The effects of control measures on the economic burden associated with epidemics of avian influenza in Italy

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ABSTRACT In 1999, Italy experienced a devastating epidemic of high-pathogenicity avian influenza (HPAI) caused by an H7N1 virus subtype. After this epidemic, a ministerial decree was passed to implement control measures for low-pathogenicity avian influenza (LPAI) due to H5 and H7 subtypes. We investigated whether these control measures have decreased the public expenditure associated with epidemics of LPAI and HPAI by comparing the direct and consequential losses of the 1999 epidemic to the losses associated with successive epidemics. The estimated total economic burden of the epidemics was about €650 million (€217 million in direct losses and €433 million in consequential losses). The 1999 epidemic accounted for most of these losses (€507 million: €112 million in direct losses and €395 million in consequential losses), whereas the total economic burden for the 5 successive LPAI was €143 million (€105 million in direct losses and €38 million in consequential losses). These results demonstrate that the implementation of a coordinated set of disease-control measures, which included both emergency and prophylactic vaccination, was able to reduce the overall costs associated with avian influenza epidemics. The results also show that the application of adequate LPAI control measures may limit the risk of emergence of an HPAI virus in an area with a high poultry density, allowing the complete disruption of the poultry market and its huge associated costs to be avoided.

Key words: avian influenza, control measure, vaccination, economic assessment

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INTRODUCTION

Since 1992, the European Union (**EU**) has financed measures for the eradication of high-pathogenicity avian influenza (**HPAI**) viruses (CEC, 1990, 1992) without any mention of support in case of low-pathogenicity avian influenza (**LPAI**). In 2005, legislation passed to fund control measures for LPAI viruses of the H5 and H7 subtypes, which can mutate into HPAI viruses (Pittman and Laddomada, 2008). In particular, in 2005, EU legislation introduced mandatory eradication measures for H5 and H7 LPAI infections and defined the financial compensation to be provided to farmers by the state in the occurrence of outbreaks of these infections (CEC, 2006a, 2009).

High-pathogenicity avian influenza is considered to have been enzootic in Italy between the end of the 19th and the beginning of the 20th century; indeed, Petek (1982) contends that a series of outbreaks occurred during 1935 to 1937. Notwithstanding, until 1997, no HPAI infections were recorded, although a series of LPAI virus isolations of different subtypes from domestic and wild birds (Franciosi et al., 1981; Petek, 1982; Papparella et al., 1994, 1995) were registered. The emergence of LPAI viruses has also been reported in numerous poultry-producing countries, EU and non-EU, and is attributed to the circulation of the virus in migratory waterfowl (Alexander, 1995). Since 1997, several HPAI and LPAI epidemics have occurred (Cecchinato et al., 2009), mainly in densely populated poultry areas (**DPPA**) in the northern regions of Veneto and Lombardy. The most devastating of these was an LPAI epidemic caused by an H7N1 virus subtype in 1999, which has been considered one of the most serious avian influenza (**AI**) epidemics that has ever occurred in Europe (Capua and Marangon, 2000). At the time, there was no specific legislation in Italy for eradicating LPAI infection, and the virus circulated in the industrial poultry population of that DPPA, eventually mutating into an HPAI form.

After this epidemic, in September 2000, a ministerial decree was passed to implement control measures for LPAI due to H5 and H7 subtypes, including emergen-

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cy and preventive vaccination, which for the previous epidemics had not been performed (Anonymous, 2000). The decree also specifies that compensation must be provided to farmers affected by these outbreaks. Since that time, 5 other epidemics have occurred, and although farmers have been reimbursed for their losses, the total economic effect of these epidemics has never been estimated. To do so, it is necessary to calculate both the direct losses (i.e., losses that stem from the disease itself, sanitary and control measures, and the lost value of culled birds) and the consequential losses (i.e., losses due to idle production factors, decreases in stock, movement restrictions, and bans on restocking) (OIE, 2007).

