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Journal of Integrative Agriculture 2015, 14(6): 1130–1141

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Impacts of bovine spongiform encephalopathy and avian influenza on U.S. meat demand

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Abstract

This paper examines the U.S. meat demand impacts of the announced outbreaks of bovine spongiform encephalopathy (BSE) and avian influenza (AI). Findings indicate that beef and chicken demand was negatively affected by BSE and AI disease outbreaks. Specifically, in the short run, U.S. consumers shift demand due to both outbreaks but more so due to domestic disease outbreaks than for outbreaks occurring overseas—the impact of U.S. AI outbreaks is about 0.5% for beef and the impact of U.S. BSE cases is around –0.42% for beef and 0.4% for pork, respectively. Regarding the BSE shock on meat demand, there is a high rate of beef demand adjusted from disturbance to the long-run equilibrium and a lower adjustment rate for chicken demand because of the repeated outbreaks of AI worldwide. In the long run, information related to severe, persistently recurring overseas animal disease outbreaks changes U.S. consumers' meat consumption patterns. Although effects of animal diseases on U.S. meat demand were statistically significant, the magnitudes were small—the impact of WHO reported human death numbers for AI is 0.005% for beef, –0.002% for pork, and –0.006% for chicken and the impact of U.S. BSE cases is 1.1% for pork and –0.7% for chicken.

Keywords: avian influenza, bovine spongiform encephalopathy (BSE) events, meat demand, demand estimation

1. Introduction

The world has experienced outbreaks of serious animal diseases, potentially raising consumer fears of contaminated meats, which might shift demand. In studies examining the interrelationship of media coverage and food consumption behavior, global avian influenza (AI) outbreaks of a highly pathogenic AI strain (HPAI) and associated human deaths have been found to negatively affect international meat demand and supply (Alexander 2007; Beach and Zhen 2008; Jin and Mu 2012). Other studies have examined the impact of bovine spongiform encephalopathy (BSE) cases on meat demand (Burton and Young 1996; Verbeke and Ward 2001; Marsh *et al*. 2008). However, the joint effect of AI diseases and BSE cases on U.S. meat demand has not been examined.

Received 25 June, 2014 Accepted 30 September, 2014
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doi: 10.1016/S2095-3119(14)60996-5

U.S. is one of the major meat exporters in the international market and has large influence on meat prices. In domestic market, U.S. consumers eat more meat per capita than consumers in almost any other country. Among all types of meat, beef and chicken are the top two animal proteins consumed. When encountering animal diseases, not matter in domestic or international market, the emergent research question is how will it affect consumers' consumption behavior? This paper will investigate three issues. First, what is the impact of media coverage of AI and isolated BSE outbreaks on meat demand in the U.S.? Second, what is the impact across domestic and international outbreaks? Third, what is the difference between short-run and long-run effects of animal disease outbreaks on meat consumption pattern?

This paper is organized as follows. Section 2 is the background introduction of AI and BSE outbreaks along with a literature review; sections 3 and 4 introduce demand models and data, respectively; section 5 interprets results of hypotheses tests and empirical estimation and section 6 concludes.

2. Background

2.1. Disease outbreaks and health risks

AI or "bird flu" is a contagious animal disease (Jin and Mu 2012). Infections can be divided into two low and high extremes of virulence, namely, highly pathogenic avian influenza (HPAI) and low pathogenic avian influenza (LPAI). LPAI is less contagious and infected species may not carry any symptoms. HPAI virus spreads rapidly with a high mortality rate among infected birds (up to 90–100% within 48 hours) and can spread to humans (Jin and Mu 2012). An HPAI type-H5N1 virus spread widely from 2003 to 2008, and reached almost 60 countries in Asia, Europe, and Africa at its peak (Sims and Narrod 2015). There have been 648 confirmed H5N1 human cases by the end of 2013 that resulted in 384 human deaths, mostly in Southeast Asia (WHO 2014).

In the United States, avian influenza outbreaks have been sporadic cases of LPAI and one HPAI (H5N2) outbreak in Texas in 2004 (Lee *et al*. 2005; Pelzel *et al*. 2006). While very rare, two LPAI cases in humans have occurred in the United States. The first was one person involved in bird culling during an outbreak of LPAI-H7N2 in Virginia in 2002 and the second was one case of LPAI-H7N2 in New York in 2003 of unknown exposure origin (CDC 2014). No human deaths associated with HPAI have been identified in the United States. There has not been a U.S. outbreak of HPAI-H5N1 or HPAI-H7N1.

BSE is commonly known as a mad cow disease and presents a public health concern because occurrences of variant Creutzfeldt-Jakob disease (vCJD) in humans have been linked to the consumption of food containing ingredients derived from BSE-infected cattle (USDA 2013). BSE was firstly diagnosed in 1986 in the United Kingdom which has had the vast majority of cases worldwide (USDA 2013). Cumulatively, through the end of 2010, more than 184 500 cases of BSE had been confirmed in the United Kingdom alone in more than 35 000 herds (USDA 2014a). However, the disease has also been detected in many other countries, including four cases in the United States from 2003 to 2012. The first U.S. case of BSE was announced on December 23, 2003 (USDA 2013) and resulted in nearly 38 000 pounds of beef being recalled as a safety measure to prevent BSE from entering the U.S. food supply (Crowley and Shimazaki 2005). Since then, three more BSE cases have been identified in the United States through April 2012; one on June 24, 2005, was identified as the first endemic case of BSE in the United States and the latter two were announced on March 15, 2006, and April 24, 2012, respectively (CDC 2014).

Both AI and BSE are animal diseases that can cause human illness. Generally, it is safe for people to eat properly cooked AI-infected poultry products but there is a risk of AI infection when the virus passes from infected poultry to humans (CDC 2014). The human form of BSE is called vCJD and those who have eaten BSE-infected bovine products containing brain or central nervous system tissue are thought to be most likely at risk, but there is no evidence of human-to-human transmission of vCJD or AI disease (Ishida *et al*. 2010).

