A System Approach for Three-Dimensional Panel Data to Estimate Poultry Trade Impacts due to Animal Disease Outbreaks

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INTRODUCTION

Highly pathogenic disease events can cause costly disruptions in international trade. These disruptions can come in the form of trade embargos, changes in exporter supply, and importer preference changes. Management of a highly pathogenic disease event can contribute to an importer country's decision in determining trade limits, if any, imposed (Marsh, Wahl, & Suyambulingam, 2005; Seitzinger & Paarlberg, 2016; USDA-FAS, 2016). It is important to know what factors influence bilateral trade of a commodity in order to understand the ramifications a disease event can have on bilateral trade and domestic markets.

Global consumer demand for poultry products has steadily increased over the last half century to surpass other meat products. Most recently, the 2015 annual U.S. poultry consumption was estimated to be 106 pounds per capita for poultry products compared to 105 pounds per capita for beef and pork combined (The National Chicken Council, 2016). In addition to growing domestic demand, U.S. poultry products are highly competitive in international markets. U.S. broiler export volumes accounted for 32% of the 2014 exports among major traders that are accounted for in USDA's production, supply, and distribution (PSD) database. One of the worst avian health disasters in U.S. history was the 2014-2015 HPAI outbreak, which started with a backyard flock in Washington in December 2014, and ended with the last detection in a commercial poultry flock in Iowa in June 2015. During the 2014-2015 HPAI outbreak U.S. layer and turkey flocks exports decreased for the first time since 2006 due to sanitary trade bans (USDA-FAS, 2016). U.S. poultry has already started recovering from the HPAI loss through repopulation and as trade bans were lifted.

The most recent outbreak of HPAI in the United States resulted in depopulation of more than 48 million birds and $879 million dollars in costs to the U.S. government (Johansson, Preston, & Seitzinger, 2016; USDA-APHIS, 2015). Highly pathogenic avian influenza (HPAI) or exotic Newcastle disease (ND) are of particular concern to the poultry industry due to their pathogenic nature and potential losses as a result of a disease event. Globally from 2000 to 2015 there were more than 400 distinct HPAI or ND disease events in non-endemic regions, or those regions that a disease is not regularly found (OIE, 2015). Each of these events had implications for domestic markets and potentially affected the global market.

Poultry trade in general can be affected as a result of a disease event, but trade disruptions can affect commodity categories differently based on disease spread risk perception of varying levels of processing (e.g., fresh, frozen, or cooked) and types of product (e.g., chicken or turkey). Disaggregating commodity data into sub-commodity product categories allows for an understanding of the impact highly pathogenic diseases can have on the trade of specific product categories; however, such disaggregation has traditionally been limited in estimation due to dimensionality of the data. Dimensionality refers to the number of different identifiers in a dataset. In this instance, time, bilateral trading partners, and product group would constitute three dimensions in the dataset. Limiting analysis to the aggregated commodities can lead to less accurate results of how the trade of a specific product category might change during a disease event.

Importing countries may choose to limit trade with an exporter known to have an ongoing disease event (Jarvis, Cancino, & Bervejillo, 2005; Marsh et al., 2005; Paarlberg & Lee, 1998). Importing countries may ban products or change the composition, or mix of imported goods, as a result of a disease event (Djunaidi & Djunaidi, 2007; Seitzinger & Paarlberg, 2016). To better understand the factors that affect poultry trade, this study evaluates disaggregated poultry product categories, or those at the six-digit Harmonized System level, for bilateral trade quantities during an outbreak of HPAI or ND over an 11-year period. Specifically, this analysis extends current methodology using a system of Hausman-Taylor estimators (HT-SUR) to determine the factors that influence the quantity of bilateral trade for three-dimensional trade data. The results from the systems methodology will be compared to the use of individual Hausman-Taylor estimated models, providing an agricultural trade analysis of the effects of pathogenic disease events on exports by product category.

METHODS BACKGROUND

A system of Hausman-Taylor estimations was first presented by Egger and Pfaffermayr (2004a) to address limitations in panel estimators across three-dimensional data. The methodology employed in this research incorporates panel unrelated regression to the Hausman-Taylor (HT) estimator creating the HT-SUR estimations, which is expected to provide efficiency gains in estimation while providing consistent estimates of the factors that influence bilateral trade during a disease event. While HT-SUR is applicable across many fields of research, it has been mainly applied in the political economy literature to assess the political factors influencing trade (Angulo, López, & Mur, 2011; Serlenga & Shin, 2007). Few studies have employed this methodology in the agricultural trade literature (Slangen, Beugelsdijk, & Hennart, 2011). Often, the methodological innovation of Egger and Pfaffermayr is overlooked in favor of the contribution to foreign direct investment (FDI) analyses (Egger & Pfaffermayr, 2004b; Egger & Winner, 2005; Fratianni, Marchionne, & Hoon Oh, 2011; Mitze, Alecke, & Untiedt, n.d.; Türkcan, 2011).

It is important for exporting partners to understand the contributing factors of trade disruptions or the change in composition in trade as a result of a highly pathogenic event. These changes can be costly when considering importer risk acceptance and long term revenue recovery (Jin, McCarl,

& Elbakidze, 2009; Johnson, Hagerman, Thompson, & Kopral, 2015; Johnson, Stone, Seitzinger, & Mitchell, 2011). Using the HT-SUR methodology, better disaggregation and efficient estimation of product categories can be estimated (Egger & Pfaffermayr, 2004a). This will allow practitioners to better understand potential impacts of a disease event and adjust business practices accordingly to potentially mitigate some of the related economic costs due to an event.

