

# Methods for Assessing the Impact of Infectious Diseases of Livestock — Their Role in Improving the Control of Newcastle Disease in Southern Africa

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## *Abstract*

A framework for the impact assessment of disease control strategies for Newcastle disease (ND) is discussed. This includes linking epidemiological and economic data to predict the relative impact of different control interventions at different levels from farm to region. Epidemiological transmission models assume that village poultry are the reservoir of ND virus for other sectors. Simple models for transmission of the virus among village chickens predict that for vaccination to be effective, it must be conducted relatively frequently with a large proportion of chickens covered. Extrapolations to transmission between village and commercial sectors are suggested. Economic issues at farm level are considered most influential. Decisions to invest in national and regional projects will depend on the assessment of social equity impacts and cost-benefit and institutional analyses to assess relative benefits of private versus public sector interventions. Capturing the perspectives of all stakeholders in the ND control intervention process is considered crucial to both enhanced impact and sustainability of any control program.

THE contributions of poultry to the economy of African countries and the livelihoods of its people are profound. FAO (FAOSTAT 2000) estimates that there are approximately 1.1 billion chickens in Africa. Sonaiya et al. (1999) have estimated that for most countries, in excess of 70% of total poultry production is from the village (family) sector and this sector provides a frequently unaccounted for economic asset of approximately US\$ 5.75 billion. Crucially, in development terms, the village poultry sector preferentially benefits the rural poor and women (Sonaiya et al. 1999). Village chickens play several important social roles and a variety of poultry husbandry and ethnoveterinary practices have developed in many areas of Africa (Gueye 1999; Ibrahim and Abdu 1996). Many contributions to these Proceedings will highlight the crucial role of poultry to rural livelihoods in southern Africa.

While the village poultry sector in Africa has evolved to be robust and sustainable, infectious diseases, particularly Newcastle disease (ND), are an

important and sometimes catastrophic constraint (Alders and Spradbrow 1999, for several individual references). Vaccination against ND is a technically feasible (Biswas et al. 1996; Fontanilla et al. 1994; Samuel and Spradbrow 1991; Tantaswasdi et al. 1992; Wambura et al. 2000) but an economically non-sustainable control strategy for village chickens in Africa (Sonaiya et al. 1999). A variety of options to reduce control costs are being explored, including production of vaccine by developing country institutes (Spradbrow and Copland 1996; Wambura et al. 2000).

The difficulties encountered in the control of ND in Africa and elsewhere in the developing world highlight the importance of considering both veterinary and socio-economic aspects in designing ND control programs. At the International Livestock Research Institute, we have used ex-ante impact assessment methods, combining both epidemiological and economic tools, in supporting decisions for the control of other infectious diseases of livestock (Mukhebi et al. 1999; Perry et al. 1999).

In this paper, we propose a preliminary conceptual framework for considering technical and socio-economic factors at different levels influencing the

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impact of control strategies for ND. We then discuss key methods to support the assessment of impact of ND control. These include a mathematical model for the transmission of ND in the village poultry system and how this model could be extended to look at transmission from village to commercial sectors. The other main category of methods considered is economic. We discuss the main economic issues associated with the control of ND for different stakeholders. As a conclusion, we propose ideas for how impact assessment methods for ND control can be further developed to support decision-making.

### **A Framework for Assessing the Impact of Control Programs for Infectious Diseases**

Currently, most assessments of the impacts of alternative decision control options depend on extrapolation from individual case studies. Unfortunately, experiences may be quite location or production system specific and thus unsuitable for widespread generalisation. The development of more general frameworks for assessing the impact of infectious diseases can serve multiple essential purposes. These include:

- providing a structure for arranging and revising key questions;
- highlighting linkages (causal or otherwise) between technical and socio-economic issues at different levels;
- helping to identify important information and knowledge gaps; and
- emphasising the roles and responsibilities of different stakeholders.