2.2. Demand models and previous study of animal disease

Due to the potential risk of animal diseases and human health, many studies have investigated the relationship between animal disease and meat demand using demand models. Demand models have long been used for examining consumer behavior given certain assumptions on the relationship between prices and quantities (Deaton and Muellbauer 1980; Piggott and Marsh 2004; Beach and Zhen 2008; Holt and Balagtas 2009).

To further consider food-safety related effects, demand models have been expanded to incorporate types of demand shifters, including food safety and product recalls (Burton and Young 1996; Piggott and Marsh 2004; Beach and Zhen 2008; Ishida *et al*. 2010); health and diet-related information (Brown and Schrader 1990; Capps and Schmitz 1991; Chang and Kinnucan 1991; Miljkovic and Mostad 2005; Adhikari *et al*. 2006; Tonsor *et al*. 2010); generic advertising (Piggott *et al*. 1996; Rickertsen 1998; Verbeke and Ward 2001; Capps and Park 2002); precommitted demand (Piggott and Marsh 2004; Tonsor and Marsh 2007) and structural changes (Eales and Unnevehr 1988; Rickertsen

1996; Davis 1997).

Few demand study has considered joint effects of AI outbreaks and BSE cases on U.S. meat demand. Kuchler and Tegene (2006) analyzed consumers' retail purchases of beef and beef products as a response to the 2003 U.S. BSE case and found consumers purchase patterns are affected no longer than two weeks following the BSE announcements. Beach and Zhen (2008) examined consumer response to newspaper articles on AI in Italy and found that expanded coverage of AI in the news lead to larger reductions in poultry purchases. Ishida *et al*. (2010) examined the impacts of both AI and BSE events in Japan on meat demand and found reductions in Japanese demand for beef and chicken due to BSE and AI events with BSE having a larger impact.

Except the occurrence of animal diseases, the timing of events also affects consumption behaviors. Mazzocchi (2003) and Mazzocchi *et al*. (2006) developed a structural time series approach as an alternative to the inclusion of a news coverage index and applied it to model the time series pattern of consumers' responses under multiple and resurgent food scares. Eakins and Gallagher (2003), Duffy (2003, 2006) derived a two-step dynamic almost ideal demand system (AIDS) model of alcohol and tobacco demand with an error correction term to take care of the time series properties in the data, assuming the cointegration rank of the system equals the number of modeled equations and prices and expenditure were weekly exogenous. Wang and Bessler (2006) used a less assumption-laden error correction model (ECM) based on time series properties allowing prices and expenditures to be endogenous and the cointegration rank to be subject to criteria inference.

This paper contributes to the literature in two aspects: (1) It examines impacts of two animal diseases (AI and BSE) on meat demand in the United States and considering events in both domestic and international markets; and (2) it develops a demand model that not only is based on economic theory but also accounts for the time series properties of demand data.

3. Demand models

The AIDS model and the Rotterdam demand model have been the most commonly applied. According to Eales and Unnevehr (1993), however, these models often ignored potential simultaneities in meat prices and quantities. As a consequence, their use in applied work may have been inappropriate because quantity supplied was likely to be predetermined, although specification tests did not clearly indicate which model was more appropriate. This leaves the discussion of which model should be used as a purely empirical question.

In this paper, we assume a price-dependent demand system form because in many cases quantities of meats are fixed in the short run due to biological production lags and product perishability (Holt and Goodwin 1997). Thus, we use an inverse AIDS model or IAIDS as proposed by Eales and Unnevehr (1993). To that model we add animal disease information indices as shifters in the intercept.

3.1. The static IAIDS model

Expanding on Eales and Unnevehr (1993), the static non-linear IAIDS model with the inclusion of animal disease indices is written as,

$$w_i=\alpha_i+\sum_{j=1}^{N}\gamma_{ij}\ln q_j+\beta_i\ln(Q)+u_i,\ \text{for } N=4 \quad (1)$$

$$\ln Q=\alpha_0+\sum_{j=1}^{N}\alpha_j\ln q_j+\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\gamma_{ij}\ln q_i\ln q_j,\ \text{for } N=4 \quad (2)$$

$$\alpha_i=\alpha_0+\sum_{k=1}^{K}\lambda_{ik}AI_k+\theta_i BSE+\sum_{s=1}^{S}\rho_{is}D_s \text{ for } K=3 \text{ and } S=3 \quad (3)$$

Where, w_i is the budget share of the *i*th good, AI_k is the AI information index in different forms as discussed below, *BSE* is a dummy variable telling if a BSE case occurred in the United States in a month, and D_s is a seasonal dummy; q_j is the quantity of good *j*.

In eqs. (1), (2), and (3), α, β, γ, ρ, λ, and θ are parameters to be estimated. Restrictions of homogeneity and symmetry are needed but involve only the fixed, unknown coefficients and so may be easily tested or imposed (Eales and Unnevehr 1993). These restrictions include adding up ($\sum_i\alpha_{i0}=1$, $\sum_i\beta_i=0$, $\sum_i\lambda_{ik}=0$, $\sum_i\theta_i=0$, $\sum_i\rho_{is}=0$), homogeneity ($\sum_i\gamma_{ji}=0$), and symmetry ($\gamma_{ji}=\gamma_{ij}$).

Elasticities from the IAIDS demand model are calculated following Green and Alston (1990, 1991) and flexibilities are their inverse. Following Eales and Unnevehr (1993), we describe own-quantity flexibilities as the percentage change in the price of the *i*th good, when the quantity demanded increases by 1%. Thus, demand is inflexible (flexible) if a 1% increase in consumption leads to a greater than (less) than 1% decrease in the marginal consumption value of that commodity. Commodities are termed as gross quantity-substitutes if their cross-quantity flexibility is negative and gross quantity-complements if it is positive (Eales and Unnevehr 1993). Scale flexibilities measure the percentage change in the normalized price of that meat in response to a proportionate increase in the supply of all meats. Scale flexibility of one commodity is less than –1 for necessities and greater than –1 for luxuries.

