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# **Avian Influenza Threat and its Potential Impact on Demand for Chicken and Eggs**

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**Selected Paper prepared for presentation at the Agricultural & Applied  
Economics Association 2009 AAEA & ACCI Joint Annual Meeting, Milwaukee,  
Wisconsin, July 26-29, 2009**

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# **Avian Influenza Threat and its Potential Impact on Demand for Chicken and Eggs<sup>\*</sup>**

## **Abstract**

A highly pathogenic H5N1 strain of avian influenza (AI) has been confirmed in 420 human cases and has caused 257 deaths in the world starting from 2003. Using face-to-face interviews, our data were collected by utilizing a stratified sampling scheme following the distribution of gender and age in three major metropolitan areas in Taiwan, including Taipei, Taichung, and Kaohsiung. The questionnaire was designed to retrieve information including AI knowledge, risk perceptions, and behavioral changes of two types of consumers, primary shoppers and general consumers. In total, 501 primary shoppers and 505 general consumers completed the survey in June 2007 and were recorded for analysis. The empirical results show several interesting findings, especially, that risk perception and some socio-economic characteristics such as age are the key factor which determines changes in purchasing behavior.

**Keywords:** avian influenza, knowledge, risk perception, Tobit model, Taiwan

**JEL classification:** M30

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<sup>\*</sup> We thank the Council of Agriculture in Taiwan for their financial support: Grant 96AS-14.6.2-BQ-B2.

# **Avian Influenza Threat and its Potential Impact on Demand for Chicken and Eggs**

## **1. Introduction**

A highly pathogenic H5N1 strain of avian influenza (AI) has been confirmed in 420 human cases worldwide and has caused 257 deaths dating back to 2003 (World Health Organization, 2009). Most of the cases occurred in Asian countries, such as China, Vietnam, Thailand, and Indonesia, but Taiwan has not been contaminated and continues in its efforts to prevent AI from occurring. Researchers still do not fully understand the impact of potential outbreaks of avian influenza on consumers' consumption behavior, especially the demand for chicken and eggs. This paper attempts to close this gap by providing a thorough economic analysis.

In the recent studies, most of the relevant literature pertained to knowledge levels and risk perceptions of avian influenza and their linkage to prevention strategies for AI, for example, Fielding et al. (2005); Olsen et al. (2005); Abbate et al. (2006); Beyhan and Aygoren (2006); Gupta et al. (2006); Southwell et al. (2006); Leggat et al. (2007); Gstraunthaler and Day (2008). Some researches focused on the preparedness of pandemic influenza, such as Coker and Mounier-Jack (2006); Mounier-Jack and Coker (2006). It is obvious that analyses of the economic impact were extremely limited.

Bloom et al. (2005) constructed two economic scenarios to estimate potential economic impacts of AI on nine Asian countries, including China, Hong Kong, Singapore, Thailand, and India. Using the Oxford Economic Forecasting global model, they predicted that the economic losses were 2.3% of the 2006 GDP from the demand shock and 0.3% from the supply shock in the first scenario (two quarters of strong demand contraction only in Asia). As predicted from the second scenario (four quarters of strong demand contraction globally), the reduction is worse than that

estimated from scenario one. They also predicted that, in the long run, a 3.6% drop-off in the GDP growth would happen in Asia should an AI pandemic occur.

Turkey was infected by AI in October 2005 with the first human case in January 2006. Goktolga and Gunduz (2006) utilized a multiple bounded Probit model to detect important socio-demographic factors which affected the decreases in chicken consumption in Turkey. Using the consumer survey data of 253 households in the Tokat province of Turkey, in May 2006, their results showed that age, household size, income, monthly chicken consumption and risk variables were important factors affecting the decrease in consumption of chicken meat after the AI outbreak. More specifically, a drop in chicken consumption would increase after an AI outbreak while the risk perception level of consumers would also increase; however, a drop in chicken consumption would decrease as the age of consumers increased.

Since Japan has been attacked by both Bovine Spongiform Encephalopathy (BSE) and AI, Ishida et al. (2006) used an Almost Ideal Demand System to examine the impact of both BSE and AI on consumers' meat demand. With incorporation of a gradual switching model of structure changes, the empirical results using monthly data from January 2000 to December 2004 showed that the BSE had a more serious impact on the demand for meats in Japan than the AI. In addition, consumers' skepticism toward food safety during a BSE or AI outbreak is only temporary; the impact lengths were estimated to be sixteen months for the BSE and only eight months for the AI, respectively. More importantly, government responses to the diseases would have strongly affected consumers' behavior towards the diseases. Therefore, it is effective for government to provide suitable strategies to handle the diseases.

Hsu et al. (2008) investigated consumers' risk perceptions and knowledge levels of avian influenza and how these factors affected chicken consumption changes in

Taiwan. Employing a survey of primary household food shoppers, they utilized multivariate analysis techniques to analyze data. By cluster analysis, respondents were divided into four groups by knowledge and risk perception levels. The behavioral changes were revealed to be different from various knowledge-risk clusters, and the reduction of chicken under the threat of avian influenza was estimated, ranging from 3.76 kilograms per month to 11.22 kilograms. Even though Hsu et al. (2008) showed that the influence of risk perceptions and knowledge levels on chicken consumption is compound by clusters, they fail to identify other factors which might have important impact on the behavioral changes in poultry meat.

