International Pork Trade and Foot-and-Mouth Disease

Shang-Ho Yang
Agricultural Economics, University of Kentucky
417 C.E. Barnhart Building, Lexington, KY 40546-0276
Phone Number: 859-257-7283; Fax: (859) 257-7290
E-mail: bruce.yang@uky.edu

Michael Reed
Agricultural Economics, University of Kentucky
308 C.E. Barnhart Building, Lexington, KY 40546-0276
Phone Number: 859-257-7259; Fax: (859) 257-7290
E-mail: mrreed@uky.edu

Sayed Saghaian
Agricultural Economics, University of Kentucky
314 C.E. Barnhart Building, Lexington, KY 40546-0276
Phone Number: 859-257-2356; Fax: (859) 257-7290
E-mail: ssaghaian@uky.edu

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Abstract

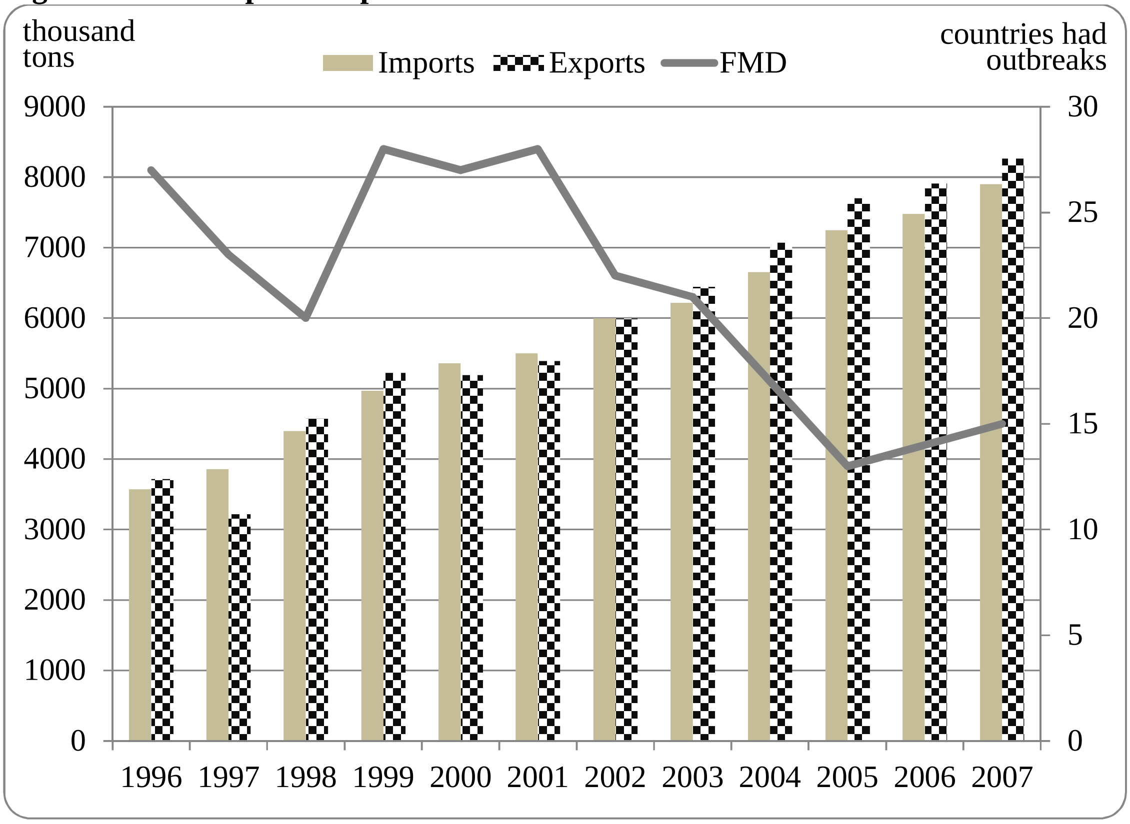
International pork trade has not only been influenced by trade agreements but also altered by consumer perceptions on disease-infected animals. This study uses a gravity model with fixed-effects to investigate how pork trade is affected by foot-and-mouth disease among 186 countries. Results confirm that pork export falls when an exporting country develops FMD. Exporters with a vaccination policy have larger negative impacts than those with a slaughter policy. Further, pork importers that develop FMD and institute a slaughter policy will import more pork, but importers with a vaccination policy import the same level of pork. In order to retain a position as a top pork exporter, a slaughter policy is often a better choice than a vaccination policy.