3.2. The dynamic IAIDS model

The dynamic IAIDS model is based on the static model above (Duffy 2003, 2006). If we assume quantities and expenditure are weakly exogenous, the dynamic IAIDS model is written as,

$$\Delta w_{it}=\alpha_{it}+\sum_{j=1}^{N}\gamma_{ijt}\Delta \ln q_{jt}+\beta_{it}(\Delta \ln Q)+\Gamma_1\Delta w_{it-1}$$
$$+\Pi_1 e_{it-m_1}+\eta_{it}\text{, for } N=4 \quad (4)$$

$$\Delta \ln Q=\sum_{j=1}^{N}\alpha_{ijt}\Delta \ln q_{jt}+\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}\gamma_{ijt}\Delta(\ln q_{it}\ln q_{jt})\text{, for } N=4 \quad (5)$$

$$\alpha_{it}=\sum_{k=1}^{K}\lambda_{ikt}\Delta AI_{kt}+\theta_{it}\Delta BSE_t+\sum_{s=1}^{S}\rho_{ist}\Delta D_{st}\text{, for } K=3 \text{ and } S=3 \quad (6)$$

Where, Δ represents the first difference operator; Δw_{it-1} captures consumers' habits and e_{it-m_1} is the estimated residual ($\hat{u}_i$) from the static IAIDS model with lag m_1; e_{it-m_1} is assumed to be a white noise stationary series process. Γ_1 is the $(N-1)\times 1$ vector and Π_1 is the $(N-1)\times(N-1)$ matrix and η_{it} is a vector of innovations that may be contemporaneously correlated with each other but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables. If Π_1 has rank r_1 with $r_1<N-1$, then w_t is cointegrated with r_1 cointegrating vectors, reflecting a long-run relationship among variables in the system (Wang and Bessler 2006).

The dynamic IAIDS model that incorporates short-run estimates will be an error correction representation of the generalized static IAIDS model (Duffy 2003, 2006). This dynamic form allows for disequilibrium in the short run by treating the error term $\hat{u}_i$ from equation (1) as the equilibrium errors and these errors tie the short-run behavior of the dependent variable to its long-run value (Eakins and Gallagher 2003).

The first-differenced terms on the right-hand side capture short-term disturbances. The error correction term e_{t-m_1} captures the long-term equilibrium relationship and Π_1 measures the speed of adjustment to the long-run equilibrium where $\Pi_1=1$ indicates instantaneous adjustment. If Π_1 is larger than or close to 1, this implies rapid adjustment and Π_1 substantially smaller than 1 indicates a slower adjustment to the long-term equilibrium. Flexibilities from the dynamic IAIDS model are short-run flexibilities. The difference between the long-run and short-run equilibrium is adjusted by Π_1, the coefficient of the error correction term.

4. Data

Demand estimation was done for consumption of beef, pork, chicken, and turkey. Monthly data on retail price and per capita consumption were obtained from the Economic Research Service, United States Department of Agriculture (USDA 2014b) from January 1989 to December 2010. The beef and pork price data give average retail values, and turkey price is measured by the retail value per pound of whole frozen birds. The chicken price is a composite price averaged across whole bird, chicken breast, and chicken legs, weighted by quantity demanded of each.

The per capita consumption data for chicken and turkey are from the USDA Poultry Yearbook. Since the per capita consumption of beef and pork is not available in the USDA Red Meat Yearbook, we divided total retail disappearance of beef and pork by population from U.S. Census Bureau Population Division.

The AI information indices were formed using the LexisNexis Academic search engine. News articles related to AI from up to 50 English-language newspapers worldwide[1] were searched using keywords "avian influenza", "bird flu", "H5N1" or "H7N2" over the period January 1989 to December 2010. The number of news articles in each month was then used to construct AI variables discussed below. In addition, we also searched for news articles associated with AI human cases.

In turn three animal disease indices were constructed. The *AI-media coverage*, gave the count of AI related stories and was expected to affect both domestic demand and excess demand. The second dummy variable named *AI-U.S.*, indicates months in which a U.S. AI outbreak occurred, namely November 2003; February 2004, and March 2004. Another dummy variable called *BSE*, was used to indicate the months when BSE announcements were made (December 2003, June 2005, and March 2006). Both of the outbreak variables, *AI-U.S.* and *BSE* variables, were anticipated to affect the domestic meat demand and supply. The fourth and final disease related variable named *AI-human deaths* gave the monthly number of AI-H5N1 confirmed human cases and was drawn from the World Health Organization (WHO) from January 2004 to December 2009 (WHO 2014), which was also anticipated to affect the international market.

Table 1 presents summary statistics on the variables. Although the budget share of turkey was relatively small, chicken and turkey were not combined because first, they were difficult to weight and second their relationships with beef and pork are different[2]. Fig. 1 shows prices of beef,

[1] Due to easily access of internet, we assumed U.S. consumers could read any newspaper in English no matter in which country the newspaper was originally published. However, we cannot read all media reports to separate positive or negative views on AI due to massive readings, and we only can identify the AI outbreak is related to poultry or human.

[2] Demand for turkey is often seasonal, so we control for seasonal effects in the model.

pork, chicken, and turkey from January 1989 to December 2010, plus the scaled cumulative numbers of articles and the numbers of confirmed AI-H5N1human cases.

From 1997, when the first H5N1 case was detected in Hong Kong (Sims *et al*. 2003), until 2003 there were an increasing number of AI newspaper articles. Since 2003, AI outbreaks occurred at unprecedented levels in scale and geographic locations with outbreaks initially through countries in the East and Southeast Asia, then into Mongolia, southern Russia, the Middle East, Europe, Africa, and South Asia, with outbreaks recurring in various countries in 2007 and later (Sims 2007; Jin and Mu 2012). With the increased number of AI news articles and confirmed AI-H5N1 human cases, turkey and chicken prices declined substantially. Vertical dashed lines in Fig. 1 indicate the three U.S. BSE announcements. With each BSE an-