From the review of related literature, researches from the consumers' prospective were limited and were mostly conducted after outbreaks occurred, which were not fully effective in helping government administrators and industry managers ease potential damages to both industry and consumers if outbreaks actually occurred. This paper will help close the gaps in the literature by providing empirical contributions to the understanding of consumer reaction to potential outbreaks of AI and the factors causing changes in consumer behavior and thus provide risk reduction strategies. The main purpose of this study is threefold. First, we compare the differences of AI knowledge and risk perceptions between two types of consumers—primary household food shoppers (primary shoppers in short) and general consumers. Second, we investigate any potential behavioral changes if AI outbreaks occur. Last, we estimate a censored regression model to depict important factors among AI knowledge, risk perceptions and socio-economic factors, which may play a crucial role in determining consumers' behavioral changes if an outbreak of avian influenza occurs in Taiwan.

The remainder of the paper is organized as follows. In the second section, a censored regression model is introduced along with the derivatives of marginal effects

from the corresponding model. Section 3 describes the data and section 4 presents the empirical results. A conclusion is provided in the last section.

## **2. Censored regression model**

Since Taiwan is still free from the AI outbreak, the most important question posed in this study is what behavioral changes would be made if a potential AI outbreak should occur in Taiwan. Consumers' responses to this hypothetical question were collected using a face-to-face interview; afterwards, a censored regression model was constructed for data analyses. In our design of the questionnaire, a respondent would answer a question about his/her behavioral changes by choosing one of three situations: (1) he/she would remain unchanged; (2) he/she would not eat chicken (or eggs) at all; or (3) he/she would reduce a certain proportion of his/her regular amount and by how much. Under this situation, consumers' responses are recorded between zero and one: zero indicates that this consumer would choose to stop eating chicken (or eggs) and one means this respondent would keep the same consumption level of chicken (or eggs) even though an AI outbreak has occurred. As to those who would reduce their consumption of chicken (or eggs), the proportion of his/her original consumption levels are recorded and thus the response variable would only vary within a limited range, stimulating a censored regression model (Tobit model) for analyses.

A conventional Tobit model (Tobin, 1958) is adopted to analyze our hypothetical consumption changes of chicken (or eggs) as though outbreaks of avian influenza happened in Taiwan. Originally, the Tobit model was formulated with one threshold of zero. In this study, we modify the Tobit model with incorporation of both upper and lower bounds. Suppose demand for chicken (or eggs), proportional to the current consumption level, can be expressed in terms of a latent variable:

$$y_i^* = x_i\beta + u_i, \text{ where } u_i | x_i \sim N(0, \sigma_u^2) \quad (1)$$

where  $y_i^*$  means the latent demand for chicken (or eggs) of consumer  $i$ ,  $x_i$  represents the explanatory variables of consumer  $i$ , and its error term  $u_i$  has an conditional normal distribution given  $x_i$  with zero mean and variance  $\sigma_u^2$ ;  $\beta$  is the marginal impact of  $x_i$  on the expectation of  $y_i^*$ . The observed dependent variable ( $y_i$ ) can be expressed as:

$$y_i = \begin{cases} 1 & \text{if } y_i^* \geq 1 \\ y_i^* & \text{if } 0 < y_i^* < 1 \\ 0 & \text{if } y_i^* \leq 0 \end{cases} \quad (2)$$

where  $y_i$  contains zeros for no demand for chicken (or eggs), ones for keeping the same demand for chicken (or eggs), or  $y_i^*$ , a proportion of the original demand for chicken (or eggs) when an AI outbreak should occur.

The parameters can be estimated by maximizing the log likelihood function:

$$\begin{aligned} \ell(\beta, \sigma_u^2) = \sum_{i=1}^n \{ & I(y_i = 1) \cdot \ln[1 - \Phi((1 - x_i\beta) / \sigma_u)] + I(y_i = 0) \cdot \ln[\Phi(-x_i\beta / \sigma_u)] \\ & + I(0 < y_i < 1) \cdot \ln[\phi((y_i - x_i\beta) / \sigma_u) / \sigma_u] \} \end{aligned} \quad (3)$$

where  $I(\cdot)$  is an indicator function, i.e.,  $I(\cdot) = 1$  if its argument is true and zero otherwise;  $\phi(\cdot)$  and  $\Phi(\cdot)$  are the probability density function (PDF) and the cumulative distribution function (CDF) of a standard normal distribution, respectively. The maximum likelihood estimation (MLE) is utilized to obtain the parameter estimates.

The interpretation of the censored regression model is not straightforward. The model combines the regression model for  $E(y_i | 0 < y_i < 1, x_i)$  and probabilities of both  $y_i = 0$  (not eat at all) and  $y_i = 1$  (remain unchanged); therefore, a change in explanatory variables has two effects: one is an effect on the probability of  $y_i$  being



observed; the other is an effect on the mean of  $y_i$ , given that it is observed.

