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HPAI Impact on EU-27's Import Demand for Cooked and Uncooked Poultry and Other Meats[1]

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Abstract

The article applied a Central Bureau of Statistics (CBS) differential model to evaluate the impact of HPAI (H5N1) virus outbreaks on EU-27's import demand for five meat products: cooked poultry, uncooked poultry, beef, pork, and other meats. One novel feature of this work is the division of poultry into two distinct import products—cooked (safe) and uncooked (less safe). Analysis shows that HPAI (H5N1) outbreaks had statistically significant impacts on EU27 import demand for meats, increasing cooked poultry and decreasing uncooked poultry, beef, pork, and other meats. The shift in import demand regime was permanent and statistically significant, making cooked poultry imports EU27's largest, averaging more than 50 percent of EU imports in 2013 and 2014.

Keywords: CBS model, Highly Pathogenic Avian Influenza (HPAI), meat import demand system, cooked poultry, uncooked poultry, structural change, EU27.

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[1] The views expressed here are those of the authors, and may not be attributed to the Economic Research Service or the U.S. Department of Agriculture.

Introduction

Outbreaks of animal disease can affect production, consumption and global trade. One disease that has had an effect on the world market for poultry meat is the Highly Pathogenic Avian Influenza virus HPAI (H5N1)[2]—commonly known as "bird flu." The disease spread out from Asia to Siberia, Russia, Central Europe, the Middle East, Africa, and eventually to the European Union (EU27) in 2006 and early 2007. Millions of EU27 birds died or were culled, and EU27 production declined 4.1 percent. Prices plunged, and demand for poultry meat declined (European Union Commission 2006).

HPAI can also infect humans. The virus outbreaks had been confirmed in 62 countries, with 650 human cases and 386 fatalities, as of February 2014 (World Health Organization 2014). Most human infections are caused by contact with live birds or with their uncooked meat. The World Organization for Animal Health (OIE, October 2005) and the David E. Swayne of the Southwest Poultry Research Laboratory (Swayne 2006) provided scientific evidence that cooking poultry meat kills the H5N1-virus, making poultry meat safer to handle and consume.

Research has shown that HPAI outbreaks have decreased the demand for poultry in many countries (Some of these studies are reviewed below). About the time of the HPAI outbreak, EU27 uncooked poultry imports started to decline and cooked poultry imports to increase. EU statistical trade data indicated that from 2005 to 2014, imports of cooked poultry meat more than doubled—from 314,000 metric tons to 665,000 metric tons—while imports of uncooked poultry declined sharply from 440,000 to 144,000 metric tons during the same period. Imports of all other meats declined substantially (Table 1).

The objective of this research is to investigate the impact of HPAI (H5N1) outbreaks on the EU27 meat import system after the 2006-2007 outbreaks. Did consumer concerns about the safety of poultry meat cause a demand shift toward safer products?

All previous studies concerning the impact of animal disease outbreaks and consumer behavior focused on the possible substitution of one fresh meat for others. For instance, following the BSE outbreaks in Europe in the 1980s and elsewhere, several economic studies demonstrated a consumer shift from fresh beef toward other fresh meats such as poultry, pork, and seafood. A unique feature of this report is splitting the potentially risky poultry meat into two categories with different levels of risk: cooked meat (where the pathogens are killed) and uncooked (that might contain pathogens).

We begin with a literature review, followed by an examination of EU-27 meat import volume, prices, and expenditure shares from January 1999 to 2014, a discussion of the methodology, empirical results, and conclusions.

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[2] Avian flu strains are classified as either high pathogenic or low pathogenic, based on the severity of the illness experienced by the bird population. With low pathogenic strains, the illnesses are not severe and affected birds usually recover.

Literature Review

There is widespread concern about HPAI because it is potentially fatal to humans. Bovine Spongiform Encephalopathy (BSE) provides another example of an animal disease that can be fatal to humans. BSE has been an issue longer than HPAI, and people's reactions to the disease might give us insights into their reactions to HPAI.

The discovery of BSE in the United Kingdom (UK) in 1986 triggered a shift away from beef consumption toward pork, chicken, and lamb (Burton and Young 1996; Henson and Mazzocchi 2002; and, Leeming and Turner 2004). Consumer fear of eating beef intensified after the British Government announced on March 20, 1996, the possible fatal link between BSE and a new variant, Creutzfeldt-Jakob disease (vCJD), which is potentially fatal in humans. Sharp declines in fresh beef consumption were reported in many other countries besides the UK (Atkinson 2003), including France (Latouche et al. 1998), the Netherlands (Mangen and Burrell 2001), Belgium (Verbeke et al. 2000; Verbeke and Ward 2001), Japan (Peterson and Chen 2005), and the United States (Schlenker and Villas-Boas 2009).

The (HPAI) (H5N1) virus was first isolated from a goose farm in Guangdong, China in 1986. The first HPAI outbreaks were reported in poultry farms and live animal markets. One year later, Hong Kong reported 18 human cases with six fatalities. Between late 2003 and early 2004, the virus reemerged and gained global attention when it was found in the poultry sectors of most East and Southeast Asian countries and spread to Russia, Kazakhstan, Turkey, the Middle East, Africa, and Western Europe in 2005-2007. As of February 2014, HPAI outbreaks had been confirmed in 62 countries, with 650 human cases and 386 fatalities (World Health Organization 2014).

