A key output of the synthesis analysis work stream will be frequency distributions of important indicators, such as disease detections, income lost by household cohort and others that illustrate the impact of HPAI. This distribution can be expressed as:

$F_i(z)$ = Probability of an outbreak in cohort *i* with control strategy *z*

Where:

z = set of control measures in place
i = a population of interest categorized, for example, by income group, region, or the entire country.

The distributions will be compared to the baseline scenario, defined by the status quo in each study country, denoted by $F_i(0)$.

Difference between the distributions $F_i(z)$ and $F_i(0)$ will show how the benefits (costs) of HPAI control are distributed among different groups, thus informing decision makers of the possible consequences of one course of action versus another. When plotted against the cost of implementing z_i a trade-off curve can be produced that shows the relative value of control option set z. The advantage of the approach is that it provides a mechanism for decision makers to evaluate a "portfolio" of mitigation techniques to obtain some desired level of safety (or maximizing safety for a given cost). The strategy a risk manager chooses depends on the risk preferences of the affected stakeholders and on their comparative advantage in implementing particular risk-reduction options.

Major steps that will support the synthesise analysis work steam output are the following:

Step 1: Review existing methodological literature on CBA and CEA in relationship to evaluating risk management strategies associated with diseases and invasive species.

Step 2: Compile an inventory for each country of available cost and benefit data from other work streams and/or other studies and collection of additional data on costs and benefits of various control options; communicating the units and level of disaggregation needed for models used in this output and collect additional data if needed;

Step 3: Simple cost/benefit analysis of various prevention/control risk management options with national collaborators

Step 4: Simple cost/effectiveness analysis of risk management options (in terms of risk reduction) using the output of the CBA above and the quantitative risk assessments done under the disease risk work stream with national collaborators

Step 5: Develop a decision/event tree model to illustrate control alternatives and potential outcomes of control and calculate the probability weighted (expected) values for each decision choices (control strategy) and the net financial outcome (cost and losses) for each event weighted by the probability of the occurrence and summed up to give the expected value for each decision choice.

Step 6: Bio-economic simulation analyses modelling the effect of various risk management strategies on biological efficacy of disease, economic efficiency, social desirability, and political feasibility

Step 7: Bio-economic simulation analyses modelling the appropriateness of the uptake of various risk management strategies into country policies and program and adoption by smallholders (in countries with behavioural experiments)

3. Modelling Approach

In the project the costs and benefits of the impacts of an intervention will be evaluated in terms of the public's willingness to pay for them (benefits) or willingness to pay to avoid them (costs). Cost benefit analysis (CBA) and cost effectiveness analysis (CEA) are quantitative economics-based techniques that are intended to improve the quality of public policies (Kopp et al. 1997). CBA allows decision makers to rank policies and those that have the larger impact on well being are considered preferable. CEA, closely related to CBA, looks to achieve the specified goal with the smallest loss in social welfare recognizing that the smallest loss might not be associated with the smallest dollar cost. For the HPAI project the objective of the CBA and CEA analyses is to provide economic and disease risk and information on the impact a set of control strategies that could be adopted in the event of an outbreak of HPAI in a country or in the case of recurrent outbreaks within a country. For the cost effectiveness analysis it is recognized that certain strategies may have economies of scale that favor large producers.

A. Modelling the direct costs of a disease

It is assumed that for HPAI that all animals infected with the disease or are possibly infected either die or are culled. The direct costs of the disease will be assessed using a partial budget model adapted from Bennett (2003)[1] to measure the direct cost of animal disease it is assumed that the direct costs of HPAI are related to the loss in expected output, increases in expenditure on non-veterinary resources due to the disease, cost of inputs to prevent the disease such that:

$$C = L + R + P$$

Where:

C = direct cost per year
L = annual loss in expected outputs and wasted inputs due to disease
R = the increase in expenditures on non-veterinary recourses due to the disease
P = annual cost of disease prevention measures

[1] Treatment of disease has been dropped as with HPAI control currently animals are only slaughtered, not treated.

B. Modelling Approach to CBA of the Intervention

Cost benefit analysis is typically used by governments to evaluate the desirability of a given intervention in markets. The goal of the analysis is to understand the efficiency of the intervention relative to the status quo in an objective quantitative way of determining whether protections should be initiated, continued, or abandoned. Economic efficiency is measured as the net contribution of an intervention to overall social welfare.