Key words: foot-and-mouth disease, pork exports, regional trade agreement, gravity model, zero-valued trade.

Introduction

Food safety scares affect consumption behavior, and food safety and animal life issues are increasingly impacting international agricultural trade. Member countries of the World Trade Organization (WTO) can apply measures of the Sanitary and Phytosanitary (SPS) Agreement to ensure safe food for consumers and further to prevent the spread of pests or disease among animals and plants. Foot-and-mouth disease (FMD) is a highly contagious viral-type disease which infects cloven-hoofed ruminant animals, such as cattle and pigs. FMD symptoms include fever, erosions, and blister-like lesion on the hooves, lips, mouth, teats, and tongue (APHIS, 2007). In swine species, about 58 countries were infected by FMD during 1996 to 2007, but the volume of the international pork exports still grew from 3.7 to 8.3 million tons (figure 1). The volume of pork imports has steadily grown from 1996 to 2007, but the volume of pork exports exhibits a drop during 1997 and 2000. The pork market and its supporting industries in importing and exporting countries were influenced by FMD, but some countries (and firms) were gaining market share but others were not.

Figure 1: Pork Imports/Exports and FMD Outbreaks



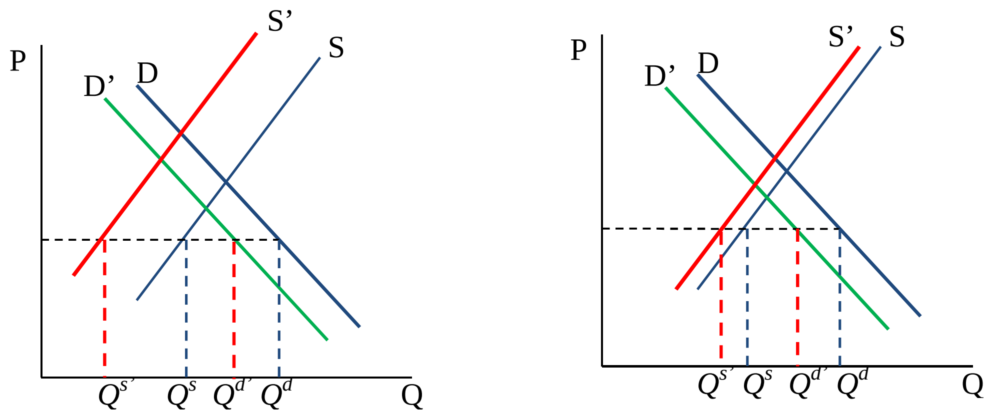
Sources: UN Commodity Trade Database and Office of International Epizootics.

These FMD-infected countries reported a total of about 255 FMD outbreaks in swine species to the Office International des Epizooties (OIE) from 1996 to 2007. Many of these FMD-infected countries were eventually able to regain a position of FMD-free regions, yet others are still suffering from it. An FMD outbreak diminishes livestock production in all stages (due to slaughtering the disease-infected herds or lower herd health) and reduces consumption for meat products in the short-run (Yeboah and Maynard, 2004; Roh, Lim, and Adam, 2006). If consumption can return to its original level within a short period of time, pork imports in an importing country may not be hindered, which implies pork exports in an exporting country could be stimulated, assuming other factors constant.

International pork trade can be hindered or stimulated by FMD outbreaks. Pork exports of an FMD-free country usually increase when the consumption levels of FMD-infected importing countries return to normal in the short-run. Yet, the FMD-infected importers may not necessarily increase imports in the short-run until their consumption level recovers. Further, pork exports of an FMD-infected country are usually hindered from the disease because of import bans by disease-free countries. Therefore, the first objective of this study is to investigate whether an FMD outbreak in a pork exporter negatively impacts trade.

