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Factors Influencing Export Value Recovery after Highly Pathogenic Poultry Disease Outbreaks

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Abstract

Many factors influence a country's international poultry market accessibility, including freedom from diseases such as highly pathogenic avian influenza and highly pathogenic strains of Newcastle disease. This study examines OIE-reported events of these two diseases over a 16-year period to determine the factors that contributed significantly to trade revenue recovery time. Results indicate that the elements influencing a measurable negative export revenue effect due to disease—including risk perceptions and whether the disease is zoonotic—differ from the elements that influence the length of revenue recovery, such as product affordability. In addition, overall global economic health and growing meat demand are elements that matter at the time an event occurs. The magnitude of elements influencing trade revenue during disease events suggests that recovery from HPAI and ND events may take months, not years.

Keywords: trade, poultry, highly pathogenic avian influenza, Newcastle disease

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Introduction

Trading partners may impose trade bans on live birds, poultry products, hatching eggs, and egg products during or after highly pathogenic poultry disease events, such as highly pathogenic avian influenza (HPAI) and highly pathogenic strains of Newcastle disease (ND). For countries that export a large proportion of their poultry production, these trade bans can be very costly. A multitude of elements may influence the length of market recovery after a disease event, such as disease type, product type and value, world supply, disease management timelines, disease event size and duration, and country credibility (FAO 2006). In addition, political changes, price changes, weather, and consumer response can impact the length of export market recovery. Although trade restrictions have been used in response to low pathogenic avian influenza events, this research focuses on HPAI and ND events reportable to OIE.

In the last two decades, HPAI and ND events have occurred in areas previously free of those diseases, especially with the introduction and spread of the H5N1 strain of avian influenza. The World Organization for Animal Health (OIE) guidelines suggest that a country previously free of avian influenza can regain its disease-free status three months after the last bird has been destroyed, all premises are disinfected, and surveillance conducted (OIE 2014a). ND outbreaks meeting OIE criteria[1] for being highly pathogenic are reportable, and the guidelines suggest disease freedom status is restored after three months following similar culling, disinfection, and surveillance criteria (OIE 2014b). The OIE defines Newcastle disease to include infection among poultry, which includes all domesticated birds used for the production of meat or eggs for consumption, products, restocking supplies, or breeding (OIE 2014c). Birds kept in captivity for other reasons and wild birds are not considered poultry, so ND in wildlife is not required to be reported. Economic consequence estimates for livestock disease events tend to be sensitive to export market reaction assumptions, especially in the case of a large world exporter. However, little information is available on which to base assumptions of export market reactions other than OIE guidelines.

Importing countries make three decisions in response to a disease event: 1) whether to ban imports from a country with an HPAI or ND outbreak, 2) whether a trade ban will apply to the entire country or a specific geographical area, and 3) the amount of time a ban will remain in effect. It is generally assumed that a trade ban will occur for a country that exports poultry products with some risk of disease spread. Expectations on trade bans due to sanitary restrictions in turn affect domestic markets and producer behavior (Ruhl 2009), making expectations of trade consequences an important part of poultry disease consequence analysis. Little trade consequence research has been done on ND. For HPAI, some analysts have used the OIE three-month guidelines to develop trade resumption scenarios for economic impact analyses. These researchers also noted that the observed length of export bans did not always match OIE

[1] Newcastle disease is defined by OIE as an infection of birds caused by a virus of avian paramyxovirus serotype 1 (APMV-1) that meets one of the following criteria for virulence: a) the virus has an intracerebral pathogenicity index (ICPI) in day-old chicks (Gallus gallus) of at least 0.7, or b) multiple basic amino acids have been demonstrated in the virus (either directly or by deduction) at the C-terminus of the F2 protein and phenylalanine at residue 117, which is the N-terminus of the F1 protein. Source. http://www.oie.int/fileadmin/Home/fr/Health_standards/tahm/2.03.14_ NEWCASTLE_DIS.pdf.

guidelines, and the lifting of bans did not always mean the export market recovered immediately (Paarlberg 2007; Junker et al. 2009; Hagerman et al. 2012; Philippidis and Hubbard 2005).

