PERSPECTIVES ON THE 2003 AND 2004 AVIAN INFLUENZA OUTBREAK IN BALI & LOMBOK[1]

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Abstract

Avian Influenza (AI) has devastated the poultry industries in Viet Nam, Thailand and parts of Indonesia in 2003 and 2004. This paper is based on discussions undertaken in October 2004 between the author and Indonesian government officials, broiler company representatives and farmers from the broiler and layer industries in Bali and Lombok on impacts of the AI outbreak. Government of Indonesia (GOI) policies and responses to the outbreak of firms in the Eastern Islands poultry industry are described. Farmer responses may be affected by five factors: (i) geographical location of the farm, (ii) time since the outbreak began, (iii) whether the farmer was a layer, broiler or kampung chicken producer, (iv) size and 'development' of the farm and (v) contractual arrangements under which production is occurring. Further research, including risk analysis, is needed to assist GOI officials in managing future outbreaks. This should include analysis of direct impacts to better understand the financial impact of AI outbreaks on industry members and analysis of indirect impacts to better understand the financial, economic and social impact of AI outbreaks on the broader Indonesian economy. A bioeconomic framework suitable for undertaking this work is developed and presented.

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In mid 2003, the Avian Influenza (AI) virus, H5N1, caused devastating losses in China, Thailand and Vietnam. By mid-2004 eight countries had reported confirmed outbreaks to the Office International des Epizooties (OIE) including Indonesia with outbreaks in 14 out of 33 provinces (FAO, 2004a). In January 2004, officials in the Indonesian Ministry of Agriculture officially reported the disease to OIE. Since then the Food & Agricultural Organisation (FAO, 2004b) has reported bird deaths in Lombok, Sumbawa and Flores, worryingly close to Australia. About that time I obtained a Development Grant from the Australian Centre for International Agricultural Research (ACIAR) to develop a research proposal to study AI impacts and policy in the layer, broiler and village poultry industries in the Indonesian eastern island provinces of Bali, Nusa Tenggara Barat (NTB) and Nusa Tenggara Timur (NTT). These provinces lie close to the Australian mainland and are the likely source of wild bird transmission of any new virus or more deadly mutation of H5N1.

There has been no socio-economic research undertaken on the 2003-2004 AI outbreak in Indonesia to date. A risk assessment is needed to support Government of Indonesia (GOI) decision making in terms of allocation of funds to fight the outbreak. Further research is needed to understand the direct and indirect socio-economic effects of this outbreak and any new outbreak. If an appropriate framework was developed it should be adaptable for other avian diseases, particularly Newcastle disease.

It is not clear whether new animal disease policies are needed or whether existing policies are appropriate. One proposal, popular with some GOI officials, is for the Eastern Islands to become a Biosecure Poultry Zone (BPZ). Depending on one's perspective, the eastern islands of Indonesia can be viewed as either a transmission pathway to Australia for animal disease or as a 'buffer zone' that, properly managed, could prevent transmission. In this vein, one of the objectives for the proposed research project would be to determine whether the Eastern Islands could be a benefit or a hazard when the next outbreak occurred and what might influence their status in this regard. In other words, should the Australian Government help create a BPZ in the eastern islands between Australia and the billion bird poultry industry of Java?

Interviews with government officials, broiler firms and farmers conducted in Bali and Lombok in September 2004 are reported in this paper with a framework to evaluate risks and impacts associated with the current AI outbreak and for evaluating various policy proposals.

1 Background

According to the FAO website, the Indonesian poultry industry has grown dramatically since the 1960s with poultry numbers reaching 1.2 billion in 1997, the last year for which aggregate figures are available. Over this period broilers and layers recorded annual growth rates of 15 per cent and eight per cent respectively. Extrapolating from these numbers, poultry numbers would be just under two billion today. Native chickens comprise about 22 per cent of the poultry population, layers about seven per cent, broilers about 68 per cent and ducks about two per cent. The provincial break-up shows Java with 60 per cent of the national flock and the three eastern island provinces Bali, NTB and NTT have about three per cent.