An FMD-infected country can apply either a slaughter or vaccination policy to protect domestic animals. The central goal of a slaughter policy is to strengthen the efficacy in controlling FMD outbreaks, so all disease-infected animals are slaughtered to prevent additional outbreaks from FMD spreading. A slaughter policy can create a larger decline in supply. The central goal of a vaccination policy is to protect healthy animals from infection. Since a vaccinated animal cannot be distinguished from an infected animal, countries with a vaccination policy usually face the FMD stigma for a longer period. Pork exports of an FMD-infected country still can be hindered at least one to two years no matter which policy is applied. However, pork imports can have two different consequences when an FMD-infected importing country adopts a slaughter versus vaccination policies.

Figure 2a & 2b: Slaughter and Vaccination Policy Adopted by Importing Countries



(2a) (2b)

It is important to understand the effects of an FMD outbreak for a pork importing country when two different policies are adopted: a slaughter policy (figure 2a) and a vaccination policy (figure 2b). FMD outbreaks create impacts on supply and demand (Yeboah and Maynard, 2004; Paarlberg, et al., 2008). Both supply and demand will decline as an FMD outbreak occurs in a country. A constant change on the demand level in figure 2a and 2b is assumed. The slaughter policy will cause a large decrease in supply (shift from S to S' in figure 2a), but supply will not fall as much under the vaccination policy (shift from S to S' in figure 2b). FMD-infected importers with a slaughter policy would likely increase their imports in the short-run (from $\overline{Q^sQ^d}$ to $\overline{Q^{s'}Q^{d'}}$ in figure 2a), so the first hypothesis is that FMD-infected importers will import more if they adopt a slaughter policy. It is not clear whether FMD-infected importers with a vaccination policy would increase or decrease their imports in the short-run (from $\overline{Q^{s}Q^{d}}$ to $\overline{Q^{s'}Q^{d'}}$ in figure 2b), so the second hypothesis is that FMD-infected importers will not specifically import more if they adopt a vaccination policy. The second objective is to test these two hypotheses and further to confirm whether FMD-infected exporters face an impeded pork trade under these two different policies.

Regional trade agreements (RTAs) are also important factors that have influenced agricultural trade in the last three decades (Baier and Bergstrand, 2007; Grant and Lambert, 2008; Lambert and McKoy, 2009; Sun and Reed, 2010). Among 186 countries, 157 exporting countries had an RTA relation with another country during 1996 to 2007. The RTA factor in this study[1] covers: Free Trade Agreements (FTAs), Economic Integration Agreements (EIAs), Preferential Trade Agreements (PTAs), and Customs Union (CU). In total, these agreements consist of 25 different trading groups (see Appendix I for definitions): AFTA, CAN, APTA, CACM, CAFTA-DR, CARICOM, CEFTA, CEZ, CIS, COMESA, EAC, EAEC, EFTA, EU27, MERCOSUR, NAFTA, PAFTA, PICTA, SAARC, SACU, SADC, SAFTA, SAPTA, SPARTECA, and TPP. Hence, the RTA factor can potentially stimulate international pork trade, so the third objective is to test whether an RTA increases pork trade among its members.

Because the analysis is for a single commodity and includes so many countries, the trade data consists of many zero trade flows (over 96% of the observations are zero). The data sources are not clear whether the zero trade flows are missing or truly zero values. If zero trade flows are excluded, it is possible that important information is being

[1] A list of all RTAs (in force) can be retrieved from: http://rtais.wto.org/UI/PublicAllRTAList.aspx

lost on low levels of trade (Eichengreen and Irwin, 1998), which leads to biased estimation due to heteroskedasticity. We apply a gravity model which has performed well for measuring the impacts when a large number of zeros are included. In addition, a Heckman model is used to investigate the effects of including zero observations in the estimation.

Recent developments in the gravity model have overcome two challenges identified by the literature. The first challenge involves possible endogeneity problems due to omitted variables. Numerous studies have shown that fixed effects can account for multilateral resistance (price) terms (Anderson and van Wincoop, 2003; Feenstra, 2004; Baier and Bergstrand, 2007; Grant and Lambert, 2008; Sun and Reed, 2010). