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Chinh C. Tran is a PhD candidate at the Department of Natural Resources and Environmental Management, University of Hawaiʻi at Mānoa. He is also a recipient of the East West Center-National Science Foundation doctoral fellowship. He was involved in the project "Coupled Natural-Human Systems and Emerging Infectious Diseases: Anthropogenic environmental change and avian influenza in Vietnam." His research centers on issues of coupled natural-human systems and infectious diseases, the trends of climate change, and land cover/land-use change and their impacts to regional and household economy.

John F. Yanagida is a Professor in the Department of Natural Resources and Environmental Management, University of Hawaiʻi at Mānoa. He received his PhD degree in Agricultural Economics from the University of Illinois, Champaign-Urbana. He has also served as a Visiting Scholar at Jilin University PRC, Visiting Lecturer at the Agricultural University of Tirana, Albania, and Visiting Researcher at the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Bangkok, Thailand. His published research has been in the areas of production economics, resource management, price analysis, applied quantitative methods, and international development.

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Economic analysis of duck production at household farm level in the context of Highly Pathogenic Avian Influenza subtype H5N1 in the Red River Delta, Vietnam.

Chinh C. Tran[1,2*], John F.Yanagida[1]

[1] Department of Natural Resources and Environmental Management, University of Hawai'i at Manoa,
1901 East-West Road, Honolulu, HI 96822, USA; E-Mail: jyanagid@hawaii.edu

[2] East-West Center, 1601 East-West Road, Honolulu, HI 96848, USA;

* Author to whom correspondence should be addressed; E-Mail: cctr222@hawaii.edu

Abstract

Occurrence of the Highly Pathogenic Avian Influenza subtype H5N1 usually results in the complete loss of the producer's entire flock due to high mortality rate and stamping out conducted to contain the virus. This study explores the expected economic impacts of HPAI H5N1 on smallholder duck producers in the Red River Delta of Vietnam. A conceptual model is developed to describe how a producer responds at each week of duck production to maximize profit and evaluate expected profits/losses of the producer in light of HPAI H5N1. The results suggests that in the case of no disease occurrence, the optimal time to sell ducks is at week 10 of the production cycle when ducks reach the age of 8 weeks. Maximum profit gained is US$ 805 for a producer with an average flock size of 794 ducks. However, the producer would suffer serious losses once the disease occurs. The expected investment loss is far higher than the maximum profit received at each production cycle and is estimated to be 3 times higher (US$ 2665.19 expected loss vs. US$ 805 maximum profit).

Keywords: HPAI H5N1, outbreaks, conceptual model, duck producer, revenue function, cost function.

3.1 Background

The first outbreaks of HPAI H5N1 in Vietnam were reported in late 2003, since then, there have been five waves and sporadic outbreaks recorded over the years. The disease was mainly confirmed in unvaccinated ducks (Minh et al. 2009; Gilbert et al. 2008). Edan and Bourgeois (2006) found the presence of the HPAI H5N1 virus was mostly in live ducks and geese which suggested that the free range duck farming system is most vulnerable (at risk) to HPAI H5N1. If several flocks of ducks enter the rice-field at once, this may create favorable conditions for the disease to spread. The free range system is considered to be a typical Asian production method which has the potential of contracting and spreading the HPAI H5N1 virus to other neighboring farms (Alhaji and Odetokun 2011; FAO 2008). Poultry sectors 3 and 4 as classified by FAO (2008) include smallholder or backyard producers which are characterized by the free range production system. While producing 80 percent of the poultry products in Vietnam, these producers are considered to be more susceptible to contracting the HPAI H5N1 infection (Thieme 2007).

Economic losses to Vietnam's poultry sector caused by HPAI H5N1 were serious and estimated to be about 3000 billion VND (US$ 187.15 million)[1] (Peyre et al. 2008; Phan et al. 2010). However, it is not clear how the disease affects duck producers at the farm level. Although the disease has been repeatedly reported over the years across the country, the frequency of occurrence at any given location is low, based on the spatial distribution data provided by the Department of Animal Health of Vietnam. Farmers are often not aware how dangerous the disease is because outbreaks may be occurring in other locations and thus fail to take precautions during the production cycle.

Occurrence of the disease usually results in the complete loss of the producer's entire flock due to high mortality rate and stamping out conducted to contain the virus (OIE 2014). The extent of the economic loss from culling of the flock (stamping out) depends on the time of the disease occurrence during the production cycle. If the disease occurs early during the production cycle, the loss will be lower since investment in production is lower at this point. If the disease occurs at the end of the production cycle when the ducks are nearly ready for sale, the producer will suffer serious economic losses.