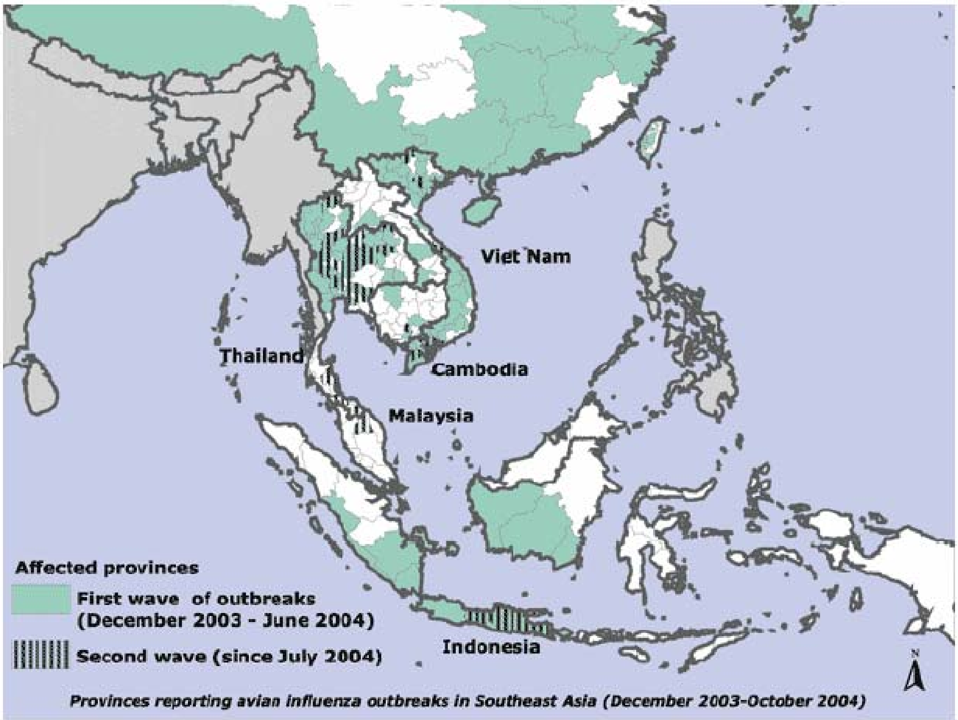
Descriptions of the AI Epidemic

'The geographic distribution, rate of spread and severity of this epizootic are unprecedented. It is estimated that more than 100 million birds have died or have been killed in stamping out measures following OIE guidelines. Two countries have used vaccination as an additional disease control tool (Indonesia and China). In addition, Pakistan is currently experiencing an outbreak of H7N3 and has adopted a strategy of stamping out combined with vaccination.… The origin of the H5N1 outbreak and the mechanism(s) for its rapid and vast dissemination, both nationally and internationally, is not yet understood. The disease has had disastrous effects on the poultry industry through its impact on international trade and domestic consumption of poultry products. The public health impact has been most apparent in Viet Nam and Thailand with the deaths of 22 people. In some countries the disease situation is not clear because of weaknesses in diagnosis, surveillance capacity and variable adherence to

obligations for timely and accurate reporting..… Countries have taken various disease control measures including culling infected flocks, quarantine and movement control, disinfection of effected premises and emergency vaccination in some countries. However, implementation of these measures should be broadened, strengthened and tailored to individual country situations. Contingency plans have been prepared and activated by non-infected countries.' (FAO, February, 2004a).

'Large areas in Sumatra and Kalimantan are suspected to be effected by the disease, and high mortalities in poultry have been reported in other islands such as Lombok, Sumbawa and Flores. Additional information on outbreak locations are required to have a better understanding of the disease situation in the country and ways of spreading.' (FAO, March, 2004b).

'The cumulative number of confirmed human cases of avian influenza H5N1 since 28 January 2004 by the World Health Organisation (WHO) is 44 with 32 deaths: 12 deaths in Thailand and 20 in Viet Nam' (WHO, October, 2004).



Map 1: Map of Disease Spread (Source: FAO, October, 2004c)

Guidelines for Control

OIE has general guidelines, easily available on the web, for control of animal diseases which authorities have adapted for the current AI outbreak. Six major steps from FAO (2004a) and other sources are described below however these steps are sometimes bunched or disaggregated into in less or more steps. The implementation of these steps in Bali and Lombok is discussed in Section 2.

1. *Surveillance.* The first step is monitoring the spread of the disease which involves both national and international co-ordination. A descriptive epidemiological breakdown of the disease by region within countries is recommended, with molecular analysis of isolates.

2. *Strategic Vaccination.* Vaccine is recognized as a strategic tool for control and can lead to elimination of AI when used with other measures. It is also valuable in reducing excreted virus, which is a source of human infection.

3. *'Stamping Out' Policy.* This includes valuation, disposal, cleaning, disinfection and other biosecurity measures. Infected animals are euthanized and disposed of within 24 hours and then premises inspected over two incubation periods of the disease (about 10 days). These operations should be carried out in a humane fashion with appropriate compensation for farmers.

4. *Movement Policy.* Movement of animals and materials is one of the most common causes of infection. Contamination can occur through introduction of new stock, on clothes and shoes and on trucks, egg trays, cages or feeders. Biosecurity can involve disinfection, isolation and restrictions on movements of people, stock and materials.

