

## Review

# Impacts of avian influenza virus on animal production in developing countries

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## Abstract

This paper reviews the (predominantly grey) literature on impacts of highly pathogenic avian influenza (HPAI) strain H5N1 and control responses on the livestock sector and associated industries in developing countries. The authors distinguish between impacts that arise directly through HPAI-related morbidity and mortality, those that are a consequence of public intervention to control or eradicate HPAI, and impacts that are mediated through market reactions. The paper further considers how these impacts propagate up- and downstream through related supply and distribution networks, how short-term reactions are followed by longer-term adjustments, how impacts include direct cost elements and foregone income, and why losses to the poultry sector will, at least to some extent, be 'passed on' on the one hand, for example through compensation, and, on the other hand, be compensated for by gains in other livestock subsectors. Differences in methodology applied in the reviewed reports result in a lack of comparability of estimates for HPAI 'costs/impacts' across countries and even within countries and are compounded by information deficits. Despite these shortcomings, the literature permits some significant conclusions to be drawn on the relative importance of direct and indirect impacts and on their distribution across different types of poultry producers. The paper ends by outlining directions of future research that combine epidemiology and economics to provide a framework for disease control decision-making.

**Keywords:** Poultry, HPAI, H5N1, Control measures, Economic impacts, Animal/poultry production

**Review Methodology:** This paper intends to provide an overview of the nature of impacts of HPAI and its control on animal production in developing countries. Systematic searches of the CAB and SCOPUS literature databases were undertaken using the search terms 'avian influenza' and 'economics', 'impacts' or 'costs'. This search only yielded 14 papers specifically dealing with HPAI impacts in developing countries, and of these a significant proportion have not been published in peer-reviewed journals. The authors were aware of many more papers (at least 50) on HPAI impact available in the grey literature, many of which are consultancy reports commissioned by development agencies. Given the importance of the topic the authors were encouraged to review the available literature despite its shortcomings. The review will limit itself to the impacts of HPAI on animal production and will neither consider human health impacts of avian influenza nor the impact of low pathogenicity avian influenza virus, although these are closely related to the topic of the paper.

## Introduction and Context

Avian influenza was first reported in its highly pathogenic form (HPAI) in poultry in a small farm in Scotland, UK, in 1959 [1]. Several epidemics have since occurred in developed countries (USA, Canada, The Netherlands and Italy). None of these, however, came close to matching

the current HPAI epidemic caused by the H5N1 strain in geographic spread, duration and economic repercussions.

HPAI caused by the current H5N1 virus was first reported in Southeast Asia in late 2003, although the virus is now considered to have emerged as early as 1996, when it was first identified in geese in Guangdong Province in southern China. It then caused disease in the

Hong Kong Special Administrative Region, where poultry and humans were affected in 1997, poultry only in 2001 and early 2002 and poultry and captive wild birds in 2002–2003. From 2003 onwards, the disease spread widely, initially through East and Southeast Asia in 2003–2004 and then into Mongolia, southern Russia, the Middle East and to Europe, Africa and South Asia in 2005–2006, with outbreaks recurring in various countries in 2007. To date, 60 countries have reported outbreaks of HPAI H5N1 in domestic poultry, wild birds or both [2]. In most of these, the H5N1 virus could be eliminated through swift and determined interventions of national animal health systems, whereas in some countries, such as Egypt, Indonesia, Vietnam and perhaps Nigeria, the virus appears to have become endemic in specific eco- and production systems, leading to resurgence of infection in poultry and humans the moment control efforts are relaxed.

Since its emergence, H5N1 HPAI has attracted considerable public and media attention, because the viruses involved have been shown to be capable of producing fatal disease in humans (as of June 2008, 385 human cases of HPAI H5N1 (leading to 243 deaths) have been reported), which has given rise to the fear that the virus might acquire the capacity for sustained human-to-human transmission and thus cause a global influenza pandemic. This fear has been the main driving force behind the international commitment to global HPAI control, to date amounting to an estimated US\$1.02 billion disbursed funds and US\$1.68 billion committed funds as of June 2007 [3], which in turn has significantly influenced national responses to outbreaks of H5N1. The latter have involved destruction of birds on a massive scale, regulation of poultry production and trade and, in some countries, large-scale vaccination campaigns. These responses often come at considerable cost to poultry producers, both rich and poor, and to the public purse.

HPAI, like other highly contagious animal diseases, affects animal production via three main pathways. First, disease causes direct losses to producers and other actors connected to the production and marketing of poultry through morbidity and mortality and the private costs associated with *ex-ante* risk mitigation (e.g. investment in animal housing) and/or *ex-post* coping measures during periods of downtime<sup>1</sup> (e.g. bridging loans if the enterprise carries significant borrowings) and the need to reinvest in replacement birds. Second, animal diseases that are 'notifiable' can have severe impacts through government intervention, which carries a cost borne by the public at large and affects producers (and associated up- and downstream actors), irrespective of the disease status of their flocks. These costs include public investment in animal health infrastructure and epidemic

preparedness. Third, disease impacts arise through market reactions, which can be particularly severe on the demand-side in the case of diseases that are associated with a public health risk. Analogous to disease control measures affecting producers even if their flocks have not contracted HPAI, market reactions can occur, irrespective of whether or not avian influenza has actually occurred in the country.

Quantification of the impacts of avian influenza (and of other epidemic diseases) is complicated by the fact that direct impacts on livestock producers will propagate up- and downstream through related supply and distribution networks, that short-term reactions are likely to be followed by longer-term adjustments, that impacts include direct cost elements and foregone income, and that losses to the poultry sector will, at least to some extent, be 'externalized'<sup>2</sup> on the one hand and, on the other hand, be compensated for by gains in other livestock subsectors. As a consequence of these 'systemic' responses, the impacts of HPAI are strongly determined by the structure and flexibility of the poultry industry in affected countries, its links with other sectors of the national economy and its integration with global markets. Furthermore, the level of disease impact is affected by where, when and into which component of the poultry industry the disease enters.

The paper will review available evidence for the direct and indirect impacts of avian influenza for each of the three 'pathways' and time scale as well as for different levels of economic analysis, namely households, the poultry sector as a whole, and national economies to the extent possible. As background against which to view the impact of HPAI, the first of the following sections will provide an overview of poultry production in developing countries. Given that in most instances it is impossible to disentangle the supply-side and livelihoods impacts of poultry morbidity and mortality from those caused by public control measures, these will be treated together in the section 'Poultry Production in Developing countries'. The next section will deal with the impacts of market reactions to HPAI, which take the form of short- to longer-term reduction in the demand for poultry products and shifts to alternative suppliers. The subsequent section will present data on short-term, up- and downstream flow-on impacts of HPAI and the following section will review (and speculate on) the medium-term repercussions of the combined impacts of HPAI on the demand and supply of poultry and poultry products. Finally, the last section will conclude and outline directions for future research that combine epidemiology and economics to provide a framework for disease control decision-making.

<sup>1</sup>Period from infection of the farm to the return to full production. During this period, there is no income from the poultry enterprise.

<sup>2</sup>Losses are partially passed on to others; for example, poultry producers may default on loans, the loss being borne by creditors, who receive compensation, which ultimately passes disease costs on to taxpayers, etc.

## Poultry Production in Developing Countries

Globally, among the livestock industries, the poultry industry has achieved the highest growth rates over the past decade (2.1% annual growth in poultry numbers and 3.7% annual growth in meat production [4], much of which is occurring in developing countries. Chicken constitute the vast majority of domestic poultry throughout the world, with ducks, geese, quail, turkeys and guinea fowl being of localized importance. Ducks are particularly prevalent in areas of lowland paddy rice production in East and Southeast Asia and the mixed farming systems of Egypt [5], where they appear to play an important role in the epidemiology of HPAI. The following provides a schematic overview of the poultry production systems in developing countries, but with a focus on chicken production and in particular the meat production systems. This focus is justified as the broiler chickens are a particularly important contributor to poultry populations throughout the world. Production systems of other poultry species are less well documented but are, in principle, similar to those of chicken, although vertical coordination and/or integration are less advanced.