Current research builds off previous work that summarized disease events affecting poultry and elements hypothesized to contribute to export market recovery times (Johnson et al. 2011; Johnson and Stone 2011a, 2011b). In addition, Johnson and others (2012) looked at events of eight different diseases affecting multiple species, including poultry, and found the percentage of a country's exports destined for Asian countries had the greatest potential to lengthen export market recovery time; however, poultry was not examined explicitly. Because the model was not statistically significant, no confidence could be placed on the conclusions.

One consideration is that trade partners may wait for additional proof of disease freedom or have already changed product source countries (Park et al. 2008), which will effectively extend trade revenue recovery beyond the OIE's three-month wait period to regain disease-free status. Several studies have examined scenarios with extended trade revenue recovery times in which trade markets were assumed to be fully closed down for multiple years (Morgan and Prakash 2006; Nogueira et al. 2011; Hayes et al. 2011). Disease events that have the potential to be zoonotic[2] are associated with longer export market recovery times (Morgan and Prakash 2006). Certain strains of HPAI have been known to transmit from poultry to humans, causing a wide range of potentially life-threatening symptoms. Since 2003, hundreds of human HPAI H5N1 cases have been reported primarily in Asia, making it an important zoonotic disease. ND infections in humans can cause mild conjunctivitis and influenza-like symptoms, mostly resulting from occupational exposure. ND is not considered an important zoonotic disease. Further, no human cases of ND have occurred from eating poultry products (CFSPH 2008).

To date, no analysis has focused on trade recovery times shorter than the OIE guidelines. The potential for widely varying trade recovery estimates has led to the use of stochastic methods for trade recovery estimation (Niemi and Lehtonen 2011, 2014). However, additional analysis of observed trade recovery is needed to develop distributions for this stochastic methodology.

This research contributes toward filling a gap in the trade and animal health economics literature by identifying and quantifying the elements that influence global poultry trade after HPAI and ND events. In order to accomplish this, the authors evaluated 71 HPAI and ND events to determine what factors have a significant influence on the amount of time needed to achieve export market recovery. Since ND and HPAI affect poultry and have similar sanitary restriction guidelines, the information from this research will be useful in refining export market reaction parameters as researchers develop scenarios for models to estimate the economic impacts of poultry diseases.

[2] OIE defines zoonosis as any disease or infection which is naturally transmissible from animals to humans. Source. http://www.oie.int/index.php?id=169&L=0&htmfile=glossaire.htm.

Data

The OIE website reports detailed information about disease events, including how many outbreaks are associated with the event. Each observation in the dataset used in this analysis represents a highly pathogenic poultry disease event in non-endemic countries, using that country's geopolitical borders to define the area. The dataset contained observations on 71 HPAI and ND events affecting birds in 25 countries on 5 continents[3] between September 1998 and August 2013. Geographical proximity of countries experiencing HPAI and ND events was examined to determine if a combination of some outbreaks was actually one event that crossed geopolitical borders. However, the cross-border clustering of outbreaks only appeared obvious in one location—ND outbreaks in Belgium and the Netherlands in 2009. Thus, clustering of outbreaks across country borders was not incorporated further into the analysis. Summary statistics for the variables included in this analysis are presented in Table 1.

Export market recovery (referred to as "recovery") was defined as the months elapsed from the first announcement of a poultry disease event until a country's monthly export revenue from poultry exports (poultry and poultry products) met or exceeded the expected monthly revenue of poultry exports. The expected monthly revenue of poultry exports was calculated using a two-year running average prior to the disease event; the average was based on the same month in the prior two years and represented the expected level of revenue if market conditions had not been interrupted by the disease event. For example, in September 2003, the two-year running average was the average of export revenues for September 2001 and September 2002. A two-year running average was chosen because export revenues include historical market conditions prior to the disease event; however, using more than two years of history could introduce variability from events that may no longer be affecting market conditions. Monthly export revenues for the 25 countries were collected for relevant poultry and poultry from Global Trade Atlas (GTA – Global Trade Information Services, Inc.).