The objective of the present study was to determine whether the application of the control measures that began to be implemented in 2000 have decreased the public expenditure associated with HPAI and LPAI epidemics. To this end, we compared the direct and consequential losses resulting from the 1999 epidemic to those associated with the successive epidemics.

MATERIALS AND METHODS

For each epidemic, we calculated both the direct and consequential losses. Direct losses refer to the costs related to disease eradication, in particular those incurred by the Italian government (co-financed by the EU) to compensate farmers for birds destroyed or disposed of during outbreaks or preemptively slaughtered on at-risk farms (at 100% of their value, 50% refunded by the EU), contaminated products (e.g., meat and eggs; 80% of their value, 50% refunded by the EU), and materials and equipment considered to be contaminated (e.g., bedding and feedstuffs, at 80% of their value, 50% refunded by EU).

Direct losses also include the costs of emergency and preventive vaccination and monitoring activities. Until 2007, in Italy, the costs for emergency and preventive vaccination were the responsibility of the poultry producers, although 100% of these costs were reimbursed by the state. Since then, the EU refunds 100% of the costs of the emergency vaccine supply and 50% of the costs for emergency vaccination; however, it does not provide funding for preventive vaccination (CEC, 2006a, 2009). The vaccination programs in Italy, which have been approved by the EU and conducted in various periods, have consistently included an intensive monitoring program, which entails performing serological and virological tests in both the vaccination area and in bordering areas. The costs of monitoring have always been covered by the Italian Ministry of Health and Regional Governments.

Consequential losses are those resulting from a prolonged stoppage period, in particular farmers' loss of income; nonabsorbable fixed costs within the production chain and in the production restart phase; loss of hatching eggs, chicks, and meat; and benefits to laid-off workers. Neither Italy nor the EU provides financial compensation for these losses, which are completely borne by the production sector. By contrast, the loss of profit due to bans on restocking for reducing poultry density is covered by regional agencies, in accordance with EU legislation (CEC, 2006b).

A variety of sources were used for the data on costs and are specified in the Results section. The epidemics that occurred from 1999 to 2007 and the control measures performed are described below.

1999 to 2000 H7N1 HPAI Epidemic

Between December 17, 1999 and April 5, 2000, there were 413 outbreaks, most of which took place in the DPPA in the regions of Veneto (158 outbreaks) and Lombardy (234 outbreaks). Approximately 16 millions birds, mainly meat turkeys and laying hens, were culled or died on the affected farms, or they were preemptively slaughtered on premises defined to be at risk of infection (Marangon et al., 2005). The H7N1 HPAI virus that caused the epidemic had mutated from an LPAI precursor, which had circulated in the poultry population of northeastern Italy for approximately 9 mo (Capua and Marangon, 2000). At the time, there was no legislation mandating the implementation of control measures for LPAI viruses, and measures were implemented only after the virus mutated into the HPAI H7N1 strain. In accordance with Directive 92/40/EEC (CEC, 1992), infected flocks were stamped out, and the infected premises were cleaned and disinfected. The infected area, which covered 5,500 km^2, was completely depopulated of poultry, including intensive, semi-intensive, and backyard flocks, so as to improve eradication procedures.

2000 to 2007 LPAI Epidemics

Between 2000 and 2007, 5 LPAI epidemics occurred, mainly in the DPPA and among meat turkeys, in particular i) an H7N1 epidemic in 2000 to 2001, ii) an H7N3 epidemic in 2002 to 2003, iii) an H7N3 epidemic in 2004, iv) an H5N2 epidemic in 2005, and v) an H7N3 epidemic in 2007 (Table 1). The preventive and control measures implemented during the Italian LPAI epidemics are those described by Busani et al. (2009) and Mulatti et al. (2009) and included:

- stamping out or controlled marketing of slaughtered birds on infected premises;
- reduction of poultry density in areas at high risk of AI, via a temporary ban or a controlled restocking of meat turkey farms (homogeneous areas);
- strengthening of biosecurity measures at the farm level;
- continuous monitoring of the epidemiological situation; and
- emergency or preventive vaccination.