Poultry production in developing countries is usually heterogeneous, with the use of different species, different production and marketing systems and the provision of a range of products and services. Typically, poultry are an integral feature of smallholder agriculture, where the majority of households keep a small (tens of birds) flock of 'indigenous', dual-purpose (meat and eggs) birds to meet household consumption needs, social obligations and minor cash expenses, the latter by sales through informal, live-bird marketing channels. These indigenous birds are reared with minimal inputs and obtain most of their feed by scavenging, but command price premiums vis-à-vis non-indigenous birds in local markets. This traditional, extensive poultry production system is virtually ubiquitous throughout the developing world and represents the activity of by far the majority of poultry producers<sup>3</sup>. Simultaneously, however, intensive, industrial poultry production systems, which follow the production model developed in industrialized countries, have been established in nearly all developing countries. This intensive, industrial system is characterized by (a) being organized by stages of production with separate primary breeders<sup>4</sup>, multipliers<sup>5</sup> and end-producers (often contract farmers), (b) a small number of breeding companies dominating the global supply of genetic stock, (c) specialization in meat or eggs and use of specific birds for each product, (d) use of

high-density feeds tailored to specific stages and lines of production, (e) increasing scales of production (thousands of birds) and (f) growing interconnectedness with the slaughter and processing industry. These two poultry production systems are extremes, between which 'hybrid' and/or intermediate, semi-intensive systems exist, that combine characteristics of the two extremes, for example, partial scavenging with feed supplementation, or indigenous birds crossed with industrial poultry lines, thereby relying on 'formal' input supply systems, but which operate at intermediate scales (hundreds of birds) and mostly rely on 'traditional', informal live-bird marketing networks.

The three described poultry production systems usually operate side-by-side in developing countries and are often even interconnected through supply (e.g. day-old chicks (DOCs) and feed) or output marketing systems (e.g. industrial broilers or 'spent hens' sold through live-bird markets used by traditional and semi-intensive poultry producers). The relative contribution of each of the three 'systems' to total poultry production will depend on the 'stage of development' of a national poultry industry, which in turn is related to the overall stage of national development (roughly described by *per capita* GDP, the share of agricultural GDP of total GDP, and urbanization), but also determined by factors such as national agricultural policies. The ability of the traditional poultry systems to expand production is limited by the availability of the scavenge-based feed resource [6]. Figure 1 displays the structure of the poultry industry of Cambodia, Vietnam and Thailand as an illustration of the evolution of the poultry sector with overall economic development.

The results in Figure 1 are consistent with the nature of agricultural production systems and the dynamic implications of economic growth. Traditional production systems rely on by-products and residue of other agricultural activities, which constrains the overall output of these systems. On the other hand, modern systems import inputs, especially feed, and thus can expand more flexibly to meet growing demand. As income in developing countries is expanding, poultry consumption *per capita* is growing, sometimes more than proportionately to income growth. Thus, *per capita* consumption growth and population growth are likely to increase overall demand and, in cases of poultry-exporting regions, production of poultry, whereas the share of poultry from traditional production is likely to decline (as seen in Figure 1).

As mentioned in the introduction, the impact of HPAI on poultry production will be determined by the severity of the epidemic on the one hand, and by the structure of the poultry industry, and its linkages with international markets on the other. Government responses in terms of prevention, control, compensation and rehabilitation policies can have a large influence on distributional aspects of disease impact.

<sup>3</sup>A particular form of traditional extensive production system is found in Southeast Asia in the form of large, transhumant duck flocks that are taken to graze in paddy rice fields post planting and post harvest.

<sup>4</sup>Lines, great grandparent and grandparent stock.

<sup>5</sup>Parent stock.

4 Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources

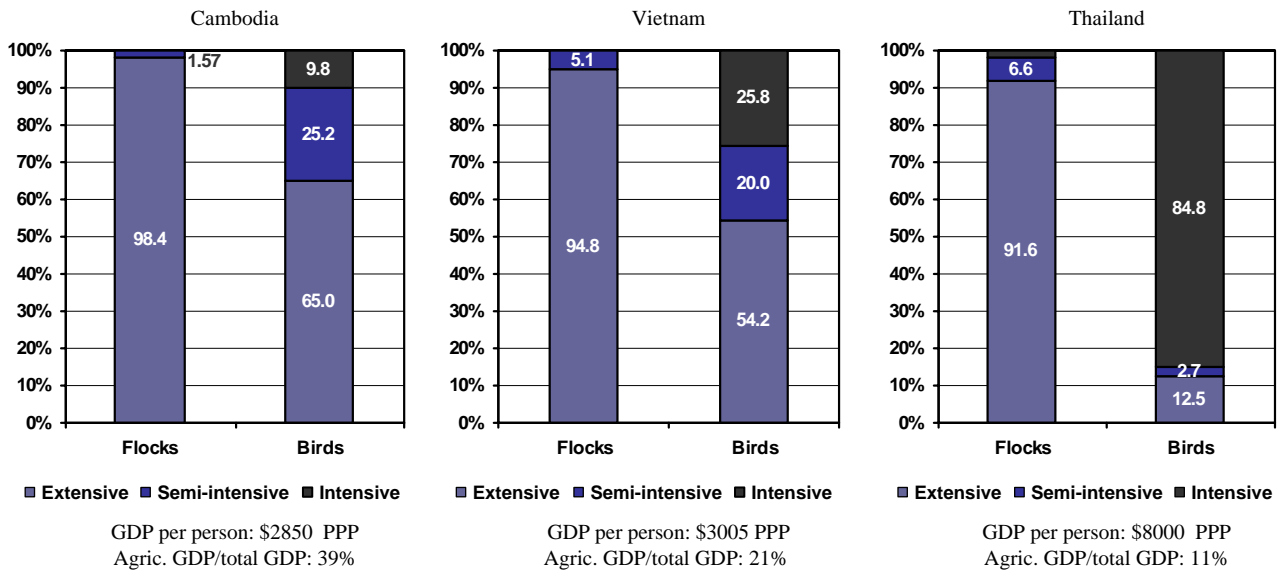


Figure 1 Share of poultry producers engaged in traditional extensive, semi-intensive and intensive poultry raising and respective share of poultry stock in Cambodia, Vietnam and Thailand

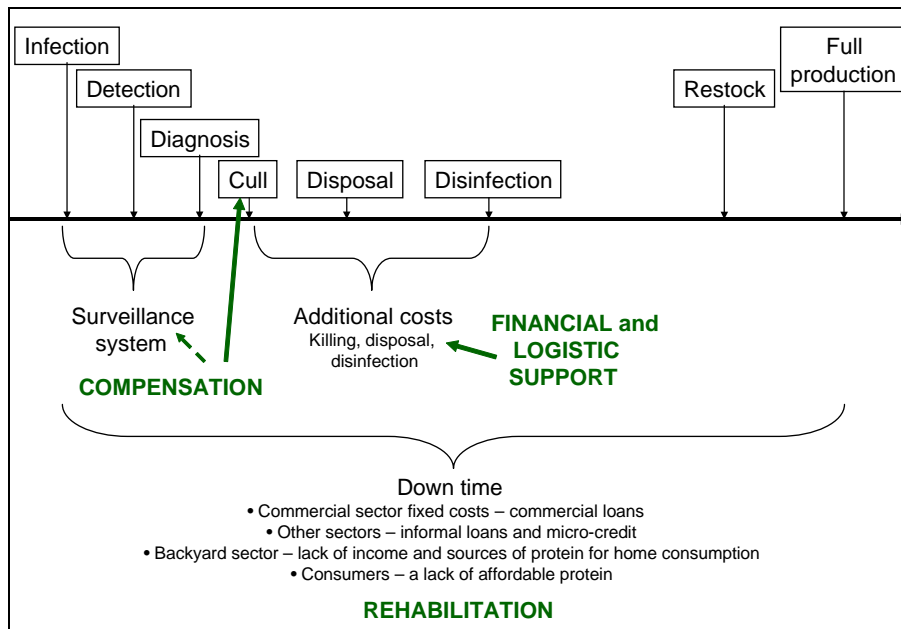


Figure 2 Sequence of events from the infection of a flock to the return to full production

**Direct/Immediate Impacts of HPAI Through Morbidity, Mortality and Public Intervention (Supply Side and Livelihoods)**

**Direct On-farm Disease Losses**

By definition, the HPAI virus results in high mortality once introduced to a chicken flock. Direct and immediate impacts of HPAI outbreaks in poultry flocks result from the loss of the current value of birds, which die or are

culled, and from foregone income from poultry raising during the ensuing interruption of production (downtime). Figure 2 presents a timeline for the sequence of events from infection to the return to full production, and indicates the 'downtime' of the farm affected.

Large numbers of poultry have died from HPAI or been culled to control the disease since it spread widely from 2004 onwards. In Thailand, 63.8 million birds were culled from the onset of HPAI outbreaks in 2004 until 2006 [7], whereas for Vietnam the figure amounts to around

**Table 1** *Ex-post* estimate of the flock-level probability of HPAI infection in 2004 in Thailand and Vietnam

Country	Infected flocks	Total No. of flocks	Probability of infection (%)
Thailand	1731 <sup>1</sup>	1 028 189 <sup>2</sup>	0.17
Vietnam	2587 <sup>3</sup>	8 300 000 <sup>4</sup>	0.03

<sup>1</sup>Source: Thai Department of Livestock Development.