MODEL SPECIFICATION

Trade data is often estimated using random effects models. Random effect estimators provide the most information when estimating panel data, but the assumptions of a random effects model are often violated, especially that of no correlation between the individual effects and the error term. An alternative estimator when this assumption is violated is the fixed effects model. The fixed effects model removes individual specific effects by decomposing the random effects estimate into two components: between and within variation. Between estimators model the cross sectional effects across time of individuals, but cannot be applied to the underlying population, as they are sample specific. Within estimators compare effects across identifiers, but do not estimate time invariant variables.

A hybrid solution to account for both the between and within variation is a Hausman-Taylor (HT) estimator (1981). This multiple step approach estimates coefficients of both the within and between estimators for variables that vary across time or are constant (i.e., time variant and time invariant variables). The HT estimator provides estimates over two-dimensional panel data. These dimensions can be time, unique identifiers, geography, et cetera. Traditionally, if a dataset is three-dimensional, a researcher must choose which dimension to collapse to facilitate estimation, or must choose to estimate M equations (where M is the number of unique identifiers in the data's third dimension). Collapsing the dataset implies averaging over that dimension, which can reduce the efficiency of the analysis. For example, if the third dimension is commodity type (e.g., whole chicken or frozen beef), and only select commodities have a response to some external factor such as a disease outbreak, collapsing the data across these commodities might lead to statistically insignificant estimates of disease impacts for aggregated data. However, there may be statistically significant impacts estimated for a specific commodity had it been modeled individually. Additionally, individual models do not account for correlations in the error terms across these models, if present.

This analysis uses the augmented gravity model of trade specification of bilateral trade which incorporates additional variables to the traditional gravity model of trade (Martínez-Zarzoso & Nowak-Lehmann, 2003).[1] The model is first estimated with a HT estimator. The HT estimator assumes that some regressors are correlated with the unknown individual effects (α_i). The HT estimator separates the variables into four categories: time variant exogenous (X_1), time variant endogenous (X_2), time invariant exogenous (W_1), and time invariant endogenous (W_2). The variables used in the gravity model are separated into these HT designations and calculated using equation (1):

$$y_{it} = X_{1it}'\beta_1 + X_{2it}'\beta_2 + W_{1it}'\delta_1 + W_{2it}'\delta_2 + \alpha_i + \varepsilon_{it} \tag{1}$$

where *i* is the unique identifier, *t* is time, y is the bilateral trading quantity, β and δ are vectors of coefficients, and ε are the residuals. Matrix dimension of *i* is N and *t* is T such that y_{it} is NTx1.

The endogenous variables are those variables that are correlated with the individual effects. The assumption that all variables are uncorrelated with the error term, $E[\varepsilon_i | W_{jit}, X_{jit}] = 0$, still holds as with other panel estimators, but model assumptions are now extended so that not all

[1] For further information on gravity models of trade see: Anderson, 2010; Anderson & Wincoop, 2000; Baltagi, Egger, Peter, & Pfaffermayr, 2014; or Fratianni, Marchionne, & Hoon Oh, 2011.

variables are uncorrelated with the individual effects, $E[\alpha_i|W_{2it}, X_{2it}] \neq 0$. Important assumptions of the HT estimator include (Cameron & Trivedi, 2009; Hausman & Taylor, 1981):

a. $E[\alpha_i|X_{1it}, W_{1it}] = 0$; $E[\alpha_i|X_{2it}, W_{2it}] \neq 0$

b. $V[\alpha_i|X_{1it}, W_{1it}, X_2, W_2] = \sigma_\alpha^2$

c. $Cov[(\alpha_i, \varepsilon_i)|X_1, W_1, X_2, W_2] = 0$

d. $V[(\alpha_i + \varepsilon_i)|X_1, W_1, X_2, W_2] = \sigma_\alpha^2 + \sigma_\varepsilon^2$

e. $Corr\,[(\alpha_i + \varepsilon_{it}\,;\, \alpha_i + \varepsilon_{is})|\, X_1, W_1, X_2, W_2] = \frac{\sigma_\alpha^2}{(\sigma_\alpha^2 + \sigma_\varepsilon^2)}$.

The first assumption implies only certain variables are endogenous. Assumption b defines the variance of the random effects model that is used in later assumptions. Assumption c describes no covariance between the individual effects and the error term. Assumption d defines total HT variance as the sum of the variance for the individual effects and the error term variance. Assumption e is the correlation between panel observations. If these assumptions are true, then the HT estimation will be consistent and efficient.

The HT estimator is a multistep process that approximates the time invariant variables through an instrumental variable approach using the time variant exogenous variables as instruments for the time invariant endogenous variables. The HT estimator then estimates a weight for a feasible generalized least squares (FGLS) estimator using the estimated variances. By using this approach, it is possible to have coefficients that can be predictive of the underlying population and include unbiased estimates of relevant time invariant variables, which are both limitations of using either of the classes of fixed effects models individually. Below is a brief description of the solution method adapted from Hausman and Taylor (1981) and Greene (2001).