Several studies have addressed impacts of HPAI outbreaks on domestic and international meat markets and have reported substantial disruption in poultry production, consumption, prices, and/or trade in many countries. In Vietnam, one month after HPAI struck Hanoi in January 2004, 74 percent of consumers initially stopped eating poultry meat or adopted alternative ways of preparing it to assure food safety (Figuie and Fournier 2008). In Taiwan, consumers were well informed about health risks associated with the disease and reduced their poultry consumption while increasing consumption of pork and seafood (Liu et al. 2007). In South Korea, Park, Jin and Bessler (2008) reported that the December 2003 HPAI outbreak, which occurred simultaneously with the first U.S. BSE case, causing poultry prices and consumption to decrease and demand for pork to rise. In Japan, Ishida et al (2010) reported that the 2003-04 HPAI outbreaks decreased domestic demand for chicken, increased demand for pork and fishery products as substitutes, and had no impact on beef. Onyango, et al. (2009) indicated that during HPAI outbreaks, consumers no longer viewed poultry meat as one homogenous product, but as three segmented products based on the perceived food safety risk. Paarlberg et al. (2007) analyzed the economic impacts of a hypothetical HPAI outbreak in the United States, concluding that the largest impact would be in the first quarter following the outbreaks.

EU-27 Meat Imports, Expenditures, and Unit-Values

Table 1 shows the yearly volume of EU imports of five classes of meats: cooked poultry, uncooked poultry, beef, pork, and all other meats. (All other meats consisted mainly of sheep, lamb, or goats, horse, and offal.) Imports of both types of poultry increased every year between 1999 and 2005. In 2006, the year (HPAI) (H5N1) virus first had a major appearance in the EU27, uncooked poultry imports declined. From 2006 to May 2014, cooked poultry volumes were generally rising while uncooked poultry volumes were declining. The fact that uncooked poultry started to decline when the EU had an HPAI outbreak is consistent with a demand shift away from uncooked to cooked poultry. In addition, Table 1 shows that beef, pork, and other meat imports were generally declining in the post-HPAI period. Figure 1 takes the quantities from Table 1 and turns them into indices with 2006 as the base, indicating a substantial increase in cooked poultry imports and a general decline in the other four classes of meat during the post-HPAI period.

Table 2 shows the unit-values for the five types of meat imports, a measure of the imported meat prices. Most years' unit values are higher than the previous ones. Uncooked poultry is always the least expensive of the five meat-types in the entire sample period. Over the post-EU-HPAI outbreak period of 2006-2014, the unit-value of pork and beef nearly doubled, while cooked poultry in comparison with uncooked poultry was imported at 39 percent premium in 2014 (Table 2). However, cooked poultry prices were less expensive than those of beef, pork and other meats.

Table 1. EU Imports of Meats by Type in Metric Tons[1]

Year	Cooked Poultry	Uncooked Poultry	Beef	Pork	Other Meat
1999	105,030	129,112	293,685	24,207	348,307
2000	195,682	129,158	285,697	14,467	344,464
2001	351,310	142,570	267,259	24,427	375,888
2002	341,426	163,079	344,388	24,158	337,053
2003	325,613	309,479	363,698	33,625	338,855
2004	231,878	368,728	425,611	40,703	335,618
2005	314,638	440,118	472,666	76,467	345,434
2006	434,333	303,383	475,759	95,788	348,999
2007	596,460	213,914	416,452	26,350	342,229
2008	651,406	213,255	301,377	43,430	339,867
2009	640,126	198,443	317,298	29,624	335,223
2010	634,180	166,793	288,292	19,193	299,154
2011	654,360	175,170	242,289	14,562	274,846
2012	694,347	173,521	233,175	15,021	240,631
2013	670,477	144,099	252,508	12,191	247,763
2014	665,330	143,539	238,678	12,305	281,002

[1] **Source.** World Trade Atlas. The First EU HPAI outbreak occurred in late January 2006.

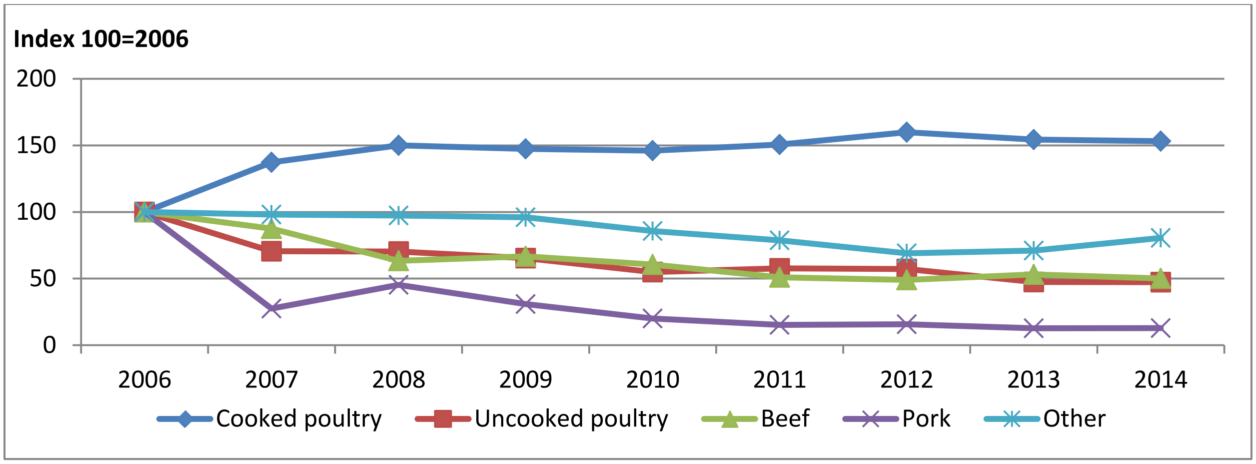

Figure 1. EU27 Indexes for Meat Imports by Volume, 2006-2014.
Source. World Trade Atlas.