The costs and benefits of the impact of an intervention are evaluated in terms of the public's willingness to pay for them (benefits) or the willingness to pay to avoid them (costs). An intervention would be considered pareto optimal if it improves the situation for some people, but does not make anybody worse off. It is recognized that it is often difficult to identify pareto optimal solutions since rarely is it possible to design a policy such that someone is not made worse off. Analysis that provides potential pareto solutions that recognize those who gain could compensate those who lose for their losses and still be better off provides decision makers with a mathematical way to determine efficient interventions. Thus for governments acceptable (intervention) policies typically are when:

$$E(\text{Benefits}) \geq E(\text{Costs})$$

Glauber and Narrod (2001) have argued that an optimal policy is when a government chooses a policy that maximizes net benefits such that:

$$E(MB) = E(MC)$$

Where:
MB = marginal benefits
MC = marginal cost

For the synthesis analysis we will use initially a simple partial equilibrium model of disease control to get at the global CBA similar to the one outlined in Rendleman and Spinelli (1999) and modified by Glauber and Narrod (2001) for analyzing the costs and benefits of alternative policies. In this approach W_D was the welfare effect in the event of a disease outbreak and W_N was the welfare effect in the event of no outbreak such that $W_N > W_D$ Thus if an outbreak occurs with probability *p*, then the expected welfare, *EW*, can be written:

$$EW = pW_D + (1-p)W_N \quad (1)$$

Now consider a risk reduction measure, ϕ, that affects the probability of an outbreak and welfare such that:

$$EW(\phi) = p(\phi)W_D(\phi) + (1-p(\phi))W_N(\phi) - C(\phi) \quad (2)$$

where $C(\phi)$ is the cost of implementing the risk reduction measure. An optimal policy maximizes (2) with respect to ϕ such that:

$$\frac{\delta EW(\phi)}{\delta\phi} = 0 \text{, or} \tag{3}$$

$$p'(\phi)W_D(\phi) + p(\phi)W_D'(\phi) - p'(\phi)W_N + (1 - p(\phi))W_N'(\phi) - C'(\phi) = 0 \tag{4}$$

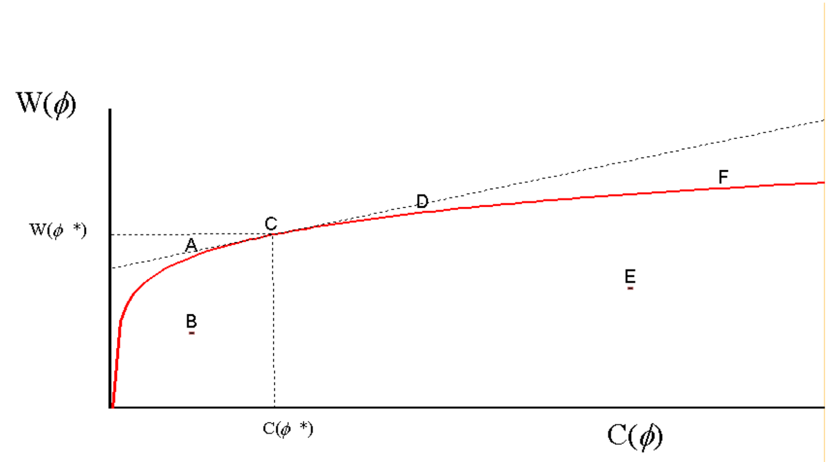
Rearranging the terms, an optimal risk reduction measure ϕ *, can be defined so that the marginal change in benefits is equal to the marginal change in costs.

$$p'(W_D - W_N) = C' - [pW_D' + (1-p)W_N'] \tag{5}$$

The left hand term reflects the net change in welfare due to the change in probability – the benefits of reducing the risk of outbreak. The right hand terms reflect the expected change in welfare due to the risk mitigation measure – the cost of implementing the measure.

The optimal risk reduction measure policy can be shown in figure 2. A, B, C, D, E, and F are risk reduction measures with associated costs and benefits. Policies A, C, D, and F lie on an efficient frontier of policy alternatives; that is, for a given cost, these policies result in the maximum possible benefits. Policies B and E are inferior policies. Policy C is the optimal risk migration policy, ϕ *, that satisfies equation (5). At this point, the marginal benefit of the risk mitigation policy is equal to the marginal cost. These options can be plotted and a frontier estimated where options below the frontier are considered inferior.

Figure 2: Optimal Risk Reduction measures



Source: Glauber and Narrod (2001)

Though cost benefit analysis traditionally focuses on efficiency by providing policy makers with an indication of the magnitude of net benefits associated with a particular policy, it also has the potential to track the distribution of costs and benefits within different segments of the population. Ideally for the case of the HPAI project one would be able to determine how costs and benefits are distributed by sector or geographic location. It is thus important to that the risk assessment identify the riskier pathways and sectors.

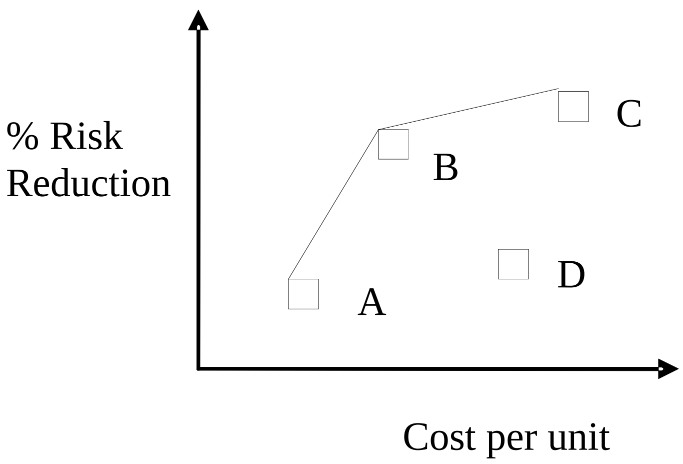
As uncertainty and variability exists with all variables used in the CBA estimates it is important that sensitivity and scenario analysis be conducted to illustrate how results may change if the value of a particular variable is changed.