<sup>2</sup>Source: National Statistic Office of Thailand. *Agricultural Census 1993 and 2003*.

<sup>3</sup>Source: FAO Vietnam outbreak database based on web notification of DAH/MARD.

<sup>4</sup>Source: General Statistics Office of Vietnam (2002).

50 million birds [8]<sup>6</sup>. For Indonesia, Hartono [9] reports that 17.1 million poultry (15 million layers, 2 million parent stock and 0.1 million broilers) died or were culled between July 2003 and January 2004, before the official announcement of HPAI by the government. In Nigeria, 0.9 million birds died or were culled in commercially-oriented farms by mid-June 2006 [10]. In this context, the report states that the total number of birds that died from HPAI may well have been higher, since information on the poultry losses in traditional backyard systems in rural areas is scant. In Egypt, an estimated 36 million poultry have died or been culled as a result of HPAI (Office of the Prime Minister). The impact was particularly severe in the Governorates of Kayloubia, Sharkia, Giza and Ismaelia in terms of average bird losses per rural person. These data, however, give no information on the impact in the backyard production systems and in the unregistered farms, where birds were also culled during the initial epidemic wave but producers were not compensated [11]. The impact in this component of the poultry sector was severe, in part because of fears of returning to the poultry business [11, 12]. In Bangladesh, between February 2007, when HPAI appeared, and June 2008, 1.6 million chickens were culled and further 277 000 died in a total of 287 outbreaks. In addition, nearly 2.2 million eggs were destroyed on affected properties [13]. One of the few reports from China states that when HPAI occurred in Anhui Province in June 2004, 145 000 poultry were infected and 9 million birds were culled [14].

Although the impact of HPAI from the loss of their poultry is severe on an individual farm, the share of poultry lost from HPAI in relation to the total population has, with the exception of Thailand, Vietnam and Egypt (which culled on a massive scale during the first wave of outbreaks), been limited. Thus, for Thailand and Vietnam, HPAI-related poultry losses in 2004 represented 25–30% of the total poultry population. In Egypt the chicken layer

sector was particularly badly affected and it is estimated that 80% of the flock either died or was culled, although overall probably 10% of the national poultry flock was reported to have died or been culled in the initial epidemic wave. In other countries, such as Indonesia, Bangladesh, Nigeria and Cambodia, the respective proportions of poultry lost are 6, 0.8, 0.6 and 0.2%.

From the perspective of an individual poultry farmer, the losses if HPAI enters are great, but the probability of infection of her/his flock with the disease is rather low. This relatively low probability has been found even in countries such as Thailand and Vietnam, which experienced severe epidemics. Table 1 shows the probability of an individual farm/flock being infected for Vietnam and Thailand in 2004, the year with the highest disease incidence. This probability is of course likely to be higher in the absence of control measures.

The risk of HPAI infection in the above countries differed between production systems/flock size classes and geographic regions. Based on reported outbreak information, Otte *et al.* [15] found that small, backyard flocks were consistently less likely to contract HPAI than larger poultry flocks both in Thailand and Vietnam. In Thailand, for example, the Central and Eastern regions of Thailand, the regions with the lowest proportion of backyard flocks (less than 20% of all flocks), and with the largest commercial flocks, constituted the 'epicentre' of the 2004 HPAI epidemic [16]. In Vietnam, infection risk consistently increased with flock size during three successive epidemic waves, reaching 100 per 1000 flocks in the largest size class during the second wave [15].

Owners of affected flocks can mitigate direct disease losses by consuming or selling sick or dead birds. A survey of 25 small-scale farms that experienced HPAI H5N1 in Vietnam found that 68% of small-scale commercial farms sold and/or ate dead poultry [17]. In Pekalongan District of Indonesia a 14 000 layer flock was infected with HPAI in August 2003 and 5000 birds died, whereas another 7000 were sold to contain losses [18]. In Sukabumi District a quail farm with 100 000 birds lost about 80% of the quail to infection with HPAI. The dead quail were disposed of by boiling and feeding them to catfish at a nearby fish farm, whereas in Bangli District, hens of a 1400 chicken layer farm that had died of HPAI were disposed of by throwing the carcasses into the pig pens [18]. In Nigeria, farmers reportedly also sold infected chicken to reduce losses [19]. Human consumption of birds destined to be culled by animal health authorities has been reported from Laos [20].

After an outbreak of HPAI, poultry production is usually interrupted for several weeks and financial losses result from the disruption of poultry and egg sales and continuing fixed costs. The magnitude of these losses is linked to the scale and mode of production and differs between poultry species. Smaller-scale, scavenging backyard production units have no or minimal investment costs in buildings and therefore are only affected by the

<sup>6</sup>In the initial waves, both Thai and Vietnamese authorities applied a policy of culling all poultry within a 5-km radius of an infected premises. Over time, in both countries, authorities moved to much more selective culling strategies leading to much lower numbers of poultry culled in subsequent HPAI waves.

**Table 2** Direct on-farm losses from HPAI on (semi-) intensive, commercial poultry farms

Country/Source	Farms studied	Loss description
Cambodia [24]	17 chicken layer farms	17 commercial chicken layer farms were studied, of which six had experienced an HPAI outbreak. The average income across the sampled farms before the outbreaks was about US\$2170 per month. Average investment costs varied between US\$11 000 and 16 000 including feed and chick costs. Infected farms did not generate any poultry-related income for at least 2 months, after which two farms restocked. Incomes of non-infected farms also dropped significantly to a minimum of about US\$700 per month due to decreasing egg prices in February and March 2004. However, this income trough was succeeded by a period of high incomes owing to increasing egg prices above the price level prior to the HPAI crisis.
Vietnam [25]	343 poultry farms	Flock size of the studied farms ranged from 151 to 2000 birds. Although not all of the farms had been infected, all flocks were culled with an estimated average loss per farm of US\$1702 (26.8 million Vietnam Dong (VND)).
Bangladesh [26]	Five chicken broiler farms	Before the HPAI outbreaks the five broiler farms had an average of 1300 chicks and 978 birds per production cycle. Before culling took place, on average 132 chicks and 250 adult birds had died per farm, which represents a lost value of US\$54 and 255, respectively. On average, 1441 chicks and 733 adult birds were culled per farm, resulting in losses of US\$589 and 749 per farm, respectively. Including US\$66 of destroyed feed, farms on average lost US\$1714 in assets. Taking into consideration income and wage losses from production downtime (12% of total losses), the average total losses amounted to US\$1971 per farm (US\$0.82 per bird).
	25 chicken layer farms	The farms had an average of 1670 birds and 2367 chicks prior to the HPAI outbreak. On average, 1520 adult birds and 1894 chicks were culled and 570 eggs destroyed per farm, which resulted in an average loss of US\$3985 for the adult birds, US\$829 for the chicks and US\$33 for the eggs. Before culling, 252 chicks and 385 birds had died on average (value of birds=US\$1120). Including destroyed feed valued at US\$184, the average farm asset loss amounted to US\$6152. Taking into consideration, income and wage losses from production downtime, estimated as 50% of total losses, farms incurred average total losses of US\$12 304 (US\$3.05 per bird).

foregone income from poultry production. Production downtime losses are higher for larger-scale commercially oriented farms, which, as a consequence of the foregone revenue, may face liquidity problems arising from having to repay loans for buildings, feed and other inputs. Farms that are affected neither by HPAI nor by 'ring' culling may also suffer losses from foregone income because of movement controls imposed by animal health authorities (e.g. in Vietnam [21]).

Variable costs such as those for feed and labour are usually reduced or saved during downtime, which, however has knock on effects on other sectors (see the section 'Short-term Indirect/flow-on Impacts' on flow-on impacts). Survey results from commercially-oriented farms that experienced HPAI outbreaks in Nigeria show that workers were retrenched in 80% of the surveyed farms and the majority of these workers were still unemployed several months after HPAI was recorded [19]. One farm was reported to have reduced the number of employees from 20 to 3 due to lower revenue and shortages of inputs [22]. Some poultry farmers did not reduce the number of workers but did reduce the salaries.

Qualitative descriptions of the negative impacts of public and private reactions to HPAI outbreaks on livelihoods prevail in the literature reviewed, whereas

quantitative economic information on the direct losses is scarce. The following provides some examples of estimates of direct losses found in the literature for (semi-) intensive commercial farms and for backyard producers.