The "recovery" is the dependent variable in this analysis, and it captures the aggregated influence of different aspects considered in the three-part decision-making process made by international trading partners in the face of a highly pathogenic poultry disease outbreak. The first decision is whether the disease event poses a health threat to the importing country's domestic poultry industry, justifying the use of sanitary restrictions in the form of a trade ban. The second decision is if the ban will be applied country-wide or to a specific geographic area. The third decision is how long those restrictions should last, conditional on a sanitary restriction being imposed.

The mean "recovery" for this dataset was 1.85 months, which is less than the 3 months suggested by OIE guidelines. The maximum is 11 months. Forty of the 71 (56%) HPAI and ND events had the minimum of zero for "recovery." A zero "recovery" indicates the monthly revenue received from poultry exports met or exceeded the expected monthly revenue from poultry exports for the

[3] North America: Canada, Mexico, United States; South America: Brazil, Chile; Europe: Austria, Belgium, Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Spain, Sweden, Switzerland, Turkey, United Kingdom; Asia: China, Japan, South Korea, Taiwan; Oceania: Australia.

month of the outbreak announcement. This is an interesting characteristic of this dataset in that it implied that any bans made by importing trade partners had no measurable negative poultry export revenue effect when HPAI and ND events occurred in certain countries. Some short-term volatility could have occurred in that initial month; however, there was not a net loss over the course of the month. This overrepresentation of zeroes in the dependent variable posed an empirical challenge, which will be addressed in the methodology section.

Disease event information was collected from the World Animal Health Information System, maintained by OIE, to create four variables that described each specific event: duration, repeat, zoonotic, and wildlife. "Duration" was measured from the first announced case (infected bird) to the last case reported, and the mean event duration was 7.56 months. On average, countries with highly pathogenic poultry disease events in the dataset experienced "recovery" (1.85 months) prior to the end of the event. If a country did not have a case for six months, it was considered free of disease and any subsequent cases were treated as a new event, more specifically as a "repeat" event of the same disease in the same country. About half (54%) of the disease events were "repeat" events.

Table 1. Summary statistics of full poultry disease event data

Common Name	Variable Description	Unit	Mean or Proportion	Minimum	Maximum
Recovery[1]	Export market recovery	Months	1.85	0.00	11.00
Duration	Event duration	Months	7.56	1.00	123.00
Repeat	Repeat disease event	0,1	0.54	--	--
Zoonotic	Zoonotic	0,1	0.55	--	--
Wildlife	Infected wildlife only	0,1	0.28	--	--
Eventcount	Count of other simultaneous event announcements	Number	1.73	1	5
Exports2Asia	Percent of export revenue from products destined for Asian countries	%	28.09	0.38	99.93
Share	Share of world export market	%	3.49	0.00	17.35
Freshfrozen	Percent fresh-frozen	%	69.22	7.08	99.04
Perdif	Percent change in export revenue in 1st month of event	%	18.33	-86.03	194.80
GDP	Percent change in global gross domestic product	%	3.15	-4.31	5.20
PerCapita	Global per capita consumption of poultry meat	kg	11.42	8.05	13.10
ER	Exchange rate	$	98.08	72.15	133.59
Agrarian	Majority of producers follow traditional production practices and marketing channels	0,1	18.31	--	--

[1]Dependent variable

There were 32 ND events and 39 HPAI events, and the HPAI events were of the following strains: H5N1, H7N1, H7N2, H7N3, and H7N7. Strain H7N1 is the only strain in this dataset not known to have zoonotic capabilities. However, that event coincided with an H5N1 event, so the indicator variable for zoonotic disease events "zoonotic" was 1 for all HPAI events and 0 for all ND events. If the disease event affected only wildlife (the disease did not enter the commercial poultry flock), the indicator variable "wildlife" was 1 for affecting wildlife only and 0 otherwise. Eight ND and 12 HPAI events (28%) affected only wildlife. Since wild birds are not considered poultry, ND in wildlife is not required to be reported immediately. All of these wild bird ND events were reported within a year, but not all were reported in the month the event occurred.

Using these event data, a variable was created for the number of simultaneous highly pathogenic poultry disease events announced in the same month by other countries ("eventcount"). The mean "eventcount" was 1.39 events and this variable accounted for an importing country's ability to perceive and manage risk based on the disease status of export market competitors.

