An *Expost* Economic Impact Assessment of the Intervention against Highly Pathogenic Avian Influenza in Nigeria

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Abstract

The risk of spread of HPAI in Nigeria was derived by using a compartmental model to outline endemic and burn-out scenarios. Two paths, low and high mortality risks, were associated to each of the scenarios. The estimated risk parameters were then used to stochastically simulate the trajectory of the disease; without intervention and with an intervention. The intervention costs the country US$ 41 million obtained through a World Bank IDA loan of US$ 50million yearly disbursed over the 2006-2010 period. The key output variables (net social welfare gain – with incremental net benefits as proxy, disease cost, and benefit cost ratio) were estimated for each randomly drawn risk parameter. On average, the results show that such an intervention would make economic sense under the endemic scenario with high mortality. The discounted costs (12% discount rate) of the disease without intervention would have amounted to US$ 145 million in total over the 2006-2010 period. The model indicates that the intervention could possibly have generated cost savings amounting to US$ 63.7 million, incremental net benefit of US$22.2 million, and a benefit cost ratio at 1.75 over the five-year period considered.

Background

Nigeria has a poultry industry with about 160 million birds estimated at US$ 250 million. The industry contributes up to 10% to the country's agricultural GDP and accounts for 36% of total protein intake of the country. The overall sector attracts investment and yields a net worth of US$ 1.7 billion a year (Federal Republic of Nigeria, 2007). Nigeria's commercial poultry sector represents 15% of its poultry population and is of significant economic importance to the country and the West Africa region. However, in spite of the sector's contribution to national and regional food security and livelihoods, infrastructure for animal health, disease surveillance, diagnosis and control are very weak. These factors exposed Nigeria to moderate to high risks of introduction and spread of trans-boundary animal diseases e.g. the highly pathogenic (H5N1) avian influenza (HPAI) as confirmed by the report of the technical committee of experts on the prevention and (eventual) control of HPAI H5N1 or bird flu in Nigeria (FDL, 2005). The necessity of this committee's work was triggered and underscored by the enormous and unprecedented social and economic impacts of bird flu in Asia where over 200 million domestic poultry had either died or been destroyed with 175 people having contracted the infection, of which, 93 had died as a direct result of HPAI infection between 2003 and 2005 (World Bank, 2006).

Although the Government of Nigeria (GoN) had developed emergency preparedness plans for dealing with any incursion of the disease into Nigeria (FLD, 2006) because of the economic significance of poultry farming and the potential for the outbreak of becoming a pandemic with incalculable consequences, the first wave of outbreaks starting from February 2006 created panic and heightened fears of a looming disaster of international proportions. More specifically, it was feared that with similarly weak infrastructure for animal health, disease surveillance, diagnosis and control across sub-Sahara Africa (SSA), the effects of HPAI escaping the boundaries of Nigeria would be disastrous for the food security and livelihoods of millions of people (Gueye, 2007). In addition, based on the trans-boundary and zoonotic nature of HPAI H5N1, it would be catastrophic if the combined devastating and ravaging effects of an influenza pandemic and HIV/AIDS were to be unleashed on the continent. The scenarios painted above, which were seriously taken and addressed with the utmost sense of urgency and responsibility, provided the near-perfect impetus for policy makers to decide to save the world first and count costs later (precautionary principle) and/or to accept inputs from cost-benefit analyses that could in other circumstances have been adjudged as unrealistic (worst-case scenario).

In the immediate aftermath of the initial outbreaks, the worst of the fears became increasingly plausible. Within Nigeria, the disease spread rapidly to 97 Local Government Areas (LGAs) in a total of 25 States and the Federal Capital Territory, and some 440,000 birds were culled in the first two months; egg and chicken sales declined by 80% within two weeks following the announcement of HPAI outbreaks; there was a media frenzy and each additional report about bird flu reduced consumption to the extent that there soon was a near total boycott of poultry products in the country with all the associated negative effects of a zoonotic and trans-boundary disease on the industry (Tiongco, 2009; Beach et al., 2008; Akinwumi et al., 2010; Rich and Wanyioke, 2010). At the West African regional level and in quick turns, Niger, Cameroon, Benin, Ghana, and Côte d'Ivoire, all confirmed outbreaks of the disease (OIE, 2011). These events galvanized the international community into action with Nigeria receiving significant in-kind aid materials e.g. disinfectants, protective gears, vehicles and equipment (Perry et al., 2011).