Estimating individual HT models for data that are composed of three dimensions would result in consistent estimates across the two included dimensions, with the third dimension determining the individual models. However, if there are unknown factors that are endogenous across the M models, this information is not incorporated into the modeling framework. To account for the relationship across the error terms in related models, a system of equations should be used, such as a system of seemingly unrelated regressions (SUR). To account for three-dimensional panel data, a HT-SUR estimation that creates a system of HT estimations (eq. 8) should be used. The key relevant aspect of this approach is that the variance of the estimator incorporates not only the combined variance of the within and between estimators, but also includes the variance across the individual HT estimators to capture those efficiency gains.

$$y_{it}^{k} = X_{1it}'\beta_1 + X_{2it}'\beta_2 + W_{1it}'\delta_1 + W_{2it}'\delta_2 + \alpha_i + \varepsilon_{it} \tag{8}$$

where *i* is the unique identifier, *t* is time, *k* is the third dimension (i.e., poultry product categories), and the other variables are defined above.

The HT-SUR uses the same steps as the HT estimator, except there is a stacking of equations. This implies that the dimensions of *y* change from NTx1 to NTKx1, where each NTx1 matrix is stacked by *k*, or the third dimension (e.g., poultry product categories). The variance is no longer σ^2I for each individual model, but now implies $\Sigma \otimes I$ where diagonal components are individual model variance covariance matrices and off diagonal components are the covariance between individual models.

To empirically test the HT-SUR model, systems of models are estimated for poultry product categories and are compared to individually estimated models. In order to correctly specify the model, a random effects model is estimated and results are tested using a Breush and Pagan Lagrangian Multiplier test to determine whether true random effects exist or if ordinary least squares regression would be better suited. The presence of random effects is statistically different from zero, thereby motivating the panel approach. Next, a Hausman specification test is performed to test between random and fixed effects models, which determines whether or not the individual effects are correlated with the error term. The Hausman specification test suggests a fixed effects model is appropriate.

DATA

The HT-SUR estimator is be applied to a subset of the three-dimensional poultry trade data set used in Thompson et al. (2015). These data are a combination of disease events of HPAI and ND and trading data from the Global Trade Information Services' Global Trade Atlas. These data consist of monthly bilateral trade for 24[2] exporting countries, from January 2004 to December 2015 for 12 different poultry categories (Table 1). Product categories are limited to those that are consumable products so as to focus on goods most impacted by trade restrictions during a disease event. Information concerning the diseases are recorded for HPAI and ND and reported on the World Organization for Animal Health (OIE) website (OIE, 2015). The OIE detailed reports on disease events included number of infected flocks, the number of outbreaks during a disease event, and the nature of a disease event in geopolitically defined countries. This study limits these events to those that are non-endemic[3] for HPAI or ND. For more information on the diseases data set see (Johnson et al., 2015).

Bilateral trade is recorded for trade between United Nation (UN) recognized trading partners so as to eliminate non-recognized trading partners such as "International Waters" or "High Seas." In addition, only trading partners that account for at least 5% of trade from the exporting country for the base year of 2013 are included in the analysis, as this is a period in

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[2] Austria, Belgium, Brazil, Canada, Chile, China, Denmark, France, Germany, Greece, Hungry, Italy, Japan, Mexico, Netherlands, Poland, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, the United Kingdom, and the United States.

[3] An endemic disease is one that is persistent in a population without external influences.

which there were no outbreaks from non-endemic trading countries and should represent a non-infected, or "normal," year's trading value.

Poultry product categories are assigned based on the six-digit level of the harmonized system code (HS code) for fourteen poultry products (Table 1). Product categories are assigned a HT-SUR model group based on the nature of the product as indicated in the product name. For example, Whole Frozen Chicken is assigned to the frozen model and Whole Fresh Chicken in the fresh model. These groupings were determined based on similar patterns of bilateral trade changes as well as feasibility in estimation. More aggregated groups such as a turkey or a chicken model are estimated, but data limitations as a result of the SUR estimation exclude more aggregated grouping.

Additional data are recorded from publically available data. Annual population and real GDP data are reported by United States Department of Agriculture - Economic Research Service (USDA-ERS) (2015). Distance and geographical indicators is published in the GeoDist database through the Centre D'Etudes Prospectives et D'Informations Internationales, or CEPII (Mayer & Zignago, 2011). Country currencies, as reported by UN's Food and Agriculture Organization Corporate Statistical Database (FAOStat) (2015a), are used to determine if a trading pair use a common currency. Annual global per capita consumption of poultry is recorded from the UN's Organization for Economic Co-operation and Development (OECD)-FAO Agricultural Outlook (2015b).

Variable summary statistics for this analysis are presented in Table 2. These include the variables necessary for a gravity model of trade: *GDP* and *population,* of both exporting and importing partners, as well as *distance* between trading partners. *Share* indicates the share of the world's export market and is included as an indicator for the relative importance of the exporter on the global market.

The two disease variables of interest are *ND* and *HPAI*, and these indicate discreetly whether there was an outbreak of either ND or HPAI in the exporting region. Additional disease information include *out year*, which is a count of simultaneous outbreaks in a given year. While some importers may not change their preferences during a global disease event, there is a possibility that with increased global disease pressure an importer may change their preferences for products through changing the types of products imported or banning imports from infected exporters.