#### *(Semi-) Intensive, commercial poultry farms*

Several assessments of the direct on-farm losses resulting from poultry mortality due to HPAI outbreaks or culling, find that commercial poultry farms suffer substantially higher farm losses [23] and [24] in Cambodia, [25] in Vietnam, and [26] in Bangladesh) than extensive producers, in absolute as well as in relative terms. However, the ability for this component of the poultry sector to cope with losses may be higher than that of smaller-scale producers, as owners often have access to larger and more powerful networks of lenders. An exemplary overview of reported losses in commercial farms in different countries is given in Table 2.

The value of the birds kept (e.g. broilers or layers) and the revenue generated per bird determine the on-farm losses. In Vietnam, losses of layer farms with higher value hens and loss of eggs stored on farm were twice as high as losses of similar size broiler farms [25].

The ability to cope with liquidity problems resulting from the lost productive poultry capital depends on existing savings, share of farm assets financed by credit,

the flexibility to postpone credit repayment, diversification of farm activities and formal and informal insurance mechanisms. More-diversified farms were in a better position to absorb the liquidity shock by increasing revenue from other activities [27]. Measures to help farmers cope with liquidity problems were implemented by the Vietnamese government and the Vietnam Bank for Agriculture and Rural Development (VBARD). The maturity of existing loans was extended and the ceiling for loans without collateral was increased from US\$1900 to US\$3170 [25].

An assessment by Seng [23] in Cambodia found that households keeping larger duck flocks suffered particularly severe short-term losses through birds dying from HPAI or being culled, as duck raising was their main source of income.

#### *Traditional, extensive backyard poultry production systems*

Backyard poultry keeping has several functions and is generally not the main household income generation activity. Production costs cannot easily be measured, since cash input costs are limited and products are used for subsistence. Thus, quantified economic losses in monetary terms are scarce in the literature. However, a wide literature stresses that poultry keeping has several advantages and functions that may not be expressed in pure monetary terms. Poultry can be easily converted into cash in the case of an emergency need and therefore serves as bank or security net for poor poultry keepers. Mainly women tend to look after the poultry and they are empowered to decide on what the extra money earned by poultry keeping is spent.

A survey conducted by GSO [25] in Vietnam estimated the direct losses of 109 village and backyard producers with flock sizes smaller than 50 birds at US\$69 (VND1084000) per farm. For 99% of the surveyed farms, the income from poultry was not the most important income source, but was nevertheless an important supply of protein, social value and quick cash. Based on data from Vietnamese household living standards surveys, Roland-Holst *et al.* [28] estimated that for the vast majority of poor poultry-keeping households, a total stock loss would represent a less than 10% income loss, while, based on the same data, Phan Van Luc *et al.* [29] estimated that traditional smallholder farmers would on average lose 2.1% of overall income through a total cull of their poultry and 0.8% from a sales ban.

In Egypt, based on interviews of 132 backyard poultry-keeping households, an average loss of US\$22 was estimated per household from the loss of birds. The poorest quintile had an average monthly income of less than US\$35, of which 52% was derived from poultry (Geerlings *et al.* [12]).

Based on an extensive survey on the economics of poultry production prior to HPAI outbreaks in West Bengal, India, Hinrichs [30] estimated the financial losses of smallholders affected by the 2008 outbreak. Prior to

the outbreak, poultry keeping contributed between 7 and 10% of the average monthly household income of US\$48, with the bottom quintile of households having a monthly income of no more than US\$31. The loss from dead birds was estimated at US\$5 for an average flock with seven traditional breed birds, comprising two adult chicken and five growing chicks. In addition to the bird loss, the foregone income was estimated at US\$14, resulting from an average 3-month production downtime and another 3–5 months until chicken or eggs are again ready for sale. Losses from dead birds and foregone income of a typical backyard-chicken-keeping household summed to US\$19. For an average smallholder poultry flock, the eligible compensation for culling was about US\$5.

#### **Control Costs**

A variety of measures to prevent and control HPAI is/can be applied, either by poultry producers themselves or by the national animal health services. Preventive measures include improvements in biosecurity, both on farm and in markets, and vaccination. Preventive measures are usually complemented by public investment in national surveillance systems and diagnostic capacity for early disease detection to limit the scale of outbreaks should they occur. Finally, once HPAI has broken out, control costs arise through culling, safe disposal of carcasses and potentially infected material (e.g. bedding and feed), disinfection of affected premises, and enforcement of movement control and other restrictions to poultry production and trade. None of the above measures on its own is sufficient to effectively control, let alone eradicate HPAI, and thus measures need to be applied in concert. The mix of control measures applied in any country depends on the infection status and disease progression within the country as well as on the ultimate goal of the disease control programme. This section will provide an exemplary overview of reported and estimated costs of each of the above control measures.

#### *Biosecurity*

Farmers themselves can invest in biosecurity measures on their farm in order to reduce the likelihood of virus introduction into their flocks (bio-exclusion) and to minimize the risk of transmitting disease within their farm and to other farms (bio-containment). Most on-farm biosecurity measures serve both objectives, bio-exclusion and bio-containment, and separate cost estimates cannot be found in the literature. The effect of biosecurity measures is not restricted to lowering the risk of HPAI incursion but also decreases the risk of other contagious diseases being introduced into a farm or flock.

The costs of farm biosecurity are composed of investment costs required to 'upgrade' farm facilities and recurrent costs such as e.g. the repeated purchase of disinfectants. Further costs may arise from changes in

labour requirements and/or changes to the farming system. For example, if previously free-ranging birds are confined in sheds for biosecurity reasons, more feed has to be bought and given to the birds, which increases production costs. Poultry owners' decisions to invest in biosecurity measures are determined by their perception of the risk of disease incursion into their flock, the economic scale of expected losses once their flock is infected, and the additional costs that would be incurred.

For traditional, extensive backyard poultry production systems, confinement of scavenging poultry would require a twofold investment. Investments in material such as bamboo fences and the costs for this would highly depend on their availability. ACI [31] estimated that in Vietnam the cost of upgrading the biosecurity of free-ranging backyard production systems to a confined broiler production system would outweigh the benefits from potential economies of scale. In addition to the direct cost of confining scavenging chicken, confinement represents a major change of the poultry production system. This major change in poultry production requires 'training' of poultry keepers to enhance adoption, the costs of which for the case of Vietnam were estimated at US\$50 per farm [32].

For (semi-) intensive, commercial poultry farms, the cost of upgrading biosecurity may be minor if these farms already meet high biosecurity standards. However, it has been found that many commercial farms still require substantial investment in biosecurity to fulfil standards set by the industry or public regulations in response to HPAI. The necessary investment costs for biosecurity upgrading of small commercial farms in Vietnam, Cambodia and Laos for example were roughly estimated to fall into the range of US\$75–100 per farm, an amount that was found unlikely to be spent by villagers rearing small flocks for commercial purposes [33]. In Cambodia, a study of the production costs and revenue before and after the HPAI outbreaks in 2004 found that farms raising 2700 chicks actually only incurred additional biosecurity costs of US\$5 per production cycle [24]. However, the study did not specify which biosecurity measure(s) was/were implemented.

Progressive tightening of biosecurity requirements by the Government of Hong Kong through licensing led to substantially increased biosecurity costs for poultry keepers (e.g. for wild-bird proofing and construction of disinfectant baths). These additional costs varied from farm to farm but in a recent offer to farmers wanting to abandon poultry keeping, about US\$19 300 was offered to compensate them for their expenditure in biosecurity improvements (Hong Kong Government Finance Committee Paper [34]). In Vietnam, biosecurity upgrading of government grandparent stock breeding farms included the installation of personnel disinfection entry units, quarantine units, clean water systems, disinfectants, sprayers, protective clothing, fencing and other items to provide an effective disease containment barrier. The average costs were US\$57 000 per farm [35].

Live-bird markets have been identified as important sources of HPAI transmission, and governments and/or local authorities are investing in improving biosecurity in these markets. In Manila, biosecurity upgrading of live bird markets involved relocation and rebuilding markets outside the city. The investment needed to rebuild one market was estimated at US\$1.3 million [36]. The total costs of upgrading live-bird markets in Vietnam were estimated at between US\$5 and 10 million [35].

#### *Vaccination*

Vaccination of poultry against HPAI is a control measure, which may serve several objectives. It can be used as part of an eradication programme to avoid culling of a large number of flocks, to reduce the number of outbreaks and the amount of circulating virus in a country or region where HPAI is endemic, or simply as an 'insurance' used by farmers against losses from HPAI outbreaks. Government-led mass vaccination campaigns of poultry against HPAI are ongoing or have been conducted in several countries, including Hong Kong, China, Vietnam, Indonesia, Egypt, Côte d'Ivoire, Pakistan and Mexico.