On its part, the GoN sought and received a World Bank IDA loan of US$ 50 million (World Bank, 2006) with the project development objectives being to (i) support the efforts of GoN to minimize the threats posed by H5N1 to humans and the poultry industry, (ii) prepare the necessary control measures to respond to a possible influenza pandemic and, (iii) prevent further spread of the disease to other parts of Nigeria. The project was implemented by the Avian Influenza Control Project (AICP) which had a total of four components: Animal Health (budget US$ 29.2 million), Human Health (US$ 18.25 million), Social Mobilisation and Strategic Communication (US$ 4 million), and Implementation Support/ Monitoring and Evaluation (US$ 6.8 million). In the entire event, Nigeria suffered two major waves of outbreaks in 2006 and 2007 with a small and final episode in July 2008. In all, there were 300 outbreaks that led to one human case fatality and the destruction of 1.3 million infected birds for which $5.4 million was paid in compensation to 3,037 affected poultry farms/farmers (World Bank, 2010)

The AICP ran from April 2006 to May 2011 during which time US$ 41 million were disbursed by the World Bank to the project. At the tail end of the project (November, 2010) and especially given the probably weighty influences of precautionary principles in the design and approval of the facility, the World Bank commissioned the International Livestock Research Institute (ILRI) to conduct an independent impact assessment of the project to determine, in as empirical fashion as possible, the degree to which the project outputs have contributed to the achievement of the project development objectives. The team evaluated both direct and indirect impacts, and intended and unintended impacts. The evaluation team assembled secondary data from various sources, including from the AICP, and designed and undertook selected studies to collect primary data on certain aspects of the interventions undertaken by the AICP. A 12% discount rate was applied throughout the studyThis paper presents an assessment of the economic impacts of the intervention. Additional question such as the existence of a socially optimal level of risk below which the generated net benefit would not be enough to justify the intervention are also investigated.

Approach and Issues

Disease outbreaks induces cost through production and productivity losses, hence causes welfare loss. These losses could be reduced and/or eliminated using strategically targeted interventions. Theoretically, an intervention strategy against any disease seeks to minimize expected net social welfare losses (or to maximize expected incremental net benefits). To further elucidate, let us assume as in Narrod (2009) an expected social welfare function defined as follows:

$$EW\left(\phi_i\right) = p(\phi_i)W_D\left(\phi_i\right) + [1 - p(\phi_i)]W_F\left(\phi_i\right) - r(\phi_i)$$

Where W_D and W_F represent the welfare under the diseased and disease-free situation and are weighted by complementary probabilities representing the composite risk parameter $p\left(\phi_i\right)$, a product between risk of spread and risk of mortality, hence a function of the vector of interventions ϕ_i that can reduce the risk or perhaps eradicate the disease, and $r\left(\phi_i\right)$ represents the cost of the intervention. Under this specification, the optimal composite risk, say $\bar{p}\left(\phi_i\right)$, under which the intervention would make economic sense can be numerically derived. At that point, the marginal benefit of the intervention equals its marginal cost and the social welfare gain of the intervention similarly equals its net benefit.

The incremental benefits represent the cost savings that have accrued to Nigeria because of the intervention. They are calculated as the difference between what would have been the total cost of the disease to Nigeria had no action been taken and what it was under the intervention. The incremental net benefits are the benefit netted of the incremental costs, which correspond to the World Bank's yearly disbursements between 2006 and 2010. A benefit cost ratio to gauge whether the intervention made sense economically is calculated using the benefit and the cost of the intervention.