C. A Modelling Approach to Cost Effectiveness Analysis

Once the CBA analysis has been completed and the quantitative risk assessment under the disease risk output, then CEA analysis can be used to pull together the results of the different scenarios along with the results of the sensitivity and uncertainty analysis to provide information on the cost and effectiveness of the various control strategies considered to support decision making and the outputs can be plotted on a trade-off curve to make it transparent to decision makers.

Figure 3 shows how four hypothetical control options (A, B, C, D) might be compared. The x-axis is the marginal cost of adding one of the new options compared to the baseline. The y-axis is the percentage reduction in risk over the baseline (no action). In this hypothetical scenario option D can be excluded as a choice since strategy B dominates D in the sense that B is both more effective and less costly. Choices of adoption strategy from a decision maker’s perspective can then be limited to non-dominated options A, B, and C (Malcolm et al., 2004).

Figure 3: Risk Cost Trade-Off Curve

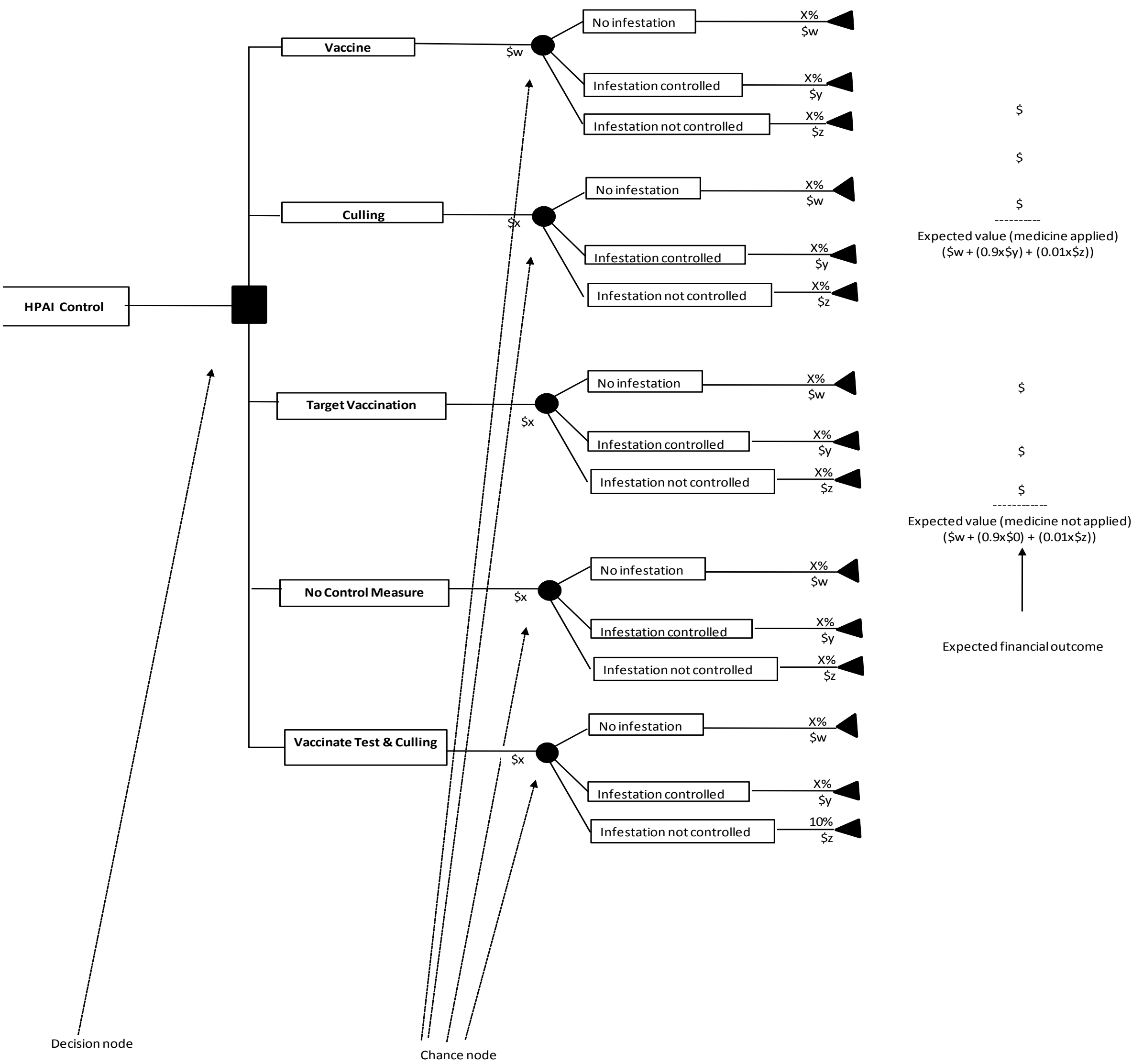


Source: Malcolm, Narrod, Roberts, and Ollinger et al 2004

D. Use of Decision/Event trees to depict decision choices associated with control actions

Optimal HPAI control strategies are subject to chance events. These can be captured in a simplified way by using a decision/event trees to depict (in approximately chronological order) alternative courses of control actions (decisions choices) and chance events with the time scale and associated costs (see Milne et al, 2007, Marsh, 1999). See figure 4 for a hypothetical decision /event tree looking at the decision to implement a HPAI control measure. The net financial outcome (cost and losses) for each event can then be weighted by its probability of occurrence and summed to give the expected value for each decision choice. As noted by Milne et al (2007) "the simplest choice criterion would be to choose the action with the highest expected value (or lowest where outcomes are costs), however in risky situations a decision-maker may wish to avoid alternative with a chance of particularly undesirable or unacceptable outcomes.

Figure 4: A hypothetical decision tree for the control of avian influenza



Source: Adapted from Milne et al 2007 and Fasina et al 2007

Note: For each of the control measure, there are actually two decision choices: to apply or not to apply; each decision will have the same chance of events: no infestation, infestation controlled, and infestation not controlled with the assigned probability of occurrence based on existing knowledge (from the disease risk outputs).

E. Bio-economic simulation model

Lastly we will use an optimization approach to simulate the effect of various risk management strategies on biological efficacy of disease, economic efficiency, social desirability, and political feasibility. We are considering three types of risk management approaches that actors have control of. These are things that the:

1) government does that impose no individual cost to operator
2) government does which do impose a costs to the operators,
3) operator can do at their own discretion.

The optimal levels of control measures would be those where the marginal benefits in terms of avoided impacts of HPAI are just equal to the marginal costs for providing the control measures. The objective is first to minimize the cost under risk of HPAI infection by choosing the level of control strategy. Basically the goal is to Max profit which is revenue a priori costs plus expected cost of disease.