Table 2. EU imports unit values in U.S. dollars per ton[1]

Year	Cooked Poultry	Uncooked Poultry	Beef	Pork	Other Meat
1999	3,198	1,989	4,572	2,403	3,494
2000	2,767	1,730	4,078	2,975	3,343
2001	2,623	1,860	3,300	2,958	3,523
2002	2,207	1,422	3,113	2,265	3,746
2003	2,455	1,515	3,439	2,322	4,122
2004	2,899	1,613	3,993	2,434	4,604
2005	2,683	1,646	3,915	2,354	4,987
2006	2,709	1,544	4,573	2,279	4,725
2007	2,966	2,315	5,655	3,728	4,985
2008	3,454	2,581	7,351	3,661	5,583
2009	3,057	2,109	5,917	3,205	5,027
2010	3,117	2,222	6,588	3,785	5,240
2011	3,452	2,486	8,606	4,720	6,619
2012	3,122	2,193	8,115	4,131	5,879
2013	3,179	2,296	7,624	4,153	5,279
2014	3,253	2,217	7,823	4,497	5,745

[1] **Source.** World Trade Atlas.
2014 data based on January-May. First EU HPAI outbreak in late January 2006.

The Applied Demand Model

The primary focus of this research is to discover what effect, if any, the outbreaks of HPAI had on EU27 meat import demand. To answer this question, we estimate a demand system for five classes of imported meats, using monthly data from January 1999 to May 2014, consisting of

185 observations, to test the system for HPAI effects. The five meats for analysis are the five classes previously discussed: cooked poultry, uncooked poultry, beef, pork, and other meats. The quantities in the applied demand analysis are metric tons. The unit values are the prices.

What Could We Expect to Find?

The rise in cooked poultry demand that started after the EU HPAI outbreak would leave us to expect that the outbreak might have something to do with the increase. One the other hand, the unit values show that cooked poultry became a better deal relative to most of the other meats in the post-HPAI period, which should also lead to an increase in its imports.

We could theoretically justify almost any change in import demand for poultry. For instance, the EU will not import poultry meat from infected countries unless it is made safe by cooking. Since uncooked meat would come from HPAI-free countries and cooked meat is free of the virus in any case, imported poultry of both types might be perceived as safer than EU-raised poultry; leading to increased demand for raw as well as cooked poultry meat. The loss of EU poultry production due to HPAI could have also expanded the demand for imported poultry. However, EU consumer concerns could as well have decreased demand for all types of poultry, even the safer cooked poultry. Our objective was to determine the actual cause behind the rise in EU demand for cooked poultry.

Reasons for Choosing the CBS Empirical Model

Our applied demand model is the CBS model of Keller and Van Driel (1985). They developed the CBS as a model of consumer demand that can be made consistent with optimization theory. Imported meat is an intermediate good; it must be further processed prior to final sale. However, Theil (1977) demonstrated that consumer demand systems like the CBS could be used to model cost-minimizing input demands. One merely needs to reinterpret some of the terms. Our demand analysis is conditional on market “scale.” Scale is a measure of the total amount of output produced from the imported meats. We will not attempt to discover if HPAI had an effect on EU27’s scale of import demand.

The CBS is a differential demand model. One advantage of differential models is that it is easy to put taste shifters directly into these models while keeping them consistent with theory. Putting demand shifts in models based on primal-dual functions, for example the Almost Ideal Demand System, AIDS is more complicated. See Alston, Chalfant, and Piggott (2000), who discussed these issues in the context of modeling advertising’s effects on demand.

The CBS has two more appealing features. First, Keller and Van Driel demonstrated that the CBS is a flexible functional form, meaning that the model is able to generate any set of demand elasticities for a given set of prices and quantities. Technically, these set of elasticities do not need to be consistent with optimization theory; making demand elasticities consistent with optimization requires restrictions on the CBS coefficients. Second, theory requires that the own-price and cross-price derivative matrix of cost-minimizing input demands should be negative semi-definite (NSD). Keller and Van Driel demonstrated that the CBS will be globally NSD if its price coefficients are locally NSD[3].

The CBS Model as Applied to Input Demand

Our discussion of the CBS model will be brief, mainly focusing on modeling the effects of HPAI on import demands. Those readers interested in more detail on the CBS and other differential models can find them in Barten and Bettendorf (1989), who discuss three differential demand models and their inverse forms, the Rotterdam, the CBS, and the differential AIDS, or DAIDS. Eales, Durham, and Wessells (1997) build a composite demand system using these three models and the NBER model.

Let $q_{i,t}$ and $p_{i,t}$ stand for the quantities and prices of imports i={cooked poultry, uncooked poultry, beef, pork, and other meat} for the months numbered "t". We can define the symbols:

$$x_t = \sum_i q_{i,t} * p_{i,t},$$
$$w_{i,t} = \frac{q_{i,t} * p_{i,t}}{x_t},$$
$$\Delta Q_t = \sum_j \frac{1}{2}\left(w_{i,t} + w_{i,t-1}\right)\Delta \ln q_{i,t},$$
$$\Delta P_t = \sum_j \frac{1}{2}\left(w_{i,t} + w_{i,t-1}\right)\Delta \ln p_{i,t}, \text{ and}$$
$$y_{i,t} = \frac{1}{2}\left(w_{i,t} + w_{i,t-1}\right)\left(\Delta \ln q_{i,t} - \Delta Q_t\right)$$

The term x_t is the total expenditure on the goods in period "t." Since we are treating the CBS as a derived demand system, x_t is the objective of the importing firms. Total expenditure is a constraint for consumer demand cases. The "w" terms are the costs shares, while ΔQ_t and ΔP_t are changes in quantity and price indices. The quantity index is often called the "scale" term. Theil demonstrated that scale is a measure of the total output produced from the inputs under certain conditions. Finally, the term $y_{i,t}$ is the endogenous variable of our CBS demand model. The CBS endogenous variables sum to zero in every time period. A basic CBS demand model can be written:

$$(1) \quad y_{i,t} = \sum_k a_{i,k} z_{k,t} + \sum_j c_{i,j}\, \Delta \ln p_{j,t} + b_i \Delta Q_t + e_{i,t}$$

Equation (1) has some new exogenous variables, the $z_{k,t}$, and their coefficients, $a_{i,k}$. The basic set of "z" variables includes an intercept and monthly dummies. The $c_{i,j}$ are estimated price coefficients and the b_i are scale coefficients. Finally, we have a random error term, $e_{i,t}$.