Table 1 Statistic summary

Variable	Description	Mean	Std. Dev.	Min	Max
p_1	Retail price of beef (cents lb^{-1})	335.52	62.24	258.20	452.57
p_2	Retail price of pork (cents lb^{-1})	251.15	34.05	187.37	336.30
p_3	Retail price of chicken (cents lb^{-1})	157	12.12	136	186
p_4	Retail price of turkey (cents lb^{-1})	41.90	22.46	7.41	103.7
q_1	Consumption of beef (lbs capita^{-1})	7.38	0.55	5.89	8.55
q_2	Consumption of pork (lbs capita^{-1})	5.58	0.51	4.29	7.06
q_3	Consumption of chicken (lbs capita^{-1})	8.52	1.40	5.15	11.17
q_4	Consumption of turkey (lbs capita^{-1})	1.58	0.15	1.01	1.93
w_1	Budget share of beef	0.47	0.02	0.42	0.53
w_2	Budget share of pork	0.27	0.02	0.22	0.31
w_3	Budget share of chicken	0.25	0.02	0.20	0.29
w_4	Budget share of turkey	0.01	0.01	0.00	0.03
exp	Expenditures on meat (cents/capita)	5 290	961	3 483	7 416
AI-U.S.	Dummy variable telling when there were AI outbreaks in the U.S.	0.01	0.11	0	1
AI-media coverage	Number of articles with coverage of AI news	94.04	231.54	0	2198
AI-human deaths	Number of confirmed AI human cases reported by WHO	90.05	160.1	0	512
BSE	Dummy variables telling when BSE outbreaks were announced in the U.S.	0.01	0.11	0	1

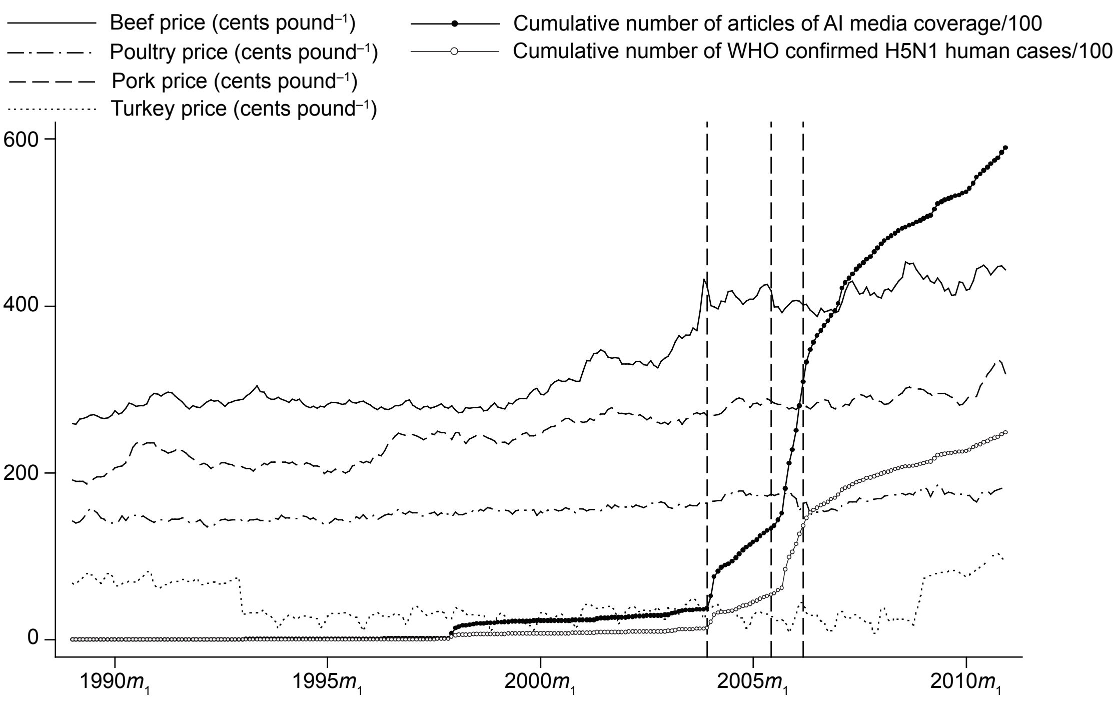

Fig. 1 Historical meat prices trend and cumulative number of articles of AI media coverage and WHO confirmed H5N1 human cases. Vertical dash lines indicate the announcement of BSE events. Number of articles on AI appearing in the media coverage is scaled by 100.

nouncement, there was a drop in beef price. However, the overall effect on meat price was hard to determine because of the interdependent relationships among beef, pork, chicken, and turkey.

5. Hypotheses tests and empirical results

5.1. Hypotheses test of time series properties

Due to the time trend that is apparent in Fig. 1, the augmented Dickey-Fuller (ADF) test was used to test whether prices and expenditure have unit roots in levels and first differences. Table 2 presents ADF test results showing that turkey budget share, price of beef, pork, and chicken are non-stationary in the levels, while all variables in their first differences are stationary.

One weakness of the ADF test is its potential to confuse structural breaks as evidence of non-stationary. Therefore, the test proposed by Clemente *et al*. (1998) was used and the results of which are shown in Table 2. Consistently, tests of most variable levels did not reject the null hypothesis of a unit root with one structural break. All variables in first differences were stationary when a gradual shift in the mean was allowed, suggesting the absence of cointegration. This indicates that the parameter and elasticity estimates in the level could be spurious (Eakins and Gallagher 2003; Mazzocchi 2006), and that the dynamic demand model would be more appropriate.

There are two popular ways to determine the rank and lag in a dynamic IAIDS model. The conventional approach is a two-step procedure involving likelihood ratio (LR) tests (Park *et al*. 2008). This procedure determines the lag length using information matrices, and then determines the rank of cointergration vectors based on a trace test (Johansen 1988). The disadvantage of this approach is the selection of the rank depending on the selection of the lag. The alternative preferred approach is the model selection method based on information criteria, which determines the lag and rank simultaneously (Phillips and McFarland 1997; Aznar and Salvador 2002; Baltagi and Wang 2007; Park *et al*. 2008).