In Vietnam, twice-yearly mass vaccination campaigns are carried out by private agents under the supervision of public veterinary services. Investments were made in cold storage for vaccines, training of vaccinators and mass communication campaigns. The total costs of delivering 364.5 million vaccinations during the first year of the campaign were estimated to be approximately US\$21 million. The total costs of vaccine, vaccine delivery and all other administrative and fixed costs for storage and organization were estimated at US\$0.06 per bird vaccinated [36]. In Côte d'Ivoire, vaccination focused on commercial and semi-commercial flocks, which make up approximately one-third of the national poultry population of 32.5 million. The total costs of delivering 31.8 million vaccinations during the first year of the campaign were estimated at US\$2.25 million. The cost to vaccinate a bird was approximately US\$0.07 [36]. Fasina *et al.* [37] conducted an assessment of potential vaccination campaign costs in Nigeria. Assuming a vaccine cost of US\$0.06 and a vaccination cost of US\$0.04 per bird and an annual administration and distribution costs for the campaign of US\$156 128, the total costs of vaccinating 70% of the national poultry population twice a year over a 3-year period were estimated at close to US\$92 million.

#### *Diagnostic capacity and disease surveillance*

In response to HPAI, public animal health services in many developing countries are increasing their expenditure on diagnostic capacity and disease surveillance. Much of the required investment in laboratory equipment and laboratory staff training is provided by bilateral and international donors.

Given the high engineering, equipment, building and design costs, establishment of a very basic diagnostic facility for two staff costs at least US\$500 000 [38].

In Hong Kong, construction of a new laboratory required an investment of US\$6.1 million. Although the laboratory was not exclusively a response to the HPAI crisis and serves for the diagnosis of other diseases as well, it was primarily needed to improve the capacity of identifying HPAI viruses [32]. Strengthening of the diagnostic capacity of six laboratories in Nigeria with one laboratory capable of carrying out virus isolation and identification while the capacity of the other five laboratories remained limited to screening and antigen detection was estimated to cost US\$3.12 million [39].

Developing countries face economic problems of sustainability with upgraded laboratories due to the high recurrent costs of consumables, which are usually not covered by donor funds. In Asia, the cost of reagents for one HPAI blood test (serology) ranges between US\$0.50 and 1.50, whereas virus isolation or real-time PCR approximately costs US\$10–20 per sample. In Thailand, the variable costs of the laboratory testing associated with a single 'x-ray' survey are reported to be in the order of US\$1 million [32], whereas in Malaysia, the surveillance and monitoring costs associated with the HPAI outbreaks in August and September 2005 were estimated at US\$533 000 [40]. Based on published government figures, it has been estimated that the recurrent costs of HPAI surveillance and monitoring in Hong Kong farms and markets have added approximately US\$0.12 to the cost of each live bird sold, i.e. about 6% of the price of live birds imported from China [41].

Agra CEAS and CIVIC Consulting [42] estimated the cost of strengthening of veterinary services and improving disease investigation capacity in Vietnam and Nigeria to be in the order of US\$30 million and US\$10 million, respectively, over a 5-year period.

#### *Outbreak control*

Culling of infected birds and birds at risk has been a widely used control measure in newly infected countries. Culling and safe disposal of carcasses and potentially contaminated material are complemented by disinfection of affected premises and movement controls. Information on operational costs of disease control is very scant in the literature.

For Vietnam, the cost of culling and disposing of carcasses was estimated to be about US\$0.25 per bird for a 200-bird flock, whereas for Nigeria these costs are estimated to reach about US\$1.00 per bird, if a culling team disposes of 1000 birds in a day [32]. Disinfection of farms after depopulation was estimated to cost in the range US\$22–110 per farm in Bangladesh [26]. In Malaysia, implementation of movement controls in the form of road blocks costs US\$50 000 per month in 2005 [40]. The Thai Department of Livestock Development calculated that US\$12.5 million and US\$26.0 million were spent in the first and second waves, respectively, for cleaning and disinfection, surveillance, movement control and public awareness campaigns [43].

In addition to bearing the cost of implementing these control measures, governments usually compensate farmers at least partially for the poultry lost through culling. Compensation does not represent a separate disease 'cost' but is a transfer payment, which, depending on how compensation funds are financed, 'redistributes' disease costs between affected and non-affected farmers and between the private and public sector. In Thailand, compensation at rates between 70 and 100% of the market price of a bird was paid for about 61 million culled birds, resulting in a total payment of US\$46.5 million to 407 338 farmers [44]. During the HPAI outbreaks in early 2004 and 2005 in Vietnam, compensation rates differed between provinces, but throughout the effective rate of compensation offered by provincial governments was only about 20–30% of the market value of the culled birds. The total amount disbursed was US\$18.5 million for 41.3 million birds [45]. The culling of 3.8 million birds in Hong Kong during the years 1997, 2001 and 2005 resulted in US\$29.2 million in compensation payments [40]. In Malaysia, US\$60 000 compensation was paid for 17 000 birds and 4300 eggs [40]. In Egypt, a total of about US\$30 million (EGP 171 million) were paid in compensation for culled birds and birds that could not be marketed because of movement restrictions. The Egyptian Poultry Association contributed around US\$6 million (EGP 35 million) to the fund established for these compensation payments (data from Principal Bank for Development and Agricultural Credit). The compensation process, however, only covered registered poultry properties and was largely stopped in mid-2006, when original fund sources dried up.

### **Direct/immediate Impacts of HPAI Through Market/consumer Reactions (Demand side and Consumer Welfare)**

#### ***Domestic Market Reactions***

Market reactions to animal diseases will depend on the balance between the changes in supply and demand for the affected livestock commodity and on the 'openness' of the affected economy. If the supply shortages outweigh the shifts in demand, price rises will occur, whereas if consumer demand falls more than supply, prices will drop. These effects will be more pronounced in a relatively closed economy, whereas they will be less marked in the case of an open economy linked to global poultry markets. The downside of the latter case, however, is that domestic markets can be affected by animal health crises occurring elsewhere.

As the HPAI H5N1 virus has shown to be able to infect humans, HPAI outbreaks in poultry have, at least in the period immediately following their notification, led to a drop in demand for poultry meat and eggs. For example, a cross-country consumer survey carried out in May 2006

**Table 3** Impact of HPAI on price and volume of broilers/poultry meat sold in major markets of affected countries

Country, beginning of market shock	Price effect	Volume effect	Duration	Source
Cambodia, Jan. 2004	75% drop	80–90% drop	By March 2004 prices back to pre-outbreak levels	VSF [24]
Indonesia, Jan. 2004	50–85% drop	33% drop	By May 2004 prices back to pre-outbreak levels	Dolberg <i>et al.</i> [44], Rushton <i>et al.</i> [51]
Vietnam, Oct. 2005	50–60% drop	50% drop	In Dec. 2005 prices were still 30% below pre-HPAI level	ACI [48]
Turkey, Oct. 2005	50% drop	50% drop	Prices took about 6 months to recover	Yalcin [46]
Egypt, Nov. 2005 <sup>1</sup>	30% drop	n.a. <sup>1</sup>	Prices took about 6 months to recover	Albrechtsen <i>et al.</i> [62]
Nigeria, Feb. 2006	n.a.	80% drop	Four months later, still 50% lower than pre-outbreak	Anon. [50]
Bangladesh, Feb. 2007	8–13% drop	n.a.	Prices were back to pre-outbreak level in July 2007	Alam <i>et al.</i> [26]

<sup>1</sup>Prices started dropping in Egypt as result of HPAI outbreaks announced in Turkey in September 2005 and had almost reached their lowest level when HPAI affected poultry in Egypt in February 2006.

revealed that in most countries a significant proportion of consumers had reduced their consumption of poultry [42]. This proportion was higher in countries affected by HPAI, e.g. Thailand where about 30% of consumers stated that they had reduced their poultry consumption, and was lower in non-affected countries, e.g. Argentina and Brazil where however this proportion was still about 15%. As a reaction to the westward spread of HPAI in early 2006, nearly 20% of the respondents of a consumer survey conducted in the European Union (EU) stated that they had reduced consumption of poultry meat by an average of 18% (with large between-country variation however) and the sales of poultry and eggs fell by 70 and 20% in Italy and France, respectively [42]. In Ghana, after the first outbreaks of HPAI in 2007, almost 50% of respondents changed eating habits. Interestingly, 75% of public and animal health workers stopped eating poultry meat [42].

The drop in demand caused by consumer anxiety about the risk of contracting HPAI can lead to a severe depression of the price for poultry and poultry products, thereby affecting the poultry industry through the combined effect of lower volumes and depressed prices. The overall impact of such a market shock will, to a large extent, depend on its duration. Table 3 presents an overview of the information on the impact of HPAI outbreaks on chicken prices and volumes traded that could be compiled from the grey literature.