According to McDonald and Moffitt (1980) and Wooldridge (2002, 2006), marginal effects of the associated regressor  $j$  for consumer  $i$ ,  $x_{ij}$  on both probabilities and expectations can be derived and expressed as:

$$\partial P[y_i = 0 | x_i] / \partial x_{ij} = \partial \Phi[-x_i \beta / \sigma_u] / \partial x_{ij} = -(\beta_j / \sigma_u) \cdot \phi[x_i \beta / \sigma_u] \quad (4)$$

$$\partial P[y_i = 1 | x_i] / \partial x_{ij} = \partial \{1 - \Phi[(1 - x_i \beta) / \sigma_u]\} / \partial x_{ij} = (\beta_j / \sigma_u) \cdot \phi[(1 - x_i \beta) / \sigma_u] \quad (5)$$

$$\partial P[y_i = y_i^* | x_i] / \partial x_{ij} = (\beta_j / \sigma_u) \cdot \{\phi[x_i \beta / \sigma_u] - \phi[(1 - x_i \beta) / \sigma_u]\} \quad (6)$$

$$\begin{aligned} \partial E[y_i | 0 < y_i < 1, x_i] / \partial x_{ij} = & \beta_j \cdot \left\{ 1 - \left[ \frac{\phi[x_i \beta / \sigma_u] - \phi[(1 - x_i \beta) / \sigma_u]}{\Phi[(1 - x_i \beta) / \sigma_u] - \Phi[-x_i \beta / \sigma_u]} \right]^2 \right. \\ & \left. + \frac{[-x_i \beta / \sigma_u] \cdot \phi[x_i \beta / \sigma_u] - [(1 - x_i \beta) / \sigma_u] \cdot \phi[(1 - x_i \beta) / \sigma_u]}{\Phi[(1 - x_i \beta) / \sigma_u] - \Phi[-x_i \beta / \sigma_u]} \right\} \quad (7) \end{aligned}$$

$$\partial E[y_i | x_i] / \partial x_{ij} = \beta_j \cdot \{\Phi[(1 - x_i \beta) / \sigma_u] - \Phi[-x_i \beta / \sigma_u]\} \quad (8)$$

Marginal effects of changes of  $x_{ij}$  on probabilities can be depicted by equations (4)

to (6). Equations (4) and (5) present the impact of changes in  $x_{ij}$  on the

probabilities of no consumption of chicken (or eggs) and remaining at the same level of chicken (or egg) consumption, respectively. It is obvious that the sign revealed from equation (4) is opposite to the sign of  $\beta_j$  but that from equation (5) is

consistent to the sign of  $\beta_j$ . That is to say, the sign of the estimated parameters are coincident to the sign of the marginal effects on the probability of keeping the same consumption level but contrast to the marginal effects on the probability of stop eating chicken (or eggs). However, in equation (6), the impact of  $x_{ij}$  on the probability of reducing consumption levels depends on the difference between the two PDFs.

Equation (7) shows that the conditional effects of the changing  $x_{ij}$  to the marginal

changes of reducing consumption levels; nevertheless, the impact seems quite complicated. As to the marginal effect of the changes in  $x_{ij}$  on all respondents, equation (8) shows that the marginal effect of the  $x_{ij}$  on the unconditional expectation depends on two parts: one is  $\beta_j$ ; the other is the difference of two CDFs. Due to the fact that  $0 \leq \Phi[-x_i\beta / \sigma_u] \leq \Phi[(1-x_i\beta) / \sigma_u] \leq 1$ , marginal effects in equation (8) would be always less than  $\beta_j$ . We will estimate these marginal effects and discuss them later.

### 3. Data

A consumer survey, using face-to-face interviews, was administrated in metropolitan areas in Taipei, Taichung, and Kaohsiung, Taiwan, in early September 2007. Responses were drawn by using a stratified sampling scheme to represent the population distribution of gender and age classes at the end of June 2007. Two groups of respondents are included in this study, i.e., primary household food shoppers (primary shoppers in short hereafter) and general consumers. According to Hsu and Liu (2000) and Hsu and Lin (2006), the sampling scheme of primary shoppers was adjusted to reveal the fact that primary household food shoppers in Taiwan are mainly females (approximately 80%). On the basis of findings in the literature and discussions with professionals and practitioners, each questionnaire consisted of three parts. In the first section, knowledge and risk perception of, and preparedness for the avian influenza were included; food safety, food labeling, and changes in consumers' buying behavior if a potential AI outbreak should occur were asked in the second part; and the final section was composed of demographic and socio-economic information of the respondent.

Personal interviews were conducted at various places, such as parks, train

stations, university campuses, hospitals, traditional markets and supermarkets, in three metropolitan areas to ensure the diversity of respondents. Primary shoppers were identified as those who were mainly in charge of buying food for the family, had purchased fresh poultry products and had heard of avian influenza; whereas general consumers were those who had heard of AI but were not primary shoppers. A present, worth about 30 NTD, was provided to each participant. The survey took approximately 25 minutes to answer all the questions in the questionnaire. In addition, a trained surveyor would assist the respondent by explaining the questions but would not interfere by providing personal judgments, especially about the section of knowledge and risk perception. In total, there were 501 valid samples out of 525 surveyed respondents of primary shoppers and 505 out of 535 of general consumers.