Per capita is the annual per capita consumption of poultry meat, which provides a variable to account for the global trend in consumption of poultry products across time. *Contiguous partners* specify whether trading partners share a common border and *common currency* specifies whether trading partners have a common currency. Both *contiguous partners* and *common currency* are variables meant to provide insights into potential trading favorability based on either proximity or reduced transaction costs in either shipping or exchange fees. To account for potential regional and cultural variability, region variables are included to indicate the regional location of the exporting partner.

RESULTS AND DISCUSSION

To compare the two methodologies presented, 12 different HT models were estimated for each of the different poultry product categories creating a baseline to compare to the four HT-SUR models (Table 1). To compare the two model results, data were limited in the individual models to only those observations that could be used in the HT-SUR models.[4] The HT and HT-SUR models were estimated using Stata (StataCorp, 2016). Full results for both models are presented in Appendix Tables 1 and 2, respectively. Selected results are presented in Table 3 for select poultry product categories assigned to the frozen model for both the HT and HT-SUR estimations. The frozen category includes chicken and turkey as well as different cuts of meat (i.e., whole and parts). The individual models are those that were estimated as an individual model and would represent the traditional method of estimating three-dimensional data. The three product categories included in the frozen model were estimated in the system of equations as part of the HT-SUR estimation.

For both the HT and the HT-SUR estimations, similar variables are estimated to be significant. An instance where this varies can be observed in the *per capita* variable, which is estimated to significantly influence bilateral trade for whole frozen turkey in the HT-SUR estimation, but is not statistically different than zero in the individual HT model. The expectation of the HT-SUR estimator is an increase in the efficiency of estimation, or lower standard errors. In this situation, there are small improvements in the standard errors, 2.57 for the HT estimator and 2.53 for the HT-SUR. The estimated coefficients differ such that given the standard error estimated, it is determined significant at the 0.1 level, or 90% confidence. This significance implies that increases in global poultry consumption by 1% decreases the quantity of bilateral trade of whole frozen turkey by 4.24%. The individual model results indicate no significant relationship between global consumption trends and quantity traded.

[4] For seemingly unrelated regression analysis observations must be consistent across identifiers. Only those observations that traded all products in the HT-SUR group could be included. While this is not optimal for estimation, this allows the researchers to compare similar modeling results.

Variables influencing trade based on the gravity model of trade specification tend to be significant in determining bilateral trade quantities. These include importer and exporter population and GDP as well as the distance between trading partners. *Importer population* significantly affects all sample models except whole frozen chicken. *Distance* significantly impacts all sample models. Directionally, distance negatively influences whole frozen chicken and frozen chicken parts, a decrease of 2.4% and 0.34% respectively for a 1% increase in distance between partners for the HT-SUR estimation. This implies that as the distance between bilateral partners increases, indicating a change in partner, the quantity traded of these products decreases. The opposite is true for frozen turkey product categories. The further the distance between trading partners the greater the quantity traded of whole frozen turkey, or an increase of 0.95% for a 1% increase in distance. These results reflect differences in preferences in importing countries as well as preferences for shipping methods.

The two disease variables *HPAI* and *ND* were predominantly insignificant influencing factors for the quantity traded of frozen poultry products. The only exception is whole frozen chicken. The quantity of whole frozen chicken is estimated to decrease during an outbreak of HPAI. These results are surprising in that a disease outbreak of HPAI is traditionally expected to influence bilateral trade. This is not to say that countries do not respond, but that in the reduced data set, it was not statistically significant for the frozen product categories. Extending this to compare all poultry product categories (Appendix 1 and 2), there are more product categories with a *HPAI* variable that are statically significant. An explanation for differences in disease impact beyond importer decision-making can be in terms of composition of trade. Some commodities might not be affected, as importers are not sensitive to those products due to preferences or risk perceptions of those products. An *ND* event is not a significant factor of trade in any of the commodity groups. This is an important point to note, that during an outbreak trade may be affected, but not so much as to significantly change the quantity traded.

Limitations of this analysis lie with an unbalanced panel in the underlying data. Given that the HT-SUR must have a balanced panel to estimate, observations were excluded when estimating both models. This limits the bilateral trade pairs that are being used in the estimation. For a balanced panel, this would not be an issue as the HT-SUR estimator would not drop those observations missing by bilateral trading pair. Consistently, the results indicate slight efficiency gains by using the HT-SUR model, motiving its potential methodological appropriateness for three-dimensional data. Future research with balanced panels could benefit from using this methodology as a way to estimate three-dimensional datasets consistently and efficiently without having to collapse across one of the dimensions.

CONCLUSION

Many factors affect global poultry trade, and are of interest to exporting and importing partners during a disease event such as HPAI or ND. Understanding the influencing factors provides increased understanding of the consequences of a disease outbreak in the exporting country for trading partners. It is as important to understand how the data are aggregated and estimated to provide the most complete understanding of the potential trade implications of a disease event. This work estimated the factors that influence bilateral trade comparing the extended HT-SUR methodology to a traditional HT approach. The empirical results provide a deeper understanding of those factors influencing the in quantity traded of a poultry product category during a highly pathogenic disease event.

The augmented gravity model of trade provided a means for specifying predictive factors of the quantity of bilateral trade. The additional information included in this analysis allows for increased predictability, accounting for changes in global tastes and preferences across time, relative importance of the exporting partner, and a measure for preferences linked to geographic proximity and potential economic favorability (e.g., *common currency)*.