Using the export revenue information, four variables were created to explain historical trading patterns of the country experiencing the poultry disease event. These variables were calculated using the two-year average of the percentage of export revenues:

- from poultry products destined for Asian countries ("exports2Asia," mean 28.09%);
- received by a country divided by total value of world exports ("share," mean 3.49%);
- and generated from fresh or frozen poultry products divided by the total export revenue of poultry products ("freshfrozen," mean 69.22%).

In addition, the authors calculated the percentage difference between the expected and actual poultry-product export revenue ("percentdif") in the month a poultry disease outbreak was announced to capture the initial change in poultry product export revenue. The "percentdif" was negative for events that experienced "recovery" of one or more months and positive for those events with zero "recovery."

The last three independent variables characterized the health of the global economy, global meat demand, and the relative price of goods from the country experiencing the disease event. The percentage change in global gross domestic product (GDP) is the average monthly percentage change in real-world GDP for the duration of the export market recovery time, collected from the International Financial Statistics of the International Monetary Fund. The global per capita consumption of poultry meat ("PerCapita") was collected from the Organisation for Economic Co-operation and Development and the global per capita consumption variable used in this analysis is the two-year annual average prior to the disease event. The exchange rate (ER) is a regional trade-weighted exchange rate of the month prior to the first announcement of a poultry disease divided by the average monthly regional trade-weighted exchange rate for the duration of the export market recovery time. For those disease events that had zero months in export market recovery time, the regional trade-weighted exchange rate of the month of the outbreak announcement was used. Data for calculating the exchange rate variable came from USDA–Economic Research Service.

The variable "agrarian" indicated that a majority of the producers in an exporting country followed traditional production practices and marketing channels, such as live bird markets. The countries included in this variable were Chile, China, Hungary, Mexico, South Korea, Taiwan, and Turkey. This subjective categorization was based loosely on the FAO classification of poultry production systems,[4] considering these countries at the time the outbreak occurred. Sectors 3 and 4 under the FAO classifications have more subsistence farms with minimal biosecurity and greater use of live bird markets.

Table 2. Summary statistics of poultry disease event data for observations with a recovery time.

Common Name	Variable Description	Unit	Mean or Proportion	Minimum	Maximum
Recovery	Export market recovery	Months	4.23	1.00	11.00
Duration	Event duration	Months	12.13	1.00	123.00
Repeat	Repeat disease event	0,1	0.35	--	--
Zoonotic	Zoonotic	0,1	0.65	--	--
Wildlife	Infected wildlife only	0,1	0.29	--	--
Eventcount	Count of other simultaneous event announcements	Number	1.97	1	5
Exports2Asia	Percent of export revenue from products destined for Asian countries	%	34.38	0.95	99.93
Share	Share of world export market	%	3.51	0.00	17.35
Freshfrozen	Percent fresh-frozen	%	67.91	12.08	99.04
Perdif	Percent change in export revenue in 1st month of event	%	-18.43	-86.03	-0.66
GDP	Percent change in global gross domestic product	%	3.44	-4.31	5.20
PerCapita	Global per capita consumption of poultry meat	kg	11.18	10.10	13.10
ER	Exchange rate	$	101.29	97.73	107.38
Agrarian	Majority of producers follow traditional practices and marketing channels	0,1	25.81	--	--

Of particular interest were those events where a "recovery" was experienced. Summary statistics for the 31 observations that experienced a "recovery" are presented in Table 2. When compared with summary statistics in Table 1, the 31 events with a non-zero "recovery" have, on average, longer "duration," fewer "repeat" events, more "zoonotic" events, more "agrarian" countries, higher "exports2Asia," and the "percentdif" statistics are negative.

[4] http://www.fao.org/docs/eims/upload/214190/ProductionSystemsCharacteristics.pdf

Methodology

The methodology used to examine the cross-sectional data associated with HPAI and ND events is a zero-inflated negative binomial (ZINB) regression model, which accounts for excessive zeroes and over-dispersion of the dependent "recovery" count variable. The ZINB model estimates the influence of various components on "recovery" when it is one or more months. Therefore, any bans imposed by an infected country's trade partners had a measurable negative trade revenue effect and consequently results in time needed for "recovery."