There is often considerable overlap between the key issues for different infectious diseases. In developing a preliminary framework for ND in Southern Africa (Figure 1) we have started by modifying a framework developed for Foot and Mouth Disease control in Thailand (Perry et al. 1999). In the ND control framework, we have tried to highlight the much greater productivity effects of ND for individual farmers in village systems.

The purpose of developing frameworks to investigate the impact of alternative disease control strategies is to help support better decisions. All conceptual frameworks will be wrong; what we hope for is something useful in improving our decision-making. The utility of impact assessment can be enhanced by a number of key elements. The first, as mentioned, is the participation of different stakeholders and key players in formulating questions and providing data and their individual 'analytical' perspectives. This is essential since control programs for infectious diseases are doomed to failure without the effective collaboration of different stakeholders. A conceptual

framework of the impact of disease control may even help to clarify the organisational and coordination requirements for control efforts.

A second key element is a good understanding of how important epidemiological and socio-economic factors influence disease control. As will be emphasised throughout this paper, considering both types of factors is essential. Data requirements to enhance our understanding are described in later sections of this paper. In improving ND control, the different mix of epidemiological and economic factors involved in choosing between alternative strategies is complex. Only a tiny fraction of potential combinations could ever be tested under field situations. Thus, models, either mathematical models of infectious disease transmission and/or economic models incorporating different socio-economic perspectives, are increasingly used as decision support tools (see Anderson and May 1990 for numerous examples of how infectious disease transmission models have usefully supported a wide variety of public health decisions). From model results, best-bet strategies can be developed and tested in the field, usually in an iterative process.

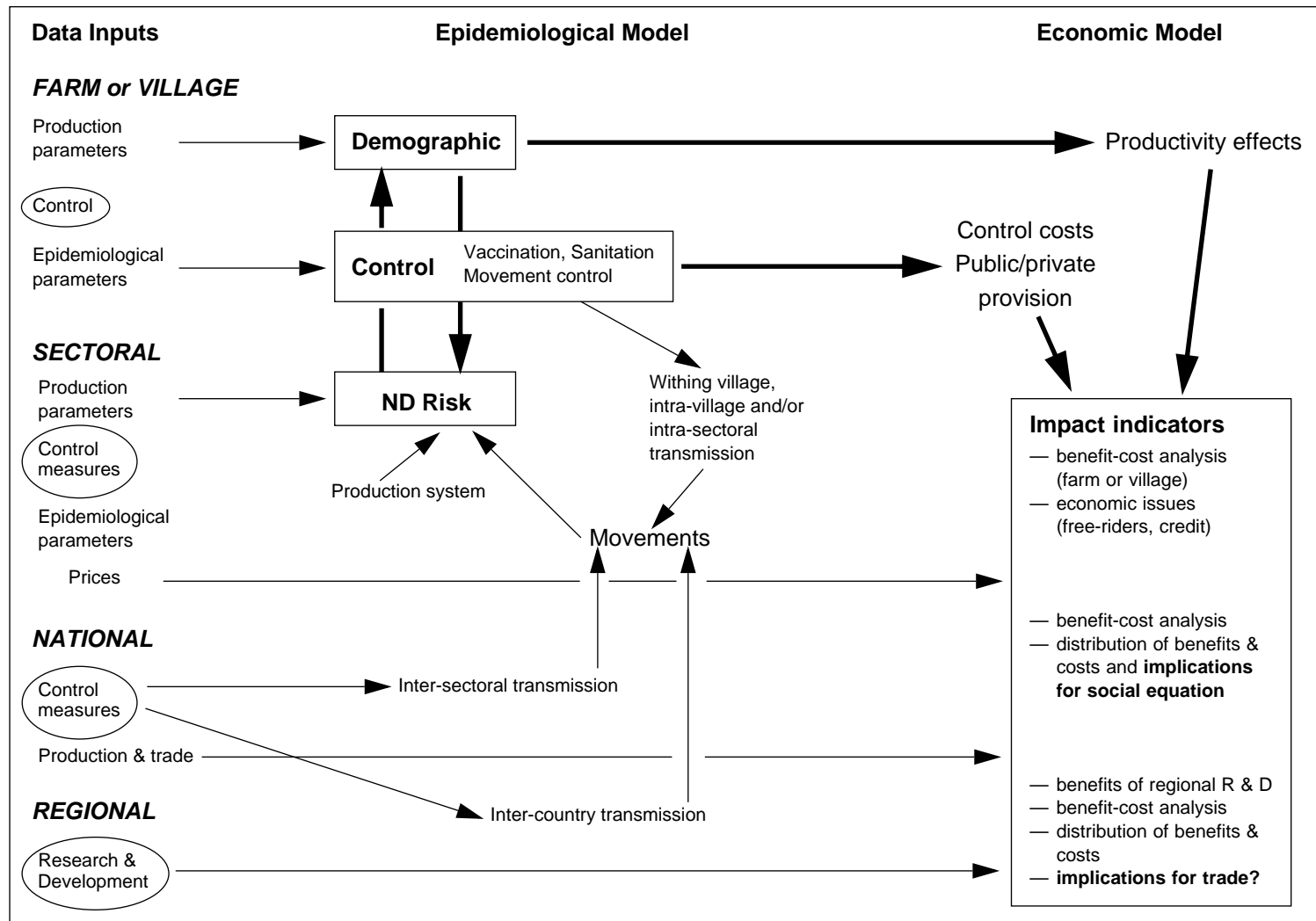
### **Preliminary Application to the Assessment of Newcastle Disease Control in Southern Africa**