Table 3 provides information criteria from model selection approach and results indicated that a lag structure (m_1) of 2 and a conintegration vector rank (r_1) of 2 has the minimum Hannan and Quinn information criterion (HQIC) loss as well as the minimum Bayesian information criterion (BIC) loss for both subsamples in the dynamic IAIDS model. Thus, the dynamic IAIDS model was estimated with r_1=2 and m_1=2 using a one-step, simultaneous, nonlinear seemingly unrelated regression (NLSUR) approach (McElroy *et al*. 1985). This method also allows for correlations in the residual variance-covariance matrix, leading to more efficient estimates and the method is more stable and robust with respect to poor initial values (Elder 1997).

5.2. Empirical results from the static IAIDS model

For the static IAIDS model, estimated parameters are presented in Table 4 with model diagnostics. A regression was run over three sample periods—January 1989 to October 2003 to represent the period without U.S. AI and BSE outbreaks, January 1989 to July 2006 to show the period with

Table 2 Unit root tests with and without structural breaks[1)]

Variable	Augmented Dickey-Fuller tests for zero structure break		Phillips-Perron test for zero structure break		Clemente, Montanes and Reyes test for one structure break			
					AO model		IO model	
	Level	Difference	Level	Difference	Level	Difference	Level	Difference
w_1	–4.250**	–14.965**	–3.947	–5.456**	–2.811	–4.421**	–4.250**	–14.965**
w_2	–5.730**	–13.221**	–2.918	–5.401**	–2.362	–4.764**	–5.730**	–13.221**
w_3	–3.386**	–21.855**	–3.573	–5.232**	–2.928	–5.489**	–3.386**	–21.855**
w_4	–2.568	–13.764**	–4.372**	–4.400**	–0.945	–5.976**	–2.568	–13.764**
lnp_1	–0.36	–13.01**	–0.40	–12.79**	–2.71	–3.85**	–3.15	–5.76**
lnp_2	–0.92	–12.91**	–1.10	–13.10**	–3.05	–3.30**	–2.93	–4.40**
lnp_3	–2.00	–19.76**	–1.60	–20.16**	–3.66**	–9.98**	–2.39	–9.44**
lnp_4	–3.95**	–15.42**	–3.53**	–15.95**	–0.65	–5.00**	–2.04	–5.43**
lnq_1	–10.28**	–30.24**	–10.78**	–31.52**	–1.98	–7.64**	–3.50	–7.57**
lnq_2	–8.26**	–25.92**	–8.33**	–29.34**	–2.01	–5.63**	–2.08	–5.75**
lnq_3	–4.45**	–34.86**	–3.37**	–51.35**	–1.91	–12.53**	–2.37	–8.63**
lnq_4	–10.46**	–25.29**	–10.36**	–27.26**	–1.87	–4.74**	–2.37	–6.96**
ln*exp*	–3.53**	–34.66**	–2.30	–44.09**	–1.15	–7.10**	–1.20	–6.89**
5% critical value	–2.88	–2.88	–2.88	–2.88	–3.56	–3.56	–4.27	4.27

[1)] The AO model captures a sudden change in a series and the IO model allows for a gradual shift in the mean of the series. The null hypothesis is that there is a unit root. ** indicates we cannot accept the null hypothesis of a unit root at the 5% critical value. The same as below.

Table 3 Model selection procedure for rank (r_1) and lag (m_1)[1)]

Lag	Rank	1989m_1–2003m_{10}		1989m_1-2006m_7	
		HQIC[2)]	BIC[3)]	HQIC[2)]	BIC[3)]
1	1	–22.7060	–22.6207	–22.6124	–22.5365
1	2	–22.7689	–22.6516	–22.6808	–22.5764
2	1	–22.8627	–22.6807	–22.7269	–22.5649
2	2	**–22.9423**	**–22.7282**	**–22.8237**	**–22.6332**
3	1	–22.8249	–22.5454	–22.7532	–22.5047
3	2	–22.8629	–22.5512	–22.8019	–22.5248
4	1	–22.7551	–22.3774	–22.6804	–22.3448
4	2	–22.7761	–22.3660	–22.7102	–22.3458
5	1	–22.8341	–22.3575	–22.7150	–22.2917
5	2	–22.8290	–22.3199	–22.7152	–22.2630

1) Bold number indicate the optimal lag and rank.
2) HQIC, Hannan Quinn information criterion. $HQIC=n\log(\frac{RSS}{n})+2k\log\log(n)$, where n is the number of observation and RSS is the residual sum of squares that results from the statistical model.
3) BIC, Bayesian information criterion. $BIC=n\ln(\hat{\sigma}_e^2)+k\ln(n)$, where $\hat{\sigma}_e^2$ is the error variance for the estimated model.

U.S. AI and BSE outbreaks, and January 1989 to December 2010 to show the overall effects[3]. Since all variables entering the static regression were stationary in first differences, interpreting the results from this regression relies on the residuals being stationary. The ADF test was used to test whether residuals from the static IAIDS equations were stationary and results, also presented in Table 4, rejected the null hypothesis of a unit root at the 1% confidence level, suggesting residuals are stationary. Thus, we could interpret estimation results as follows.

Considering only the impacts of AI media coverage, the results from the first sample period showed that AI media coverage increased the U.S. pork budget share and had insignificant impacts on other U.S. meat budget shares. It is expected that chicken demand would be negatively affected; however, impacts on chicken demand are insignificant. Two possible explanations: (1) there was no AI outbreaks reported in the United States and there was no confirmed human death resulting from AI as reported by the WHO during this period, and (2) poor consumers are attracted by the reduced chicken prices due to AI outbreaks.