$$\max_{T_p, T_{si}, N_{pi}, a_i, b_i} \text{Profit} = \text{Pp}\, Q_i - \left[w_p X_p + p_m C_m + w_{pN} N_{pi} + w\left(T_p + T_{si}\right) + p_a a_i + p_b b_i \right] - \pi_i(a, b) * C_d$$

where the parameters are defined as follows:

Q_i = poultry output, which is a function of farm and hired labor, flock size of the farm, and other fixed and variable inputs

Pp = poultry output price

wp = vector of farm input prices other than household labor and birds

Xp = farm inputs other than household labor and birds

pm = price vector for consumption goods

Cm = vector of consumption goods

wpN = input price per unit for poultry

N pi = flock size of the farm

w = wage rate

Tp = amount of time working on farm to produce poultry

Tsi = amount of time spent for on-farm disease surveillance

pa = price of HPAI vaccine

pb = price vector for biosecurity inputs

and the decision variables are defined as follows:

ai= takes a value of 0 if without vaccine, and 1 with vaccine

bi = vector of biosecurity measures

π_i = probability of an outbreak

Cd = cost of disease including financial compensation for culling as a control measure

Note that *i* above refers to a single class of operator and different classes are likely to have different costs and maybe sets of control options. In addition, the probability of outbreak is determined by what the individual operator does and what other operators do, and will differ between farms and along the value chain. Institutional costs for monitoring control measures and training will be covering costs both at the farm level and along the value chain.

4. Data needs for conducting the CBA and CEA

The CBA and CEA can be used to look at society's willingness to pay for both the indirect and direct costs. As much of the information needed will be collected in the process of other work streams, efforts will be made to coordinate data collection. The indirect cost of the disease will come from the macro-economic models under the economic and livelihood work stream. The direct costs will be developed under the synthesis analysis and data collected in each country through household and institutional surveys which is discussed later in this brief.

From disease risk output:

- Data of outbreak, status of outbreak, incidence and prevalence, epidemiology unit affected (e.g. farm, village, region, nation)
- Morbidity and case fatality rates
- Species and population affected and the number of susceptible, disease, dead, destroyed and slaughter animals
- Number of animal culled preventively in area of outbreak

From economic and livelihood impact output

- Data on poultry production, prices of inputs and outputs, revenues, costs of production including labor and transport costs, and capital investments and how HPAI alters that—this means looking at different scenarios or HPAI situation: from without infection, to sporadic, to endemic

From institutional mechanisms output

- Inventory of different institutional mechanisms to control HPAI (ie. information on public animal health services—number of veterinarians, diagnostic laboratories, etc., public disease control measure, and public regulations (ideally how has this changed over time—2000 to present)
- Parameter estimates capturing the effectiveness of various institutional control measures: parameters could include early detection rates, increase in number of reported cases, costs associated with implementing preventive and control measures including incentives and compensation given, rates of return of control measures