The calculation of HPAI costs follows Bennett et al. (1999) and Bennett (2003) with the difference that the composite risk is estimated from outbreak data used in the computation of the disease costs. The total cost of HPAI, which is the sum of the disease direct and indirect costs, is defined as follows:

$$C(\phi_i) = DC(\phi_i) + IC(\phi_i)$$

The direct costs of each of the AI outbreaks refer to the monetary values of physical losses due to the disease (Bennett et al. 1999).These physical losses are the results of mortality associated with HPAI, which include chicken death and egg losses, cost of control and prevention, including culling, vaccination, and surveillance. The indirect cost is derived using a ratio derived by Diao et al. (2009). They used a dynamic CGE model to estimate the direct cost due to HPAI in Nigeria between and the indirect cost due to production and consumption linkages. Their estimated direct cost amounted to between Nigerian Naira (NGN) 20 and 61 billion (US$ 135 and 412million) and indirect cost to between NGN24 and 76 billion (US$ 162 and 514 million). In this study, the direct costs are fully accounted and assume the indirect cost as 1.24 times of the direct cost as in Diao et al. (2009).

Projected mortalities were derived first using the disease risk parameters as described above. Background information on production and disease evolution are necessary. Data on outbreaks, incidence, prevalence, number of affected States, number of susceptible chickens, number of infected chickens, number of dead chickens, number of culled chickens were gathered from secondary sources. Additional data on compensation cost, cost of culling and disposal per bird were gathered from AICP. The cost of restocking for 2006 was obtained from an OIE study (OIE, 2007) then expressed in a per lost bird basis and applied throughout. The production and price data are from FAO (2010) and rapid surveys in affected States.

All key output variables (disease cost, incremental benefits, incremental net benefits, and benefit cost ratio) were simultaneously derived using a spreadsheet model. The model randomly drew from the distribution of the risks of spread and the risk of a chicken in affected States to get infected and iteratively solved for the key output variables. The resulting outputs were a set of 500 possible solutions, which encompassed all possible scenarios with respect to the evolution of the disease.

Risk Assessment and Scenario Derivation

The estimation of economic impacts of HPAI outbreak in Nigeria was based on mortality/culling losses incurred in the course of the outbreak. The magnitude of these losses was assumed to depend on the risk of disease spreading between States and the risk of a bird dying from the disease following exposure in the affected States.

There are at least two levels of aggregation between the data at State and farm levels that should have been considered (i.e., local government area and village) to minimize ecological fallacy. This could not be done because the outbreak dataset used had more reliable information at higher (State) than lower (village) levels.

Risk components

The risk of introduction of the disease is not considered in this analysis because the focus is on an outbreak that had already occurred. Though multiple introductions of the virus might have occurred over the three-year period when the outbreak was active, these introductions were not considered as being independent events since they happened at a period when HPAI epidemic was active in many parts of the world.

The risk of spread of HPAI in Nigeria was analysed using a simple compartmental Susceptible-Infectious (SI) model assuming that all newly infected States were infected by indirect contact with infectious States during the same wave of the epidemic. Two scenarios were considered: (i) the outbreak burns out due to a reduction in the number of susceptible States, and (ii) the outbreak becomes endemic after a short peak. The assumption made for the first scenario was that re-stocking was done 90 days after culling and adequate biosecurity measures were put in place that protected a large proportion of the newly introduced birds from getting exposed to the virus. For the second scenario, it was assumed that restocking was done routinely after 90 days but biosecurity measures were inadequately implemented. In the latter case, the replacement stock has an equal chance of being exposed to the disease as the indigenous population.

Two of the four parameters used in the model namely; i) spread and ii) the transmission coefficient were estimated using the outbreak data set. The transmission coefficient, ($\beta = 0.02$), which defines the risk of a State getting infected in a day, was estimated as described in the inset below:

Duration of infectiousness, which was assumed to be equal to the duration between the dates when the outbreak was reported and when depopulation was done at the State level. A mean of 49 days was obtained. To do this, the outbreak dataset was collapsed at the State level in order to obtain one record/State/phase of the outbreak. The first phase occurred between

January and August 2006 while the second occurred between November 2006 and November 2007. The incubation period of the disease, was assumed to be three days. Trajectories for these scenarios are given in Figure 1.

The average deterministic risk estimates over a one-year period are 0.13 and 0.27 for burn-out scenario and endemicity, respectively. Mean proportions of poultry that died (combining case fatalities and culled birds) out of the total population at risk in 2006 and 2007was derived for the States that had population at risk data. This comprised 11 out of 16 States in 2006 and 12 out of 20 States in 2007. The mean proportions obtained were 2% and 1% for 2006 and 2007, respectively.