Demographic and socio-economic characteristics of respondents are listed in Table 1. As to primary shoppers, since gender is under control to reflect the population, our sample shows that about 80% of the respondents were females. In addition, approximately 75% of the respondents were married, and almost one third were housewives. On the other hand, gender was almost evenly distributed in the group of general consumers; less than 60% were married and only 12.4% were housewives. The mean age of respondents for both groups was close to 39 years old, with an average of 3.8 persons living in one household. As to education level of the participants, more than half of the respondents had a college education in both groups. This phenomenon shows that relative large portions of the population in these three metropolitan areas possess a relatively high education level in general and those with higher educational levels were the ones who were willing to participate in the consumer survey. Nevertheless, the distribution of occupations in both groups is similar, except primary shoppers were more likely to be housewives whereas more students were interviewed as general consumers. The average monthly household

income was 64,990 NTD (about 1,970 USD) for primary shoppers and 77,108 NTD (about 2,335 USD) for general consumers.

[Insert Table 1 about here.]

#### **4. Empirical Results**

Our empirical results are discussed as follows. First, we make a comparison of knowledge levels and risk perceptions between the primary shoppers and general consumers. Next, we compare the changes in purchasing behavior for chicken and eggs by both high and low knowledge levels and risk perceptions, respectively. Then, parameter estimation from the censored regression model is presented followed by a discussion of their marginal effects. Finally, implications from the Tobit model are discussed.

##### **Comparison of knowledge levels and risk perceptions**

Table 2 presents the percentage of correct answers about AI knowledge for both primary shoppers and general consumers, respectively. Similar to the Eurobarometer study (2006), both groups of consumers in Taiwan answered the statement ‘if a chicken is contaminated by avian influenza on a farm, all the poultry on that farm must be destroyed immediately’ with the highest percentage of correct answers, with the accuracy rate of 92.22% and 91.02% for primary shoppers and general consumers, respectively. However, the most incorrect responses were from both groups when answering the question ‘it is not dangerous to eat the meat of a chicken vaccinated against avian influenza,’ with only 36.13% and 37.62% of accuracy rate for primary shoppers and general consumers, respectively. Among these seven statements, the accuracy rates for both groups were not statistically different except for two questions related to transmission of the H5N1 virus between humans and elimination of the virus via thorough cooking. Our survey results reveal that the correctness of answers of the primary shoppers is statistically lower than that of the general consumers.

[Insert Table 2 about here.]

Table 3 shows six scores for each the AI risk perception question asked in the questionnaire.<sup>1</sup> The average scores of both primary shoppers and general consumers are calculated separately and compared using a *t*-statistic. The results show that basically primary shoppers are more conservative than general consumers since most scores are higher for primary shoppers, especially about four risk items, i.e., risk of AI infection from traveling to areas with AI outbreaks, risk of AI infection from purchasing wild or smuggled live birds, risk of AI infection from eating not thoroughly cooked poultry meat, and risk of AI infection from eating not thoroughly cooked eggs.

[Insert Table 3 about here.]

### **Comparison of buying behavior changes**

From the comparisons of knowledge and risk perception levels, it is obvious that general consumers seem to have a higher understanding of AI knowledge; whereas primary shoppers are more risk-perceptive. How would consumers' behavior change accordingly? We simply use a cross-table to make a brief comparison by using a chi-square test. Under potential AI outbreaks, the behavior changes between primary shoppers and general consumers are different. Table 4 presents the proportion of buying behavior of both chicken and eggs. In the upper panel, 43% of primary shoppers would not eat chicken at all but only 28.23% of general consumers would not eat chicken at all. The chi-square test statistics also show the same results that the behavior changes between primary shoppers and general consumers are statistically different. As to eggs, results of the lower panel show that more primary

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<sup>1</sup> Following Hsu et al. (2008), risk perception is measured by two sets of four-point Likert scales, including the possibility of happening and severity if AI happened. Each set of the Likert scale is measured from one to four, and then the score for each risk statement is measured by a multiplication of the two scales, ranging from 1 to 16. The variable *Risk-perception* is measured by a sum of the scores from six risk statements, and therefore, it varies between 6 and 96.

shoppers would still not eat eggs at all than general consumers with the chi-square test statistic indicating a significant difference.

[Insert Table 4 about here.]

Additionally, we attempt to examine any differences of behavioral changes by knowledge levels and risk perceptions. Data were classified by high and low levels of knowledge and risk perceptions.<sup>2</sup> The results are presented in Tables 5-6. In Table 5, comparisons among the two types of consumers by knowledge levels show that there exist differences between observations of low and high knowledge levels. The results show that there seems to be no difference among people with low and high knowledge levels except for primary shoppers of chicken. However, Table 6 reveals that consumers' purchasing behaviors are statistically different between low and high risk perceptions. No matter what products are chosen (either chicken or eggs) and among primary shoppers and general consumers, risk perception seems to play a critical role in behavior changes. Later, the Tobit model is used to evaluate again the impacts of knowledge and risk perceptions on changing purchasing behavior.

[Insert Tables 5–6 about here.]