If there is no HPAI H5N1 occurrence, then the producer continues production as usual. Profit earned depends on the producer's decisions – continue production, sell in the market or cull flock because of disease – at each period of production. The objective is to maximize profit. In any case, the decision to cull is always not desired since it results in complete loss of production. In most cases, the decision to sell yields profit. However, the farmer should determine when is the optimal time to sell the ducks in order to maximize profit. The situation is made more complicated given the probability of HPAI H5N1 occurrence or detection. It is also unclear what the magnitude of economic impacts from HPAI H5N1occurrence will be on duck producers.

The overall objective of this study is to explore the expected economic impacts of HPAI H5N1 on smallholder duck producers in the Red River Delta of Vietnam. More specifically, the study (i) develops a conceptual model using a dynamic optimization process by constructing the Bellman equation to optimize the producer's decision of maximizing profit; (ii) uses the conceptual model's results to evaluate expected profits/losses of the producer in light of HPAI H5N1 and (iii) conducts sensitivity analysis to determine changes of expected profits/losses under given changes in the model's parameters.

3.2 Analytical methods

3.2.1 Conceptual model

Consider a smallholder producer who raises ducks for meat. Assume that the producer's income is derived solely from the sale of ducks. In other word, the producer focuses all resources for the production of ducks. The producer has a free range duck farming system which is considered at risk of contracting HPAI H5N1. Given this farming system, the disease may occur at any point during the production cycle. To study its economic consequences, a dynamic economic model was developed based on characteristics of production. Following the optimality principle in dynamic programming developed by Richard E. Bellman (1957), the model was expressed as the Bellman equation, which addressed the fundamental problem regarding the need to optimally balance present rewards versus expected future rewards (Miranda and Fackler 2002). The framework for the Bellman equation for duck production is shown in Figure 1.

[1] Exchange rate at 1USD = 16,030 VND as of 12/31/2007 by the State Bank of Vietnam.

The objective function of the Bellman equation is to maximize profit from duck production. The equation involves several components, including state variables, action space, state transition and reward function, to be dynamically observed over time. To develop the dynamic model, several assumption are made: (i) all ducks are either bought, sold or culled simultaneously; (ii) there is no own-consumption of ducks produced on the farm; (iii) production activities and market prices for adult ducks are stable; (iv) no ducks are either sick or have died from other diseases (than possibly HPAI H5N1); all ducks must be culled when the disease occurs; (vi) ducklings are purchased at the first day of age and raised till 12 weeks old at which point the flock starts to experience significant reductions in their rate of growth; (vii) vaccination for HPAI H5N1 is not available; and (viii) the first two week of a production cycle is a cleaning period to remove viruses and contaminated materials within the farm before the new flock of ducklings arrive.

This is an infinite horizon $T = \infty$ with time t measured in weeks. State variables are the week of the production cycle and the detection of HPAI H5N1. The week of the production cycle is denoted by a, ranging from 1 to 14 or $a \in \{1,2,...,14\}$, where $a = \{1, 2\}$ represents the cleaning period, implying that there is no ducks on the farm in this period. Ducklings enter the farm from week 3. The maximum length of a production cycle is 14 weeks at which the maximum age of the duck is 12 weeks old. The detection of HPAI H5N1 is represented by $d \in \{0,1\}$, where $d = 1$ implies that the disease is detected and d = 0 if the disease is not present or undetected. State variables are given as:

$$\begin{cases} a \in \{1,2,...,14\} & \text{Week of production} \\ d \in \{0,1\} & \text{The detection of HPAI H5N1} \end{cases} \quad (1)$$

At the beginning of each week, the producer observes the farm situation and disease status to decide whether to continue to feed, sell, or cull the flock of ducks. These decisions are components of an action space.