Additional data needs

- Cost of improved biosecurity at household level (changes in housing structure, keeping wild birds from accessing feed and water supplies, thorough cleaning of all clothing, shoes, an equipment before coming into contact with birds); Testing and diagnostic – cost per test for diagnostic test and routine serology

- Vaccination costs and frequency if done
- Education and technical assistance; training costs
- Surveillance costs to promote rapid disease reporting (farm level and value chain level) (public and private costs)
- Labour and distribution cost of control measures such as number of veterinary officers, valuers, cull teams, control strategy teams, travel requirements, disposal capacity (fed ministry)
- Lab costs –(budgets of vet institutes or private labs)
- Compensation costs +Eradication estimates (could be based on compensation paid out)
- Cost of depopulation and appropriate disposal, loss of market value in the event of an outbreak.
- Decontamination costs/cleaning and disinfection of infected and culled premises
- Disposal costs and associated transportation costs (incinerations, on-farm disposal, or off farm disposal)
- Travel and subsistence of staff working in the field + salary of culling teams

5. Obtaining additional data

Information on type of mitigations in practice and their costs relative to type of actor along the value will be collected through household surveys of farms, the ministry, and along the value chain to obtain information of the type of mitigations in practice and their costs relative to type of producers. An advantage of this method is that it captures the cost of individual households and institutions of implementing control measures. The Tiongco brief (2008) and the synthesis of the background paper (Tiongco lists what is currently been collected on the current control measures in each country).

6. Proposed simulation scenarios

There are a number of possible simulation scenarios that can be run. Below is a sample. The ones chosen will mirror those simulation scenarios under the disease risk output.

- No intervention (results in a predicted number of infected farms/ Assumptions alter the size and variability of the predicted number of infected farms
- Improved surveillance and increased flock segregation (including improved biosecurity and changes in patterns of poultry/people movement)
- Stamping out strategy
- Modified stamping, only culling animals with clinical signs
- Vaccination (once, twice, targeted, ring vaccination)
- Movement restrictions (live market and poultry movement)
- Targeted pre-emptive depopulations
- Combination of strategies

7. Methodological Framework linking outputs of the work streams

The figure 5 below is a proposed methodological framework depicting how these output fit together and Table 2 summarizes the output needs from the various work streams to ensure that linkages between work streams.