The ZINB simultaneously estimates the influence of components on all three decisions made by importing countries as they are reflected by measurable export revenue changes. Since 56% of the events showed no export revenue loss relative to a historical trend, these events had a zero count value for "recovery," and therefore a zero-inflated model was an appropriate model. In addition, the variance of our dependent variable recovery time was large (9.36) relative to its mean (1.85), suggesting over-dispersion in the data, confirming our choice of a ZINB model as opposed to the zero-inflated Poisson regression. The benefit of using the ZINB model is that the negative binomial distribution does not assume equal mean and variance.

While theory suggests the ZINB model was the best specification, other models were explored as alternatives including a two-stage regression model that used a logistic regression to estimate whether a country would have an export revenue impact or not. We looked at the predictive power of these models by predicting the ex post outcomes of the data set.

$$(1) \qquad Model\ Predictive\ Score = \sum_j (Predicted\ Recovery_j - Actual\ Recovery_j)^2$$

By taking the difference of the terms and squaring them, we created a way to score each model. In all comparison models the ZINB model had the lower score, suggesting the better predictive model.

For the ZINB model used, the standard logistic, or logit, link function was assumed. This link function estimates the process that generates the excess zeroes. The logit function estimates components that contribute to zero "recovery." The log likelihood function can be specified as (StataCorp 2013):

$$(2) \qquad \ln L = \sum_{j\in S} \ln\left[F_j(z_j\gamma) + \left(1 - F_j(z_j\gamma)\right) p_j^m\right] + \sum_{j\notin S}[\ln(1 - F_j(z_j\gamma)) + ln\Gamma(m + y_j) - ln\Gamma(y_j + 1) - ln\Gamma(m) + mlnp_j + y_j\ln(1 - p_j)]$$

Where: $m = 1/\alpha$

$p_j = 1/(1+\alpha\mu_j)$

F_j = inverse of the logit link

$\mu_j = \exp(x_j\beta)$

$$S = \{y \mid y_j = 0\}$$

Note the logistic function was included in both the estimation for determining a count of zero and for the estimation of the count variable. This implies that the two components are solved simultaneously. The difference between $z_j\gamma$ and $x_j\beta$ are the different functional components of the model. The z_j variables are those components that contribute to a zero count and γ is the vector of coefficients to be estimated; these include "wildlife," "share," "eventcount," "agrarian," "zoonotic," and "repeat." The probability of a zero count is determined by the logit function as well as the count function, where p_j accounts for the count function and F_j accounts for the logit function. The x_j variables influence the number of recovery months with β being the estimated vector of coefficients that include "duration," "repeat," "wildlife," "zoonotic," "eventcount," "exports2Asia," "share," "freshfrozen," "perdif," "gdp," "percapita," "er," and "agrarian." The zero-inflated component included variables that would be known at the time of the event announcement and would potentially influence the initial trade ban decision. The count component includes all possible variables, including variables reflecting event response information influencing decisions on the geographic extent of trade restrictions and duration of recovery.

Results

The ZINB results showed a significant model with a Wald Chi^2 of 319.77 (p value of the Chi^2 <0.00). The lnalpha p value was <0.00, confirming the choice of a negative binomial over the simpler Poisson model. The zero-inflated regression coefficients are reported in Table 3. The zero-inflated component of the regression model was interpreted as the influence independent variables have on changing the odds of observing a zero in "recovery." The sign indicates whether the odds of observing a zero increase or decrease. A variable that increased the odds of observing a zero included the occurrence of a disease event where the infection occurred only in "wildlife" populations. In addition, as more simultaneous events were announced in the same month by competing export countries ("eventcount"), the greater the odds a country would have a "recovery" of zero months. We posit that, as the number of simultaneous events increases, importers learn more about their risk of infection and refine their responses as a result.

However, if the majority of producers in the exporting country experiencing a poultry disease event follow a traditional style of production and marketing ("agrarian"), the poultry disease is known to have zoonotic capabilities ("zoonotic"), or the event is a repeat event (repeat"), the odds that country would have a zero "recovery" decline.