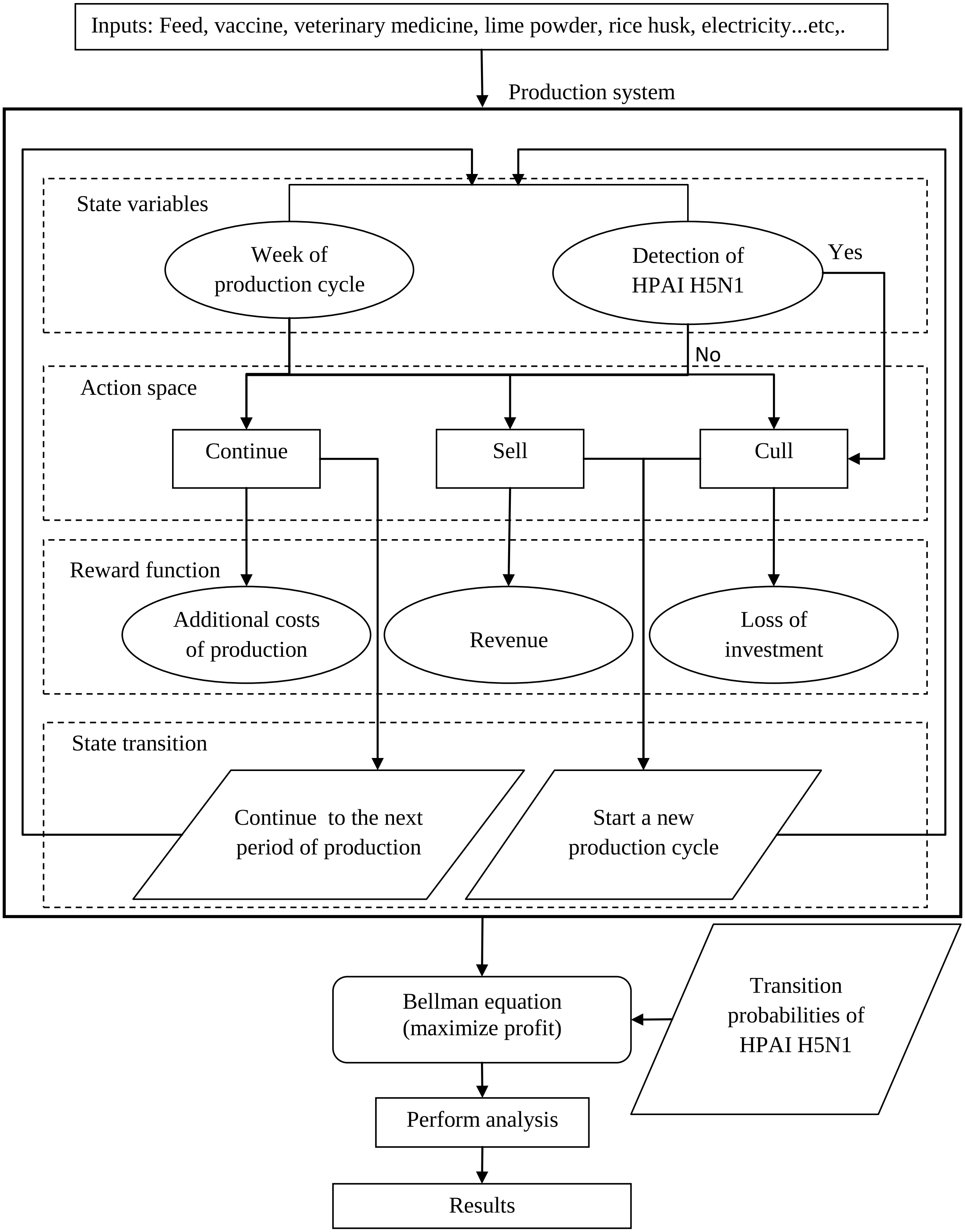

Figure 1: A framework for the conceptual model.

Let x = {continue, sell, cull} denote the producer's action. The *action space* can be introduced by an equation system:

$$x = \begin{cases} \{\text{continue}\} & \text{if } a \le 2 \,\&\, \forall d \\ \{\text{cull}\} & \text{if } 2 < a < 14 \,\&\, d = 1 \\ \{\text{continue, cull, sell}\} & \text{if } 2 < a < 14 \,\&\, d = 0 \\ \{\text{cull, sell}\} & \text{if } a = 14 \,\&\, d = 0 \\ \{\text{cull}\} & \text{if } a = 14 \,\&\, d = 1 \end{cases} \qquad (2)$$

The system equation (2) indicates that a new production cycle starts with 2 week cleaning period before a new flock of duckling arrives. When the length of the production cycle is less than or equal to 2 weeks, the producer has only the option to continue. From weeks 2 to13, two cases are possible: (i) if HPAI H5N1 occurs, which means state d = 1, the producer has to cull all the ducks in the flock, a mandatory requirement to prevent the spread of the disease; (ii) if there is no disease, d= 0, then all options – continue, sell, cull – are available. At the week a = 14, the producer has to sell if there is no disease occurrence, but if the HPAI H5N1 virus is detected within the farm, the producer must cull all ducks immediately. Subsequently, another production cycle begins starting with the cleaning period, after all ducks are sold or culled.