Looking at results from the second sample period, which included U.S. AI outbreaks and human deaths from AI in other parts of the world, we find significantly increased beef demand. The magnitude of the effect on U.S. meat demand was much larger when AI outbreaks occurred in the United States, as would be expected. Pork demand was

Table 4 Estimation results from the static IAIDS and model diagnostics[1)]

Sample period	Meat	Model estimation				Model diagnostics			
		AI-U.S.	AI-media coverage	AI-human death	BSE-U.S.	DW test on residual[2)]	Unit root test on residual	RMSE[3)]	R^2
Jan 1989–Oct 2003	Beef		–0.0036			2.2164	–8.340***	0.0080	0.9997
			(0.0023)						
	Pork		0.0032*			2.5930	–8.629***	0.0060	0.9995
			(0.0017)						
	Chicken		0.0001			1.8368	–8.180***	0.0069	0.9992
			(0.0019)						
Jan 1989–July 2006	Beef	1.0231*	–0.0006	0.0168***	–0.3473	1.9522	–5.051***	0.0092	0.9996
		(0.5730)	(0.0004)	(0.0023)	(0.4321)				
	Pork	–0.4283	–0.0002	–0.0051***	0.9061	2.2027	–8.103***	0.0071	0.9993
		(0.4352)	(0.0003)	(0.0018)	(0.5625)				
	Chicken	–0.5372	0.0007**	–0.0136***	–0.6775	1.5601	–5.292***	0.0068	0.9993
		(0.4232)	(0.0003)	(0.0017)	(0.4140)				
Jan 1989–Dec 2010	Beef	0.8375	0.0005*	0.0052***	–0.3704	2.5680	–9.995***	0.0085	0.9997
		(0.5184)	(0.0003)	(0.0005)	(0.3862)				
	Pork	–0.4167	–0.0005**	–0.0022***	1.1046**	2.4600	–10.460***	0.0064	0.9994
		(0.3916)	(0.0002)	(0.0004)	(0.5075)				
	Chicken	–0.3822	–0.0001	–0.0055***	–0.6996**	2.4733	–11.409***	0.0058	0.9995
		(0.3541)	(0.0002)	(0.0003)	(0.3475)				

1) Coefficients and standard errors are multiplied by 100.
2) DW is the Durbin-Watson (DW) tests on residuals with the null hypotheses that residuals from the regression are independent.
3) RMSE is the root mean squared error. The same as below.
* and *** indicate significance at the 10 and 1% level; standard errors are in parenthesis. The same as below.

3 Sample of January 1989 to October 2003 is the sample where no animal disease incidence occurred in the United States; January 1989 to July 2006 is the sample where animal disease incidence occurred in the United States.

only affected by the numbers of AI human deaths. Chicken demand declined, indicating that beef and chicken were substitutes. U.S. chicken demand was also impacted by AI media coverage with a significant positive effect. This likely reflects the result of reduced demand worldwide and consequent impacts on U.S. chicken exports and price. Although thousands of chickens and turkeys were slaughtered and quarantined when there was an AI outbreak in the United States, the quantity was small compared to the size of U.S. production. With both shifts in domestic supply and demand as well as a shift in excess demand internationally, the slight increase in chicken demand was the aggregate effect.

Using the whole sample period, beef demand increased and pork demand decreased as increased numbers of articles of AI media coverage and numbers of WHO reported AI human deaths occurred. Chicken demand declined as the number of WHO reported AI confirmed human deaths increased. Although the impact of WHO reported AI human death numbers on U.S. meat demand were statistically significant, the magnitudes were small: 0.02% for beef, –0.005% for pork, and –0.01% for chicken in the January 1989 to July 2006 period with yet smaller impacts when the whole sample period was used. These results suggested that the impacts of overseas AI human deaths diminished over time.

In addition to the implications of AI on U.S. meat demand, the impacts of BSE cases were also examined. BSE cases increased pork demand and decreased chicken demand in the whole sample period and had insignificant effects on beef, suggesting beef and pork are substitutes. It is possible that the AI effects offset the BSE effects. In the long run, it appeared that the severity and the duration of AI mattered more than the few one-time BSE shocks. Nevertheless, results show that animal disease outbreaks had negative impacts on meat demand. These were consistent with the results found in Beach and Zhen (2008), in which they examined effects of AI outbreaks on meat demand in Italy and argued that similar but smaller impacts on chicken consumption in the United States would be expected.

Table 5 reports the long-run uncompensated own- and cross-price flexibilities, the scale flexibilities, and the appropriate standard errors from the static model. Note that all own-quantity flexibilities were negative and statistically significant, as theoretically expected, indicating beef, pork, and chicken demands in the United States are quantity inflexible. In addition, beef was a quantity-substitute for pork and chicken with all signs negative. Beef was determined to be necessity (scale flexibility <-1) and pork and chicken were determined to be luxuries (scale flexibilities >-1). These results are consistent with Eales and Unnevehr (1993), in which they found all meats (except pork) to be necessities and are own-price inflexible.

When the AI media coverage flexibility was examined, pork and chicken consumption was increased by media coverage of overseas disease outbreaks before 2004. However, chicken and pork demand reduced when taking account the aggregate effects from shifts in demand and supply from both the domestic and the international markets. Also people may have switched some consumption to pork when the BSE disease outbreaks were announced. Since AI and BSE disease information was overlapping in the time period examined, both possibilities exist in a long-run equilibrium. A short-run analysis may provide insight into which reason was more important.

As expected, information related to human deaths

Table 5 Long-run own- and cross-price and scale flexibilities[1)]

	Jan1989–Oct 2003			Jan 1989–Jul 2006			Jan 1989–Dec 2010		
	Beef	Pork	Chicken	Beef	Pork	Chicken	Beef	Pork	Chicken
Beef	–0.8713***	–0.1457***	–0.0885***	–0.9248***	–0.1156***	–0.0774***	–0.8914***	–0.1266***	–0.0700***
	(0.0248)	(0.0093)	(0.0057)	(0.0251)	(0.0083)	(0.0055)	(0.0193)	(0.0067)	(0.0040)
Pork	–0.1119***	–0.8316***	–0.0142***	–0.0405	–0.8412***	–0.0283***	–0.0677***	–0.8347***	–0.0251***
	(0.0254)	(0.0112)	(0.0037)	(0.0301)	(0.0086)	(0.0051)	(0.0223)	(0.0074)	(0.0048)
Chicken	0.0036	0.0139	–0.8590***	0.0346	–0.0117	–0.8600***	–0.0103	–0.0242***	–0.8568***
	(0.0363)	(0.0145)	(0.0083)	(0.0340)	(0.0125)	(0.0082)	(0.0230)	(0.0079)	(0.0030)
Scale	–1.0771***	–0.9773***	–0.8737***	–1.0998***	–0.9192***	–0.8573***	–1.0681***	–0.9269***	–0.9248***
	(0.0261)	(0.0343)	(0.0443)	(0.0261)	(0.0356)	(0.0386)	(0.0216)	(0.0288)	(0.0290)
AI media coverage	–0.0072	0.0112	0.0005	–0.0012	–0.0008	0.0025	0.0010	–0.0018	–0.0005
AI human deaths				0.0324	–0.0171	–0.0482	0.0100	–0.0076	–0.0196
AI-U.S.				0.0218	–0.0182	–0.0204	0.0178	–0.0160	–0.0203
AI-BSE				–0.0074	0.0385	–0.0257	–0.0079	0.0423	–0.0372