We imposed the following restrictions on the coefficients to make the CBS estimates consistent with theory:

[3] Why all the concern about NSD? Researchers may want to use these estimates in future analyses of EU imports. One of the present authors has used published demand elasticities in building policy-analysis models. Sometimes these published estimates have not been NSD. Although the own-price elasticities of demand were negative, after inversion some of the own-quantity flexibilities of demand were positive!

(2) $\sum_i a_{i,k} = 0, \forall k,$

(3) $\sum_i c_{i,j} = 0, \forall j,$

(4) $\sum_i b_i = 0,$

(5) $\sum_j c_{i,j} = 0, \forall i$, and

(6) $c_{i,j} = c_{j,i}, \forall\ i, j.$

In order for the CBS to be globally NSD, a matrix made of the $c_{i,j}$ coefficients must also be NSD. We imposed (equations 2-6) on the CBS estimates and also required that the matrix of $c_{i,j}$ be NSD.

As we noted above, the CBS endogenous variables sum to 0 in each time period. This makes the covariance matrix of the errors singular. The solution to estimating these types of demand systems is to drop one of the equations from the model and estimate the rest. One then uses (2), (3) and (4) to estimate the parameters of the excluded equation. If we use the maximum likelihood estimation, MLE, the estimates are independent of the excluded equation (Barten 1969).

Dynamic Adjustment

Because a month is a relatively short period, we modified (1) to allow for dynamic adjustment:

(7) $$y_{i,t} + \sum_{l=1}^{L_y} \phi_l y_{i,t-l} = \sum_k a_{i,k} z_{k,t} + \sum_{l=0}^{L_x} \theta_l \left[\sum_j c_{i,j}\, \Delta \ln p_{j,t-l} + b_i \Delta Q_{t-l}\right] + e_{i,t}$$

The symbols ϕ_l and θ_l are lag coefficients for the endogenous and exogenous; θ_0, the "lag" coefficients for the current prices and scale is set to 1. We have an implicit ϕ_0 that is also 1. Note that (7) may have different lag lengths for the endogenous and exogenous variables. The structure in (7) ensures that the CBS model is consistent with theory in all lengths of run.

The price and scale elasticities are going to vary over the length of run. The shortrun, cost-minimizing price and scale elasticities of the CBS demand function are:

(8) $\frac{c_{i,j}}{w_i}$, the short-run price elasticity of product "i" with respect to price j, and

(9) $1 + \frac{b_i}{w_i}$, the short-run scale elasticity of demand for product i.

The long run elasticities are:

(10) $\frac{c_{i,j}}{w_i}\frac{\sum_l \theta_l}{\sum_l \phi_l}$, the longrun price elasticity of product "i" with respect to price j, and

(11) $1+\frac{b_i}{w_i}\frac{\sum_l \theta_l}{\sum_l \phi_l}$, the longrun scale elasticity of demand for product i.

Note that we have dropped the time subscripts from cost-share terms (the w_i) in the elasticity formulas. CBS and other differential demand system elasticities vary with different budget shares. If all the b_i coefficients are 0, the scale elasticities are all 1 and EU meat import demand is consistent with constant returns to scale, CRTS. One of the side-issues we test is CRTS. We also test lag lengths for the endogenous and exogenous variables.

Differential Models and Demand Shifts

We model HPAI as a demand-shifting effect. The HPAI effects work much like the intercepts and seasonal dummies already included in the model. Typically, the intercept in a differential demand model is treated as a "taste" shifter (See Keller and Van Driel, 1985). Since we are dealing with input demands, the intercept will measure some mix of taste and technology changes. The monthly dummies are also taste/technology shifters; we would expect that there are more seasonal shifts in consumer tastes than in meat-processing technology. We would further expect that HPAI would affect consumer tastes for the final outputs more than meat-processing technology.

Barten and Bettendorf (1989) showed how the endogenous variables of the different differential demand models relate to one another. If there are no changes in prices or scale, the CBS and DAIDS endogenous variables are the same, at least at the derivative level. The DAIDS endogenous variable is the change in $w_{i,t}$, the cost share. If a good's intercept is positive, that implies an increasing share of total input cost will be spent on the good, all other things held the same (One good's positive intercept will need to be offset by one or more different good's negative intercept). In theory, we could solve for the price and scale effects on demand and then solve intercept, seasonal, and other taste-shifting effects. Any non-price, non-scale factor that increases the cost share by 1% in one month will basically increase the cost share 1% for all following months[4].

The intercepts and seasonal dummies are not differenced. If we take the first difference of a trend, we get an intercept. The intercept terms in differential demand models imply a type of trend in tastes and technology, or at least a trend in the cost shares.

The 12 monthly dummies and the intercept are perfectly collinear. We decided to identify the monthly dummies by making the 12 of them sum to 0 for each meat. The "trend" implied by the combination of the intercept and monthly dummies changes month-to-month. However, because we make the monthly dummies for each meat sum to 0 over the year; the seasonal effects cancel

[4] The lagged-endogenous-variable effects built into the dynamic specification will modify this effect.

and the intercept measures that "pure" trend effect (Another side issue we also test is the significance of the intercepts and monthly dummies).