Risk estimates and scenario derivation

Given the high uncertainty associated with the HPAI risk estimates defined above, two risk scenarios (i.e., the best and the worst case scenarios) that are expected to enclose the plausible risk levels are provided for each risk estimate. Composite risk estimates for the various scenarios analysed are presented in Table 1.

The collapsed data of infected birds at the State level were used to simulate an empirical distribution of a bird being infected. The empirical distribution is a non-parametric distribution that is flexible to accommodate all probability distributions, including the rare event types. The risk of spread was also simulated using a truncated normal distribution generated from the previously described average risk spread estimates. Both the risk of spread and the risk of a bird becoming infected were assumed to evolve stochastically around an average level from one year to the next, assuming the disease had already been introduced country. Figure 2 and 3 illustrate the distribution of the risk of spread and the risk of infection. Model estimates of average stochastic risk of spread were 0.2746 and 0.1663 under the endemicity and burn-out scenarios, respectively. Average risks of mortality were 0.0088 and 0.0174 for the low and high mortality risk scenarios, respectively.

Results

Table 2 presents a comparison between observed and expected birds' mortalities from culling and the disease itself under the four previously outlined scenarios. These estimates were based on the stochastic averages of the spread and mortality risk parameters. The results show that the incremental number of birds that would have been saved by the intervention between 2008 and 2010 under the burn-out scenario would be 46,960 and 93,794 for the high and low mortality paths. The number of birds that would have been saved would not be enough to warrant the investment from a financial standpoint. Hence, the analysis mainly dwelt on the two scenarios of endemicity. The descriptive statistics on the key output variables are provided in Table 3.

If no intervention had been carried out, the average cost of HPAI to the Nigerian economy over the 5-year period (2006-2010) would have amounted to US$96 million under the low mortality path and US$ 145 million under the high mortality path. The spread of the potential cost of the disease was also evaluated. As indicated in Table 4, there was 70% chance that the disease would cause economic damage of at least US$ 145 million under the most disastrous scenario and 90% chance that it would be greater than US$ 52 million. We also derived the cost of the disease with the intervention having been implemented and found that the total cost of the disease under these circumstances would amount to US$ 81.27 million. The cost savings as the results of implementing the intervention is the incremental benefits of the intervention. They represent the amount of money that accrued to Nigeria because of the intervention. Over the five-year period, the incremental benefits added to US$ 63.7 million. When netted out of the Bank disbursements during the same period yielded US$ 22 million of incremental net benefits. This amount is the net gain of the intervention. The distribution of the generated incremental net benefits of the intervention ranged from a minimum of US$65 million to a maximum of US$700 million. The derived incremental net benefits and the amount of money invested in the project are then used to calculate the benefit cost ratio of the project. The derived BCRs range between zero and 20.75. The average benefit cost ratio amounts to 1.75 (Table 4). It indicates for the endemic scenario with high mortality path, the intervention would have made economic sense. However, there is no certainty to the economic justification, as it is determined by the magnitude of the risk of bird infection in affected State. In any case, as illustrated in Table 4, there is a less than 50% chance that the investment would not be economically justified under the endemic scenario with high mortality path.

A breakeven analysis was conducted to find the minimum HPAI risks (of spread and of infection) that would justify the investment. Various combinations of risk of spread and risk of bird infection led to the threshold benefit cost ratio, as the two parameters simultaneously determine losses. Notwithstanding, our findings indicate that a risk of spread between 0.23 and 0.27 and a risk of bird infection between 0.012 and 0.017 would justify an intervention. With both estimates the disease would be prolonged and with the high mortality rates, the potential economic damage would be high enough to justify the intervention. At breakeven risk level, the disease would have caused economic damages amounting to US$ 118 million over the five-year period.