The evolution of state variables over time with respect to the producer's actions is represented via a *state transition*. The change in the week of production cycle is characterized by deterministic systems based on the actions in (3).

$$a_{t+1} = \begin{cases} 1 & \text{if } x_t = \{\text{sell, cull}\} \\ a_t + 1 & \text{if } x_t = \text{continue} \end{cases} \qquad (3)$$

Where a_{t+1} is the week of the production cycle at time t+1. Equation (3) indicates that if the producer elects to sell or cull all ducks at time t, a new production cycle is started, meaning that the week of production is $a_{t+1} = 1$. If the producer chooses to continue to feed ducks, then at the next period, the week of production is $a_{t+1} = a_t + 1$

The probability of HPAI H5N1 contamination is assumed to follow a Markov process and can be represented by transition probabilities:

$$P(d' \mid d, x) = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \qquad (4)$$

where $p_{11} + p_{12} = 1$ and $p_{21} + p_{22} = 1$.

Following each action – continue, sell, or cull – in the action space, the producer receives a reward, represented via a *Reward function*. The producer's objective is to maximize the expected production profits over the infinite time horizon. The per-period reward function is specified below:

$$f(a) = \begin{cases} -C(a) & \text{if } x = \text{continue} \\ R(a) - C(a) - F & \text{if } x = \text{sell} \\ -C(a) - F & \text{if } x = \text{cull} \end{cases} \qquad (5)$$

where $C(a)$ is a cost function of production at week a. The cost of production varies depending on the specific period of production and often includes feed costs, duckling price, veterinary costs, and other costs. The producer's benefit is the net farm income. The term $R(a)$ represents a revenue function at week a. This function characterizes the relationship between the market value of ducks and their weight. The term F represents a fixed cost associated with the cleaning period, such as the cost of lime powder and other sterile powders.

The immediate reward depends on the producer's action. The reward equation above states that if the producer chooses to keep raising ducks, the immediate benefit is the negative costs because of the feed costs, $f(a) = -C(a)$. By selling ducks, the immediate reward is equal to the revenue function minus the cost function, $f(a) = R(a) - C(a) - F$. Culling ducks would result in the sum of the negative cost function $C(a)$ plus a negative fixed cost F, $f(a) = -C(a) - F$.

Bellman equation

From the equation systems (4) and (5), a Bellman equation for the dynamic optimal decision making process is formulated:

$$V(a) = \mathrm{Max} \begin{cases} -C(a) + \delta \sum p(d' = p_{d_j} \mid d) V(a') & \text{if } x = \text{continue} \\ R(a) - C(a) - F + \delta \sum p(d' = p_{d_j} \mid d) V(a') & \text{if } x = \text{sell} \\ -C(a) - F + \delta \sum p(d' = p_{d_j} \mid d) V(a') & \text{if } x = \text{kill} \end{cases} \quad (6)$$

where $V(a)$ is the value function that represents the sum of current and expected future rewards $V(a')$, given the transition probability $p(d' = p_{d_j} \mid d)$ and the discount factor δ. The formulation of the discount factor is given: $\delta = 1/(1+r)^t$ where r is the discount rate and i is the compounded period.

Each decision directly affects future benefits. Intuitively, if the producer chooses to keep ducks, it means that he/she believes that future rewards are greater than rewards from immediate sales. A "sell" action benefits the producer as they earn income from this activity. A “cull” action is always the worst option as it causes serious losses for the producer. Consequently, the occurrence of HPAI H5N1 would cause complete loss of the investment as the producer must exterminate the entire flock. The Bellman equation illustrates an optimal expected profit following an optimal action in the context of HPAI H5N1.

3.2.2 Statistical analysis

The conceptual model consists of several parameters, including (i) discount factor used to translate expected benefits or costs in any given future time period into present value terms; (ii) probabilities of HPAI H5N1; (iii) fixed costs of exterminating infected ducks and cleaning after sale; and (iv) cost and revenue functions of duck production.

The cost and revenue functions are important components of the producer's rewards. They are estimated with a quadratic functional form. This functional form accurately captures the underlying relationships between revenue/cost and their explanatory variables and has been widely used in several studies such as the relationship between revenue and price of the commodity, water used in production of the commodity and composite input factor as shown in the research (Moolman, Blignaut, and Van Eyden 2006; Moore 1999; Huffman 1988; Moore and Dinar 1995). Let C and R respectively represent the cost and revenue functions. The quadratic functional forms are given in the equations 7 and 8:

$$C = \alpha_0 + \alpha_1 * a + \alpha_2 * a^2 + \varepsilon \quad (7)$$

$$R = \beta_1 * a + \beta_2 * a^2 + \gamma \quad (8)$$

where a and a^2 are independent variables representing week of production and its square; and ε and γ are error terms reflecting the determinants of the outcome. In the cost function (equation 7), α_0, α_1 and α_2 are unknown parameters to be estimated, where α_0 is a constant denoting fixed costs and α_1 and α_2 indicate variable costs.