Table 1. Characteristics of the low-pathogenicity avian influenza (LPAI) epidemics (2000 to 2007) in the Veneto and Lombardy regions and associated costs[1]

Epidemic	Duration of epidemic (mo)	Subtype and pathogenicity	Vaccine and vaccination strategy[2]	Total number of outbreaks	Number (%) of outbreaks by species and production types	Number of outbreaks in vaccinated farms	Number of vaccinated farms	Total costs[3] (€)	Vaccination campaigns[4] (€)
Aug. 2000 to Mar. 2001	7.2	H7N1 LPAI	Monovalent A/ck/PK/95-H7N3 Emergency DIVA	78	73 (93.6%) meat turkeys 3 (3.8%) quails 1 (1.3%) laying hen 1 (1.3%) other species	1	293	13,796,000	8,065,389
Oct. 2002 to Sep. 2003	11.6	H7N3 LPAI	Monovalent A/ck/IT/1999-H7N1 Emergency DIVA	388	337 (86.9%) meat turkeys 3 (0.8%) quails 13 (3.4%) laying hens 12 (3.1%) broiler breeders 23 (5.9%) other species	88	731	63,683,000	36,628,440
Sep. to Dec. 2004	2.8	H7N3 LPAI	Bivalent A/ck/Italy/22A/98-H5N9 A/ck/Italy/1067/99-H7N1 Preventive DIVA	28	27 meat turkeys 1 quail	27	652	10,276,000	
Apr. to May 2005	1.1	H5N2 LPAI	Bivalent A/ck/Italy/22A/98-H5N9 A/ck/Italy/1067/99-H7N1 Preventive DIVA	15	15 meat turkeys	13	431	5,170,000	
May to Oct. 2007	5.2	H7N3 LPAI	Bivalent A/mallard/It/4810-79/04-H7N4 A/ck/It/22A/98-H5N9 Monovalent A/ck/Italy/AG-473/1999-H7N1 A/ck/Italy/1067/99-H7N1 Emergency DIVA	6[5]	6 meat turkeys	0	386	1,169,000	4,014,471

[1]Data source: Veterinary Epidemiology Department of Veneto Region.

[2]DIVA = differentiating infected from vaccinated animals strategy.

[3]Excluding vaccination campaign.

[4]Vaccination campaigns: from November 2000 to May 2002, from December 2002 to March 2004, from October 2004 to December 2006, from October 2007 to April 2008.

[5]A total of 16 outbreaks were detected, but only 6 were in industrial poultry farms, from August 22 to October 2, 2007. The remaining outbreaks occurred in ornamental or rural poultry flocks that reared different poultry or ornamental bird species.

In addition, since 2006, the control measures stipulated in the EU legislation (CEC, 2006a, 2009) have been enforced.

Vaccination for LPAI Control

Vaccination was performed in the DPPA using a heterologous vaccine according to the differentiating infected from vaccinated animals strategy; a suitable discriminatory test was used to monitor any spread of the virus on vaccinated farms. From 2000 to 2007, four vaccination programs were implemented. Only poultry species with a long production cycle were targeted (i.e., meat turkeys, layers, capons, and, in the 2002 to 2004 vaccination, also broiler and turkey breeders). The first emergency vaccination plan was put in place in 2000 to 2002 after the reemergence in the DPPA of the LPAI H7N1 subtype virus after the eradication of the HPAI virus. The second emergency vaccination program was implemented in 2002 to 2004 to control the 2 H7N3 LPAI epidemics that had occurred in domestic poultry in the same DPPA. After the detection of several LPAI virus incursions in this area, which was considered as evidence of the continuous risk of introduction of new AI virus strains in the industrial poultry population, a bivalent (H5 and H7) preventive vaccination program was implemented from October 2004 to December 2006. In 2007 to 2008, a fourth vaccination program was implemented to limit the spread of an H7N3 LPAI virus that had been introduced, first on rural and hobby poultry farms and then on industrial meat-turkey farms (Cecchinato et al., 2009).