5. *Wildlife Management.* Most public agencies are cagey about killing wildlife and OIE and FAO are not exceptions in this regard. There are potential costs from mass killing of wildlife since birds play a role in controlling insect pests in crops. However, wildlife can contaminate through 'seeding' of the virus as they fly over farms and though direct contact with farm animals. It may be desirable to separate domestic and wild animals.

6. *Human Disease Controls.* To prevent the disease spreading to humans individuals at higher risk such as vets, cullers, lab workers, health care workers etc need to be identified and vaccines, anti-virals, protective clothing and appropriate training may be used. There is also a strong public health policy component.

2. Interviews with Government, Industry & Farmers

Interviews were conducted with government officials from the Disease Investigation Centre (DIC) in Bali, provincial offices of Balai Pengkajian Teknologi Pertanian (BPTP) and from the Quarantine Service and District Agricultural & Livestock Offices in Bali and Lombok. Five firms dominate the broiler industry in Indonesia with over 95 per cent of production under contract (Fabiosa, Jensen & Dong Yan, 2004) so representatives of Nusantara Unggasjaya Mataram (NUM) were also interviewed. NUM is a Thai multi-national producing poultry and pigs under contract and participating in livestock feed markets in Thailand, Indonesia, Malaysia and China. The firm dominates broiler production on Bali and Lombok, competing with two other firms for production contracts amongst smallholders. (The latter two firms declined to be interviewed.) This is in contrast to the layer industry which is more fragmented, and, while having some very large operators, is mainly comprised of small family firms (Farelly, 1996). One layer and two broiler farmers on Lombok and one layer and one broiler farmer on Bali were interviewed, five farmers in all. There was not time to interview producers of kampung (local) chickens.

Incidence of the Disease and Asymmetric Information

Most government officials, the agribusiness firm and growers agreed that clinical symptoms were observed in layers but not broilers in Bali, and in neither layers nor broilers in Lombok. Although apparently tests for antibodies were positive for most districts of Bali and a number of districts in Lombok, clinical symptoms were not observed in Lombok, Flores or Sumbawa. This position is at variance with FAO reports (see above) and anecdotal evidence. A well positioned GOI official told me informally there had been 'sporadic outbreaks' of AI on Lombok.

It is not clear what the actual incidence of AI was on animals or humans in Bali or in any of the other eastern islands in 2003 and 2004. At issue are the many interests that emerge in any disease outbreak: feed suppliers, processors, wholesalers, retailers, consumers, local politicians, the travel industry and so on. In this context, there was a lot at stake when Avian Influenza reached this part of the world. The tourism-based Balinese economy had been rocked by both the bombing of the Sari Club and the SARS epidemic in 2002. These events caused real hardship, driving Bali from rivaling Jakarta for highest per capita income in the country to a position of relative poverty. Avian influenza was already connected with human deaths in Viet Nam and Thailand and a significant outbreak in Bali would be catastrophic for an already ‘wounded’ tourist industry.

Biosecurity Responses by Farmers

Three factors seemed to influence how farmers responded to the AI outbreak. The first factor concerns industry structure and whether farmers were contracted to agribusiness firms or operating independently. Contracted broiler growers on Lombok were forced to de-stock for a month when contracts were suspended while non-contract broiler growers tried to ‘ride out’ the crisis, holding stock back from market and eventually producing overweight chickens (up to 4kg) of little value. The biosecurity response by contracted broiler producers in Lombok clearly reflected the desires of the contracting firm. The firm had always required vaccination for Newcastle disease but never vaccination for AI. Following the start of the outbreak, the firm required additional spraying and footbaths but not AI vaccination. Contracted producers were paid for de-stocking on the contract price set prior to the outbreak and, while losing income for a month, did not suffer as much as if they had de-stocked at prevailing prices which fell 60 per cent with the advent of AI. Both contracted farmers interviewed reported independent broiler producers going bankrupt because of lost markets, low broiler prices and heavy discounting of overweight birds ~ all market effects from the dramatic consumer reaction to news of the disease. Two months after re-stocking by contracted producers, prices increased dramatically in Lombok following improved consumer confidence and a supply shortfall caused by a ban on imported chickens from Java and Bali.

The independent broiler producer in Bali lost his market and grew birds out to over 5kg, instead of 2.1kg, making them almost un-saleable even if normal markets had prevailed. His birds were sold cheaply for ceremonial uses and many were given away. He eventually de-stocked incurring further losses. This firm was diversified, selling chicken and pig feed and vet products to neighbors and marketing neighbors’ produce around Bali. This diversification helped it to survive the worst of the financial shocks from the disease.