Assuming that the producer only receives revenue from selling ducks. It implies that the producer's revenue R = 0 if there is no duck sale. As a result, the constant is taken out from the revenue function (equation 8). The estimation of the function provides the values of the parameters β_1 and β_2.

In estimating of the econometric model, there may exist problems that lead to unreliable results. Heteroskedasticity which implies that the error terms in the model are no longer independently and identically distributed is one of the problems. Heteroskedasticity results in incorrect test statistics such as t and F tests and confidence intervals. Therefore, it is critical to test for heteroskedasticity problem by performing the Breusch-Pagan and White tests. These tests are commonly used for detecting heteroskedasticity (Verbeek 2008).

If there is no heteroskedasticity problem, then OLS is the best method for the estimation of the cost and revenue functions. If heteroskedasticity exists, a Weighted Least Squares (WLS) method is used to correct for the problem of heteroskedasticity by transforming the error term. In the case of heteroskedasticity, the use of weights implies that observations are expected to have error terms such that higher variances are given a smaller weight in the estimation process. Feasible Generalized Least Squares (FGLS) is a technique that yields BLUE estimators when heteroskedasticity exists by minimizing a weighted sum of squared residuals (Verbeek 2008).

3.2.3 Data

This study focuses on smallholder duck producers in the Red River Delta, Vietnam. A two round survey procedure was designed. The baseline survey in the first round was followed by a follow-up survey in the second round. The baseline survey collected basic information about producer household characteristics and economic activities. The follow-up survey focused on duck production. The sample size is determined based on the formula for estimating a population proportion π by the sample proportion: $\mathrm{n} = \pi(1-\pi)(\frac{\mathrm{z}}{\mathrm{M}})^2$, where n is the sample size that has margin of error M and z-score z. In calculation of the sample size, a 95% confidence level which has z = 1.96 is desired. The population proportion π is set at 0.5 as a safe approach and the desired margin of error is 0.1. Then, the sample size for each system is:

$$\mathrm{n} = \pi(1-\pi)(\frac{\mathrm{z}}{\mathrm{M}})^2 = (0.5)(0.5)(\frac{1.96}{0.1})^2 = 96$$

Prior to the survey, a pilot investigation was conducted with the support of the local office of agricultural extension to understand duck production systems in the area and to contact duck producers for the survey. A total of 98 duck producers in two provinces, Hai Duong and Bac Ninh, were invited to participate in the study. Data were collected on a basis for the entire production cycle, from the beginning of a new production cycle until sale. All production information, including costs of production and growth rate of ducks, were gather on a weekly basis to estimate cost and revenue functions. Data were collected from September 2012 to January 2013. The survey results indicate that the average duck flock size and average duck weight for sale are respectively 794 heads and 2.49kg. Average market price for a kilogram of duck meat was 1.94$US in the period from August 2012 to January 2013. Details on the descriptive statistics of duck production are shown in Table 1.

Table 1: Descriptive statistics of duck production (Data collected from September 2012 to January 2013)

Variable	Mean	Std. Dev.	Min	Max
Flock size per farm (head)	794	495	50	2500
Average market price ($US/kg)	1.94	0.14	1.67	2.15
Average weight per duck sold (kg)	2.49	0.37	2	3.7
Total costs of production per farm ($US)	2870.95	1734.49	294.56	7255.00
Revenue per farm ($US)	3592.79	2345.21	235.86	9883.03
Profit per farm ($US)	721.84	760.29	-2238.13	2629.41

Other parameters used in the conceptual model, including:

(i) A discount rate of 9% per year or 0.173% per week as of December 31, 2012 for Vietnam was obtained from the World Fact Book 2012 by the Central Intelligence Agency (CIA 2013). The weekly discount factor is computed as: $\delta = \frac{1}{1+0.00173} = 0.9982$;

(ii) An average annual probability of 0.0102 for HPAI H5N1 occurrence was estimated by Tran et al. (2013);

(iii) Average fixed costs for exterminating of infected ducks and duck farm cleaning after sale was calculated as US$22.41 from the data collected.

3.3 Results and discussion

3.3.1 Econometric estimations

The Breusch-Pagan and White tests were performed under hypothesis of homoskedasticity against unrestricted heteroskedasticity. The results shown in the Table 2 strongly indicate the existence of heteroskedasticity in both the cost and revenue functions.

Table 2: Breusch-Pagan and White tests for Heteroskedasticity

Functional forms	Breusch-Pagan	White
Quadratic cost function	Chi2 = 142.42 Prob > chi2 = 0.0000	Chi2 = 179.53 Prob > chi2 = 0.0000
Quadratic revenue function	Chi2 = 617.92 Prob > chi2 = 0.0000	Chi2 = 348.95 Prob > chi2 = 0.0000

To correct for heteroskedasticity, Feasible Generalized Least Squares (FGLS) was applied. Table 3 reports the results of the FGLS estimation applied to the quadratic functional forms of the revenue and cost functions.