Conclusion

Outbreak data in Nigeria were used to simulate the risk of spread of HPAI to States in Nigeria and the risk of bird infection. These risk parameters were applied to assess the potential cost of HPAI to Nigeria under four scenarios (i. burn-out with low mortality, ii. burn-out with high mortality, iii. endemic with low mortality, and iv. endemic with high mortality) had the intervention not been carried out. Our findings indicate that for both burn-out scenarios, the number of birds that would have been saved would not have been enough to warrant the investment of US$ 41 million. This conclusion, for the burn-out scenarios, is purely financial as it discounts the possibility of loss of human lives and the application of precautionary principle informed by the poor state of infrastructure and known weaknesses of the Veterinary Service in Nigeria at the time of the outbreak. From a global view point, the potential evolution of the disease to a pandemic could have been enough to warrant such an investment given concerns within the international community on the high likelihood of the disease becoming endemic in Nigeria.

Nevertheless, the analyses show that under the scenario where the disease became endemic with high mortality risk, the investment would generate incremental net benefits significant enough to justify the investment. In reality, the Nigeria HPAI outbreaks claimed more than 1.3 million birds and could not be classified under any of the two burn-out scenarios explored in this paper. Similarly, the outbreaks did not persist with high mortality as the last one occurred in July 2008. If the intervention is perceived to have helped to avert the endemic and high mortality scenario, then the benefits would have by far exceeded the cost, hence the investment could been seen to have been highly justified. There also are multiple positive externalities that are difficult to account in the calculations of the benefits of the intervention. For example, the investment has helped Nigeria to improve its infrastructure for health services delivery, strengthened its public health and veterinary services capacity in biosecurity protocols and communications to deal with disease outbreaks of significant magnitude. So, the lessons learnt from this intervention including the induced behavioral changes within the populace and the knowledge of what to do when confronted with similar situations in the future are incalculable. From the financial, economic and welfare standpoints outlined also in this paper, an overall conclusion could be reached that the intervention was useful.

References

Akinwumi, J., Okike, I. and Rich, K. M. (2010). Analysis of the poultry value chain and its linkages and interactions with HPAI risk factors in Nigeria. International Food Policy Research Institute Washington, D. C. and International Livestock Research Institute, Nairobi, Kenya. HPAI Research Report No. 39. 99pp.http://www.ifpri.org/publication/analyses-poultry-value-chain-and-its-linkages-and-interactions-hpai-risk-factors-nigeri-0

Beach, R H., Kuchler, F., Leibtag, E., and Zhen, C. (2008). The effects of avian influenza news on consumer purchasing behaviour: a case study of Italian consumers' retail purchases. United States Department of Agriculture (USDA) Economic Research Report Number 25. August 2008. 31 pp.

Bennett, R. 2003. The 'direct costs' of livestock diseases: The Development of a System of Models for the Analysis of 30 Endemic Livestock Diseases in Great Britain. Journal of Agricultural Economics 54, 1: 55-71.

Bennett, R., K. Christiansen, and R. Clifton-Hadley. 1999. Estimating The Costs Associated With Endemic Diseases Of Dairy Cattle. Journal of Dairy Research. 66:455-459.

Diao X., V. Alpuerto, and M. Nwafor. 2009. Economywide Impact of Avian Flu in Nigeria – A Dynamic CGE Model Analysis. HPAI Research Brief | No. 15 – Year: 2009.

Ezedinma C., P. Kormawa and J. Chianu. Urban Household Demand for Meat and Meat Product in Nigeria: An Almost Ideal Demand System Analysis, Paper prepared for presentation at the Farm Management Association of Nigeria Conference, Jos, Nigeria, September 18-21, 2006

FAO [Food and Agriculture Organization of the United Nations]. FAO Statistical Database FAOSTAT. 2010. Available online at www.fao.org. Last accessed on March 26, 2012.

FDL [Federal Department of Livestock & Pest Control Services] (2006b). Comprehensive Emergency Preparedness and Differentiated Action Plan for the Surveillance and Control of Highly Pathogenic Avian Influenza in Nigeria. Version 1.4, September 2006. 90pp.

FDL [Federal Department of Livestock & Pest Control Services] (2005). Strategies for prevention of introduction, disease surveillance networking and contingency plan for a disease emergency. Report of the technical committee of experts on the prevention and control of HPAI in Nigeria. December 2005. 41pp.

Federal Republic of Nigeria (2007). Avian Influenza Control and Human Pandemic Preparedness and Response Project National Baseline Survey Final Report December 2007

Gueye, E. F. (2007). Evaluation of the impact of HPAI on family poultry production in Africa. World Poultry Science Journal, Vol. 63: pp391-400.