### **Estimates of Tobit model**

Excluding those who do not consume chicken (or eggs) regularly, observations of the two types (primary shoppers and general consumers) are pooled to increase the credibility of the analysis. Several factors, such as knowledge levels about AI, risk perception scores, and socio-economic characteristics, were included in the censored regression models of chicken and eggs, respectively. In this study, our model specification for equations of chicken and eggs is constructed as:

$$x_i\beta = \beta_0 + \beta_1 \cdot \text{Risk - perception} + \beta_2 \cdot \text{Knowledge} + \beta_3 \cdot \text{Male} + \beta_4 \cdot \text{Married}$$

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<sup>2</sup> According to the medians of the knowledge levels of the two separate groups, primary shoppers and general consumers, data were classified into high and low groups.

$$\begin{aligned}
& + \beta_5 \cdot Age + \beta_6 \cdot Senior + \beta_7 \cdot College + \beta_8 \cdot Graduate + \beta_9 \cdot Public \\
& + \beta_{10} \cdot Business + \beta_{11} \cdot Housewife + \beta_{12} \cdot Income + \beta_{13} \cdot HS + \beta_{14} \cdot Shopper \quad (9)
\end{aligned}$$

Definition of the explanatory variables and their expected signs are presented in Table 7. As indicated earlier, consumers who are more risk perceptive would stop eating chicken (or eggs) or reduce consumption levels; therefore, the variable *Risk perception* would expect to negatively affect the demand for chicken (or eggs), should AI outbreaks occur in Taiwan. In contrast, people with more correct knowledge about AI would understand how to correctly treat chicken (or eggs) and thus would not choose to reduce or stop eating them; hence, the expected sign is positive. In addition, female, elderly, and married consumers would expect to behave conservatively; therefore, the dummy variable of male respondents would positively impact the demand for chicken or eggs but the dummy variable of married people and the continuous variable *Age* would negatively influence the demand for chicken (or eggs). Since chicken and eggs are normal goods, income presume to be positively affect the demand for chicken and eggs. As to the dummy variable of primary household food shoppers, since they play a crucial role of taking care of the nutritional needs of all family members, it is expected that they would be more conservative and thus the expected sign should be negative. As to dummy variables for education levels and vocations of the respondents, we use the education level less than or equal to junior high school as a reference group; as to occupation, only three dummy variables are used and thus those occupations not in public or business sectors nor housewives are treated as a reference group. Their impacts on demand for chicken and eggs are uncertain.

[Insert Table 7 about here.]

The parameters are estimated by using the MLE; the estimates of the Tobit models for chicken and eggs are revealed in Table 8. There were only 968

observations for chicken included in the estimation (and 967 observations for eggs). If Taiwan happened to have AI outbreaks, among 968 respondents, 344 of them would choose “not eat chicken at all,” i.e.,  $y_i = 0$ ; whereas 225 observations would remain unchanged of their chicken consumption ( $y_i = 1$ ). In addition, as to changes in egg consumption, only 205 out of 967 consumers would choose not eat eggs if AI outbreaks occurred in Taiwan; 341 respondents would remain the same. As to the goodness of fit of the models, the pseudo R-squared statistics of chicken and eggs are 0.0659 and 0.0537, respectively; it is reasonably low when cross-sectional data are used. The likelihood ratio (LR) test statistics are 135.21 for chicken equation and 107.89 for egg equation, respectively, indicating that model specifications are statistically significant.

[Insert Table 8 about here.]

Coefficient estimates, including their standard error, are reported in Table 8. In addition, parameter estimates of the standard deviation  $\sigma_u$  of the normal distribution for chicken and eggs (in equation 1) are expressed under the variable *Scale*. Most of the coefficients have the expected signs and some of the explanatory variables are statistically significant. Parameter estimates for chicken and egg equations are almost of the same signs except the dummy variable of respondents with a diploma of senior high school; however, both coefficients are insignificant. Among all explanatory variables, risk perception and age are the important factors because both are statistically significant in each equation. As expected, they are negative. The estimated coefficients represent the marginal effect of changing the explanatory variable to the expected value of the latent variable  $y_i^*$  ( $\partial E(y_i^* | 0 < y_i^* < 1, x_i) / \partial x_j$ ). However, the latent variable is not observable; the meaning of this marginal effect should not be overstated. Meaningful impact can be calculated by using the



equations (4)–(8) as indicated in the previous section.

Risk perception has a negative impact on the demand for chicken and eggs, as expected, indicating that consumers are more risk-averse. As to knowledge, a positive sign of the coefficient estimates indicates that the more correct AI knowledge possessed by a consumer, the higher the percentage of demand for chicken and eggs should an AI outbreak occur; however, this effect is statistically significant in the egg equation but not in the chicken equation. Another important factor is age, which also has a negative influence on demand for chicken and eggs, meaning that the older the consumers, the less the demand for chicken and eggs. Male respondents are usually more tolerant to severe events like AI outbreaks; hence, the coefficients are positive and statistically significant in the chicken equation. In addition, parameter estimates of married respondents, housewives, and primary food shoppers are all statistically negative, revealing that these characteristics would reduce chicken demand should AI outbreaks occur. As to eggs, the impacts of the former factors are insignificant. Some of the dummy variables of education or vocation such as *College* and *Public* are statistically significant but not all of them; hence, we do an F-test to examine whether education and vocational dummies are important factors in the Tobit model. The F-test statistics of education and vocation for chicken equation are 1.42 and 1.21, respectively, and 1.83 and 1.62 for egg equation; all of them are not statistically significant.