#### **Basic epidemiological model**

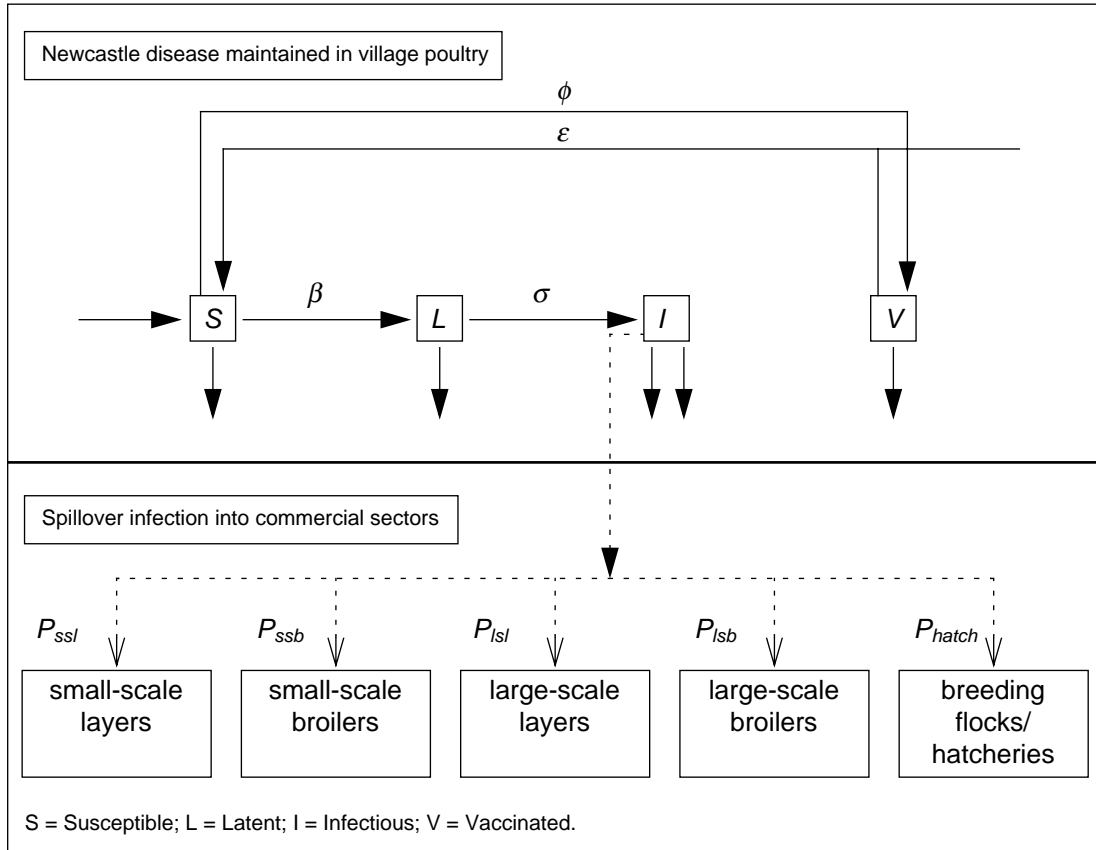
The main purpose of the epidemiological model for ND is to link demographic information for different poultry sectors to disease transmission parameters in order to assess the impact, on disease occurrence, of alternative control options. Our initial 'naive' approach is to structure the model as outlined in Figure 2.