Narrod C. (2009). Approach for Evaluating the Impact of HPAI Control Options. A collaborative research project funded by DFID and implemented by the International Livestock Research Institute (ILRI), International Food Policy Research Institute (IFRPI), Royal Veterinary College (RVC). HPAI Research Brief | No. 7 – Year 2009.
http://www.ifpri.org/sites/default/files/publications/hpairb07.pdf

OIE [World Organisation for Animal Health] (2011). Disease outbreak map. http://web.oie.int/wahis/public.php?page=disease_outbreak_map (accessed March 2011).

OIE [The World Organisation for Animal Health], 2007. Economic analysis –Prevention versus outbreak costs. Final Report Part I. Submitted by Civic Consulting - Agra CEAS Consulting Part I. Berlin, Germany, September 2007, 251p.

Perry, B., Randolph, T., Bett, B., Grace, D., Globig, A., Fadiga, M., Sones, K., Henning, J., Pali, P., Poole, J., Hannah, H., Ekanem, E., Abdu, P., and C. Molokwu, 2011. Independent impact assessment of the World Bank-funded Nigeria Avian Influenza Control and Human Pandemic Preparedness and Response Project (NAICP). Project Report. http://www.aicpnigeria.org/documents/NAICP%20Independent%20Evaluation%20_Main%20Report%20plus%20Annexes_21%20April%202011_1-1.pdf (accessed 10 November 2011).

Rich KM and Wanyioke F. (2010). An assessment of the regional and national socio-economic impacts of the 2007 Rift Valley Fever outbreak in Kenya. American Journal of Tropical Medicine and Hygiene 83 (suppl 2):52-57.

Tiongco, M. M. (2009). Controlling avian flu and protecting people's livelihoods in Africa and Indonesia. A collaborative research project funded by DFID and implemented by the International Livestock Research Institute (ILRI), International Food Policy Research Institute (IFRPI), Royal Veterinary College (RVC). HPAI Research Brief | No. 6 – Year 2009. http://www.ifpri.org/sites/default/files/publications/hpairb06.pdf

World Bank. 2006. Nigeria - Avian Influenza Control and Human Pandemic Preparedness and Response Project. Washington D.C. - The Worldbank. http://documents.worldbank.org/curated/en/2006/03/6759863/nigeria-avian-influenza-control-human-pandemic-preparedness-response-project-nigeria-avian-influenza-control-human-pandemic-preparedness-response-project

World Bank. 2010. Nigeria - Avian Influenza Control and Human Pandemic Preparedness and Response Project. Unpublished aide memoire of the 8th Supervision Mission.

Table 1: Composite risk estimates for the various risk scenarios considered

Scenario		Risk estimate		Composite estimate
Spread	Mortality	Spread	Mortality	
Burn-out	Low	0.13	0.01	0.0013
Burn-out	High	0.13	0.02	0.0026
Endemic	Low	0.27	0.01	0.0027
Endemic	High	0.27	0.02	0.0054

Table 2: Observed and projected mortalities under the counterfactual scenario (Thousand birds)

		2006	2007	2008	2009	2010
Actual	Died	612	135	2	0	0
	Culled	405	360	3	0	0
	Total	1,017	496	5	0	0
Scenarios						
Burn-out Low	Died	612	135	46	23	11
	Culled	405	77	37	19	9
	Total	1,017	212	83	42	21
Burn-out High	Died	612	184	90	45	22
	Culled	405	151	74	37	18
	Total	1,017	335	163	82	41
Endemic Low	Died	612	155	151	151	151
	Culled	405	127	124	124	124
	Total	1,017	282	274	274	274
Endemic High	Died	612	304	296	296	296
	Culled	405	250	243	243	243
	Total	1,017	554	540	540	540

Table 3: Descriptive Statistics of the Effects of AI and Intervention against AI on Key Output Variables over 2006-2010 under the High Mortality Path

Variable	Risk of Spread	Risk of Infection	Disease Cost	Incremental Benefits	Incremental Net Benefits	Benefit Cost Ratio
Stochastic average	0.27	0.02	144.97	63.70	27.22	1.75
Standard deviation	0.06	0.02	115.99	115.99	115.99	3.18
Minimum	0.10	0.00	52.66	-28.61	-65.10	-0.78
Maximum	0.45	0.09	820.08	738.81	702.33	20.25

Note: The results are averages of 500 possible solutions. Benefits and net benefits are the 2006 total values of yearly streams over the 2006-2010 period. A 12% discount rate was applied.