The second factor influencing adoption of biosecurity was ‘product type’. Broiler growers responded differently to the crisis than layer growers and, presumably, to kampung chicken growers. Layers are more valuable than broilers and vaccines can be amortized over a 21 month cycle rather than 35 days, the growing cycle for broilers. This dramatically influences incentives to vaccinate and undertake biosecurity, and egg producers in Bali and Lombok had introduced vaccination after the outbreak while broiler growers had not. The layer farm in Lombok had 17,000 birds when the farmer heard news of the outbreak on Bali and immediately vaccinated his birds. He paid Rp.1000/vaccine initially but this fell to Rp.500/vaccine then finally to its current level of Rp.300/vaccine. He reported differences between vaccines, finding the Chinese vaccine worked best and the locally produced one not at all. He introduced his own biosecurity with footbaths, spraying and canceling visits to the farm. The other layer farm, in Bali, was run by the *kepala desa* (village head) who negotiated a compensation deal with the government for his *desa*. He destroyed 2000 out of his own 7000 birds while his village destroyed 400,000 birds out of one million. He has since undertaken re-stocking, introduced footbaths and now vaccinates all his birds for AI. He said his greatest loss came from lost egg income, not destruction of the birds. Kampung chickens are a different product to broilers and are viewed by consumers as superior being leaner, tastier and having less chemicals. Also, they are twice as expensive per kilogram. These birds have different production cycles and cost structures to other poultry products and so biosecurity is likely to be different.

Picture 1: Mohamad Sayuti, a Lombok broiler producer under contract to Nusantara Unggasjaya Mataram, a Thai multi-national, inspects new birds following the firm's re-stocking program.

The third factor in the uptake of biosecurity is the state of development of the poultry industry. The poultry industry has gone through three stages: traditional systems, semi-commercial systems and commercial systems (Farelly, 1996). Traditional systems are associated with low productivity and high mortality rates however the dual purpose chickens may adapt to climate and resist disease better than chickens in more commercial systems. Semi-commercial farms are medium size family farms similar to those visited in this study. They are characterized by specialization in either egg or meat production, chickens are housed in coops, feed is purchased rather than foraged and farmers often have contractual arrangements with feed suppliers or processors leading to partial-vertical integration. True commercial systems are characterized by large size and usually over 70 per cent of variable costs are feed. These firms have size economies in gathering disease related information, purchasing specialized inputs to fight disease, implementing biosecurity measures and influencing government policies.

Government Services & Support

The most important government office in the eastern islands in the context of the AI outbreak was the Disease Investigation Centre (DIC) which had overall strategic responsibility for the disease outbreak and employed vets and scientists responsible for lab and epidemiological work. Field work supporting DIC activities is undertaken by officials from the Provincial Livestock Service. DIC in Bali is one of seven DIC regional offices around the country and has responsibility for animal disease investigation in the three provinces of Bali, NTB and NTT. It has laboratories in Bali and a smaller one, capable of AI molecular testing, in Mataram, Lombok. DIC incorporates an Emergency Center that has produced a Master Plan for Bali. The Director, Dr Anak Agung Gde Putra SH, reports directly to the Director of the Directorate General of Livestock Services (DGLS) in Jakarta, Dr Tri Satya Putri Naipospos. The major actions overseen by DIC during the outbreak so far are vaccination of two million poultry on Bali, new controls on movements of birds and eradication and destruction of layers on Bali.

The Director favors 'stamping out' policy over vaccination and sees the kampung chicken as the major epidemiological threat. Flocks of these birds roam freely mixing with neighbors' flocks and covering a lot of territory in their daily scramble for food. Testing by DIC found positive antibodies in kampung chickens in 75 out of 350 villages on Bali. I observed kampung chickens roaming though villages and fields including scavenging grain under commercial poultry coops. Other disease vectors included day-old chicks which are all imported from Java, traded poultry products, movements of trucks and possibly wild birds.

The Director made a strong case for the conduct of an economic risk analysis in the proposed project which could be used to encourage the GOI to spend more money on the AI problem. Dr Agung said disease-related losses in the poultry industry may be minor *vis a vis* potential human losses and losses to the tourist and pig industries. Bali has a population of 2.85m people, about 50,000 tourists at any one time and 1.5 million pigs.

Restricting Product & Material Movements

The Quarantine Service protects each island in the Indonesian Archipelago from contamination from foreign and domestic animal diseases. The Service has its own vets and access to the DIC laboratory in Mataram. The quarantine vets pointed out they were concerned with a range of diseases, especially Newcastle disease, and felt too much fuss was being made about AI.