Figure 5: Methodological Framework

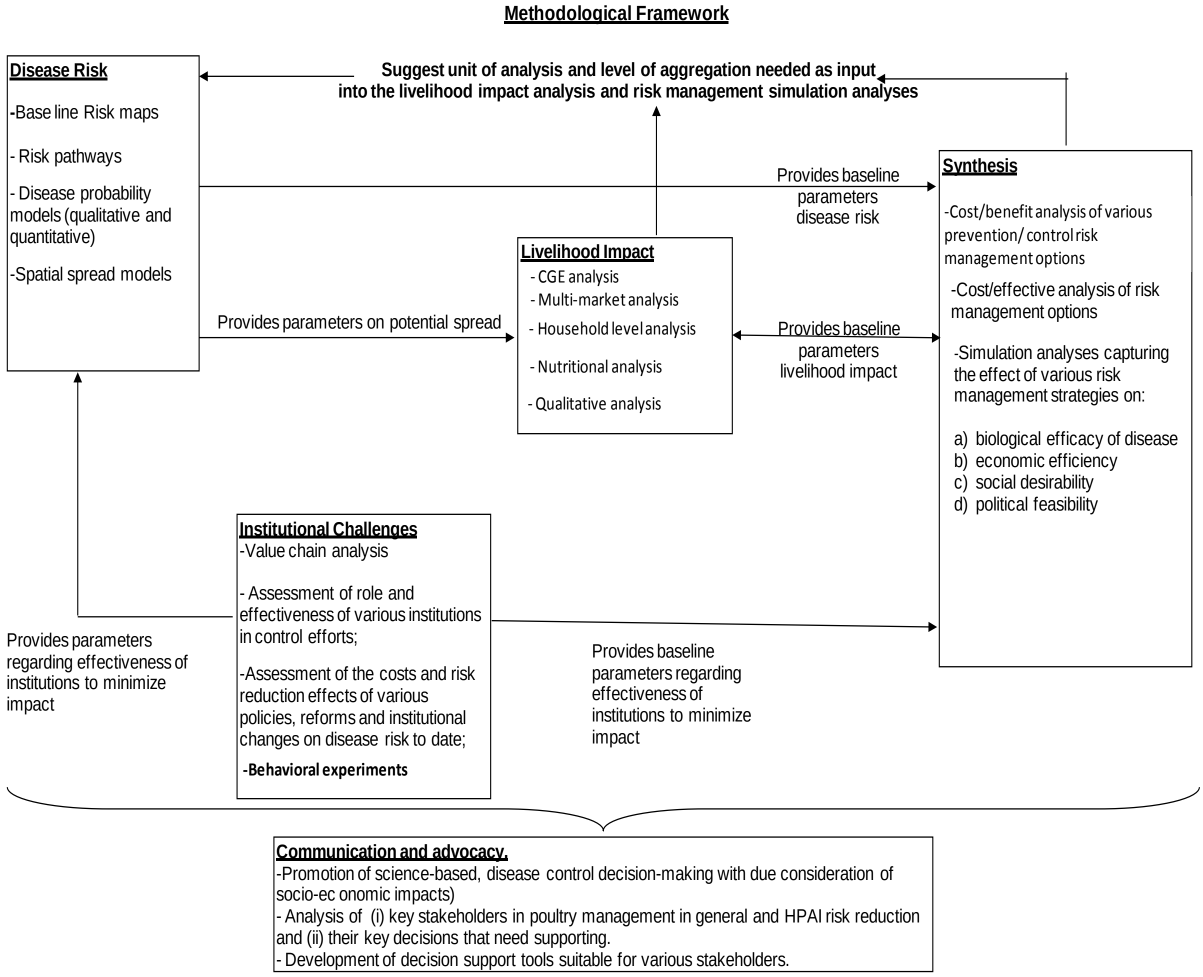


Table 1 lists the form in which the outputs are needed so as to be used by the other works streams. Below that each of the needs are described in more detail.

Table 1: Outputs need by other workstreams

Work stream	Outputs needed by other work streams
Disease risk	• Risk maps –the probability that a poultry producer with a given profile (size, socio-economic category, biosecurity measure, etc) within a given location will experience an outbreak for all 5 countries translated into "pixels"; needed by livelihood impact and synthesis analysis • Disease probability models (risk assessments) –distribution of potential frequencies of HPAI outbreaks and the range of possible outcomes (probabilities) in the form of parameter estimates of each control measures (or combination). These would include institutional and household level control measures as well as the variability and uncertainty of effectiveness of control measures by a given profile for all 5 countries; needed by livelihood impact and synthesis analysis • Spatial spread models - Using the risk assessments above and mathematical (epidemiology or ecological models to capture spatial spread) state and transition probabilities in the form of a parameter estimate of predictive disease spread with and without the control measures (and combination of control measures) in place for all 5 countries; the synthesis analysis is also interested in how changes in system parameters induced by mitigation measures can be used to determine the effectiveness of preventing disease spread resulting from such measures needed by livelihood impact and synthesis analysis • Note: Ideally at sub-regional level (would like to get as close as possible to the household (HH) level.) If these cannot be obtained, some form of simulation model that would predict the probability of spread between sub-regions in each study country will be needed.
Livelihood impacts	• Macro and micro level impacts of HPAI on the economy disaggregated for the household level as much as possible needed by syntheses analysis
Institutional mechanisms	• Value chain analysis of the poultry sector, key linkages, market failures, incentives, and interactions with risk pathways; flow chart of the potential pathways in which poultry inputs and outputs are marketed – needed for the disease risk output • Evaluation of mitigation practices and associated risks- an inventory of the different institutional mechanisms used to control HPAI - needed for disease risk and synthesis analysis outputs. • Parameter estimates capturing the effectiveness of the various institutional control measures to minimize impact of HPAI at the household level and along the value chain with actors of a given profile - needed for disease risk and synthesis analysis outputs • From the inventory the synthesis analysis team will work with the national partners to obtain cost data regarding implementation of control measures at the institutional level, along the value chain, and at the household level so as to run simulations - needed for the synthesis analysis

A. Disease risk output

The disease risk output provides an understanding the biological-risk system, including assessment of interventions to date on risk, and enhanced intervention predictive capacity associated with the potential further spread of HPAI. The proposed outputs under this umbrella include a series of reports containing baseline risk maps, identification of major pathways in which disease could spread or enter the country, creation of event trees and disease probability models (qualitative and quantitative), and mathematical spread models.

i. Risk Maps and linkage to livelihood impact output

One immediate approach to understanding potential risky areas is to link existing HPAI prevalence data using geographic information system (GIS) tools, and developing the statistical relationships between outbreaks and various potential spread mechanisms such as transportation, markets, wetlands, infrastructure, etc. Through this exercise, HPAI prevalence data can be evaluated and assembled into a GIS environment to produce HPAI risk maps (identifying, for example, high, medium, and low risk regions) for each study country in a manner that allows for the identification of high-risk areas for propagating the spread in an epidemiologically underpinned manner (see Boender et al 2007). In order to do this the output required by the economic and livelihood impact analysts from the risk maps is the probability that a poultry producer with a given profile (size, socio-economic category, biosecurity measure, etc) at a given location will experience an outbreak.

ii. Pathway analysis and linkage to institutional mechanism output

The second output of the disease risk module is a risk pathway analysis which aims at describing the multiple pathways and events that can lead to the undetected spread of HPAI in a country. In general poultry can become infected through direct contact with infected birds or through contact with contaminated carcasses, manure, or poultry by-products. People (e.g., shoes, clothing), equipment (e.g., cages, vehicles), insects, rodents, or other agents contaminated with the virus can also spread the disease (Jacob, et al. 2006). Marketing practices, particularly marketing of live birds, are important because another key source of potential infection is the transmission of disease between regions through movement of animals, people or infected material (Beach 2007). To assess these potential pathways, input from the value chain analysis under the institutional mechanisms work stream will be a crucial input for the risk pathway analysis. The pathway however may differ by country depending on the structure of the industry, the sources of inputs, and the marketing practices.