The central feature of this structure is the transmission of ND virus (NDV) in village chickens under a non-endemic situation. The very simple assumptions for the village transmission model are listed in Table 1 and input parameters in Table 2. The current model considers only susceptible, latent, infectious and vaccinated classes of chickens. Recovered chickens (Alders and Spradbrow 1999) are ignored. The primary route of infection for commercial poultry is assumed (either directly or indirectly) to be from village chickens. Different commercial sectors could have different probabilities of infection.

The main use of this preliminary model is to highlight the need for frequent and high proportion coverage required in village vaccination programs under epidemic situations (Figure 3). The vaccination frequency and coverage estimates presented



**Figure 1.** Example of a conceptual framework for the impact assessment of Newcastle disease control.



**Figure 2.** Model structure for Newcastle disease in village poultry.

**Table 1.** Model assumptions of an initial ‘naive’ model of Newcastle disease virus transmission in village chickens.

1. NDV persists in village poultry populations (Bell and Mouloudi 1988).
2. Most village poultry populations are large enough to maintain NDV without external introduction due to the high basic reproductive rate of NDV.
3. The village poultry population is assumed to be a single free-mixing host population. Spatial heterogeneity ignored at smaller (local) scale, could be introduced at larger (national and regional) scales.
4. Village poultry are an important source of infection to small and large-size commercial poultry farms. Transmission between commercial farms is much less important (Bell and Mouloudi 1988; Sen et al. 1998).
5. The probability of NDV infections in these sectors is proportional to the incidence in the village poultry sector.

**Table 1. Cont.** Model assumptions of an initial ‘naive’ model of Newcastle disease virus transmission in village chickens.

6. The probability of a ND outbreak in small and large-size commercial poultry operations is different but once an outbreak occurs all susceptible poultry will be affected.
7. Village poultry form a single, homogeneous, free-mixing population.
8. There are four epidemiological classes, susceptible, incubating, infectious and vaccinated.
9. All rates are exponential and constant with age and sex.
10. There is no recovery from ND.
11. Each vaccination round is conducted in a single day, with a proportion  $\nu$  of the population vaccinated.
12. The model is simulated on a daily time scale for a one-year period.
13. The disease can be introduced into the population at any time over the course of the year.

should be considered as only relative rather than absolute values and may even be incorrect by some order of magnitude, since our initial assumptions and structure have ignored a number of potentially key features (see below).

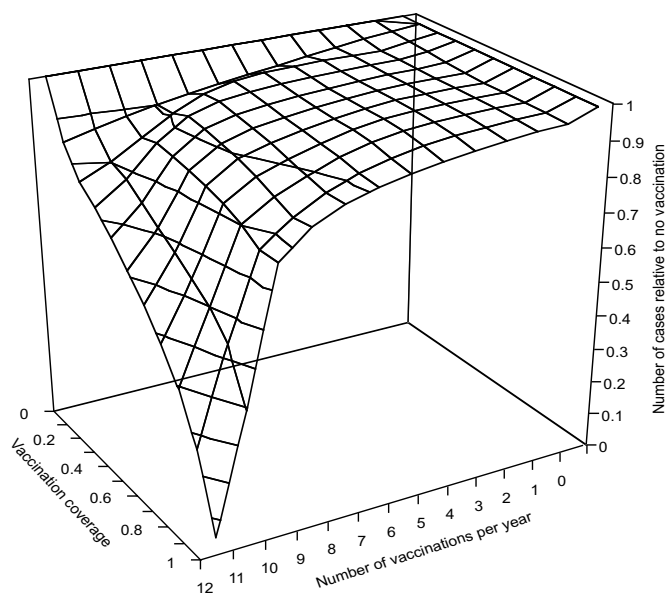
To make this model more useful, not only for the transmission of ND in village chickens but also for its spread between village and different commercial sectors, additional work is required. Currently, the model ignores the possibility of recovered chickens. This is likely to be important in village situations, particularly after the disease becomes endemic. Ignoring this possibility causes the model to predict ND outbreaks that are shorter and more severe than