Picture 2: Day-old chicks from East Java being inspected by a Quarantine Service official in Mataram

Following the AI outbreak, movements in live birds (including fighting birds) between Java and the eastern islands, including Bali and Lombok, were banned although chilled and frozen poultry meat and day-old chicks are still traded. The ban on live birds has a positive effect on broiler prices in Lombok where the local product competes with Javanese and Balinese imports and seasonal supplies of wild fish. Currently, Bali and Lombok producers are lobbying to have chilled and frozen meat included in the ban on biosecurity grounds.

Day-old chicks must have a DGLS certificate from Java (where most come from) and eggs from Java are held for two days, inspected and then re-packed and the old boxes burned and trucks sprayed. The owner of the eggs pays Rp.6000 for the inspection and bears the cost of the delay.

Picture 3: Six wheel poultry truck from Surabaya being sprayed by Quarantine Services official in Mataram

Compensation

The only producer amongst the five interviewed who received compensation was the egg producer in Bali. He faced capital losses from destruction of 2000 birds, lost production, lost value in culls that became worthless and lost more capital as the price of layers fell from Rp.14000 to Rp.5000. He was paid Rp.2000/bird compensation which he said was too low. He also said the government had continually reduced offers of compensation starting at Rp.10000/bird and working down to Rp.2000.

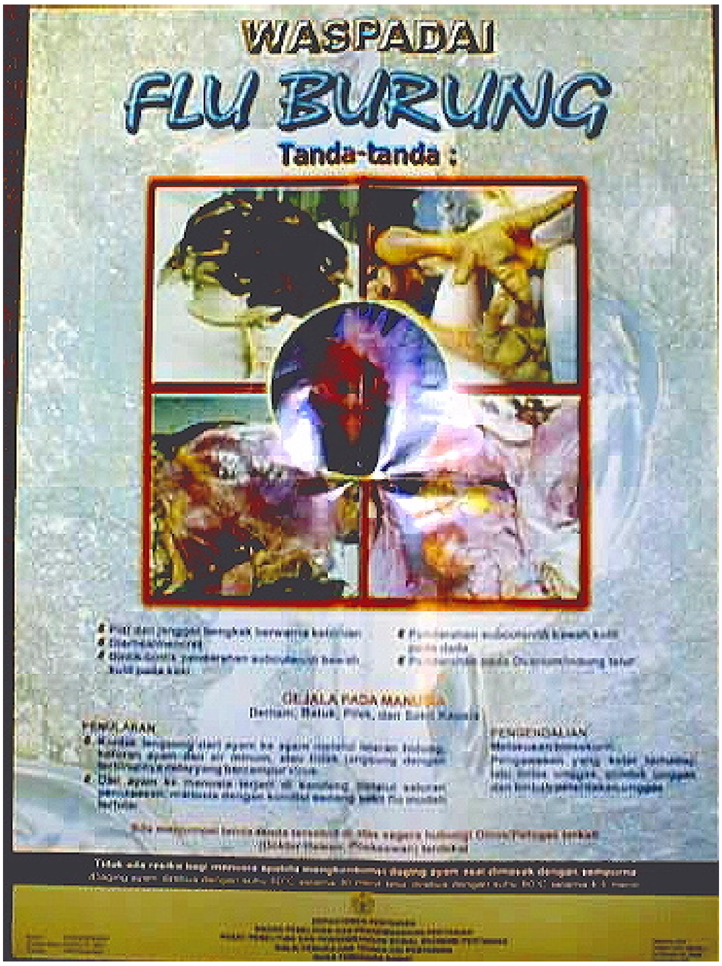
Total compensation paid to layer producers in this *desa* was Rp.8b with the maximum compensation paid per farmer being Rp.10m. (The current USD rate is Rp.8000.) That is, the policy was directed at smallholders, not large commercial firms. No compensation payments were made or offered to growers in Lombok.

Extension

Balai Pengkajian Teknologi Pertanian (BPTP) has provincial offices in Bali and Lombok and is a research and extension service with special interests in livestock nutrition. Unlike DGLS, it employs sociologists and economists so has a good understanding of the socio-economic background of the AI epidemic. It provides disease extension to smallholders and had a colorful poster of diseased birds used as a teaching aid with smallholders.

The other source of extension services was the District Agricultural & Livestock Office. It employs vets, para-medics (assistant vets) and extension people in Bali and Lombok at district level. They provide local monitoring of animal diseases in horses, the ubiquitous Bali cattle, goats and poultry and, in competition with merchants, sell vet products to farmers.