### **Marginal effects for chicken and eggs**

Marginal effects can not be adequately explained from the estimated coefficients of the Tobit models as explained earlier. The effects of changes in explanatory variables on probabilities of the three situations and the expected values of the demands for chicken and eggs can be calculated according to equations (4)–(8). The estimated marginal effects for chicken and eggs are presented in Tables 9 and 10,

respectively. Standard errors of the estimated marginal effects are calculated at the mean values of the explanatory variables by using the delta method; they are excluded in order to save space; however, we use conventional p-values to indicate their statistical evaluation.

[Insert Tables 9–10 about here.]

The Tobit model can provide us two marginal effects of the impact of explanatory variables: probabilities and expected values. Table 9 presents the marginal effects for chicken. Risk perception, gender, marriage status, age, education, housewife, and primary shoppers have a significant effect on probabilities and the expected values of demand for chicken. To be more specific, if AI outbreaks occur in Taiwan, married consumers would increase about 10.9% in probability not to eat chicken at all over not-married consumers; college-graduated and above consumers are more likely not to eat chicken at all than consumers possessing a lower education level. A male consumer would have a 5.5% probability more than a female to maintain the same consumption patterns; a primary household food shopper would have 7% more in probability not to eat chicken than general consumers.

As to the impact on the changes of demand for chicken, the conditional expectations are relatively small, ranging from –3% to 2% of its original consumption. However, the impact of the selected explanatory variables on the unconditional expectations of demand for chicken reveals several interesting findings. First, among all those significant factors, married consumers would reduce, on average, 11.5% of their current consumption level than non-married consumers; consumers with college degrees would decrease 10.3% compared with consumers with education levels of junior high school or lower. In addition, food shoppers would buy, on average, 7% less than general consumers of their current chicken consumption. Housewife and female consumers would reduce about 6.8% of their current

consumption level than consumers of other occupations and male consumers.

Finally, every increase in the risk perception score would reduce the demand for chicken, on average, 0.3%; but as the knowledge level increases, the demand for chicken increases by 2.4%, on average, even though it is not statistically significant.

Similarly, the same explanatory variables were used to fit the egg equation; the empirical results turn out to be slightly different. In Table 10, *Risk-perception* and *Age* are still the variables, which are statistically significant, along with *Knowledge* and *Public*. As to the marginal effect on probability, people working in the public sector would increase their probability of no consumption of eggs by 6.7% compared with consumers in other occupations; housewives, compared to other types of occupations, would increase the probability of reducing their egg consumption by 1.4%. In addition, the unconditional marginal effects of knowledge shows that, with an increment of consumers' scores on knowledge, the egg consumption would raise 2.4% of their original consumption level; however, an increment of age, on the contrary, would drop about one percent of the current egg consumption. Finally, different from the results of chicken equation, types of respondents (whether they were primary shoppers or general consumers) are not important; their coefficients and marginal effects are not statistically significant.

## **5. Summary and implications**

H5N1 avian influenza has taken over three hundred lives in the world; its impact on the demand for chicken and eggs are also affecting related industries and forcing governments to provide strategies to protect both consumers and producers. Our study, from a consumers' prospective, collected and analyzed the data from Taiwan to reveal the potential impacts of avian influenza on the demands for chicken and eggs.

Our empirical results show that risk perception about AI, knowledge of AI and some socio-economic conditions are important factors. Demand analyses in our

study provide valuable information for policy makers in several aspects. First, risk perception would play a key role to determine consumers' behavioral changes, in our case, chicken and eggs. Hence, policy makers would take serious actions to reduce consumers' concerns of risk and strengthen consumers' confidence to the food safety issue. Second, knowledge is crucial to saving the chicken and egg industry. Our empirical results show that consumers would reduce less of their original consumption level of chicken or eggs if consumers possessing more correct knowledge of AI. This finding reinforces the importance of education programs about AI. Third, socio-economic factors, such as gender, age and education and consumers are primary household food shoppers or not would determine demand changes. Strategies should be taken; special foci should be on these groups of consumers. Our empirical results provide new evidence for the influence of the occurrence of AI to the demands for chicken and eggs. Meanwhile, our empirical results reinforce several important factors which are crucial to the analysis.

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Table 1. Demographic and socio-economic characteristics of respondents

Characteristic	Primary shoppers (n=501)	General consumers (n=505)
Gender (%)		
Male	19.96	47.92
Female	80.04	52.08
Marriage (% , married)	74.25	58.81
Average age (in years)	39.35	38.35
Educational level (%)		
Junior high school or less	7.03	7.95
Senior high school	30.72	22.47
College	52.41	54.27
Graduate school	9.84	15.31
Occupation (%)		
Public sector <sup>a</sup>	11.29	15.00
Industrial sector	8.07	11.60
Business sector	25.40	24.80
Housewives	32.86	12.40
Students	5.85	15.80
Others <sup>b</sup>	16.53	20.40
Average monthly household income (NTD <sup>c</sup> )	64,989.82	77,108.43
Average household size (in persons)	3.76	3.87

Note: n= sample size.

<sup>a</sup>. Public sector includes military, government, or educational institutions.