[1)] We calculated Marshallian own- and cross-price flexibilities using equation $\varepsilon_{ij}=-\delta_{ij}+\frac{\gamma_{ij}+\beta_i(\alpha_j+\sum_{i=1}\gamma_{ij}\ln q_k)}{w_i}$ and the scale flexibilities using equation $f_i=-1+\frac{\beta_i}{w_i}$, where δ_{ij} is the Kronecker delta with $\delta_{ij}=1$ if $i=j$ and $\delta_{ij}=0$ if $i\neq j$

generated greater attention from people and consequently consumers became more cautious when purchasing meat. In the long term, beef demand increased as the number of WHO confirmed AI human deaths increased, while pork and chicken demand decreased. The decrease in pork demand in the whole period may be associated with the 2009 H1N1 outbreaks in the United States and because it was labeled as "swine flu" (Attavanich *et al*. 2011) and was not controlled in this study. However, we observed the same pattern of meat consumption responses to AI human deaths in the period before 2009.

Domestic disease outbreaks have opposite effects. Pork and chicken consumption reduces when U.S. AI outbreaks while beef and chicken demand reduces when U.S. BSE cases were announced. Table 4 also presents results of model diagnostics. All Durbin-Watson (DW) tests on residuals are statistically insignificant, suggesting there is no serial correlation. In addition, all model estimates give a high R^2 and the root mean squared error (RMSE) is very small, both indicate the static model fits data well.

5.3. Empirical results from the dynamic IAIDS model

There are three criteria to determine a preferred long-run equilibrium model (Eakins and Gallagher 2003) that could be used in estimating the dynamic IAIDS model. Frist, whether the estimated flexibilities imply a downward sloping demand curve, which we have observed in Table 5; second, whether the regression model passes various diagnostic tests, such as goodness-of-fit and serial correlation, etc.; third, whether the model indicates a stationary pattern of residuals. Model diagnostics in Table 4 suggested that residuals from the static IAIDS model is stationary and without serial correlation and fits the data well. Thus, this section presents the dynamic IAIDS model estimation results, as reported in Table 6.

Results from the dynamic IAIDS model are consistent to that from the static IAIDS model, except fewer variables are statistically significant and magnitude changes. In the short term, we find that media coverage of AI outbreaks overseas has insignificant effects on demand for all meats. However, consumers' response to animal disease is to increase beef demand by about 0.5% when AI outbreaks are ongoing in the United States and to increase pork demand by about 0.4% and reduce beef demand by about 0.4% when BSE cases are announced by U.S. government. These results show that adverse information from domestic animal disease matters more for short-run meat consumption than does information on disease outbreaks or deaths overseas.

Results also showed shifts in meat demand consumption habits were strong and significant at the 1% confidence level for all three samples, which indicates consumers were persist in their consumption behaviors over time after the 1990s.

The error correction term parameter Π_1 in Table 6 for beef was –12% when there were no AI and BSE cases in the United States, which implies 12% of the disturbance to the long-run equilibrium in the previous period adjusted back to long-run equilibrium in this period. However, with the animal disease outbreaks in the United States, the adjustment rate increases to 30%, indicating a quicker

Table 6 Estimation results from the EC-IAIDS model[1)]

Sample period	Meat	AI-U.S.	AI-media coverage	AI-human death	BSE-U.S.	Δw_{t-1}	$u_{beef,\ t-2}$	$u_{pork,\ t-2}$	$u_{chicken,\ t-2}$	RMSE	R^2
Jan 1989–Oct 2003	Beef		0.0336			–11.1821***	–11.9550*	–12.3468	–3.5983	0.0040	0.8725
			(0.0334)			(2.5491)	(6.5747)	(8.2662)	(6.3261)		
	Pork		0.0179			–7.9512***	4.0262	3.3013	4.3918	0.0031	0.9290
			(0.0255)			(2.3362)	(5.0379)	(6.3276)	(4.8332)		
	Chicken		–0.0261			–6.1812**	–3.7455	–6.6925	–10.5372**	0.0034	0.7391
			(0.0283)			(3.1049)	(5.5451)	(7.0431)	(5.3526)		
Jan 1989–Jul 2006	Beef	0.5226**	0.0084	0.0041	–0.3989***	–12.7952***	–29.9868***	–24.9069***	–19.7354**	0.0043	0.8533
		(0.2356)	(0.0339)	(0.0084)	(0.1288)	(2.3516)	(7.6247)	(8.7519)	(8.5523)		
	Pork	–0.2292	0.0105	0.0052	0.3710**	–9.3800***	5.6888	0.7484	–3.0699	0.0030	0.9323
		(0.1613)	(0.0232)	(0.0058)	(0.1873)	(2.1080)	(5.2317)	(6.1330)	(6.1115)		
	Chicken	–0.2843	–0.0060	–0.0113	0.0025	–7.6040***	4.4136	1.5689	–0.3776	0.0039	0.7188
		(0.2144)	(0.0308)	(0.0076)	(0.1722)	(2.7641)	(6.9959)	(8.1480)	(7.7560)		
Jan 1989–Dec 2010	Beef	0.5211**	0.0124	0.0020	–0.4188***	–10.9211***	–30.1533***	–13.2837**	–20.8174**	0.0045	0.8413
		(0.2374)	(0.0336)	(0.0067)	(0.1346)	(2.1534)	(8.5169)	(6.5043)	(9.4714)		
	Pork	–0.1971	0.0015	0.0016	0.3961**	–9.2270***	1.7190	4.4262	0.3583	0.0032	0.9233
		(0.1673)	(0.0237)	(0.0047)	(0.1909)	(1.9230)	(5.9993)	(4.4580)	(6.6950)		
	Chicken	–0.3040	–0.0017	–0.0058	–0.0126	–7.9034***	4.6507	–4.7119	–4.1110	0.0040	0.6983
		(0.2126)	(0.0300)	(0.0059)	(0.1726)	(2.4709)	(7.6468)	(5.8834)	(8.4790)		

[1)] Coefficients and standard errors in this Table are all multiplied by 100 to make them more comparable.

adjustment after domestic disease outbreaks. Compared to AI disease, U.S. consumers have been more aware of and had prior knowledge of the health risk of BSE disease and the safeguards against BSE due to effective information provided by government agencies (e.g., USDA); thus, they behave more rationally.