Adding HPAI Shifts

Most of the disease-event studies cited above deals with a single outbreak of a disease. Those studies that track responses over time generally find that the initial response to an outbreak is more extreme than the longer-term responses. We wanted our HPAI effects to allow for differences in the short- and longrun responses. We also need to deal with the fact that the EU had a number of HPAI outbreaks spread over 14 months.

Table 3 shows the "events" we built into our model. The first EU HPAI cases were discovered so late in January 2006 that we treat February 2006 as the first outbreak month. The EU had outbreaks in February and March 2006. We also make April 2006 an "outbreak" month to allow for lagged responses to the first two months of outbreaks. There were outbreaks in July 2006; August 2006 gives us a potential lagged response to those outbreaks. There were more outbreaks in January and February 2007; we made March 2007 a lagged-outbreak month.

Table 3. The Outbreak Months

Events	**Month**	**Disease Dummy Number**
Greece & Bulgaria, Jan 30-31 put in February	Jan-06	
Italy and others	Feb-06	1
Poland and others	Mar-06	2
Lagged month	Apr-06	3
⁞	⁞	⁞
Spain, July 7	Jul-06	4
Lagged month	Aug-06	5
⁞	⁞	⁞
Hungary	Jan-07	6
UK turkey farm	Feb-07	7
Lagged month	Mar-07	8

We allowed HPAI to have three types of effects on demand: temporary, permanent, and trend. With eight events and three types of responses, we are adding 24 outbreak dummies to the model. These we denote $v_{t,o,d}$. The subscript o is for the "outbreak", o=1,2,…8. The "d" subscript is for the disease effect, d= {temporary, permanent, trend}.

We start with the trend effect. As noted above, non-0 intercepts imply a non-linear trend in demand. We allowed HPAI to change the intercepts. Statistically significant changes in the intercepts imply a change in these trends. The dummy variable for a trend effect would be 0 before the event and 1 in the event month and all following months.

As discussed above, anything that changes demand in one period changes it in all following periods. We would get a permanent change in demand if HPAI causes a one-time change demand in any (or all) outbreak months. The dummy variable for a permanent change is 0 for all months except the outbreak month, where it is 1.

For the temporary effects, we make the dummy variable 1 in the outbreak month and -1 the following month. The temporary effects work like the monthly dummies except that the monthly dummies cancel out over the course of a year and the temporary effect cancels itself out the following month. Note that one can get the permanent dummy for an outbreak by taking the first difference of the trend dummy and that of the temporary dummies by differencing the permanent ones.

Our most complex model defines the disease effects using three sets of estimated parameters. These are g_o, λ_d, and $f_{i,d}$. The term g_o is defined over the eight basic outbreak types; λ_d is defined over the response types, {trend, permanent, temporary} and $f_{i,d}$ over the meats and response types. If we set all the λ_d=0, we can write the model with HPAI effects as:

$$(12) \quad y_{i,t} + \sum_{l=1}^{L_y} \phi_l y_{i,t-l} = \sum_k a_{i,k} z_{k,t} + \sum_{l=0}^{L_x} \theta_l \left[\sum_j c_{i,j} \Delta \ln p_{j,t-l} + b_i \Delta Q_{t-l} \right] + \sum_{o,d} v_{t,o,d}\, g_o f_{i,d} + e_{i,t}$$

With the side constraints:

$$(13) \quad f_{i,d} = 0 \ \forall d$$

$$(14) \quad \textstyle\sum_o g_o = 1, \text{ and}$$

$$(15) \quad g_o \geq 0.$$

Equation (13) allows us to identify the disease effects for the excluded equation. We need (14) as an arbitrary equation to identify the system as a whole. For instance, we could double each *g* and halve each *f* and get the same net disease effect.

The disease-effect structure in (12) means that HPAI effects are consistent across the events. If one month's outbreak temporarily increases cooked poultry demand, all month's outbreaks temporarily increase, or at least do not *decrease* cooked poultry demand. That is why we require that each g_o be positive. Because the *g's* are shared across the types of reactions, events that cause large temporary effects also cause (relatively) large permanent and trend effects.

Our most complicated model uses distributed lags of the dummies; this is where the λ_d come into play. We introduce a non-stochastic state variable, $s_{d,t}$. Note that this is defined over the adjustment type. The state-variable is created-estimated using the following formula:

(16) $s_{d,t} = \lambda_d s_{d,t-1} + \sum_o g_o v_{t,o,d}$, with the side restriction that: $0 \leq \lambda_d \leq 1$.

Equation (16) defines the state variable as a first-order process of its lagged value, the g_o, and the disease dummies. The larger the value of λ_d, the longer it takes the state variable to adjust. For the more complicated model, the CBS function is written:

(17)
$$+\sum_{l=1}^{L_y} \phi_l y_{i,t-l} = \sum_k a_{i,k} z_{k,t} + \sum_{l=0}^{L_x} \theta_l \left[\sum_j c_{i,j} \, \Delta \ln p_{j,t-l} + b_i \Delta \right.$$
$$+ \sum_d s_{d,t} f_{i,d} + e_{i,t}$$

The slower adjustment of the state variables to HPAI shocks will make for more drawn-out adjustment to the HPAI events. We have put upper and lower bounds on the λ_d. If a λ_d is 1, we get an interesting effect; basically the underlying dummy variable gets undifferenced. Temporary effects become permanent effects; the implicit permanent effect's λ_d is 0. Making the permanent λ equal to 1 turns the permanent effect into a trend shifter. If the trend λ is 1, we end up with a squared trend.