would be expected under field situations. Empirical data on the proportion of chickens surviving ND would make this initial model more realistic and useful. Empirical field data on natural ND occurrence and its changes after the application of control measures is also crucial to uncover failures in model assumptions.

At present, we have not extended the model to consider the spread of ND to (and perhaps between) and impact in commercial sectors (Akhtar and Zahid 1995). Demographic data for each sector and empirical field data on outbreaks in each sector with temporal data linking them to outbreaks in village poultry and other sectors are required.

**Table 2.** Parameter estimates used in the initial Newcastle Disease village chicken model simulation.

Parameter	Symbol	Estimate	Source
Life expectancy	$1/\delta$	2 years	
Exponential growth rate	$R$	0.05 per year	
Initial population size	$N$	50 000	
Carrying capacity	$K$	100 000	
Latent period	$1/\sigma$	5 days	Merck Manual 1986
Infectious period	$1/\alpha$	4.5 days	Wambura et al. 2000; Fontanilla et al. 1994
Duration of immunity	$1/i$	126 days	Rehmani 1996
Vaccination coverage	$V$	varies, 0–1	
Vaccinations per year	$F$	varies, 0–12	



**Figure 3.** Example of a conceptual framework for the impact assessment of Newcastle disease control.

Epidemiological models provide a powerful tool for understanding how disease incidence is likely to evolve under different control strategies. This knowledge alone, however, is insufficient for making decisions on whether to implement a given control strategy. These decisions require additional information about the costs and benefits associated with control strategies to determine their economic viability and the likelihood that they can be successfully implemented.

### **Economic analysis of Newcastle disease and its control**

A common strategy for assessing the economic impact of infectious disease control is to perform a cost-benefit analysis of a specified control or eradication project for the use of investors and stakeholders in that project. Incorporating outputs from epidemiological models provides considerable relevancy and decision-making power to this approach (see as an example Perry et al. 1999). However, expanding this focus to address many of the economic issues likely to be important to different stakeholders implicated in the conceptual framework presented in Figure 1 will be necessary. Economic questions of interest will range from the poultry keeper's decision to protect his/her chickens from ND by vaccination, to decisions by an NGO or a government agency to introduce and promote the use of vaccines, through to the level of priority accorded to development of appropriately designed vaccine technologies by regional research systems. A range of techniques will be required, from traditional financial analyses of projects through institutional analyses (Leonard et al. 1999; Sandiford and Rossmiller 1997) to welfare analysis and other methods addressing key social equity concerns (see McDermott et al. 1999 for a range of economic issues applied to smallholder livestock systems).

#### *Issues and analytical approaches*

As indicated in Figure 1, decisions regarding ND depend on the scale and perspective of the decision-maker, varying from the individual farmers up to the policy makers and investors at regional level. Accordingly, decision-making at the various levels addresses different types of questions. Table 3 offers examples of typical questions that are likely to be relevant at each level, as well as the methodologies for economic analysis that are often found useful. In most cases, some type of standard cost-benefit analysis will likely be appropriate, either in the form of a partial budgeting approach that considers the impact of the disease or its control during a single production cycle, or a multi-period project analysis when evaluating a longer-term

intervention. In the latter case, the epidemiological model becomes critical in accurately predicting how disease incidence will evolve over time under each control scenario. Otherwise, as is often done, future disease incidence may be estimated based simply on the analyst's best guess, e.g. Sen et al. (1998).