RESULTS

The direct and consequential losses for each epidemic are described below. The characteristics of each epidemic and the total costs are described in Table 1.

1999 to 2000 H7N1 HPAI Epidemic

Direct Losses. The direct losses totaled approximately €112 million, and they were predominantly concentrated in the Veneto and Lombardy regions, where the highest number of outbreaks was recorded (Figure 1). The HPAI control measures did not include vaccination. The early detection of the HPAI outbreaks was prevalently dependant on the official identification of either clinical events, in conformity with the standard case definition of HPAI, or the testing of poultry flocks that exhibited clinical symptoms such as increased and progressive mortality, not necessarily indicative of AI. To rapidly detect HPAI outbreaks, active surveillance programs based on the clinical inspection of poultry holdings located in areas at high risk of AI were implemented. Furthermore, veterinarians and farmers were encouraged to submit carcasses or samples for AI testing from clinically affected poultry flocks. Given that HPAI viruses immediately kill poultry, the implementation of serological monitoring systems to detect antibodies is unfeasible and useless. For this reason, the data pertaining to the costs associated with the 1999 to 2000 HPAI epidemic-monitoring activities were not significant and have not been included.

Consequential Losses. The data on consequential losses were provided by the Italian Board of Poultry

Regions	Direct losses values (€)
Friuli Venezia Giulia	1,068,260
Lombardy	55,968,276
Piedmont	271,539
Sardinia	86,319
Sicily	NA
Umbria	NA
Veneto	54,517,045
total	111,911,439

Figure 1. The 1999 to 2000 high-pathogenicity avian influenza epidemic: geographical distribution of avian influenza outbreaks and direct losses. Data source: Veterinary Epidemiology Department of Veneto Region. NA = not available.

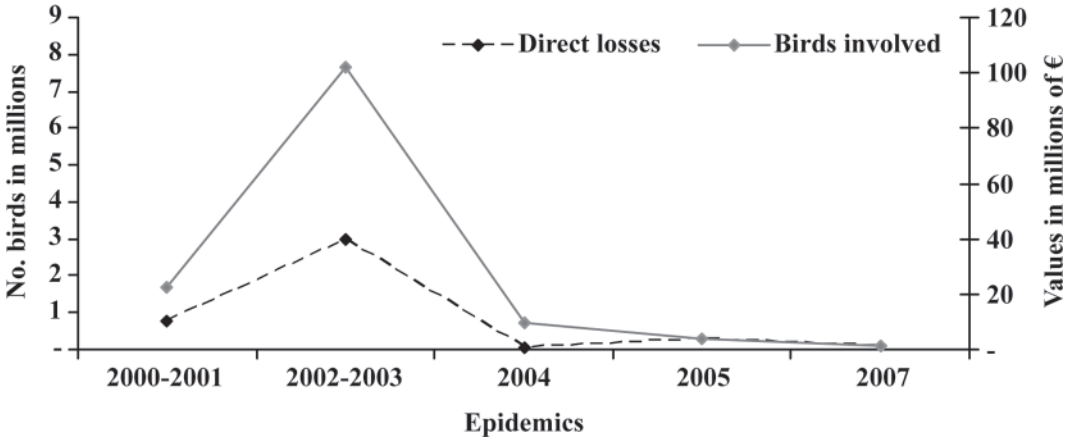

Figure 2. The 2000 to 2007 low-pathogenicity avian influenza epidemics: yearly distribution of direct losses (€) and of the number of birds stamped out or controlled marketed in infected and at-risk premises. Direct losses were excluding the vaccination campaign. Data source: Veterinary Epidemiology Department of Veneto Region.

Producers and are an estimate of losses incurred by the Italian poultry industry. These losses totaled more than €395 million (Table 2). Consequential losses were incurred predominately in the regions of Veneto (65%), where the largest poultry processing plants are located, and Lombardy (34%). The high consequential losses were related to the decrease in the poultry supply, the increase in the production costs due to the death and destruction of birds, and the implementation of intensive biosecurity and control measures.