The figures in Table 3 should only be taken as indicative of relatively severe, short-term disruptions of major formal markets, as disease control measures may result in the diversion of product flows through smaller markets and informal channels, offsetting some of the apparent loss in trading volumes and values. For instance, in Turkey's capital, Ankara, prices and volumes of broiler meat dropped by 32 and 54%, respectively, in response to HPAI, whereas in Erzurum, a relatively small market in Eastern Turkey, the price decreased by only 12%, and sales volumes increased by 78% [46]. Also, as seen in

Vietnam, some small-scale producers will increase their home consumption as a reaction to difficulties in marketing their produce [47]. Little to no published information could be found for poultry products other than those derived from chicken.

Some actors in the poultry market who are perceived as supplying safe poultry products have been able to, at least temporarily, benefit from widespread consumer concerns. Thus, in Vietnam for example, prices of chicken in supermarkets were 25–35% higher than pre-outbreak prices in December 2005, at a time when poultry prices in traditional wet markets were still below pre-outbreak levels [48].

The closest substitute for poultry meat in non-Muslim countries is pork, and in some countries/regions, fish and soya act as a substitute. A drop in supply of and/or demand for poultry meat will generally lead to a concomitant increase in demand for these substitutes. In Cambodia and in Vietnam for example, prices of non-poultry meats rose by 30% as a consequence of the first epidemic wave in 2004 [48]. This price rise offset the losses of poultry farmers that also raised pigs and passed losses on to consumers, putting meat out of the reach of poorer households, particularly in urban areas. In Turkey, meat of small ruminants and cattle are the only meat substitutes, and in 2006, real beef prices were 12–15% higher than those of 2005 [46]. Similarly, in Egypt, beef prices rose by 15% in 4 months after HPAI affected the national poultry flock [49]. In Bangladesh, both beef and fish prices increased when poultry demand dropped suddenly in late January 2008. The prices for fish remained high even when broiler chicken and egg prices rose above pre-market shock prices. It is assumed that the poultry sector had contracted and a supply constraint led to lower availability of poultry products and higher prices for both poultry and fish.

The time that elapses until poultry prices recover is variable and determined by the severity of the outbreak and the resulting downscaling of production, measures

taken by the industry to promote poultry consumption, and by the occurrence of human cases. As seen in Table 3, in Cambodia, prices recovered within 2 months and thereafter continued to rise to a level 25% above pre-outbreak prices [24] as a result of supply shortages owing to a ban on importation of DOCs from neighbouring Thailand. In Egypt, supply constraints for the layer industry led to a sharp increase of egg prices from February 2006 onwards. By September 2006, egg prices had tripled and stayed high for the following 12 months [49].

### **International Market Effects**

International markets for livestock commodities react very quickly to outbreaks of transboundary animal diseases by banning the importation of all potentially risky products from affected countries. In the case of poultry meat and/or eggs, developing countries are normally net importers and thus usually not severely affected by export ban. A few notable exceptions, however, exist among the 'higher income developing countries', and Thailand, Turkey and Brazil are net exporters of poultry meat, with Thailand and Turkey having experienced HPAI outbreaks.

In 2005, Turkey exported 44800 tonnes of poultry meat (about 4% of production), at least half of which went to three countries: China (including Hong Kong), Azerbaijan and Iraq. In 2006, exports of poultry products decreased by 69% during the HPAI epidemic [46], but exports to Azerbaijan increased sharply, more than doubling, while Asian demand for Turkish poultry fell by more than half and Iraqi demand by 40%. This strong trade diversion appeared to help stabilize overall exports, which fell back to 38000 tonnes, but remained well above the 2004 level of 29000 tonnes. However, given that only a relatively small share of Turkey's poultry meat production had been destined to international markets, the drop in domestic demand proved to be of much more consequence for the Turkish poultry industry than the international trade restrictions.

The situation is different for Thailand, which had established itself as the fourth largest exporter of poultry meat prior to the incursion of HPAI in 2004 (only Brazil, USA and EU exported more). In 2003, Thailand exported nearly 485000 tonnes of poultry meat (nearly 40% of production), of which around two-thirds were exported frozen and the remainder pre-cooked [7]. The EU and Japan were the main export destinations for Thai poultry meat. After the notification of HPAI by Thai authorities in early 2004, Thai poultry products were immediately banned from major international trade flows and total exports in 2004 dropped to 218000 tonnes, or 45% of the 2003 figure. These bans, however, were not uniformly applied to all types of poultry products, and the volume of frozen meats exported in 2004 dropped to less than 10% of the 2003 figure, whereas Thai exporters were able to

compensate some of this decline by increasing the volume of pre-cooked exports by 25% from 154000 to 194000 tonnes. This shift in poultry meat exports towards pre-cooked products resulted in an over-proportional increase in export revenue from the latter by 32%, as between 2003 and 2004 the price ratio of pre-cooked to frozen poultry products rose from 1.36 to 1.44.

Brazil benefited from trade bans placed on unprocessed poultry meat from Thailand. Between 2003 and 2005, Brazil nearly doubled the revenue from the export of unprocessed poultry meat from US\$1516 million to US\$2971 million. Over the same period, Brazil also increased its export revenue from processed poultry products from US\$220 million to US\$398 million [50].

### **Short-term Indirect/flow-on Impacts**

Direct impacts of disease outbreaks on producers are propagated up- and downstream through the poultry industry and, given horizontal economic linkages, to other sectors as well. The magnitude of these links will determine the extent of the 'flow-on' impacts in a particular country.

### **Upstream Supply Industries**

#### *Feed industry*

Information on the impact of HPAI on the feed industry is scant in the literature reviewed and, where reported, estimates are often based on convenience samples rather than systematic surveys. In Vietnam, for example, one major feed producer reported 90% drop in demand, whereas another reported a 60–70% drop [48]. In Indonesia the demand for poultry feed was estimated to have dropped by 45% during the initial phases of the epidemic [44]. In Nigeria, poultry feed sales dropped by 82% after HPAI was reported in early 2006 and had only reached 43% of pre-outbreak levels by May 2006 [19], and a drop of similar magnitude (70%) is reported for Egypt [49]. Yalcin [46] has reported that, in Turkey, concentrate feed production of the 50 largest feed mills between January and April 2006 was 6–11% lower than that in the same period of the previous year, but that it recovered after May 2006. A larger loss to the Turkish feed industry is said to stem from delays in payment of the feed bills by poultry producers. In Thailand, the feed mills of the Thai Broiler Processing Exporters Association incurred losses of about US\$300 million (Baht 12430 million) during the outbreak in 2004 [7].

Feed mills may compensate some of the losses they suffer from lower demand for poultry feed by switching to production of pig feed or fish feed, as was the case in Vietnam and Bangladesh, respectively, and may themselves reduce purchases of feed grains. For example, maize prices were reported to have gone down in Benin because

of the reduced demand for maize for poultry feed in Nigeria [42].

#### DOCs

Major HPAI outbreaks and related control measures as well as the decline in demand for poultry and poultry products will invariably lead to reduced requirements of DOCs. In Indonesia, in affected areas, demand decreased by 58% for broiler DOCs and by 40% for layer DOCs, whereas prices dropped from US\$0.24 (Rupia 2200) to US\$0.02 (Rupia 200) per DOC [33, 44, 51]. Similarly, the demand for DOCs declined sharply and their farm gate price dropped from US\$0.25 to 0.10 in northern Vietnam [20], and Cargill Vietnam was forced to close down its chick breeding farm in 2005. In Egypt, prices for DOCs dropped by 80–90% between October 2005 and March 2006 [49]. In Turkey, as a result of declining demand for DOCs, the number of breeding hens decreased by 24% between October 2005 and April 2006, and most producers of DOCs had to sell their breeding eggs as table eggs [46]. In Nigeria, 60% of the 5 million DOCs produced per week in commercial hatcheries were not sold and subsequently caused severe losses for the producers (Poultry Association Nigeria, cited in [19]).

Contraction of the breeding population delays recovery of the poultry industry once HPAI has been controlled and thereby increases supply gaps if import restrictions on poultry and poultry products are kept in place. These shortages translate into price increases both of end products, as mentioned previously, and of intermediate products, such as DOCs. In Cambodia for instance, with only one domestic supplier of DOCs, the import ban on DOCs from neighbouring countries resulted in a 32% price increase of DOCs [52] from December 2003 to May 2004. In Egypt, where about 4 million broiler parent stock layers were culled during the HPAI epidemic (about 50% of the pre-epidemic population), the price of DOCs in August 2006 was nearly double the price in October 2005, before prices declined as a result of reduction of consumer demand [49]. In Bangladesh there were reports of reductions in demand and price of broiler DOCs during the 2008 epidemic wave, which have subsequently led to a drastic reduction in the production of DOCs. The latter may in part be explained by the presence of HPAI, and also general problems with higher feed prices squeezing farm-level profits and higher human basic food grain prices reducing demand.