In the context of ND in sub-Saharan Africa, three types of economic analysis are likely to be pertinent, at least initially, among those listed in Table 3:

- (1) farm-level partial budget analysis in the village sector;
- (2) national or regional-level welfare analysis of improved control in the village sector; and
- (3) analysis of delivery pathways for inputs and services.

Of these, the first two would require incorporating an epidemiological component to accurately capture the impact of control.

Emphasis on these three approaches is based on the underlying assumption that controlling ND with a vaccine is primarily a private good in the sense that the benefits of using a vaccine are captured primarily, and often solely, by the individual producer. In the context of endemic ND, using vaccine on an individual farm, or even intensively in a given region, will only have a significant impact on the risk of disease faced by other producers in the same or another sector if it is regularly and repeatedly used by nearly all farmers in that region. Thus, the possibility of non-vaccinators gaining 'free-rider' benefits is relatively unlikely.

Since nearly all benefits are captured at farm level, this is the appropriate level at which to analyse the economic feasibility of control. The widespread use of ND vaccines in commercial poultry production units suggests that economic incentives for their use are already well established and recognised. For commercial systems, economic analysis would concentrate mainly on choosing the optimal control strategy for maximising firm profits. For backyard systems, in which diseconomies of scale, low market orientation, and information asymmetries are likely to be associated with high transaction costs for disease control, the issues are more likely to focus instead on constraints to adoption and use of vaccines. The attention given to improving the effectiveness and efficiency of delivery pathways for vaccines is particularly relevant if these high transaction costs are to be reduced.

Under the current ND situation in Africa, vaccination is predominately a private good. Lack of immediate national and regional direct benefits may hamper support for large-scale publicly financed disease control campaigns. However, if there are to be both other compelling arguments and other types of investments (e.g. support to research on improved

**Table 3:** Economic issues and approaches at each decision-making level.

Level of analysis	Issues	Approaches
Farm/enterprise	<ul style="list-style-type: none"> <li>• Will the control strategy be adopted as indicated by its financial feasibility (i.e., profitability)? (Or related, which strategy optimises returns to investment in control?)</li> </ul>	<ul style="list-style-type: none"> <li>• Partial budgeting and/or gross margin analysis*</li> <li>• Farm models (linear programming, simulation)*</li> </ul>
Sectoral/production system	<ul style="list-style-type: none"> <li>• Will the necessary inputs and services be available to producers through effective, sustainable delivery systems?</li> <li>• Are there spillover benefits in one production system due to improved control in another (esp. reduced risk of outbreaks in commercial sector due to improved control in village sector) that might justify intersectoral transfers or subsidization?</li> <li>• Are production system-specific interventions economically justified?</li> </ul>	<ul style="list-style-type: none"> <li>• Market and institutional analyses</li> <li>• Farm-level analysis incorporating spillovers*</li> <li>• Project cost-benefit analysis of public interventions*</li> </ul>
National/regional	<ul style="list-style-type: none"> <li>• Are national or regional-level interventions economically justified?</li> <li>• What are the equity impacts of control? (producer versus consumer gains; gains captured by the poor versus higher-income groups)</li> <li>• Are there spillover benefits at the national or regional level, especially with respect to: <ul style="list-style-type: none"> <li>— reduced risk across production systems</li> <li>— less need for movement controls</li> <li>— enhanced trade opportunities?</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Project cost-benefit analysis of public interventions*</li> <li>• Welfare analysis (economic surplus analysis) taking into account market effects*</li> <li>• Trade analysis, including institutional/regulatory aspects*</li> </ul>

\*Using information generated by epidemiological modelling.

technologies and extension campaigns to introduce and promote vaccine use or to improve the efficiency and effectiveness of delivery pathways targeting subsistence-oriented village systems) that may be appropriate and necessitate economic evaluation. Such investments should also be supported by compelling non-financial objectives such as improving incomes, food security, or social equity. In this case, in addition to the farm-level analysis, it would be appropriate to conduct a welfare analysis that would take into account the eventual impact of reduced production costs on market supply and prices, to assess both the capacity of the intervention to generate sufficient social economic benefits and to what degree the benefits would accrue to producers versus consumers, or to the poor relative to the well-to-do. Such issues can be addressed by aggregating the results of the farm-level analysis to a higher level, and incorporating supply and demand considerations using an economic surplus approach.