Table 3: FGLS estimation results

Functions		Coeff.	Std. Err.	p	95% Conf. Interval	
Cost function	Intercept	327.37***	46.66	0.000	235.75	418.98
	a	-45.15**	21.18	0.033	-86.74	-3.57
	a^2	10.67***	2.27	0.000	6.21	15.14
Revenue function	a	110.45**	37.28	0.003	37.16	183.72
	a^2	49.84***	7.23	0.000	35.63	64.05

** significant at the 0.01 level; and *** significant at the 0.001 level, two-tailed test

The terms a and a^2 respectively represent the week of duck production and its square in weeks. The results reveal that all parameters for both the quadratic cost and revenue functions have statistically significant effects on costs and revenues for duck production. The functional forms are summarized in equations below.

$$C = 327.37 - 45.15*a + 10.67*a^2 \quad (8)$$

$$R = 110.45*a + 49.84*a^2 \quad (9)$$

where C denotes the cost function and R is the revenue function. These functions together with the discount factor, probabilities of HPAI H5N1occurrence and fixed costs of cleaning were used in the conceptual model. A dynamic optimization process was then employed to define the producer's optimal decision at each period of production. Results from this process were then used to calculate expected losses under the context of risk from contracting the HPAI H5N1 disease.

3.3.2 Simulation results

The computational analysis using dynamic optimization suggests that the optimal duration for a production cycle is 10 weeks, including the cleaning period in the first 2 weeks and 8 weeks for raising ducks in the case of disease free status. Figure 2 presents the optimal action at each period of the production cycle. The "cull" decision is not applied in any period of production except when the disease occurs since this is a mandatory requirement to eradicate and prevent the spread of the H5N1 virus. In case of no disease occurrence (d=0), it is suggested that the optimal action is to continue production from week 1 to 9 and sell all flocks of ducks in week 10 when they reach the age of 8 weeks.

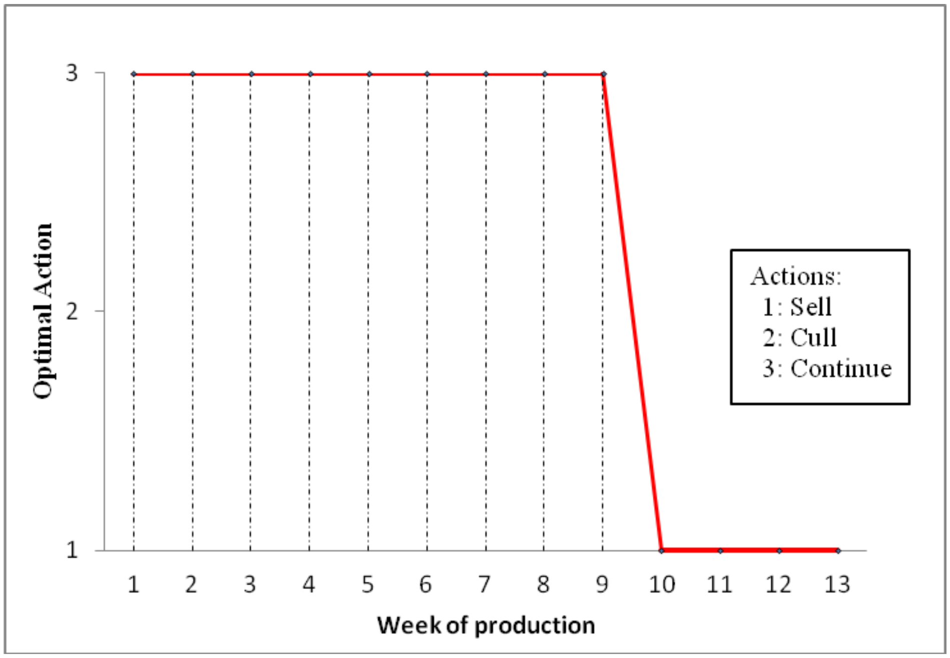

Figure 2: Optimal action at each period of the production cycle

The profit level estimated for a producer with an average of 794 ducks (Table 1) at each week of production is presented in Figure 3. Negative profit is found at the first 3 weeks of production. It is the producer's initial investment. It includes the costs of lime powder and disinfectants to disinfect duck production premises for cleaning period at the first 2 weeks and the purchase of ducklings at week 3. Positive profit is gained beginning from week 4 and continues increasing until it reaches the maximum at the optimal time for sale at week 10. The average producer receives a maximum profit of US$ 805 (Figure 3). Profit gradually decreases if the producer sells ducks late since the growth rate of costs is faster than the growth of revenues and become negative after week 13.