None of the five farmers interviewed had received extension services from the provincial or district government officials. Their initial sources of information were primarily TV and newspapers and they obtained more detailed information from grower organizations, feed suppliers and telephone calls to relatives growing poultry in Java. One had accessed a tourist internet café in Denpasar to get more information. The two contracted broiler producers in Lombok attended meetings with Nusantara Unggasjaya Mataram to learn about the disease threat and the firm's new biosecurity policy.



Picture 4: Colorful poster used by Balai Pengkajian Teknologi Pertanian extension officers in Lombok to teach smallholders about AI symptoms.

Based on the farm interviews it is not clear what extension services were provided by the District Agricultural & Livestock Office or by BPTP officials. These officials did not contact the farmers I interviewed however could easily have been busy with village-level AI extension or with other commercial producers not interviewed.

3 Economic Analysis of the AI Outbreak

The AI outbreak has posed two economic dilemmas for the Indonesians. The first dilemma is that risks associated with the disease in the future are only understood in the most general way. A thorough risk analysis needs to be undertaken if the GOI is to make sound judgements about the amount of effort needed to fight the disease in future. The second dilemma concerns whether money used to fight the disease is efficiently allocated between the various components of the AI eradication program. Should the Indonesians do more of some things and less of others?

Risk Analysis

Risk analysis can be used to measure likely impacts in the future from either a continuation of the current AI outbreak or from a new outbreak. Animal disease risks are divided into (i) direct risks (ii) indirect risks and (iii) human loss risks. Direct risks are the likely financial impacts of the disease on those in the industry. Poultry farmers face losses from de-stocking, low prices and lost business and may face additional costs from undertaking biosecurity measures. Poultry meat and egg consumers face losses from higher prices and inconvenience if there are doubts about what products are safe. Indirect risks include financial impacts of the disease on individuals and firms linked to the poultry industry. These include upstream and downstream firms supplying services at various points in the value chain and other adversely effected industries. For example, vet product suppliers have benefited from the AI outbreak while poultry processors have lost. Other, more broadly based indirect risks concern macroeconomic employment and income effects. Human deaths also represent risks. Firstly the possibility of personal losses from losing loved ones and, secondly, losses in the tourist and travel industries after customers go elsewhere following local deaths.

Modelling Direct Effects

Benefit-cost ratios are the central tool in considering whether funds allocated to fighting animal disease are used efficiently (McInerney, 1996). Benefit-cost ratios may refer to direct impacts from the disease within the poultry industry or to indirect effects in the broader community through the effects of the disease on employment, investment and related industries. Issues may surround (i) the absolute number of dollars being spent and (ii) whether existing allocations are efficiently distributed between the sub-programs in the overall disease program. A bioeconomic model is used to obtain these benefit-cost ratios.

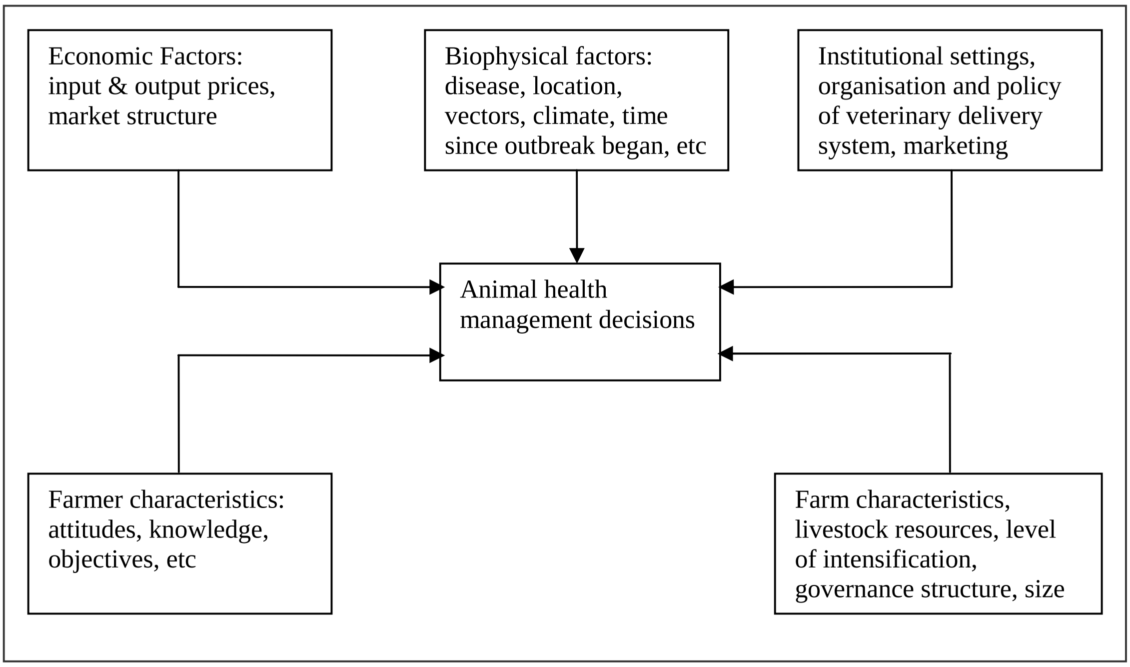


Figure 1: Factors influencing farmer decision making in the direct effects animal disease model adapted from Chilonda and Van Huylenbroek (2001, p. 690).