Finally, improved disease control may reduce barriers to cross-border movements of poultry and poultry products, and thereby improve opportunities for trade. In the current context, trade opportunities are limited. In the future, though, analysis of such opportunities as an additional benefit or cost of better controlling ND may become increasingly relevant.

#### *Economic data requirements*

The various types of economic analysis outlined above generally require similar types of data. Most are related to valuing the incremental costs and benefits of each control strategy considered. The categories described below are certainly not exhaustive.

#### *Direct production losses avoided and their value*

The principal direct production loss associated with ND is mortality. Valuing these losses avoided at farm level under a given control intervention requires first identifying the representative age structure of losses by production system, and then assigning the appropriate market price or future value of production foregone for chickens at each age.

#### *Indirect production losses*

An outbreak of ND may engender additional financial costs that need to be enumerated. These include the opportunity cost of idle production capacity and any extra sanitary measures undertaken.

#### *Control costs*

These will primarily concern the cost of procuring and applying the vaccine, but may also include

interest on working capital tied up in control inputs at farm level, as well as any intervention project costs incurred.

#### *Household economic system*

To evaluate the potential for individual poultry keepers to adopt a given control strategy, it may be necessary to collect additional information about the role that poultry play in the household economy and the degree of market orientation of its poultry activities.

#### *Sector-level information*

To aggregate costs and benefits at the sector level, numbers of poultry kept under each production system are required, together with information about length of production cycle.

#### *Poultry market information*

For welfare analysis of a control strategy, it will be necessary to have market-level data on supply and demand for poultry and poultry products (including price elasticities), and prices.

### **Future Initiatives**

In this paper, we have tried to initiate consideration of the impact assessment of ND control using a combination of epidemiological and socio-economic methods. We have argued that a comprehensive view of control efforts needs to be made beyond individual case studies. We recommend that an overall decision-making framework be developed to include the 'perspectives' of all stakeholders. As non-experts of ND, our initial efforts are imperfect. Hopefully, experts and stakeholders in the region will take up the challenge to collaborate with us to improve this. As a first step, the epidemiological and economic analyses presented need to be improved by incorporating existing empirical data from the region and developing further studies to address key information gaps. This effort can benefit from the inputs of all stakeholders. International institutes such as the International Livestock Research Institute (ILRI) can play a supportive role to assist farmers, NGOs and governmental organisations in this important task.