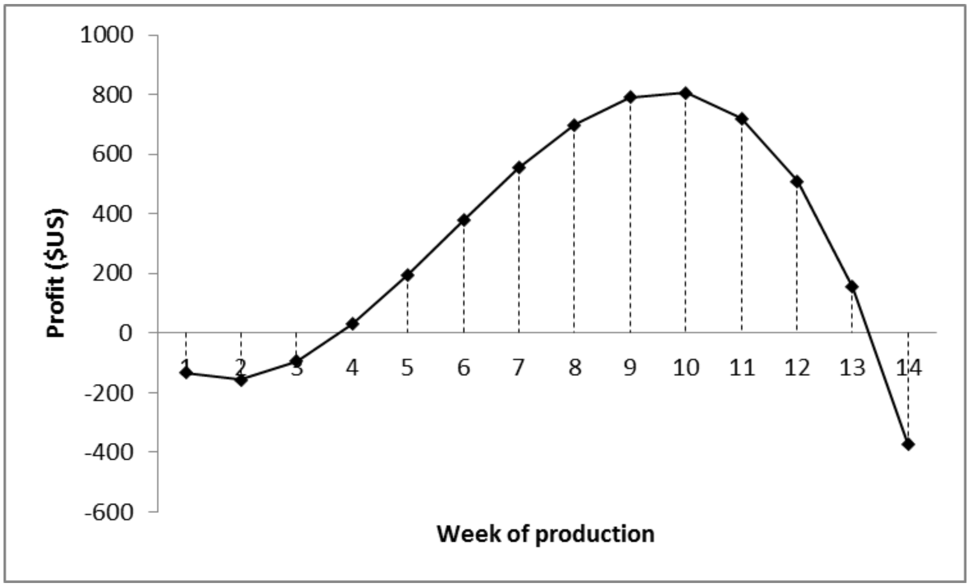

Figure 3: Estimated profit obtained at each week of the production cycle

The producer can earn profit only if there is no HPAI H5N1 occurrence. However, it is possible that the disease may occur at any time during production, given the existence of the HPAI H5N1 virus. Once it happens, the producer suffers complete loss of production since all ducks are culled in order to eradicate the disease. Hence, the loss in this situation is measured by the costs of production. The severity of the loss depends on the time of disease occurrence. If the disease occurs in the early state of production, for example week 3 when ducklings enter the farm, the loss is measured at US$ 874.59 (Table 4). The major loss comes from the purchase of ducklings for this period. At this time, feed cost together with other costs such as electricity and rice husk is only a small part of the total cost.

If the disease occurs in weeks 4 or 5 of production, the losses imposed on the producer are estimated at US$ 1208.08 or US$ 1601.45, respectively. Vaccination against common diseases in ducks is scheduled during this period. The common diseases in ducks are duck virus hepatitis, duck plague or duck virus enteritis, riemerella anatipestifer infection, avian cholera, colibacillosis and aspergillosis. The costs of vaccines and labor for vaccination constitute a major proportion of total cost. During the first 3 weeks of age, ducks are mainly kept in a closed house and fed with industrial feed because they are weak and vulnerable in the outside environment.

Starting from week 6 of production, when ducks reach the age of 4 weeks, they have access to neighboring rice fields rice fields, ditches, rivers or channels during the day. Although the free grazing duck system is still being used, duck producers tend to shift their production to a closed house system with access to limited areas such as ponds or lakes within the farm. Integrating duck-fish production is becoming a common system in Hai Duong and Bac Ninh provinces where the survey was conducted. This system is also found in Ha Tay, Ha Nam, Nam Dinh and Hung Yen provinces (Desvaux et al. 2008). The duck farm is often located in the area near rivers or channels and close to rice fields. This type of farming primarily uses industrial or semi-industrial feed derived principally from unhusked rice and corn. Rice paddy fields contribute only a small portion of duck feed, based on the survey data. Later in the production process, feed cost become the largest cost component. The extent of economic loss from disease occurrence increases substantially later in the production period due to increasing costs such as feed.