The major factors contributing to farmers' decisions about disease measures are shown in Figure 1. The most important variables are biophysical factors such as time since the disease began and proximity of the disease incidence to the farm. Other important variables are the institutional environment, characteristics of the farm and farmer and economic factors such as prices of inputs and outputs and market structure.

Three important domain elements in the AI problem discussed previously were structure of the industry, type of product being produced and state of development of the industry. Two further domain elements are (i) time since the outbreak was first detected and (ii) location or proximity of the farm to the disease frontier. For example, early in an outbreak the benefit-cost ratio from, say, expenditures on monitoring the disease may be high while benefit-cost ratios for restrictions on movement of materials may be low. This would signal resources should be allocated away from movement restrictions to monitoring. Later in the epidemic, benefit-cost ratios for monitoring may become low while benefit-cost ratios for restrictions on materials movement may become high. This would signal that resources should be moved back to movement restriction policy. In the same vein, as the epidemic moves east across the archipelago benefit-cost ratios are likely to be higher for policy located nearer the infection frontier rather than areas already devastated.

The bioeconomic model presented below explains how farmers make decisions about adoption of biosecurity in an AI disease environment and provides a framework for analysing the decision problem. The framework below is simplified by suppressing domain elements (except for time) and epidemiological factors however it captures the major economic arguments.

Farm households are divided into two groups: group *j* undertaking no controls for disease ($c_j^* = 0$) and group *i* undertaking controls, ($c_i^* \geq 0$) and government policy, CM_2, is fixed. Group *j* farmers choose values of farm inputs, l_j, to maximise expected profit, π_j:

$$\max_{l_j} \pi_j(l_j, c_j = 0)$$
$$= - pr_j(CM_1, CM_2, c_j = 0, t) w\, l_j + (1 - pr_j(CM_1, CM_2, c_j = 0, t))(p_b q(l_j, c_j = 0) - w\, l_j)$$

subject to

$$\frac{\partial\, pr_j(CM_1, CM_2, c_j = 0, t)}{\partial t} = B(CM_1, CM_2, c_j = 0, t)\,. \qquad (1)$$

The first RHS term is the probability farm *j* is infected and loses all its stock. The loss is the variable cost of producing the birds, wl_j, where w is unit input prices. The probability of infection is determined by the 'halo' effect from disease control undertaken by the *m* farms in group *i*, CM_1, where $CM_1 = \sum_{i=1}^{m} c_i^*$, government control measures, CM_2, and time elapsed since the start of the disease outbreak, t. The second RHS term is the probability the farm remains free of infection multiplied by expected profit from the poultry. Profit is comprised of revenue, $p_b q(l_j, c_j = 0)$, where p_b is price of birds and $q(.)$ is number of birds, minus costs, $w\, l_j$, defined above.

The probability of infection, $pr_j(.)$, can be viewed as a proxy for the severity of the epidemic and, from epidemiological models such as Rogers (1988), is likely to be state dependent. For the AI problem the differential equation of motion for $pr_j(.)$ is a function of several arguments: the halo effect (CM_1), the farmer's own control efforts (c_j), the effects of government policies (CM_2) and time (t), all working through a yet to be specified biophysical function, $B(.)$.

The decision problem for group *i* farmers is similar to group *j* farmers however c_i is now a control variable along with l_i and costs now include costs of control where p_c is the unit price of private disease controls:

$$\max_{c_i, l_i} \pi_{ci}(c_i, l_i) = -pr_i(CM_1, CM_2, c_i, t) w\, l_i + (1 - pr_i(CM_1, CM_2, c_i, t))(p_b q(l_i, c_i) - w\, l_i - p_c c_i)$$

subject to

$$\frac{\partial\, pr_i(CM_1, CM_2, c_i, t)}{\partial t} = B(CM_1, CM_2, c_i, t). \qquad (2)$$

From the standpoint of economic theory, it would be quite odd to find farmers split so neatly into two groups like *i* and *j* however in developing countries dichotomous groups of 'adopters' and 'non-adopters' do occur in these situations. The dichotomy may be caused by 'lumpiness' in costs of acquiring information with a large fixed cost, say, achieving a certain standard of education or owning a television, creating an impossible hurdle for low income groups wishing to obtain better information. This type of market failure, arising from incomplete information, is discussed in the context of model 3 below. Another aspect of this formulation is group *j* farmers cannot be excluded from the halo effect resulting from action by group *i* farmers so there is a free-rider problem. This will result in under-investment in disease control in the absence of appropriate government policy. In fact, even if all farmers were in group *i* there would still be under-investment in private controls because of the public good character of disease control resulting from the halo effect.