<sup>b</sup>. agricultural sector is included.

<sup>c</sup>. Household income is measured by New Taiwan Dollars.

Table 2. Percentage of correct answers to each statement of AI knowledge

Statement <sup>a</sup>	Primary shoppers (n=501)	General consumers (n=505)	t-statistic
The avian influenza virus cannot be easily transmitted between humans.	54.49	61.19	-2.15**
Even when it is contaminated, poultry is not a health risk if it is thoroughly cooked.	55.29	62.38	-2.29**
Humans can catch avian influenza by touching contaminated birds.	87.82	86.73	0.52
The vaccination against seasonal influenza is not effective against avian influenza.	61.48	64.36	-0.94
The avian influenza virus contained in an egg or present on its shell can be eliminated by prolonged cooking.	46.91	50.10	-1.01
If a chicken is contaminated by avian influenza on a farm, all the poultry on that farm must be destroyed immediately.	92.22	91.09	0.65
It is not dangerous to eat the meat of a chicken vaccinated against avian influenza.	36.13	37.62	-0.49

Note: \*\* indicates p-value < 0.05; n= sample size.

<sup>a</sup> Questions are adopted from Eurobarometer (2006).

Table 3. AI risk perception scores by consumer types

Item <sup>a</sup>	Primary shoppers (n=501)	General consumers (n=505)	t-statistic
Risk of AI infection from visiting slaughter houses and live bird markets	11.38	11.18	0.97
Risk of AI infection from touching live birds and their droppings with bare hands	12.34	11.96	1.86*
Risk of AI infection from purchasing wild or smuggled live birds	12.24	11.74	2.37**
Risk of AI infection from traveling to areas with AI outbreaks	12.29	11.76	2.52**
Risk of AI infection from eating not thoroughly cooked eggs	11.34	10.73	2.91***
Risk of AI infection from eating not thoroughly cooked poultry meat	11.74	11.09	3.20***

Note: \* indicates p-value < 0.10; \*\* indicates p-value < 0.05; \*\*\* indicates p-value < 0.01. n= sample size.

<sup>a</sup> Score of risk measure was calculated using product of possibility of happening and severity if happened for each observation.



Table 4. Proportion of buying chicken and eggs under potential AI outbreaks

Changing situation	Primary shoppers	General consumers	$\chi^2$
Chicken (n=987)			28.63***
Not eat at all	42.97	28.23	
Reduce	39.31	43.14	
Remain unchanged	17.72	28.63	
Eggs (n=986)			6.74**
Not eat at all	24.29	18.70	
Reduce	43.93	42.89	
Remain unchanged	31.78	38.41	

Note: \*\* indicates p-value < 0.05; \*\*\* indicates p-value < 0.01.  
n= sample size.

Table 5. Proportion of buying chicken and eggs under potential AI outbreaks by types of consumers and knowledge levels

Changing situation	Primary shoppers (n= 491)		General consumers (n= 496)	
	Low knowledge	High knowledge	Low knowledge	High knowledge
Chicken:				
Not eat at all	45.58	40.75	30.05	26.96
Reduce	32.74	44.91	38.42	46.42
Remain unchanged	21.68	14.34	31.53	26.62
Test statistic: $\chi^2$	8.96**		3.19	
Eggs:	Primary shoppers (n= 494)		General consumers (n= 492)	
	Low knowledge	High knowledge	Low knowledge	High knowledge
Not eat at all	24.67	23.97	19.40	19.21
Reduce	42.73	44.94	39.80	45.02
Remain unchanged	32.60	31.09	40.80	36.77
Test statistic: $\chi^2$	0.25		1.35	

Note: \*\* indicates p-value < 0.05.  
n= sample size.

Table 6. Proportion of buying chicken and eggs under potential AI outbreaks by types of consumers and risk perceptions

Chicken:	Primary shoppers (n= 491)		General consumers (n= 496)	
	Low risk perception	High risk perception	Low risk perception	High risk perception
Changing situation				
Not eat at all	37.78	47.37	27.00	29.61
Reduce	40.00	38.72	35.74	51.50
Remain unchanged	22.22	13.91	37.26	18.89
Test statistic: $\chi^2$	7.41 <sup>**</sup>		21.99 <sup>***</sup>	
Eggs:	Primary shoppers (n= 494)		General consumers (n= 492)	
	Low risk perception	High risk perception	Low risk perception	High risk perception
Changing situation				
Not eat at all	22.12	26.12	16.86	20.78
Reduce	40.71	46.64	35.63	51.08
Remain unchanged	37.17	27.24	47.51	28.14
Test statistic: $\chi^2$	5.59 <sup>*</sup>		19.80 <sup>***</sup>	

Note: <sup>\*</sup> indicates p-value < 0.10; <sup>\*\*</sup> indicates p-value < 0.05; <sup>\*\*\*</sup> indicates p-value < 0.01.  
n= sample size.