Table 4: Percentile Distribution of the Effects of AI and Intervention against AI on Key Output Variables under the High Mortality Path

Percentiles	Risk of Spread	Risk of Infection	Cost of inaction	Benefits	Net Benefits	Benefit Cost Ratio
10%	0.20	0.00	53.36	-27.91	-64.39	0.00
30%	0.24	0.00	55.14	-26.14	-62.62	0.00
40%	0.26	0.00	64.40	-16.87	-53.35	0.00
50%	0.27	0.02	124.20	42.93	6.45	1.18
60%	0.29	0.02	150.53	69.26	32.78	1.90
70%	0.31	0.02	173.61	92.34	55.86	2.53
75%	0.31	0.03	190.12	108.85	72.37	2.98
80%	0.32	0.03	201.70	120.43	83.95	3.30
85%	0.33	0.03	222.25	140.98	104.50	3.86
90%	0.35	0.04	276.87	195.60	159.12	5.36
95%	0.37	0.07	401.91	320.64	284.16	8.79

Note: The results presented in each column should be interpreted separately. They are based on the 500 possible solutions. The risk parameters and the benefit cost ratio are unitless while cost of inaction, benefits, and net benefits are in US$ million over five year period with 2006 as base year. A 12% discount rate was applied.

Figure 1: Risk of spread of a HPAI outbreak in Nigeria

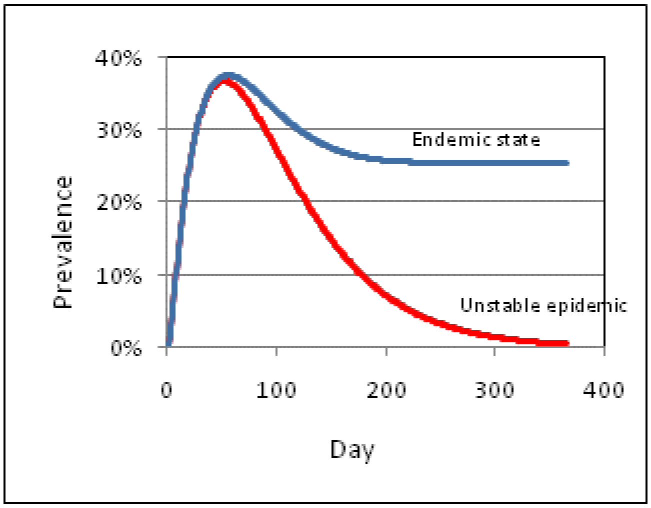

Figure 2: Simulated Risk of Spread of HPAI to Other States

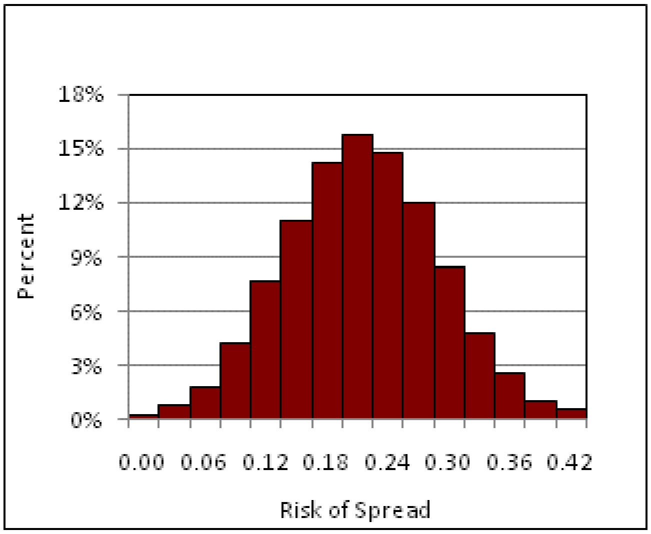

Figure 3: Simulated Risk of Bird Infection in Affected States