Special Econometric Issues

Our specification of the HPAI effects raises a testing problem that Davies (1977) was the first to identify. He called it the "nuisance parameter" problem. Suppose that we want to test whether or not HPAI changed the trends in demand. We could test that hypothesis by running a model where all five *f* coefficients for the trend effect are 0. This would be a 4-degree of freedom restriction considering the restriction (13). However, if all the trend-*f* is 0, we cannot identify λ_{trend}. These nuisance-parameter cases violate the conditions that make coefficient tests asymptotically normal or chi-square. If we eliminate HPAI effects entirely, we cannot identify the g_o either—compounding the nuisance-parameter issue. Recall that the g_o and λ_d coefficients have upper and lower bounds; these bounds also violate the conditions that produce asymptotic normality.

We will use likelihood-ratio tests for model restrictions. For the nuisance-parameter cases, we will evaluate these tests using Monte-Carlo analysis. We will employ a constrained model's estimates to generate "new" observations and an empirical distribution for the tests. We can compare the actual test result to the Monte-Carlo test distribution to determine whether the actual test is significant.

Empirical Results and Interpretations

We performed some initial tests on the basic model structure prior to testing the HPAI effects. We started with six lags for the endogenous and exogenous variables in the dynamic specification outlined by equation (12). None of the exogenous-variable lags θ_l , l=1…, six are significant. The first two lags for the endogenous variables were statistically significant. We used the 2-endogneous variable lag model to test the intercepts, monthly dummies, and for constant returns to scale (CRTS). The intercept and 3 of the monthly dummies, April, October, and November, were statistically insignificant, as were the CRTS restrictions. These intercept, dummy, and CRTS restrictions were jointly insignificant as well. We used a model with these restrictions to test for the HPAI effects.

Testing HPAI Effects

Table 4 shows the likelihood ratio tests for excluding the HPAI effects from the model. In addition to the likelihood ratio tests, we show the estimated λ associated with each set of restrictions. Recall that when a λ's f coefficients are set to 0, that λ cannot be identified. The first three rows of Table 4 are tests of eliminating one of the HPAI-d type effects. If eliminating an HPAI effect were a 4-degree of freedom restriction and if these tests were chi-square tests[5], none of the single-elimination tests would be significant.

Table 4. Likelihood Ratio Test for HPAI Effects

		λ Estimates for the Constrained Models[1]		
Restrictions	**Test**	Temporary	Permanent	Trend
Temporary out	4.75		0.000	0.000
Permanent out	4.55	0.984		0.611
Trend out	1.39	0.293	0.509	
Temporary only	6.15	1.000		
Permanent only	6.15		0.000	
Trend only	52.99			0.000
All three out	56.54			

Note. [1] When an effect has been excluded, its cell is blank.

The next three rows show what happens when we use only one of the three HPAI effects, eliminating two of them. Note that results of the two tests; using only the temporary or the permanent effects are the same. They are not just the same to the decimal show in the table, they are exactly the same. If we use only a temporary effect, its λ goes to 1, turning the temporary effect into a permanent effect. Using only the permanent effect makes its λ go to 0. The permanent-only and temporary-only models are actually the same. The test value, 6.15, is not significant for a chi-square with 8 degrees of freedom. However, the tests for using only the trend effects or eliminating all three disease effects would be highly significant if they were distributed chi-square.

We did two sets of Monte-Carlo analysis on these tests. First, we evaluated the test statistic for using only the permanent effects, dropping temporary and trend. We used the permanent-only model's coefficient estimates to generate simulated sets of data. We used this simulated data to test the effect of adding back in the two (other irrelevant) types of effects, saving all the test

[5] The nuisance-parameter issue will prevent this test from being asymptotically chi-square. See Davies (1977).

iterations. We set up our Monte-Carlo program to do 5,000 iterations of the test but ended up stopping the program early.

Why did we stop early? We are using the conventional 5% critical value for our tests. We do not really need to know what the true 5% value for our test statistic is; we just need to know if our test statistic is above or below that value. Supposing that the value 6.15 was actually significant at the 5% level or above, we would see values 6.15 or greater 5% of the time (or less) in our Monte-Carlo iterations. In 383 iterations 337 of the tests, 88%, were larger than 6.15. With 383 observations 88% is highly significantly different from 5%. The second set of Monte-Carlo iterations tested eliminating the permanent effect for the model as well. We stopped early again, as in 726 iterations none of the Monte Carlo tests exceeded the actual test. With 726, an estimated 0% is also highly significantly different from 5%, implying that the actual test value is significant at over the 5% level.

HPAI Estimates and Implications

We allowed for three sets of HPAI terms; only one of these is significant, the "permanent" set. There is no change in the trend effect due to HPAI—an appealing effect given that the pre-HPAI meat import demand had no taste-technology trend either. Our final model uses only the permanent HPAI shifts. Since the λ for the permanent effects went to 0, we imposed that on the model as well. That means our HPAI effects can be written by multiplying the permanent *v* dummies, and the f_i and g_o coefficients as in equation (12). Table 5 shows the estimated permanent *f* coefficients and their standard deviations:

Table 5. HPAI Estimates and Effects[1]

	Disease Coefficients for Permanent Effects			**Longrun Shift in EU Import Demand Due to HPAI**		
	Estimate	Standard Deviation	z Statistic	Estimate	Standard Deviation	z Statistic
Cooked Poultry	0.1169	0.0549	*2.13*	0.0674	0.0317	*2.13*
Uncooked Poultry	-0.0696	0.0252	*-2.76*	-0.0401	0.0145	*-2.77*
Beef	-0.0218	0.0511	*-0.43*	-0.0126	0.0296	*-0.43*
Pork	-0.0869	0.0166	*-5.23*	-0.0501	0.0095	*-5.25*
Other Meat	0.0614	0.0532	*1.15*	0.0354	0.0308	*1.15*

Note. [1]Based on 5,000 Monte-Carlo iterations.