iii. Risk assessment and linkage to livelihood impact, institutional mechanism, and synthesis analysis outputs

From pathway analysis, an event tree can be developed to start the building of the probabilistic model (risk assessment). The third diseases risk output is to determine the probability of a specific event occurring at each of a number of important steps where initially controls do not take place (baseline scenario), and then to determine the probability with prospective controls in place that reflect the variability and uncertainty of effectiveness of these control measures. The Monte Carlo simulations will simulate the range of possibilities at each risk-increasing or risk-decreasing step so as to capture the wide range of possible outcomes at each element in the event tree model. The control measures will apply to a wide range of activities from the household to institutional level.

This work stream will need input from the assessment of role and effectiveness of various institutions in control efforts that is done under the institutional mechanisms work stream.

The output of the risk assessment can then be combined with economic information to determine the initial economic and livelihood impact if disease control measures were put in place. The economic and livelihood impact models aim to determine the distribution of potential frequencies of HPAI outbreaks and the range of possible outcomes (probabilities) in the form of parameter estimates that apply to each control measures (or combination of measures). These include institutional and household level control measures as well as the variability and uncertainty of effectiveness of control measures by a given profile that may differ by study country.

iv. Spatial spread model and linkage to livelihood impact, institutional mechanism, and synthesis analysis outputs

To date, most applications of GIS to HPAI have been to map locations of existing outbreaks in bird flocks and in humans as a useful visualization tool (e.g., WHO 2006, Moukomla 2004, Pfeiffer et al.). Such approaches are static to a degree and do not reflect spatial spread under different scenarios, so their application to predictive spatial modelling is limited. Given the location of producers relative to sources of transmission, it is possible that responses may be affected not only by type of spread but also by distance of the farmers to potential pathways. This project has thus been designed to produce spatial spread models that identify control mechanisms appropriate for producers of different location and sizes.

The first goal of the spatial spread model is to construct spatially explicit models that represent the national poultry sectors / industries and the transmission of HPAI using published information and local knowledge in relation to poultry production systems, species distribution, density and market flows.

Once developed, the model will be applied to country-specific potential control scenarios including, but not limited to the following (see Pfeiffer TOR for spatial spread models, 2008):

- The type of control measures for each country/region will be assessed against a baseline control scenario (i.e., current measures).
- Improved surveillance and increased flock segregation (including improved biosecurity and changes in patterns of poultry/people movement).
- Movement restrictions, ring culling and pre- and post-outbreak vaccination strategies (including ring-vaccination).
- Evaluation of the outcomes in terms of epidemiological impact (change in prevalence/incidence of infection and incidence of disease in poultry) and other indicators which can feed directly into the economic and livelihood impact and synthesis analysis outputs (numbers of birds culled, number of vaccinations required, etc)

Outputs of these scenarios will be critical inputs into the economic and livelihood impact models and the models developed for the synthesis analysis. The outputs these analyses require are: a) quantitative estimates of probability that a poultry producer with a given profile (size, socio-economic category, biosecurity measure, etc) will transition from a non-infected to an infected state, at the sub regional level, and b) distribution of potential frequencies of HPAI outbreaks and the range of possible outcomes of each control measure (or combination) as well as the variability and uncertainty of effectiveness of control measures by a given profile.

B. Economic and Livelihood impact

The economic and livelihood impact outputs provides an enhanced understanding and enhanced predictive capacity concerning of the role of poultry in livelihoods and the impact on poor poultry producers of HPAI and its control. The economic and livelihood impact output is an umbrella work stream incorporating three types of impacts – economic (macro), livelihood (HH), and nutritional. A combination of quantitative and qualitative analyses will be used to capture this impact of HPAI on the livelihoods in the study countries; the specific methods will be chosen based on the country situations (role of the poultry sector in the study countries economy) and available data.

The economic impact of HPAI can be felt both directly and indirectly. The direct impacts are in terms of production costs associated with losses of poultry, due to the disease and to control measures such as culling birds, with impacts extending not only to farmers but also to upstream and downstream sectors such as poultry traders, feed mills, breeding farms etc. The secondary or indirect impacts related to sharp shifts in market demand which result primarily from spontaneous efforts by consumers to reduce their subjective or perceived probability of becoming infected, as well as from trade restrictions on poultry trade imposed by governments seeking to prevent transmission of the disease. In so far as consumers switch from domestically produced poultry to other domestically produced foods, there ought not to be a large impact at the overall macroeconomic level, although there will be severe impacts on the poultry sector itself.