#### Veterinary products and feed additives

Information on the impact of HPAI on the demand for veterinary products and feed additives is provided by Yalcin [46] for Turkey: sales values of vaccines, drugs, vitamins and feed additives to the poultry industry dropped by 25, 44, 55 and 30%, respectively, during the outbreak period, whereas sales value of disinfectants increased by 20%. Overall, the total value of sales to the poultry industry dropped by 29%.

### Downstream Processing and Distribution Agents

#### Wholesalers and retailers

As mentioned previously, trade volumes and prices tend to be severely affected during HPAI crises, not only causing losses to producers but also to traders and middlemen, who are largely neglected in the literature reviewed. Losses to traders result from decreased trade volumes and thereby represent foregone income, analogous to the effect of 'downtime' on producer income. In Laos, traders and market sellers experienced an average 40% reduction of their income over the 2 months of a poultry trade ban imposed by the government after HPAI broke out in broiler farms around Vientiane [53]. Decreased trade volumes increase marketing cost per unit of product traded owing to fixed costs associated with trading such as office/shop rents, etc. In the case of Bangladesh, Alam *et al.* [26] estimated that HPAI increased the marketing cost of broilers and eggs by 5 and 14%, respectively. Depending on whether reduced trade volumes are a result of demand or supply constraints, traders may adjust their margin up- or downwards. This adjustment increases their losses if they are forced to decrease their margin (in the case of a demand constraint) or mitigate their losses if they are in a position to increase their margin (in the case of a supply constraint).

#### Slaughterhouses and cold stores

Capacity use of slaughterhouses decreases during HPAI outbreaks, whereas demand for cold storage space may concomitantly increase. Ibrahim *et al.* [49], for example, report that in Egypt, slaughterhouses stopped operating completely at some stage of the HPAI crisis (about 205 slaughterhouses). In Turkey, slaughterhouse throughput dropped by 12% during and by another 21% after the HPAI outbreak before gradually recovering. Over the same periods, broiler meat in cold storage increased by 121 and 163%, respectively, whereas the costs of cold storage increased by 258% during HPAI and 228% after HPAI [46].

#### Restaurants and catering sector

HPAI is also reported to have had significant effects on restaurants and formal as well as informal food outlets. For example, after the Vietnamese government banned the sale of chicken, Thai-owned Kentucky Fried Chicken franchised stores in Vietnam had to close shop for weeks before reopening and changing the menu to serve fish instead of chicken (*Financial Times*, 29 January 2004). In Nigeria, the consumption of poultry in restaurants, fast-food outlets, and from roadside roasted chicken sellers dropped by 81% after HPAI was reported in the country in February 2006, and by May 2006, sales had only recovered to 68% of pre-HPAI levels [19]. Outlets that have not specialized on poultry products may have recouped some of their losses through increased sales of other food items.

### **Horizontal Economic Linkages**

Direct losses and income foregone in the poultry sector can have repercussions on other economic sectors. The magnitude of these cross-sectoral impacts depends on sector linkages and the severity of the impact on the poultry sector.

An important linkage between the poultry sector and rice production exists in the Mekong countries. As ducks are important for pest control in paddy rice, rice farmers in the Mekong Delta complained that the reductions of duck numbers in the rice fields resulted in increased damage from golden snails, increased occurrence of viral diseases in the spring–winter crop in 2006, and as a result lower net incomes [54].

Prior to the HPAI epidemic in 2006 in Egypt, the Principal Bank for Development and Agricultural Credit had a policy of lending money to small- and medium-scale poultry producers and at the time of the crisis had lent about US\$56 million (EGP 300 million) to these types of producers. The government recommended that this public bank restructure loans to the poultry sector, allowing producers a grace period until they had restocked. The deferral of loans passed some of the losses of poultry producers to the public finance sector. Similarly, in Thailand the government provided free-range duck raisers with soft loans at 2% interest rate to help them recover from productive asset losses and to relocate their production units [55]. The opposite occurred in Turkey, where interests paid for loans increased by 80% during HPAI and by 560% after HPAI due to increased demand for credit resulting from depressed incomes from poultry sales and increasing costs of cold storage and biosecurity [46].

In Turkey, expenditure on advertisements to reassure consumers of the safety of poultry products increased by 390% during HPAI, and by 297% after HPAI [46].

### **Medium/longer Term Impacts**

Medium- and longer-term impacts of HPAI in developing countries will depend on the structure of the poultry sector prior to the incursion of the disease, the severity of the epidemic, and the policy response and implementation capacity to the public and private sectors. Furthermore, the various poultry 'subsectors' are likely to be affected in different ways and to different degrees. Given the very heterogeneous nature of the poultry sector within and between countries, medium- and longer-term impacts of HPAI in developing countries as a whole will be variable and are hard to predict.

Some general conclusions may perhaps be drawn from country cases chosen to represent specific combinations of disease incidence and policy response. Thailand and Vietnam represent a situation of high disease incidence and strong policy response, whereas Egypt and Indonesia

may illustrate the case of high incidence but relatively weak policy response. Conversely, Malaysia may illustrate the situation of low disease incidence and strong policy response, whereas Cambodia illustrates the case of low incidence and moderate policy response. For the latter two 'scenarios', medium- to longer-term impacts on the poultry sector are likely to be minimal, and the main effect of disease incursion stems from its short-term effects including adopted control measures.

Thailand and Vietnam are probably the two severely infected countries that have put the largest efforts into the elimination of HPAI and in which, as a consequence, the disease has induced the largest structural changes. Most of these changes are unlikely to be reversed. In Thailand, the free-grazing transhumant duck system was prohibited and the duck owners (approximately 3000) had to register and convert to a housed production system. Chicken farmers that have open poultry houses are not allowed to restock with DOCs unless they upgrade to closed-housing types, which requires a major up-front investment. Large poultry companies that contracted poultry production to individual farmers prior to HPAI have moved away from contract farming to full vertical integration in order to increase control over all stages of production. These measures led to further concentration of poultry production, as evidenced by the results of a telephone survey carried out in 2007, in which farmers known to have produced broilers in 2003 were asked whether they were still in the business. Only 49% of these farmers could still be contacted, and of those that could be contacted, 29% had given up broiler production. A similar survey among farmers that had kept layers in 2003 revealed that 44% of those which could still be contacted (39 out of 97) had switched to other activities [7]. As mentioned previously, the HPAI crisis also accelerated the shift of poultry exports from unprocessed frozen to pre-cooked meats. Rather than being reversed, this trend is likely to continue and large integrated poultry producers will probably incorporate or expand food processing capacities in their operation.

As in Thailand, HPAI is accelerating structural change of Vietnam's poultry sector with government providing incentives for upscaling and modernization of semi-industrial commercial and industrial production systems. As a result of this, between 2005 and 2006 alone, semi-industrial chicken production, despite producers leaving the sector, increased its share in total national production from 20 to 28% [56]. The scale biases in livestock development policy will sharpen the disadvantages of rural small-scale producers. Further effects of HPAI in Vietnam have been to reduce the number of outlets available to small-scale poultry producers, limiting their commercial opportunities to within-commune trade and some inter-commune trade, thereby also reducing income opportunities for smaller market traders. Larger wholesale/processors are increasingly linking with large farms on a contract basis or as a fully owned subsidiary [31]. The

**Table 4** Main medium- to longer-term impact of HPAI in relation to severity of the epidemic and nature of public intervention

	Severity of HPAI epidemic	
	Many outbreaks over an extended period	A few outbreaks over short periods
Government reaction		
Decisive	(Accelerated) restructuring of poultry sector with consolidation of larger-scale industrial sector and exit of smaller-scale commercial producers and service providers	Relatively quick return to pre-epidemic status
Indecisive	Private investment in poultry sector expansion diminished and increased production costs leading to higher import dependency and/or higher consumer prices	Reduced private investment in poultry sector development

ban on free-range duck production around Ho Chi Minh City has forced farmers to either leave the sector or to relocate their enterprises to other provinces [48].

For countries in which HPAI has spread widely but in which the public sector has not taken a strong role in disease control, such as Egypt and Indonesia, continued presence of the disease is likely to stimulate private investment in HPAI risk management by commercial producers, such as reliance on vaccination and improved biosecurity, on the one hand, and, on the other hand, reduce private investment in expansion of or even withdrawal from poultry production. Ultimately, the consequences of these reactions are likely to be 'retarded' poultry sector development, which should lead to higher consumer prices for poultry products and will affect food security if imports remain restricted.