Using the HT-SUR estimator, this work bridges the gap from the political economy literature to agricultural trade in showing the gains in estimator efficiency as measured by reduced standard errors by using a systems approach for three-dimensional panel data. The data used in this analysis are a unique bilateral trade data across time and product categories. The use of the HT-SUR allows researchers to be uncompromising on data dimensionality, typical of panel data analyses in the agricultural economics literature. Often compromises come in the form of aggregation across one of the dimensions, which can smooth out potential effects of contributing factors. By using the HT-SUR this aggregation is not necessary, providing a framework for a three-dimensional analysis. The presented methods are not limited to trade, in that any data set with three-dimensions and time variant and time invariant variables that have individual effects could be estimated using this methodology, gaining in efficiency without compromising one of the dimensions or consistency in estimation. Using the methodology, future work includes estimation of trade impacts of distorting events as well as determining the factors of trade of other agricultural sectors to improve the available information to exporting and importing countries.

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Table 1: Poultry Product Categories used in Bilateral Trade Analysis

Product Short Name	Product Name	HS Code	HT-SUR Model
Whole Chicken: Fresh	Commodity: 020711, Meat And Edible Offal Of Chickens, Not Cut In Pieces, Fresh Or Chilled	20711	Fresh
Whole Chicken: Frozen	Commodity: 020712, Meat And Edible Offal Of Chickens, Not Cut In Pieces, Frozen	20712	Frozen
Chicken Parts: Fresh	Commodity: 020713, Chicken Cuts And Edible Offal (Including Livers) Fresh Or Chilled	20713	Fresh
Chicken Parts: Frozen	Commodity: 020714, Chicken Cuts And Edible Offal (Including Livers) Frozen	20714	Frozen
Whole Turkey: Frozen	Commodity: 020725, Turkeys, Not Cut In Pieces, Frozen	20725	Frozen
Whole Turkey: Fresh	Commodity: 020726, Turkey Cuts And Edible Offal (Including Livers), Fresh Or Chilled	20726	Fresh
Turkey Parts: Frozen	Commodity: 020727, Turkey Cuts And Edible Offal (Including Liver) Frozen	20727	Frozen
Shell Eggs	Commodity: 0407, Birds' Eggs, In Shell, Fresh, Preserved Or Cooked	407	Eggs
No-Shell Eggs	Commodity: 0408, Birds' Eggs, Not In Shell And Egg Yolks, Fresh, Dried, Cooked By Steam Etc., Molded, Frozen Or Otherwise Preserved, Sweetened Or Not	408	Eggs
Cooked Turkey	Commodity: 160231, Meat Or Meat Offal Of Turkeys, Prepared Or Preserved, N.E.S.O.I.	160231	Prepared
Cooked Chicken	Commodity: 160232, Prepared Or Preserved Chicken Meat, Meat Offal Or Blood, N.E.S.O.I.	16032	Prepared
Cooked Other	Commodity: 160239, Meat Or Meat Offal Of Chickens, Ducks, Geese And Guineas, Prepared Or Preserved, N.E.S.O.I.	160239	Prepared

Source: Global Trade Information System – Global Trade Atlas

Table 2: Variables used in quantity trade analysis

Name	Variable Description	Unit	HT Description	Mean	Min	Max
Quantity[1]	Exporting quantity	Pounds	TV, Exogenous	281,484	1	120,000,000
$Population_b$	Population for trading partner b[2]	Per Capita	TV, Exogenous	83,800,000	102,918	1,360,000,000
GDP_b	Real GDP for trading partner b[2]	Billions of USD	TV, Exogenous	1,841.75	0.71	16,271
Distance	Distance between trading partners	Kilometers	TIV, Endogenous	2,497	60	19,080
Share	Annual share of world export market	%	TV, Endogenous	0.05	0.00	0.33
Highly Pathogenic Newcastle Disease	Binary variable indicating if ND was reported	0,1	TV, Endogenous	0.02	0	1
Highly Pathogenic Avian Influenza	Binary variable indicating whether HPAI was reported	0,1	TV, Endogenous	0.07	0	1
OutYear	The number of simultaneous disease events in a given year	Number	TV, Exogenous	5.28	0	15
Percent Capita	Annual global per capita consumption of poultry meat	%	TV, Exogenous	12.15	10.7	13.74
Contiguous Partners	Binary variable to indicating partners who are geographically contiguous	0,1	TIV, Exogenous	0.45	0	1
Common Currency	Binary variable indicating trading partners who share a common currency	0,1	TIV, Exogenous	0.27	0	1
Asia	Binary variable for exporting country	0,1	TIV, Exogenous	0.10	0	1
Europe	Binary variable for exporting country	0,1	TIV, Exogenous	0.70	0	1
South America	Binary variable for exporting country	0,1	TIV, Exogenous	0.03	0	1
North America	Binary variable for exporting country	0,1	TIV, Exogenous	0.06	0	1
Africa	Binary variable for exporting country	0,1	TIV, Exogenous	0.06	0	1
Oceania	Binary variable for exporting country	0,1	TIV, Exogenous	0.01	0	1
Middle East	Binary variable for exporting country	0,1	TIV, Exogenous	0.04	0	1

[1] Dependent Variable; [2] b = exporter, importer: HT Description=Hausman Taylor variable description; TV: Time Variant; TIV Time Invariant

Table 3: Selected Results for Estimated Factors Influencing Bilateral Poultry Trade Comparing Hausman-Taylor to Hausman-Taylor - Seemingly Unrelated Regression Models