The greatest costs were for the loss of poultry meat, hatching, and table egg production. This was consequent to the prolonged stoppage period imposed on farms by the veterinary authorities and to the early slaughtering of birds, which was part of the program to depopulate the DPPA.

Nonabsorbable fixed costs related to the production chain (i.e., in slaughterhouses, hatcheries, and meat- and egg-processing plants) were mainly attributable to the stoppage period and the subsequent production restart phase. In addition to nonabsorbable fixed costs, in the period of production stoppage, people employed in the poultry production chain also had to be laid off, and there was a loss of income for farmers.

LPAI Epidemics

Direct Losses. The trend in direct losses and in the number of birds involved in the LPAI outbreaks that occurred between August 2000 and October 2007 is shown in Figure 2. The prevention strategies put in force in the DPPA (Mulatti et al., 2009) contributed to the overall reduction in the number of affected farms (Table 1) and birds and consequentially reduced the direct losses. There was a peak in the number of birds and direct losses in the 2002 to 2003 epidemic, which in comparison to the other epidemic was larger (Table 1). From 2002 to 2003 to 2007, the number of birds involved in the epidemics decreased from 7,660,005 to 73,158 (99%), and the losses due to the eradication of outbreaks decreased from €40,000,000 to €1,168,702 (97%). The cost of slaughtering and destroying the birds was directly proportional to the number of affected birds.

Vaccination Costs. Vaccination costs have been divided into the costs for actual vaccination and those for monitoring. Vaccination costs were calculated based on the cost of a single dose of vaccine in 2007 (i.e., €0.049). Given that the results refer to different years, the cost of vaccination was adjusted according to the national consumer price index for healthcare services and health costs (ISTAT, 2009). The cost of a single dose for each year was multiplied by the number of vaccine doses distributed annually. Added to these were staff costs for vaccine administration, €0.125 per administered dose (L. Busani, ISS, personal communication). The total cost of vaccination, from 2000 to 2008, exceeded €43 million.

Table 2. The 1999 to 2000 high-pathogenicity avian influenza epidemic: contribution of different production factors to consequential losses[1]

Description	Consequential losses, € (%)
Loss of hatching eggs, chicks, and meat	154,937,070 (39)
Unabsorbable fixed costs in farms, incubators, and slaughterhouses	77,468,535 (20)
Unabsorbable fixed costs in production restart phase	56,810,259 (14)
Benefits to laid-off workers	54,227,974 (14)
Loss of income by farmers	51,645,690 (13)

[1]Data source: Italian Board of Poultry Producers.

Monitoring Costs. From 2000 to 2008, approximately 676,000 serological tests were performed in the vaccination area and bordering areas on samples collected on both vaccinated and unvaccinated farms; the latter were located both within and outside of the vaccination area. The total monitoring costs, which were adjusted for the various years using the same criteria adopted for vaccination costs, totaled slightly more than €5 million. The cost of virological tests was also annually adjusted with the same procedure. The total cost of these tests was approximately €379,000. The total cost of vaccination and monitoring programs exceeded €48 million.

Consequential Losses. Generally, consequential losses were not well documented and were thus difficult to assess and quantify. In this study, the loss of profit due to the ban on restocking from 2000 to 2004 and the losses of hatching eggs, chicks, and poultry meat during the different LPAI epidemics were taken into account. Financial data on the ban on restocking were provided by the Agricultural and Food Office of the Veneto and Lombardy regions.