The HPAI coefficient for cooked poultry is positive and statically significant, while those for uncooked poultry and pork are negative and statistically significant. On the other hand, coefficients of beef and other meat were negative and positive, respectively, but statistically insignificant. These estimates imply that HPAI increases the demand for cooked poultry while decreasing it for uncooked poultry—essentially the results we would expect if the internal HPAI outbreaks made EU meat importers or their customers more concerned about the safety of uncooked poultry. Table 5 also shows the longrun impact of the HPAI demand shifts on EU27 meat imports. These coefficients are the *f* estimates divided by the sum of the lagged-endogenous variable coefficients.

Table 6 shows that the endogenous variable lag coefficients have quite small standard errors. The lagged endogenous coefficients are all positive; this makes current demand negatively related to lagged demand. Our estimates show that EU import demand has a tendency to overreact in the short run to changes in prices and HPAI.

The pattern of EU27 reaction to HPAI is going to depend on the g_o. Table 7 shows these estimates and confidence intervals. We show 95% confidence intervals rather than standard errors because the sign constraints on the *g* will insure that they are not normally distributed[6]. Our estimates imply a relatively small initial effect of HPAI in February 2006; the market reaction was stronger in March 2006. The next two "events" have 0 estimated weights. The remaining four event months all have non-0 weights.

Figure 2 shows our simulations of how demand shifted over time in response to HPAI. We only show 2006 and 2007 as the HPAI effects stabilize in mid-2007, a few months after the last EU outbreak. The largest changes in demand are associated with the outbreak in January 2007 (Figure 2; Table 7.)

Table 6. The Endogenous Variable Lag Estimates[1]

	Lag 0	**Lag 1**	**Lag 2**
Estimate[2]	**1**	0.4650	0.2701
Standard Deviation		0.0315	0.0345
z Statistic		*14.77*	*7.84*

Note. [1] Standard deviations and z statistics based on 5,000 Monte-Carlo iterations.
[2] The lag-0 estimate is fixed to 1.

[6] Even without the sign constraints, these estimates are unlikely to have a normal distribution. Normality is an asymptotic distribution for these types of models with nonlinearity and lagged-dependent variables. We have only eight observations to measure the HPAI effects, meaning they have no asymptotic properties.

Table 7. The "g" Estimates, the Weights for Each of the "Outbreak" Months

			95% Confidence Interval[1]		
Date	**Type of Event**	**Estimated Weight**	Upper Bound	Lower Bound	**Iterations when MC[2] Estimates are 0**
February-06	outbreak	2.65%	12.96%	0.00%	1,669
March-06	outbreak	17.53%	27.54%	6.22%	9
April-06	post-outbreak	0.00%	10.62%	0.00%	2,473
July-06	outbreak	0.00%	11.19%	0.00%	2,508
August-06	post-outbreak	26.22%	36.23%	14.28%	0
January-07	outbreak	35.58%	46.32%	22.07%	0
February-07	outbreak	8.98%	18.94%	0.00%	409
March-07	post-outbreak	9.03%	18.95%	0.00%	355

Note. [1] 95% confidence interval based on the 2.5th and 97.5th percentile of 5,000 Monte Carlo iterations.
[2] MC = Monte-Carlo.

The Model's Own and Cross-Price Elasticities

Table 8 shows the own and cross-price elasticities of demand implied by our CBS coefficient estimates. The Appendix has the CBS coefficient estimates underlying these elasticities. We use average budget shares for the post-HPAI period to calculate these coefficients. The scale elasticities are not shown in Table 8; when we accepted the hypothesis that EU27 import demand was consistent with constant returns to scale, we fixed the scale elasticities to 1.