	Whole Frozen Chicken	**Frozen Chicken Parts**	**Whole Frozen Turkey**	**Whole Frozen Chicken**	**Frozen Chicken Parts**	**Whole Frozen Turkey**
HT-SUR Model	Frozen	Frozen	Frozen	Individual	Individual	Individual
Importer Population	-5.86	9.26***	-13.65***	-5.77	8.91***	-14.76***
	(4.85)	(2.33)	(4.98)	(4.93)	(2.37)	(5.06)
Importer GDP	-1.27	0.98	8.92***	0.28	1.34	9.25***
	(2.19)	(1.10)	(2.17)	(2.22)	(1.12)	(2.20)
Exporter GDP	11.08***	-2.47**	-1.19	10.30***	-2.79**	-0.92
	(2.37)	(1.15)	(2.83)	(2.41)	(1.17)	(2.89)
Exporter Population	-3.47	-10.57**	21.15**	-12.20	-11.80**	18.01*
	(10.21)	(4.91)	(10.73)	(10.38)	(5.00)	(10.93)
Distance	-2.40***	-0.34***	0.95***	-2.25***	-0.25***	1.04***
	(0.23)	(0.09)	(0.14)	(0.23)	(0.09)	(0.14)
Per Capita	6.48**	0.58	-4.24*	6.83**	1.05	-3.42
	(2.61)	(1.30)	(2.53)	(2.64)	(1.33)	(2.57)
Share	0.94**	1.27***	0.61	1.08**	1.30***	0.61
	(0.47)	(0.23)	(0.51)	(0.48)	(0.23)	(0.52)
ND	0.30	0.10	-0.32	0.23	0.13	-0.31
	(0.42)	(0.20)	(0.42)	(0.43)	(0.20)	(0.43)
HPAI	-1.14***	-0.08	0.42	-1.15***	-0.09	0.39
	(0.40)	(0.17)	(0.36)	(0.41)	(0.17)	(0.37)
Out Year Count	0.06**	-0.00	-0.02	0.07**	0.00	-0.01
	(0.03)	(0.01)	(0.03)	(0.03)	(0.01)	(0.03)
Contiguous Partners	-0.32	-0.65***	-0.02	-1.00**	-0.69***	-0.19
	(0.45)	(0.23)	(0.34)	(0.46)	(0.24)	(0.34)
Common Currency	2.82***	1.40***	-0.39	3.74***	1.51***	-0.29
	(0.43)	(0.33)	(0.32)	(0.45)	(0.35)	(0.33)
Constant	222.25	100.16	-336.25	538.83*	149.74	-206.15
	(302.75)	(136.41)	(296.02)	(308.18)	(139.85)	(301.72)

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

APPENDIX

Appendix 1: Estimated Factors Influencing Bilateral Poultry Trade Using Hausman-Taylor Individual Models

	Whole Fresh Chicken	Whole Frozen Chicken	Fresh Chicken Parts	Frozen Chi Parts
Importer Population	0.93	-5.77	0.54	8.91***
	(1.47)	(4.93)	(1.56)	(2.37)
Importer GDP	0.62	0.28	-0.65	1.34
	(0.46)	(2.22)	(0.58)	(1.12)
Exporter GDP	-0.07	10.30***	2.00***	-2.79**
	(0.61)	(2.41)	(0.71)	(1.17)
Exporter Population	-7.63***	-12.2	1.78	-11.80**
	(1.93)	(10.38)	(2.31)	(5.01)
Distance	0.12***	-2.25***	-0.22***	-0.25**
	(0.03)	(0.23)	(0.04)	(0.09)
Per Capita	2.86***	6.83**	1.66**	1.05
	(0.58)	(2.64)	(0.68)	(1.33)
Share	0.51***	1.08**	1.04***	1.30***
	(0.13)	(0.48)	(0.15)	(0.23)
END	0.05	0.23	0	0.13
	(0.12)	(0.43)	(0.14)	(0.20)
HPAI	-0.29**	-1.15***	-0.2	-0.09
	(0.12)	(0.41)	(0.14)	(0.17)
Europe	-0.11	-15.11***	4.96***	-1.44**
	(0.72)	(1.59)	(0.88)	(0.56)
North America	0.98	-0.91	7.74***	3.71***
	(0.71)	(0.97)	(0.87)	(0.34)
Out Year Count	0	0.07**	0	0
	(0.01)	(0.03)	(0.01)	(0.01)
Contiguous Partners	-0.11	-1.00**	0.05	-0.69**
	(0.09)	(0.46)	(0.11)	(0.24)
Common Currency	0.86***	3.74***	1.11***	1.51***
	(0.08)	(0.45)	(0.11)	(0.35)
Constant	217.77***	538.83*	-93.15	149.74
	(59.43)	(308.18)	(70.41)	(139.85
Observations	2,235	480	2,235	480
R-squared	0.141	0.56	0.191	0.681