On the quantitative side the type of analysis envisioned include, partial equilibrium (multiple and single markets) analysis so as to show inter-linkages between sectors, country/region-wide CGE analysis household level analysis (where it makes sense) econometric analysis using localized surveys analysis (possible micro-simulations), and nutritional analysis. Each of these analyses has the potential to capture the impact of various shocks (disease spread or policy) on livelihoods from the outputs of the disease risk models.

i. Macro-economic impacts and linkages to the synthesis analysis[2]

The overall impact of the disease (including that of control measures) on the economy at large can occur and other agents employed in the poultry value chain will be affected. Disease shocks also affect the available supply of poultry products due to mortality (from disease and also from both demand as well as supply side. As consumer perceptions change with the occurrence of HPAI, the demand of poultry products will be affected and therefore the livelihoods of producers because of mitigation measures such as culling) and this will affect market prices. Both control and mitigation policies are expected to reduce the overall rate of disease incidence and thereby affect the economy favorably.

a. Develop multi-market models and CGE models (where done) to initially be run with arbitrary shocks then later integrate with disease risk output once completed with inter-linkages between sectors (SAMs with disaggregated poultry sectors) which captures spatial dimensions of HPAI

[2] see Roy brief, 2008

outbreak and control measures which captures disease shocks as well as shocks following control measures

b. Integrate with household data to implement micro-simulations to assess the impact on livelihoods and nutrition

What the macro-economic modelers are interested in as output from the disease risk models is the probability that a poultry producer with a given profile (size, socio-economic category, biosecurity measure, etc) will experience an outbreak. They are ultimately interested in state and transition probabilities that is to say that during any time period, depending on various factors, birds in a country have a probability of remaining in that state or move to another state (a transition). The modelers will use the initial disease risk maps to do the initial cut of the potential economic and livelihood impact of spatial spread of HPAI to different regions and refine the analysis when the risk assessment and spatial spread models are completed. The macro-economic analysis will provide the baseline scenarios for the synthesis analysis and the scenarios of various disease and policy shocks and control measures at the macro level on agents and on income (and hence poverty).

ii. Household livelihood impacts and linkages to the synthesis analysis [3]

The goal of the household impacts is to estimate the impact of HPAI on the livelihoods (revenue) of poultry producers of all sizes in study countries. In addition in a small group of countries the livelihood impact models will also look at how: HPAI shocks and/or stresses results in poultry asset loss (either via price and/or via loss of poultry), asset loss affects household behavior, i.e. livelihood strategies and diversification patterns (e.g., investment in biosecurity, shifting to other livelihoods activities), changes in household behavior or livelihoods strategies affect livelihood outcomes (e.g., income and food security), disease control policy (e.g., compensation) affects household livelihood outcomes and household livelihood outcomes determine the efficacy of disease control policy.

What the livelihood modelers are interested in as output from the disease risk models is what is the percentage of poultry producers are likely to lose in case of an outbreak the probability that a poultry producer with a given profile (size, socio-economic category, biosecurity measure, etc) will experience an outbreak. For the countries in which household surveys (Indonesia and Nigeria currently proposed) will be done the modelers will use the initial disease risk maps to identify where the household surveys will be done. The outputs of the livelihood analysis will provide an understanding of the impact of control measure on livelihood which in turn will effect adoption. This will be used in the simulation analysis done within the synthesis analysis.

iii. Nutritional impact of HPAI and linkages to the synthesis analysis [4]

The overall aim is to investigate the impact of HPAI shocks on human nutrition. With this in mind there are two objectives. The first objective is to characterize the importance of animal source foods (ASF), and more specifically poultry and poultry products, in the population diet and nutrition and second to identify the factors associated with animal source foods and poultry and poultry product consumption. The focus will be on vulnerable population groups: infants and young children (less

[3] see Birol brief 2008
[4] See Iannotti and Roy brief 2008

than 5 years); pregnant and lactating women; and women of reproductive age (15-45 yrs). They will use existing data on: household characteristics and expenditures, dietary intakes, anthropometry and nutrition biomarker measures, morbidity recalls, primary sources conduct cross sectional analysis to characterize the importance of poultry and poultry products in nutrition of country population. The second objective will be using panel data analysis in countries where it exists examine the long-term consequences of potential HPAI shock on nutrition-related outcomes in population

The outputs of the nutritional analysis will provide an understanding of the impact of HPAI on micronutrients. Outputs of these findings will be used in simulation analysis done within the synthesis analysis.

C. Institutional Challenges and linkages to the disease risk and synthesis analysis

The institutional challenges output provides an enhanced understanding of the institutional roles in controlling HPAI, response capacity, and interaction of institutions, and the role of incentives in institutional effectiveness. The proposed outputs under this umbrella include reports detailing: 1) market interactions and linkages in poultry markets with potential economic/public health effects; 2) assessment of role and effectiveness of various institutions in control efforts; 3) assessment of the costs and risk reduction effects of various policies k reforms, and institutional changes on disease risk to date; and 4) behavioural experiments to see what actually might work. The disease risk output needs the outputs of the poultry market interactions and linkages for their pathway analysis. The disease risk work stream and the synthesis analysis work streams need and inventory of the different institutional mechanisms used to control HPAI as well as parameter estimate capturing the effectiveness of the various institutional control measures on minimizing the impact of HPAI at the household level and along the value chain.

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