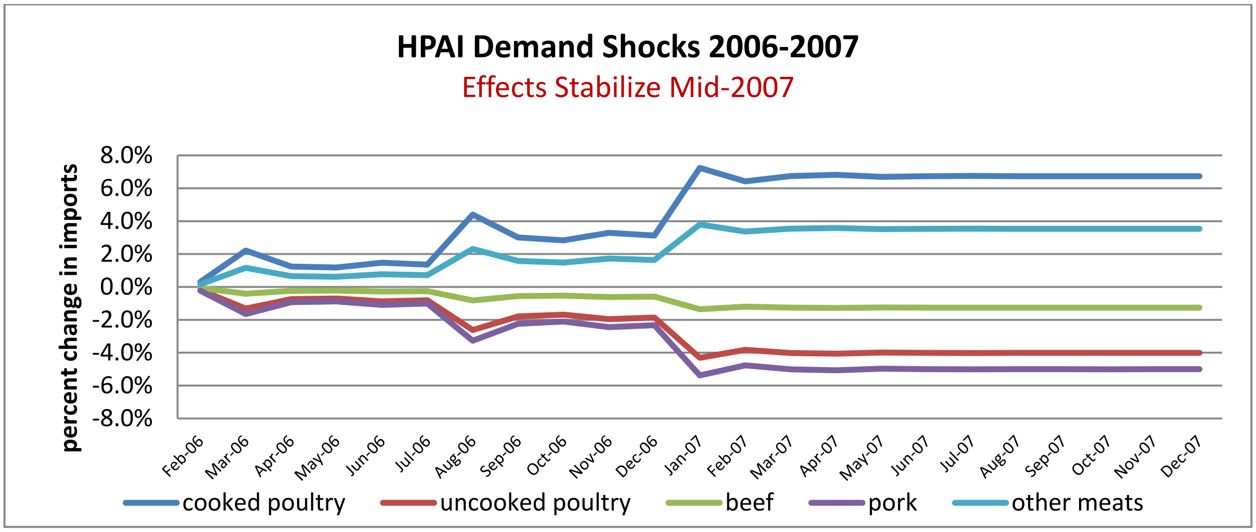

Figure 2. The HPAI Demand Shifts Implied by the Estimates

Table 8. Longrun Cost-Minimizing Price eElasticities of Demand

	Prices				
Quantities	**Cooked Poultry**	**Uncooked Poultry**	**Beef**	**Pork**	**Other Meat**
Cooked Poultry	-0.274	0.045	0.054	0.040	0.135
Uncooked Poultry	0.206	-0.109	-0.138	0.012	0.029
Beef	0.053	-0.029	-0.059	0.026	0.010
Pork	0.777	0.052	0.519	-0.640	-0.708
Other Meat	0.165	0.008	0.012	-0.044	-0.141
Cost Shares, Post-HPAI Average	32.03%	6.91%	33.22%	1.63%	26.21%

All the own-price elasticities are inelastic. We might generally expect that the demand for imports would be highly elastic. Typically, EU27 meat imports are a small part of domestic consumption-production and small changes in domestic conditions can lead to large percentage changes in trade. These, however, are cost-minimizing elasticities subject to output scale; these demands are likely to be much less elastic than the unconditional import demand elasticities.

Cooked poultry's cross-price elasticities with the four other meats are all positive, implying that it is a substitute for the rest of the meats. Import demand for cooked poultry increased as a substitute for uncooked poultry due to customer concern about the safety of uncooked poultry. In addition, due to the lower relative prices of cooked poultry, it was partly substituting for beef, pork, and other meat, causing EU 27 import demand for cooked poultry to increase.

Conclusions

After its HPAI outbreak, EU cooked poultry imports trended upward, while the other four meat classes we examined decreased over time. Our estimates were designed to determine what drove these trends in EU meat imports. The estimates show that HPAI is associated with statistically-significant increases in the demand for cooked poultry and statistically significant decreases in the demands for uncooked poultry and pork. Pork demand had a slightly larger percentage decrease than uncooked poultry demand (Figure 2). However, pork import volumes are the by far the smallest of the five meats (Table 1). The HPAI-related demand shift for uncooked poultry implies a much larger shift in the tonnage of uncooked poultry imports than the percentage decline in pork imports. However, as Figure 2 shows the EU market's response to HPAI was largely completed by mid-2007. The trends in meat imports after that are largely driven by price changes. Cooked poultry prices became an increasingly good bargain compared to the rest of the meats in the post-HPAI outbreak period.

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Appendix

The $c_{i,j}$ coefficient estimates and their Monte-Carlo "z" statistics are found in Table A1. Because these coefficients are symmetric, we show only the upper-triangular terms. Our use of "z" statistics in Table A1 is slightly misleading. For example, it would appear that two of the own-price terms are statically insignificant: uncooked poultry and beef. The $c_{i,j}$ were estimated subject to the condition that their matrix is NSD. None of the own-price terms is greater than or equal to 0 in any of the Monte-Carlo iterations. The monthly dummies and their z statistics can be found in Table A2. In this case the z statistics are more meaningful.

Table A1. ci,j Parameter Estimates and z[1] Statistics

		Cooked Poultry	**Uncooked Poultry**	**Beef**	**Pork**	**Other Meats**
Cooked Poultry	Estimate	-0.1522	0.0247	0.0303	0.0220	0.0751
	z statistic	*-4.28*	*1.77*	*1.36*	*2.48*	*2.87*
Uncooked Poultry	Estimate		-0.0131	-0.0166	0.0015	0.0035
	z statistic		*-1.38*	*-1.75*	*0.28*	*0.29*
Beef	Estimate			-0.0340	0.0147	0.0056
	z statistic			*-1.66*	*2.07*	*0.30*
Pork	Estimate				-0.0181	-0.0201
	z statistic				*-3.60*	*-2.50*
Other Meats	Estimate					-0.0642
	z statistic					*-2.23*

Note. [1] 'z" statistics based on 5,000 Monte Carlo iterations

Table A2. Monthly Dummy Estimates[1] and z Statistics[2]

Table A2. Monthly Dummy Estimates[1] and z Statistics[2]

		Jan	**Feb**	**Mar**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Dec**
Cooked Poultry	Estimate	0.0081	0.0093	-0.0483	0.0100	0.0099	0.0174	0.0037	0.0058	-0.0159
	z statistic	1.38	1.65	-8.66	1.80	1.73	2.96	0.65	1.04	-2.90
Uncooked Poultry	Estimate	-0.0026	-0.0055	-0.0045	0.0048	-0.0002	0.0073	0.0100	-0.0006	-0.0087
	z statistic	-0.96	-2.12	-1.74	1.90	-0.07	2.74	3.88	-0.22	-3.39
Beef	Estimate	-0.0146	-0.0086	-0.0309	-0.0174	0.0385	0.0094	0.0181	0.0171	-0.0116
	z statistic	-2.64	-1.59	-5.85	-3.32	7.06	1.68	3.26	3.26	-2.17
Pork	Estimate	-0.0061	-0.0032	-0.0001	0.0040	-0.0008	0.0017	0.0022	0.0011	0.0011
	z statistic	-3.69	-1.97	-0.04	2.68	-0.49	1.02	1.32	0.73	0.70
Other	Estimate	0.0152	0.0080	0.0837	-0.0014	-0.0475	-0.0357	-0.0339	-0.0234	0.0351
	z statistic	2.63	1.43	15.10	-0.24	-8.44	-6.30	-5.94	-4.16	6.37

[1] The monthly dummies sum to 0 over the year. Those for April, October, and November are set fixed to 0 and not shown.
[2] ‘z” statistics based on 5,000 Monte Carlo iterations