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Whole Frozen Turkey	Whole Fresh Turkey	Frozen Turkey Parts	Shell Eggs
Importer Population	-14.76***	6.40***	31.16***	4.04
	(5.06)	(1.16)	(4.57)	(2.82)
Importer GDP	9.25***	0.56	-1.15	0.21
	(2.20)	(0.44)	(1.99)	(1.49)
Exporter GDP	-0.92	-0.39	8.54***	-6.12***
	(2.89)	(0.54)	(2.35)	(0.84)
Exporter Population	18.01*	-3.54**	-56.60***	-24.42***
	(10.93)	(1.68)	(10.02)	(4.50)
Distance	1.04***	0.78***	2.26***	0.70***
	(0.14)	(0.03)	(0.17)	(0.14)
Per Capita	-3.42	1.40***	-7.82***	8.66***
	(2.57)	(0.49)	(2.34)	(1.38)
Share	0.61	1.18***	0.94*	0.3
	(0.52)	(0.12)	(0.49)	(0.25)
END	-0.31	-0.09	-0.22	0.12
	(0.43)	(0.10)	(0.40)	(0.33)
HPAI	0.39	-0.31***	-0.43	-0.09
	(0.37)	(0.10)	(0.35)	(0.24)
Asia	-	-	-	-1.79***
	-	-	-	(0.59)
Europe	2.40***	7.29***	14.64***	-1.60***
	(0.86)	(0.51)	(1.24)	(0.51)
North America	5.47***	7.91***	14.25***	-0.5
	(0.70)	(0.51)	(0.70)	(0.54)
Out Year Count	-0.01	0.01*	0.01	0.02
	(0.03)	(0.01)	(0.02)	(0.02)
Contiguous Partners	-0.19	-0.06	-2.96***	-0.54***
	(0.34)	(0.07)	(0.35)	(0.14)
Common Currency	-0.29	0.51***	1.95***	1.23***
	(0.33)	(0.07)	(0.41)	(0.13)
Constant	-206.15	-95.03**	837.05***	497.56***
	(301.72)	(48.19)	(286.69)	(93.66)
Observations	478	2,235	480	3,511
R-squared	0.623	0.391	0.817	0.064

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Egg Products	Cooked Turkey	Cooked Chicken	Cooked Other
Importer Population	5.90***	-7.80***	-1.66	-9.90***
	(1.35)	(2.35)	(1.13)	(1.35)
Importer GDP	-4.19***	-0.18	0.22	-1.65*
	(0.73)	(1.42)	(0.68)	(0.84)
Exporter GDP	1.72***	2.92***	0.37	-1.39**
	(0.44)	(0.98)	(0.49)	(0.65)
Exporter Population	-9.92***	-8.19**	2.29	2.49
	(2.27)	(3.35)	(1.61)	(1.97)
Distance	-0.10*	0.22***	-0.84***	0.21***
	(0.06)	(0.07)	(0.04)	(0.05)
Per Capita	5.74***	3.97***	3.13***	6.73***
	(0.76)	(1.16)	(0.57)	(0.71)
Share	0.68***	0.40***	-0.11	-0.18*
	(0.14)	(0.15)	(0.08)	(0.10)
END	0.06	-0.14	0.06	-0.06
	(0.18)	(0.19)	(0.09)	(0.11)
HPAI	0.15	0.04	-0.14	0.13
	(0.12)	(0.19)	(0.09)	(0.12)
Asia	-0.85***	-	-	-
	(0.26)	-	-	-
Europe	0.59***	2.99***	-	1.34**
	(0.22)	(0.31)	-	(0.58)
North America	1.46***	-	1.95***	-0.75
	(0.23)	-	(0.15)	(0.58)
Middle East	-	-4.47***	4.45***	-
	-	(1.04)	(0.53)	-
Out Year Count	0	0	0	0
	(0.01)	(0.01)	(0.01)	(0.01)
Contiguous Partners	0.13**	0.91***	-0.03	-0.41***
	(0.06)	(0.17)	(0.09)	(0.10)
Common Currency	0.79***	1.32***	1.03***	0.53***
	(0.06)	(0.16)	(0.08)	(0.10)
Constant	88.00**	514.20***	-29.57	242.17***
	(41.33)	(122.43)	(54.09)	(66.61)
Observations	3,511	1,922	1,922	1,905
R-squared	0.149	0.159	0.289	0.211

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix 2: Estimated Factors Influencing Bilateral Poultry Trade Using Hausman-Taylor - Seemingly Unrelated Regression

	Whole Fresh Chicken	Fresh Chicken Parts	Whole Fresh Turkey	Shell Eggs
HT-SUR Model	Fresh	Fresh	Fresh	Eggs
Importer Population	1.55	-0.25	6.19***	0.57
	(1.46)	(1.55)	(1.15)	(2.81)
Importer GDP	0.72	0.09	0.63	0.65
	(0.46)	(0.58)	(0.44)	(1.47)
Exporter GDP	-0.52	0.95	-0.44	-6.22***
	(0.61)	(0.71)	(0.54)	(0.83)
Exporter Population	-8.99***	-2.29	-4.46***	-28.75***
	(1.91)	(2.29)	(1.67)	(4.47)
Distance	0.08***	-0.24***	0.78***	0.24*
	(0.02)	(0.04)	(0.03)	(0.14)
Per Capita	3.14***	3.30***	1.63***	10.41***
	(0.57)	(0.68)	(0.48)	(1.38)
Share	0.58***	0.97***	1.16***	0.37
	(0.13)	(0.15)	(0.11)	(0.25)
END	0.05	0.02	-0.09	0.19
	(0.12)	(0.14)	(0.10)	(0.33)
HPAI	-0.31**	-0.27*	-0.33***	-0.19
	(0.12)	(0.14)	(0.10)	(0.23)
Asia	-	-	-	665.35***
	-	-	-	(92.99)
Europe	248.34***	4.42***	-52.53	665.31***
	(58.66)	(0.87)	(48.00)	(92.98)
North America	249.57***	7.30***	-51.90	666.43***
	(58.67)	(0.87)	(48.00)	(92.99)
Middle East	248.55***	-	-59.90	667.27***
	(58.87)	-	(47.99)	(93.04)
Out Year Count	-0.00	0.01	0.01*	0.03*
	(0.01)	(0.01)	(0.01)	(0.02)
Contiguous Partners	-0.21**	0.08	-0.18**	-0.22*
	(0.09)	(0.11)	(0.07)	(0.13)
Common Currency	0.80***	1.25***	0.51***	0.73***
	(0.08)	(0.10)	(0.07)	(0.13)
Constant	-	72.67	-	-
	-	(69.87)	-	-
Observations	2,235	2,235	2,235	3,511
R-squared	0.139	0.185	0.390	0.056