The count component of the ZINB model indicated the factor by which recovery time would be multiplied. For example, disease event duration changed the revenue recovery time by a factor of 1.01. This result means that as the duration of the disease event grew longer, so did the time to trade recovery, but not as much as the exchange rate, which had a factor of 1.18. As the exporting country's exchange rate became stronger relative to the U.S. dollar, the export goods become relatively more expensive on the world market. Or, if a country's exchange rate were to decline, making export goods relatively less expensive on the world market, the country's revenue recovery occurred more rapidly. The other variable that significantly lengthens “recovery” is number of total events occurring in that same time period around the world (“eventcount”). For each additional event of that same disease (HPAI or ND), the revenue recovery time changes by a factor of 1.17.

Table 3. Results of zero-inflated negative binomial model.

Zero-Inflated Component	
Variables	**Odds Ratio**
Constant	**-6.55
Wildlife only	***17.94
Share of world export market	-0.46
Count of other events	***5.52
Agrarian	***-38.86
Zoonotic	***-53.49
Repeat	***-16.79
Count Component	**Relative Ratio**
Constant	***0.00
Event duration	***1.01
Repeat	***0.32
Wildlife Only	0.95
Zoonotic	1.02
Count of other events	**1.17
Percent of exports to Asia	1.01
Share of world export market	1.02
Percent fresh-frozen	1.00
Percent change in export revenue in 1st month of event	***0.97
Agrarian	*0.65
Percent change in global GDP	***0.91
Per capita consumption	1.00
Exchange rate	***1.18

Note. Asterisks denote a statistically significant difference at the 10 percent (*), 5 percent (**), and 1 percent (***) levels.

Interestingly, if the current HPAI or ND event was preceded by another event of the same disease (by at least 6 months), the exporting country could expect market recovery time to change by a factor of 0.32 compared with non-repeat events. If the majority of a country’s producers are “agrarian,” the expected “recovery” will change by a factor of 0.65. An increase in “perdif” changes recovery time by a factor of 0.97; however, it is important to note the meaning of an increase in “perdif.” Countries that have a trade recovery necessarily have a negative change in revenue during the first month of the events, so an increase in “perdif” is actually making the initial shock to export revenue smaller. Thus, an interpretation of this factor is that a smaller initial revenue loss is more quickly recovered. Finally, as the global economy strengthens, measured by the percentage change in global GDP, demand increases and “recovery” is shorter, as indicated by the factor 0.91.

Discussion

The results are interesting to consider in the context of the three decisions importing countries make when their suppliers experience highly pathogenic avian disease events. First is the decision of whether or not to impose restrictions on poultry products originating from the country where the event is happening, as indicated in the zero inflated component. This decision appears to be based largely on perception of risk for the spread of avian disease from the country where the event occurred and on a general risk perception. The largest component influencing the odds of observing a non-zero recovery time is the threat to human health posed by HPAI strains with zoonotic potential.

The second decision importing countries make is whether to recognize limited disease control areas, as examined in the count component of the model. Recognition of limited disease control areas or ‘regionalization’ is developed in bilateral agreements. Since initially applying trade bans to a region will be highly correlated with the “perdif” variable, some impacts of regionalization are represented in the model. The percent difference in poultry product export revenues would include any trade revenues realized as a result of importing countries accepting a regionalization strategy proposed by exporters. Thus, if a regionalization strategy is used for trade bans then the percent change in expected revenue (“perdif”) would be smaller than if the country did not regionalize. This analysis did not specifically examine the potential impact of decisions to accept regionalization beyond the first month due to the lack of information available on all bilateral agreements made during these disease events.

The third decision importing countries make is how long to keep restrictions in place, also examined in the count component of the model. Disease specific aspects, such as duration, play a role in determining how quickly export revenue recovers, but other general economic aspects like GDP and exchange rate also contribute to export revenue recovery. This means that expectations on future poultry disease consequence analyses may need to be more multifactorial than many *ex ante* analyses have considered in the past.