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### **References**

- Akhtar, S. and Zahid, S. 1995. Risk indicators for Newcastle disease outbreaks in broiler flocks in Pakistan. *Preventive Veterinary Medicine*, 22: 61–69.
- Alders, R. and Spradbrow, P. 1999. Newcastle Disease in Village Chickens: A Field Manual. June 1999 revision, Brisbane, University of Queensland, 45 p.
- Anderson, R.M. and May, R.M. 1990. *Infectious Diseases of Humans — Dynamics and Control*. Oxford U.K., Oxford University Press, 757 p.
- Bell, J.G. and Mouloudi, A. 1988. A reservoir of virulent Newcastle disease virus in village chicken flocks. *Preventive Veterinary Medicine*, 6: 37–42.
- Biswas, H.R., Haoque, M.M., Oxley, M. and Prodhan, M.A.M. 1996. A comparative study on the protection of indigenous chickens against Newcastle disease induced by Australian NDV4HR and locally produced conventional vaccines in Bangladesh. *Preventive Veterinary Medicine*, 26: 157–164.
- Fontanilla, B.C., Silvano, F. and Cumming, R. 1994. Oral vaccination against Newcastle disease of village chickens in the Philippines. *Preventive Veterinary Medicine*, 19: 39–44.
- Fraser, C.M. and Mays, A., ed. 1986. *The Merck Veterinary Manual*. 6<sup>th</sup> edition. Rahway N.J., U.S.A., Merck Co. Inc., 1677 p.
- Gueye, E.F. 1999. Ethnoveterinary medicine against poultry diseases in African villages. *World's Poultry Science Journal*, 55: 187–198.
- Ibrahim, M.A. and Abdu, P.A. 1996. Ethno-agroveterinary perspectives on poultry production in rural Nigeria. In: McCorkle, C.M., Mathias, E. and Schillhorn van Veen, T.W. ed. *Ethnoveterinary Research and Development*. London, U.K., Intermediate Technology Publications, 103–115.
- Leonard, D.K., Koma, L.M.P.K., Lt, C. and Woods, P.S.A. 1999. The new institutional economics of privatising veterinary services in Africa. In: Perry, B.D. ed. *The economics of animal disease control*. *Revue Scientifique et Technique Office International des Epizooties*, 18(2): 544–561.
- McDermott, J.J., Randolph, T.F. and Staal, S. 1999. The economics of optimal health and productivity in smallholder livestock systems in developing countries. *Revue Scientifique et Technique Office International des Epizooties*, 18(2): 399–424.
- Mukhebi, A.W., Chamboko, T., O'Callaghan, C.J., Peter, T.F., Kruska, R.L., Medley, G.F., Mahan, S.M. and Perry, B.D. 1999. An assessment of the economic impact of heartwater (*Cowdria ruminantium* infection) and its control in Zimbabwe. *Preventive Veterinary Medicine*, 39: 173–189.
- Perry, B.D., Kalpravidh, W., Coleman, P.G., Horst, H.S., McDermott, J.J., Randolph, T.F. and Gleeson, L.J. 1999. The economic impact of foot and mouth disease and its control in Southeast Asia: a preliminary assessment with special reference to Thailand. *Revue Scientifique et Technique Office International des Epizooties*, 18(2): 478–497.

- Rehmani, S.F. 1996. Newcastle disease vaccination: a comparison of vaccines and routes of administration in Pakistan. *Preventive Veterinary Medicine*, 25: 241–248.
- Sandiford, F. and Rossmiller, E., 1997. Studying policy delivery systems. In: Williams, R.E. ed. *Political economy of the common market in milk and dairy production in the European Union*. FAO Economic and Social Development Paper No. 142, Annex 1. FAO, Rome, 139–171.
- Samuel, J.L. and Spradbrow, P.B. 1991. Selective oral vaccination against Newcastle disease by creep feeding young chicks in an open-range poultry flock. *Preventive Veterinary Medicine*, 10: 273–82.
- Sen, S., Shane, S.M., Scholl, D.T., Hugh-Jones, M.E. and Gillespie, J.M. 1998. Evaluation of alternative strategies to prevent Newcastle disease in Cambodia. *Preventive Veterinary Medicine*, 35: 283–295.
- Sonaiya, E.B., Branckaert, R.D.S. and Gueye, E.F. 1999. Research and Development Options for Family Poultry. In: Gueye, E.F. ed. *First INFPD/FAO Electronic Conference on Family Poultry*. Rome, FAO.
- Spradbrow, P.B. and Copland, J.W. 1996. Production of thermostable Newcastle Disease virus in developing countries. *Preventive Veterinary Medicine*, 29: 157–59.
- Tantaswasdi, U., Danvivatanaporn, J., Siriwan, P., Chaisingh, A. and Spradbrow, P.B. 1992. Evaluation of an oral Newcastle disease vaccine in Thailand. *Preventive Veterinary Medicine*, 12: 87–94.
- Wambura, P.N., Kapaga, A.M. and Hyera, J.M.K. 2000. Experimental trials with a thermostable Newcastle disease virus (strain I-2) in commercial and village chickens in Tanzania. *Preventive Veterinary Medicine*, 43: 75–83.