Table 4 summarizes the most prominent medium- to longer-term impacts of HPAI on national poultry sectors under different scenarios of severity of the epidemic and intensity of government intervention.

## Conclusions/recommendations

### Review Results

Most of the information on the impacts of avian influenza in developing countries was found in consultancy reports commissioned by national and/or international organizations, whereas very little peer-reviewed literature was available on the subject. The reports often do not clearly describe their 'materials and methods' and vary widely in the 'disease cost/impact' components considered, time frame, and inclusion of follow-on losses and of substitution effects. As a result, there is a lack of comparability of estimates for HPAI 'costs/impacts' across countries and even within countries.

One component of the 'cost of HPAI' found in a number of reports is that of direct bird losses, estimated as the product of the number of birds that died or were culled and the average value of a bird. However, widely different average values are at times assumed. In Nigeria, for example, the estimated farm value of the 0.9 million birds lost was US\$4.82 million (Naira 617.4 million) [19],

i.e. an average value of more than US\$5 was assumed per bird, whereas for Indonesia, Rushton *et al.* [51] estimated the national losses from 16.2 million poultry died or culled at US\$16.2–32.4 million, based on a value range of US\$1–2 per bird, subject to its weight or being broiler or layer. Although certainly there is a wide range of values individual birds can have, e.g. grand-parent stock will be much more valuable than broilers, such widely differing 'average' bird values across assessments are surprising. It also appears that many reports use market values of finished birds when calculating the cost of stock losses, when actually many, if not the majority, of birds that die or are culled are pre-market age.

Different estimates of HPAI-related 'losses' can also be found for similar periods within the same country. For Vietnam, direct losses from culled birds, lost production, costs of culling and disinfection in 2004 were estimated by the Government of Vietnam to amount to about US\$205 million (VND 3226 billion) [25]. An estimate by the World Bank [57] for the same period arrived at a national loss of US\$120 million, i.e. 60% of the government estimate.

Inaccuracies in disease impact assessments stemming from variable methodological approaches and differing valuations are compounded by major information deficits. Depending on incentives or disincentives for disease reporting such as compensation or culling, the real incidence and impact of HPAI may be under- or over-reported. Thus, for Bangladesh, it is likely that losses in the commercial layer and breeding units have been under-reported and that backyard systems have not reported disease either through a lack of information or because of problems of receiving compensation [13]. Exaggeration of HPAI losses or attribution of poultry deaths from other disease to HPAI are said to have occurred in some countries where compensation funds of the central government are disbursed by local authorities (anonymous, personal communication).

Despite the above shortcomings in the available literature on HPAI impacts, several general conclusions can probably be drawn.

- Firstly, the loss of poultry dying from HPAI is dwarfed by the impacts resulting from consumer/market reactions, which affect the entire industry, irrespective of

the infection status of a particular enterprise. This actually offers wide scope for mitigating the impact of HPAI through well-designed public HPAI risk management programmes.

- Second, in countries in which traditional, extensive backyard poultry keeping is still widely practised, these often poor poultry keepers, although individually usually being relatively resilient to the impact of poultry diseases (owing to their diversified livelihoods portfolio), will, collectively, carry the largest share of the burden of HPAI. Thus, this producer stratum, which in many countries still represents the majority of poultry keepers, will require special consideration in national HPAI control programmes as they are accustomed to recurrent poultry losses, have little incentives to comply with disease control programmes or to invest in biosecurity [58] and cannot be effectively policed by public animal health agencies.
- Third, commercial poultry producers and market agents specialized in poultry represent the category of producers/households individually most severely affected by HPAI and HPAI control measures (as, for example, demonstrated by the high 'drop-out' rates in Thailand), even if collectively they may not carry the bulk of the HPAI burden. The reason for this is that in developing countries, commercial poultry producers usually only represent a minority of producers, but a minority whose livelihoods are threatened by longer lasting HPAI outbreaks and/or protracted control measures because of their investments and specialization in poultry.
- Fourth, within the commercial sector, it appears that the impact of HPAI on layer producers has generally been more severe than on broiler producers, even if the latter have usually suffered from more severe consumer reactions (e.g. higher drop-out rates in layer than broiler producers in Thailand). One reason may be that for layer producers, stock losses represent a larger share of invested capital lost and downtime is considerably longer (see Table 2), but it also seems that layer producers are more frequently affected by HPAI than broiler producers (e.g. Egypt and Indonesia), which may be explained by more frequent 'contacts' for egg collection.
- Fifth, given the extensive ramifications intra- and inter-sectoral linkages, any assessment of the consequential impacts of HPAI on the industries feeding into or off the poultry sector requires comprehensive and detailed economic models that are normally not available and any figures on such impacts should be treated with caution.

### **The Way Forward**

Any agricultural activity, including livestock operations, is subject to random interruption and losses from

disease. Management practices tend to adjust to such random shocks as producers use saved resources, loans, as well as insurance and/or compensation to restock and continue operations, as long as it is profitable on average. Furthermore, periods where shocks occur in some regions, but not others, reduce supply and enhance profits for the unaffected regions, possibly enough so that average profitability is not affected much, and sometimes actually may increase. In the case of HPAI, there is pressure from the international community for at-risk countries to control outbreaks because of possible externality effects, and more importantly, outbreaks trigger reduction of consumer demand, owing to safety concerns, that may drastically reduce the average profitability of the industry. Thus, both considerations of external pressures, as well as profitability, suggest that more efforts should be directed at containing HPAI than other diseases with similar health risks to poultry.

Policy design requires development of models that incorporate epidemiological considerations into economic decision-making models. These models should predict producers' profit-maximizing behaviour in response to policy interventions, and derive policy solutions given these behavioural patterns. Producer behaviour consists of decisions about whether and how much to produce, as well as choices about disease management. Government policies may include direct controls like quality standards, monitoring requirements, and financial incentives. Some solutions may involve public-private collaboration, for example, regional preventative measures, vaccination programmes, and various certification/quality assurance processes.

The model developed in Beach *et al.* [59] is a starting point in building an epidemiological model depicting transmission of HPAI. In this model, the reproductive coefficient  $R_0$  is a multiplicative function of parameters characterizing the infection, and these parameters can be affected by control policies and efforts, as well as by modification of behaviour. These control policies require public and private investment, and thus an expanded model can be used to pursue cost-effective and social welfare-maximizing policies. There is already a body of literature in environmental health economics that follows this approach [60]. Sproul *et al.* [61] introduce a preliminary framework that considers a sequential decision-making process and incorporates interventions into a risk-generation function, but this new line of modelling is in its infancy. Using this approach, Sproul *et al.* [61] attempt to capture optimal tradeoffs between preventative and monitoring efforts. The model generalizes easily to a social planner's optimization problem and should be expanded along conceptual, numerical, and statistical or econometric lines. The conceptual analysis should allow for heterogeneity (in terms of location, income, environmental conditions, etc.), interaction among economic agents and market power considerations. Numerical

simulations should be directed at identifying under what conditions to pursue specific control strategies. For example, vaccination, government-administered monitoring and tracing of sick animals, control of infectious carriers, development of new disease control technologies, and best management practices could all be investigated through numerical simulations. These simulations will also be crucial in determining the tradeoffs between various alternative policy tools and the costs and benefits of each. Statistical or econometric analysis will be required to estimate key epidemiological parameters governing the spread of the disease and behavioural parameters under various conditions. Statistical analysis should be used to test the effectiveness of alternative strategies, including their impacts on the well-being of farmers and on the spread of disease.

Since health and safety concerns are likely to affect the demand for poultry, further research is needed to quantify these effects and establish mechanisms to enhance product quality and consumer confidence in safety, thus raising farmer incomes. Strategies to enhance consumer confidence may vary between the industrial and traditional poultry sectors. These efforts should be integrated with other marketing efforts to better place and market 'traditional' poultry, with the aim of developing a market niche that will generate extra premiums. This may require introducing quality control activities that will modify the performance and the structure of traditional producers, but that will improve their livelihoods in the long run.

Any policy analysis has to incorporate significant uncertainty regarding parameters of the disease and its dynamic nature. Modelling efforts should aim to produce strategies resulting in robust and effective outcomes under various conditions, and controls that are adaptive. One of the major challenges in developing policies is asymmetric information between farmers and policy-makers, which will restrict the set of feasible effective policies. Increases in monitoring capacity of regulators and improvements in information technologies may ultimately lead to a shift in policies with more flexibility and more efficiency as a result of increased information. Thus, technological change and medical knowledge will lead to evolving policy interventions and improved outcomes over time.

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