In the Veneto region, to reduce turkey density, 2 different bans on the restocking of a certain number of meat-turkey farms located in the areas with the highest turkey densities were enforced. The first ban involved 137 meat-turkey farms and lasted from October 2003 to April 2004; the second ban involved 45 meat-turkey farms and lasted from May to November 2004. Furthermore, a compulsory ban on the restocking of poultry farms in areas at high risk of AI virus spread was applied during the 2000 to 2001 H7N1 epidemic and the 2002 to 2003 and 2004 H7N3 epidemics, to reduce poultry densities and limit transmission in case of AI virus circulation in the DPPA. Farmers were reimbursed for the loss of income caused by production restocking bans; reimbursement was calculated utilizing the following formula: €0.046 per square meter (this formula takes into account the cost of the maximum number of turkeys raised by square meter) multiplied by each day of stoppage. The amount was obtained by subtracting variable costs associated with the exercise of the activity (such as electricity, disinfection material, and medication) from the global fee, estimated as a percentage of the average market value. The aforementioned estimate was implemented with reference to the gross margin for farmers who autonomously undertook all production phases. The total consequential losses exceeded €3 million in 2000 to 2001, approximately €24 million in 2002 to 2003, €10 million in 2004, and €1 million in 2005.

DISCUSSION

The European strategy on animal health is based on the principle that "prevention is better than cure" and in the Commission's communication to the Council, the European Parliament, the European Economic and Social Committee, and the Board of Regions, it was stated that, "Animal health is a concern for all European citizens. This concern stems from the public health and food safety aspects of animal health but also from the economic costs that animal disease outbreaks can trigger and the animal welfare considerations, including the implications of disease control" (EC, 2007).

Outbreaks of infectious animal diseases have a major financial effect on the community as a whole, and they raise ethical concerns about the mass destruction of animals. Thus, prevention policies, in addition to being based on appropriate measures for preventing and managing disease, should optimize the allocation of economic resources, lessening the financial burden on society and reducing the effect on a public that is no longer willing to uncritically accept large-scale animal slaughter. This necessarily entails that the state adopt a proactive approach. To decrease the number of birds stamped out for AI control and in response to ethical concerns and the growing demand for improved animal welfare, vaccination has been used in various countries throughout the world (Peyre et al., 2009). Vaccination can also be useful as a long-term measure and can be implemented to prevent AI in areas where a high risk of AI virus introduction has been identified.

With regard to the costs of AI control, the present study shows that direct costs related to the LPAI epidemics in 2000 to 2007 are slightly more than one-fourth of the costs of the 1999 to 2000 HPAI outbreak. It should be stressed that the estimate of consequential losses for the LPAI epidemics did not include the 2007 H7N3 LPAI epidemic because this epidemic affected almost exclusively the rural poultry sector, mainly composed of hobby farms with no or limited market activities (Cecchinato et al., 2009). Given that there were much fewer outbreaks in this epidemic and the duration was shorter, the consequential losses would not have significantly affected the total estimated costs for the LPAI epidemics. Moreover, for the LPAI epidemics, the control measures, which included the controlled marketing of infected slaughtered birds in the 2002 to 2003 epidemic (Marangon et al., 2005) and vaccination, allowed the total disruption of the poultry market to be avoided, thus limiting financial losses, unlike that which occurred in the 1999 to 2000 HPAI epidemic. Public spending in this sector has been reduced through the use of adequate control procedures and the availability of a well-structured, recently consolidated legal framework for AI control (CEC, 2006a).

The main limitation of this study concerns the assessment of the costs made using a deterministic method to describe, as faithfully as possible, the direct costs in the various epidemics without considering items for which there was no financial information. Thus, we calculated the value of vaccination and monitoring, whereas other data losses were obtained from reliable sources.

Our study shows that despite the continuous introduction of LPAI viruses of the H5 and H7 subtypes in the DPPA, AI vaccination, together with appropriate disease control measures (Mulatti et al., 2009), may reduce both government spending for interventions and

the financial losses of poultry producers. This consideration is also supported by the evolution of the 1999 LPAI epidemic, for which no appropriate disease-control measures were applied, which allowed the H7N1 HPAI virus to emerge.

Although controlling LPAI infections is a major challenge, particularly in DPPA, our results show that by modulating the application of adequate control measures, it is possible to effectively limit the risk of disease spread and the related costs. Thus, the present study demonstrates that investing in a proactive approach (prevention) is better than having an expenditure resulting from a reactive approach (cure) and for this reason could be a useful source of information for conducting impact assessment of the EU animal health law.

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