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Egg Products	Cooked Turkey	Cooked Chicken	Cooked Other
HT-SUR Model	Eggs	Prepared	Prepared	Prepared
Importer Population	3.41**	-8.86***	-1.52	-9.80***
	(1.34)	(2.32)	(1.12)	(1.34)
Importer GDP	-3.75***	-1.78	-0.19	-1.76**
	(0.72)	(1.40)	(0.67)	(0.83)
Exporter GDP	1.36***	3.02***	0.55	-1.23*
	(0.43)	(1.03)	(0.52)	(0.65)
Exporter Population	-9.30***	-12.29***	0.98	-1.64
	(2.26)	(3.29)	(1.59)	(1.95)
Distance	-0.23***	0.30***	-0.78***	0.10*
	(0.06)	(0.07)	(0.04)	(0.05)
Per Capita	6.08***	6.16***	3.69***	7.17***
	(0.75)	(1.15)	(0.57)	(0.70)
Share	0.64***	0.32**	-0.09	-0.17*
	(0.14)	(0.15)	(0.08)	(0.10)
END	-0.08	-0.13	0.07	-0.06
	(0.17)	(0.19)	(0.09)	(0.11)
HPAI	0.18	0.09	-0.11	0.25**
	(0.12)	(0.19)	(0.09)	(0.12)
Asia	-0.70***	-	-	-
	(0.26)	-	-	-
Europe	0.55**	706.55***	9.66	0.49
	(0.22)	(120.28)	(53.86)	(0.58)
North America	1.52***	703.53***	11.54	-1.51***
	(0.23)	(120.31)	(53.87)	(0.58)
Middle East	-	698.97***	13.95	-
	-	(120.38)	(53.99)	-
Out Year Count	-0.00	0.01	0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)
Contiguous Partners	0.12**	1.06***	0.17**	-0.60***
	(0.06)	(0.15)	(0.08)	(0.09)
Common Currency	0.74***	1.98***	1.00***	1.13***
	(0.06)	(0.15)	(0.08)	(0.09)
Constant	123.05***	-	-	375.02***
	(41.00)	-	-	(65.83)
Observations	3,511	1,905	1,905	1,905
R-squared	0.146	0.155	0.267	0.193

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

	Whole Frozen Chicken	Frozen Chicken Parts	Whole Frozen Turkey	Frozen Turkey Parts
HT-SUR Model	Frozen	Frozen	Frozen	Frozen
Importer Population	-5.86	9.26***	-13.65***	33.01***
	(4.85)	(2.33)	(4.98)	(4.50)
Importer GDP	-1.27	0.98	8.92***	-1.35
	(2.19)	(1.10)	(2.17)	(1.96)
Exporter GDP	11.08***	-2.47**	-1.19	6.82***
	(2.37)	(1.15)	(2.83)	(2.32)
Exporter Population	-3.47	-10.57**	21.15**	-46.24***
	(10.21)	(4.91)	(10.73)	(9.84)
Distance	-2.40***	-0.34***	0.95***	2.12***
	(0.23)	(0.09)	(0.14)	(0.17)
Per Capita	6.48**	0.58	-4.24*	-8.51***
	(2.61)	(1.30)	(2.53)	(2.31)
Share	0.94**	1.27***	0.61	1.16**
	(0.47)	(0.23)	(0.51)	(0.48)
END	0.30	0.10	-0.32	-0.24
	(0.42)	(0.20)	(0.42)	(0.39)
HPAI	-1.14***	-0.08	0.42	-0.42
	(0.40)	(0.17)	(0.36)	(0.34)
Europe	-15.39***	-1.84***	1.96**	13.87***
	(1.56)	(0.55)	(0.85)	(1.23)
North America	-0.90	3.62***	5.41***	14.21***
	(0.95)	(0.33)	(0.69)	(0.69)
Out Year Count	0.06**	-0.00	-0.02	0.00
	(0.03)	(0.01)	(0.03)	(0.02)
Contiguous Partners	-0.32	-0.65***	-0.02	-2.16***
	(0.45)	(0.23)	(0.34)	(0.34)
Common Currency	2.82***	1.40***	-0.39	1.11***
	(0.43)	(0.33)	(0.32)	(0.39)
Constant	222.25	100.16	-336.25	442.41
	(302.75)	(136.41)	(296.02)	(280.55)
Observations	478	478	478	478
R-squared	0.556	0.680	0.622	0.814

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1