Table 4: Expected Loss of production in case of disease occurrence at each period

Week	Loss ($US)	Probability	Expected loss (US$
3	874.59	0.125	109.32
4	1208.08	0.125	151.01
5	1601.45	0.125	200.18
6	2078.04	0.125	259.76
7	2661.19	0.125	332.65
8	3374.24	0.125	421.78
9	4240.53	0.125	530.07
10	5283.40	0.125	660.43
Expected loss per production cycle			2665.19

Table 4 indicates that the estimated loss increases substantially from US$ 2078.04 in week 6 to US$ 2661.19, US$ 3374.4 and US$ 4240.53 in week 7, 8 and 9, respectively, if the disease occurs during these periods. The most serious loss is measured at week 10 of production when ducks are optimally ready for sale in the market to gain maximum profit. The loss is the estimated at US$ 5283.40. This includes all investment costs for the entire production cycle.

Assuming that the producer behaves optimally i.e., using 10 weeks for production, including the first 2 weeks for cleaning the farm, the actual time for a typical flock of ducks to be on the farm is 8 weeks. Therefore, the probability of disease occurrence at any time is 0.125. Let E(x) represent the expected loss of duck producer per cycle. The formulation of the expected loss is given $E(x) = \sum x * P(x)$, where x represents the total loss at any week of the production cycle if the disease occurs during that week and p(x) is the probability of each possible loss value. The expected loss of production is then estimated at $US 2665.19 (Table 4) when the disease occurs.

3.3.3 Sensitivity analysis

Sensitivity analysis is applied to reveal how the estimated profit in case of disease free status and expected loss in case of HPAI H5N1vary given the changes in parameters employed in the dynamic model. Parameters tested are the coefficient values given at the 95% confidence interval of the revenue and cost functions that were estimated using econometric analysis shown in Table 3. The range of the parameters are shown in the Table 5.

Table 5: Parameters of the revenue and the cost functions at the 95% confidence intervals

Parameters	Revenue function	Cost function
a	[37.16, 183.72]	[-86.74, -3.57]
a^2	[35.63, 64.05]	[6.21, 15.14]
Cons		[235.75, 418.98]

Different combinations of parameters were generated and estimated using the same computational procedure as applied in the previous analysis.

Table 6: Results of the comparative static analysis (units = $US)

Variable	Mean	Std. Dev.	Min	Max	95% Conf. Interval	
Estimated profit in case of disease free status	1358.68	808.51	360.32	2658.92	780.31	1937.05
Expected loss in case of HPAI H5N1	2269.52	1250.48	754.33	4000.9	1374.98	3164.06

Table 6 above represents the results of the comparative static analysis. The table shows that the producer expects to gain with 95% confidence between US$ 780.31 to US$ 1937.05 per production cycle in the case of being HPAI H5N1 disease free. In the case of disease occurrence, however, the producer suffers expected losses ranging US$ 1374.98 to US$ 3164.06 per production cycle.

3.4 Conclusion

This study develops a conceptual model using a dynamic optimization process to optimize the producer's decision at each period of the production cycle such that profits from production are maximized. The results are then used to evaluate the producer’s expected loss under the likelihood of contracting the HPAI H5N1 virus. The model results indicate that in the case of no disease occurrence, the optimal time to sell ducks is at week 10 of the production cycle when ducks reach the age of 8 weeks. Maximum profit gained is US$ 805 for a producer with an average flock size of 794 ducks. If the disease occurs at any time during the production cycle, the result is a complete loss since all ducks are culled in order to eradicate the disease. The expected loss is estimated at US$ 2665.19. Sensitivity analysis further discovers substantial variability in expected profit under the disease free status and expected loss under disease occurrence. Given variability in the parameters of the revenue and cost functions, the results show that with 95% confidence, the producer's profit ranges from US$ 780.31 to US$ 1937.05 if disease free, but suffers expected losses ranging from US$ 1374.98 to US$ 3164.06 if HPAI H5N1 occurs.

This study emphasizes the economic impact of HPAI H5N1 on a single producer at the farm level. The result suggests that a duck producer would suffer serious losses once the disease occurs. The expected investment loss is far higher than the maximum profit received at each production cycle and is estimated to be 3 times higher (US$ 2665.19 expected loss vs. US$ 805 maximum profit). If the disease is found in the flock and eradication is necessary, the economic loss can be devastating to the average duck producer. This shock can have long term consequences. Studies by Barnett et al. (2008); Carter & Barrett (2006); Carter et al. (2004) and Dercon (1996, 2005) have found that production may face severe difficulties to recover without financial assistance.

At the national level, each HPAI H5N1 event can cause devastating economic losses as well as public health consequences. It not only impacts duck producers in the infected areas and human health in these areas but neighboring areas are also placed at risk. Dramatic decreases in duck meat demand and declines in market prices affect the entire production sector. The disease indirectly impacts other economic sectors of the country such as tourism. Therefore, it is crucial for the government and policy makers to develop new disease prevention programs that are more successful in containing and preventing the HPAI H5N1 from recurrence.

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