To interpret the results of the second and third decisions in more practical terms of months and weeks, consider the following. While holding all other variables constant and using the mean “recovery” of 4.23 months in this dataset, a country experiencing a highly infectious poultry disease event could expect to have a 1.4-month shorter “recovery” if the event is a repeat. A country could expect to have a “recovery” that is three weeks (0.72 months) longer for each additional event that is announced in the same month in different countries, when holding all other variables constant. These are two examples of how such components can impact (increase or decrease) “recovery” and the magnitude of influence on “recovery.”

While a single component can change "recovery" by a little over a month, components will interact with each other when they occur simultaneously in a highly infectious poultry disease event. However, the magnitudes presented here indicate that situations in which export revenue recovery takes years for HPAI and ND is probably less common than one might think. Since export revenue reflects both changes in the price and quantity of goods exported, industry flexibility may speed revenue recovery through changing product types for export. Since the dependent variable is calculated based on the level of poultry and poultry product export revenues after an outbreak announcement (compared to the two year running average), this includes the changes in revenue received from exports of cooked and processed products. This was the case in Thailand after the HPAI event in 2003 (Sirimongkolkasem 2007).

Finally, only three of the independent variables considered had a significant influence on importer decisions in both components of the model — "eventcount," "repeat," and "agrarian." Furthermore, these variables appeared to feature differently into each decision. The increase in the number of simultaneous events announced the same month ("eventcount") increased the chance of a country not having a recovery time, but also lengthened revenue recovery time by a factor of 1.17. This relationship may indicate the influence of both poultry demand and risk perception in the world market. While multiple poultry product sources are experiencing disease simultaneously demand for poultry products must still be met. "Eventcount" may also represent collective risk aversion after trade barriers are in place, but may not reflect individual country risk aversion that can be impacted by the disease status of the importing country. In a country experiencing a "repeat" of a disease previously reported, the odds of having no measurable negative trade effects decreased; however, "recovery" will be shorter in duration compared with a first-time incident. This relationship may reflect both a perception of risk based on repeated disease events and benefits from prior negotiations to resume trade, or mechanisms already in place for a country to adequately provide proof of disease freedom. For the "agrarian" variable, if the majority of a country's producers followed traditional production practices and marketing channels, the odds of no measurable negative trade effects decreased; however, "recovery will be shorter in duration compared with industrial countries. This result may point to an importing country's perception of an "agrarian" country's ability to respond to a poultry disease event. As evidence of adequate response becomes available, the perceived risk lessens, which results in a shorter "recovery." These results highlight the complexities involved in trade access decisions based on sanitary concerns.

Conclusions

Assurance of disease freedom is only one of many considerations that influence demand for live birds, eggs, and poultry products on the world market. This analysis showed the influence of other aspects contributing to export market recovery times after a poultry disease event. Tastes and preferences in the form of consumer risk perceptions proved significant, as events of zoonotic diseases resulted in longer recovery times and a smaller initial revenue loss shortened recovery. The importance of regional trade relationships and the health of the global economy influenced recovery time. When looking at the changes in price or affordability of an exporter's meat products, relative to their competitors, the increase in exchange rate lengthened recovery time. There are other considerations that are difficult to quantify that influence export revenue recovery times, such as political pressures. Our model explains much of the variation in the data, so we are likely capturing some of the variation due to political pressures indirectly.

While this analysis looks at the collective decisions made at the global market level, risk perceptions may vary among specific importing countries depending on their disease freedom status at the time one of their trading partners announces an event. Future research can examine the effect of bilateral variability in trade restrictions and time to export quantity recovery. Estimating time to quantity recovery is more challenging due to the need to measure output units in a common way; however, it may present a valuable extension to the current analysis.

Expectations of trade recovery after an animal disease event are often based on OIE guidelines; however, this study has shown that considerations in export revenue recovery time extend beyond OIE disease status. The context of the global economy and characteristics specific to the country where the disease event occurred also played an important role in determining export revenue recovery. This analysis showed that basic trade theory has trumped those guidelines in specific situations. Furthermore, the variability of observed outbreaks indicates potential effects of importer risk aversion. This study illustrates that in instances of HPAI and ND, export revenues are likely to recover in months rather than years.

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