The problem can be reformulated to find optimal settings for all the control variables including the government policy variable, CM_2. Social welfare is defined as the sum of profits in groups *i* (which has *n* members) and *j*, (which has *m* members,) minus the cost of government policy intervention:

$$\max_{c_i, l_i, l_j, CM_2} \pi_{social}(CM_2) = \sum_{j=1}^{m} \left((1-F)\pi_j(c_j^* = 0, l_j^*)\right) + \sum_{i=1}^{n} F\, \pi_i(c_i^*, l_i^*) \; - p_g CM_2$$

subject to

$$\frac{\partial\, pr_j(CM_1, CM_2, c_j = 0, t)}{\partial t} = B(CM_1, CM_2, c_j = 0, t)$$

$$\frac{\partial\, pr_i(CM_1, CM_2, c_i, t)}{\partial t} = B(CM_1, CM_2, c_i, t)$$

$$F = f_3(I, pr_j(.), pr_i(.) | \mathrm{I}). \qquad (3)$$

p_g is the unit cost of provision of disease control for government and *F* is the likelihood farmers are members of group *i* so use private controls, $c_i > 0$. *F* is determined by probabilities of infection with and without private control action, time, *t*, and on information held by the farmer, *I*. *I* can be a second control variable for government if one wanted to conduct an *ex ante* evaluation of the impact of an education campaign following a disease outbreak.

The solutions for the two private models, (1) and (2), are obtained from the First Order Conditions for the two Hamiltonians which are solved simultaneously for optimal values of the control variables (Chiang, 1992) using numerical algorithms in a program like Mathematica. The solution for model (3) is more complicated since it incorporates controls for both government and farmers who have different objectives at least inasmuch as the government presumably wants to keep the costs of government disease controls down. There are disease models incorporating strategic behaviour and solved as non-cooperative games (McCarthy, McDermott and Coleman, 2003) however specifying threat functions across the five domain elements in this problem would be computationally impossible. The solution technique I propose proceeds in two steps. In the first step, farmers view government control variables as exogenous and the two private models, (1) and (2), are solved for a range of values for CM_2. In the second step, values for the private and government control variables from step one are 'slotted' into the welfare equation in model (3) and the combination of controls that maximises (3) is chosen as 'best'. The 'solved' model can then be manipulated to produce dynamic multipliers to calculate benefit-cost ratios for the policy part of the study.

Modelling Indirect Effects

The AI outbreak is expected to have impacts beyond the poultry industry. Presumably, it has already affected prices of a broad range of foods as consumers substitute away from chicken products. It is also likely to affect employment in linked industries such as retailing, transport, refrigerated storage, vet services, fisheries and the like as well as in the travel and tourism industries where panic associated with the disease can cause aeroplanes and hotels to empty quickly. As well as these localised, indirect effects, more general wage and employment effects are likely to occur in other sectors because of production, consumption and saving linkages to agriculture. In this context, food prices are the most likely factor to impact on poverty (de Janvrey, Graff, Sadoulet and Zilberman, 1999).

Analysis of indirect effects of the AI outbreak on real income and other economic variables would be best undertaken using a computable general equilibrium (CGE) model (Winters, de Janvrey, Sadoulet and Stamoulis, 1998). A number of CGE models have been developed for the Indonesian economy with the model by Oktaviani (2000) being an obvious candidate for use in this project because it is disaggregated by commodity.

4 Concluding Comments

Avian influenza is one of a number of diseases reducing productivity in Indonesian livestock industries. However it stands out because of its virulence, often drastic direct effects on farm production and indirect effects on tourism, travel and the rest of the economy. AI also stands out because historically, unlike Newcastle disease, it has killed large numbers of people. If the GOI is to deal effectively with these problems, officials need to know the risks and likely impacts associated with AI epidemics. Methodologies for obtaining this type of information need to be developed now, not after new epidemics occur. In the same vein, Australian officials also need to know risks and likely impacts from AI epidemics occurring in Indonesia both to offer effective aid if needed and to better protect Australian interests.

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