Table 7. Definition of the explanatory variables

Variable	Definition	Expected sign
Risk perception	Scores of risk perception, ranging from 6 to 96.	—
Knowledge	Knowledge level, ranging from 0 to 7.	+
Male	Male=1; Female=0	+
Married	Married=1; else=0	—
Age	Ages in years	—
Senior	Highest education level is senior =1; else=0	?
College	Highest education level is college =1; else=0	?
Graduate	Highest education level is graduate =1; else=0	?
Public	Occupation in public sector =1; else=0	?
Business	Occupation in business sector =1; else=0	?
Housewife	Housewife=1; else=0	?
Income	Monthly income of a family in NTD	+
HS	Household size in persons	+
Shopper	Primary shopper=1; general consumer=0	—

Table 8. Parameter estimates of the censored regression model

Variable	Chicken		Eggs	
	Coef.	S.E.	Coef.	S.E.
Risk perception	-0.007***	0.002	-0.006***	0.002
Knowledge	0.022	0.026	0.050**	0.025
Male	0.148**	0.068	0.091	0.064
Married	-0.248***	0.084	-0.115	0.079
Age	-0.016***	0.004	-0.018***	0.003
Senior	-0.114	0.118	0.005	0.110
College	-0.223*	0.121	-0.149	0.113
Graduate	-0.219	0.146	-0.077	0.138
Public	-0.098	0.096	-0.179**	0.090
Business	-0.108	0.075	-0.096	0.071
Housewife	-0.149*	0.090	-0.116	0.084
Income	0.009	0.007	0.010	0.007
HS	0.018	0.021	0.022	0.020
Shopper	-0.155**	0.061	-0.024	0.057
Constant ( $\beta_0$ )	1.687***	0.248	1.792***	0.232
Scale ( $\sigma$ )	0.799***	0.034	0.755***	0.031
Pseudo $R^2$		0.0659		0.0537
LR test statistic		135.21***		107.89***
Total observations		968		967
Observations of $y = 0$		344		205
Observations of $y = 1$		225		341

Note: \* indicates p-value < 0.10; \*\* indicates p-value < 0.05; \*\*\* indicates p-value < 0.01.

Table 9. Marginal effects for chicken

Variable	Probability of			Expectation of	
	Not eat at	Reduce	Remain unchanged	Conditional	Unconditional
Risk perception	0.003 <sup>***</sup>	−0.001 <sup>***</sup>	−0.002 <sup>***</sup>	−0.001 <sup>***</sup>	−0.003 <sup>***</sup>
Knowledge	−0.010	0.002	0.008	0.003	0.010
Male	−0.066 <sup>**</sup>	0.011 <sup>**</sup>	0.055 <sup>**</sup>	0.018 <sup>**</sup>	0.068 <sup>**</sup>
Married	0.109 <sup>***</sup>	−0.016 <sup>***</sup>	−0.093 <sup>***</sup>	−0.031 <sup>***</sup>	−0.115 <sup>***</sup>
Age	0.007 <sup>***</sup>	−0.001	−0.006 <sup>***</sup>	−0.002 <sup>***</sup>	−0.007 <sup>***</sup>
Senior	0.052	−0.012 <sup>*</sup>	−0.040	−0.014	−0.052
College	0.100 <sup>*</sup>	−0.019	−0.081 <sup>*</sup>	−0.028 <sup>*</sup>	−0.103 <sup>*</sup>
Graduate	0.103	−0.030	−0.073 <sup>*</sup>	−0.027	−0.099
Public	0.045	−0.011	−0.034	−0.012	−0.045
Business	0.050	−0.012	−0.038	−0.013	−0.050
Housewife	0.069	−0.017	−0.052 <sup>*</sup>	−0.018 <sup>*</sup>	−0.068 <sup>*</sup>
Income	−0.004	0.001	0.003	0.001	0.004
H-size	−0.008	0.002	0.007	0.002	0.008
Shopper	0.070 <sup>**</sup>	−0.014 <sup>**</sup>	−0.056 <sup>**</sup>	−0.019 <sup>**</sup>	−0.071 <sup>**</sup>

Note: <sup>\*</sup> indicates p-value < 0.10; <sup>\*\*</sup> indicates p-value < 0.05; <sup>\*\*\*</sup> indicates p-value < 0.01.

Table 10. Marginal effects for eggs

Variable	Probability of			Expectation of	
	Not eat at	Reduce	Remain unchanged	Conditional	Unconditional
Risk perception	0.002***	0.001***	−0.003***	−0.001***	−0.003***
Knowledge	−0.018**	−0.007*	0.025**	0.007**	0.024**
Gender	−0.031	−0.014	0.044	0.012	0.043
Married	0.039	0.018	−0.057	−0.016	−0.055
Age	0.006***	0.003***	−0.009***	−0.002***	−0.009***
Senior	−0.002	−0.001	0.002	0.001	0.002
College	0.051	0.021	−0.072	−0.020	−0.071
Graduate	0.028	0.009	−0.037	−0.011	−0.037
Public	0.067*	0.016***	−0.084**	−0.025**	−0.087**
Business	0.034	0.012	−0.046	−0.013	−0.046
Housewife	0.042	0.014*	−0.055	−0.016	−0.056
Income	−0.002	−0.001	0.002	0.001	0.002
H-size	−0.007	−0.003	0.010	0.003	0.010
Shopper	0.008	0.003	−0.012	−0.003	−0.012

Note: \* indicates p-value < 0.10; \*\* indicates p-value < 0.05; \*\*\* indicates p-value < 0.01.