For chicken demand, 11% of the disturbance to the long-run equilibrium was adjusted when there was only media coverage of AI outbreaks overseas. When there were AI and BSE outbreaks within the United States, the adjustment rate decreased to 0.3 and 4% for later two sample periods, respectively, suggesting there was longer disturbance in demand in response to domestic events, although coefficients are statistically insignificant. Due to massive media coverage of AI outbreaks and increasing numbers of AI human deaths, it would be expected to take a long time for chicken demand to adjust back to the long-run equilibrium.

Table 7 gives estimates of short-run own- and cross-price and scale flexibilities. Compared to results in Table 5, the short-run own-price flexibilities of beef, pork, and chicken were close to their long-run flexibilities but are smaller in magnitudes. This suggests that in short-run, all meats are more own-price flexible. In other words, in long-run, with a 1% increase in meat consumption would lead to a larger changes in its normalized price compared that in short-run.

Table 7 also shows that beef is more scale flexible while pork and chicken are less scale flexible. Combined with the error correction coefficients in Table 6, the quantity frequencies of demand for beef did not move far from the corresponding long-run flexibilities as the adjustment rates were fast. In short-run, outbreaks of AI and BSE in the United States would increase beef and pork consumption, respectively, but the magnitudes are much smaller than that in long-run.

6. Conclusion

Analyses were done on the economic impacts that animal disease outbreaks (e.g., AI and BSE) and media coverage had on U.S. meat demand. This was done using static and dynamic versions of the IAIDS model, the dynamic one using error correction terms (i.e., dynamic IAIDS)[4]. The results find that beef and chicken demand was negatively affected by BSE and AI disease outbreaks. Specifically, in the short run, U.S. consumers shift demand due to both outbreaks but more so due to domestic disease outbreaks than for outbreaks occurring overseas—the impact of US-AI outbreaks is about 0.5% for beef and the impact of U.S. BSE cases is around –0.42% for beef and 0.4% for pork, respectively. Regarding the BSE shock on meat demand, there is a high rate of beef demand adjusted from disturbance to the long-run equilibrium and a lower adjustment rate for chicken demand because the repeated outbreaks of AI worldwide.

In the long run, information related to severe, persistently recurring overseas animal disease outbreaks changes U.S. consumers' meat consumption patterns. Although effects of animal diseases on U.S. meat demand were statistically significant, the magnitudes were small—the impact of AI human death numbers is 0.005% for beef, –0.002% for pork, and –0.006% for chicken and the impact of U.S. BSE cases is 1.1% for pork and –0.7% for chicken. These findings contribute to the understanding of how consumers respond to animal health outbreaks that also pose a human threat, as well as how media information impacts

Table 7 Short-run own- and cross-price and scale flexibilities

	Jan 1989–Oct 2003			Jan 1989–Jul 2006			Jan 1989–Dec 2010		
	Beef	Pork	Chicken	Beef	Pork	Chicken	Beef	Pork	Chicken
Beef	–0.7936***	–0.1183***	–0.0935***	–0.7978***	–0.1111***	–0.0958***	–0.7951***	–0.1109***	–0.0969***
	(0.0092)	(0.0049)	(0.0082)	(0.0093)	(0.0047)	(0.0084)	(0.0086)	(0.0043)	(0.0076)
Pork	–0.1193***	–0.8084***	–0.0622***	–0.1120***	–0.8117***	–0.0684***	–0.1115***	–0.8100***	–0.0692***
	(0.0052)	(0.0049)	(0.0052)	(0.0048)	(0.0043)	(0.0051)	(0.0045)	(0.0040)	(0.0045)
Chicken	–0.0914***	–0.0635***	–0.8412***	–0.0939***	–0.0696***	–0.8317***	–0.0950***	–0.0706***	–0.8319***
	(0.0088)	(0.0052)	(0.0107)	(0.0089)	(0.0050)	(0.0107)	(0.0080)	(0.0045)	(0.0094)
Scale	–1.0254***	–0.9967***	–0.9756***	–1.0245***	–0.9932***	–0.9819***	–1.0277***	–0.9842***	–0.9858***
	(0.0088)	(0.0118)	(0.0145)	(0.0088)	(0.0108)	(0.0153)	(0.0079)	(0.0098)	(0.0134)
AI media coverage	0.0676	0.0633	–0.0969	0.0170	0.0372	–0.0224	0.0250	0.0052	–0.0064
AI human deaths				0.0079	0.0177	–0.0401	0.0038	0.0055	–0.0205
AI-U.S.				0.0112	–0.0086	–0.0113	0.0112	–0.0073	–0.0122
BSE-U.S.				–0.0086	0.0140	0.0001	–0.0090	0.0146	–0.0005

[4] We also test the homogeneity and symmetry restrictions for both the static IADIS and dynamic IADIS model. Please see test results in Appendix.

consumption patterns.

A most recent study shows that climate change is the factor of the outbreaks of current highly pathogenic avian influenza A virus (HPAI H5N1) in bird and may play a greater role in the future (Mu *et al*. 2014), particularly in China. Thus, the examination of AI impacts will have important implication of animal disease prevention and mitigation strategies in countries with higher probably of AI outbreaks in the future.

Appendix associated with this paper can be available on http://www.ChinaAgriSci.com/V2/En/appendix.htm

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(Managing editor WENG Ling-yun)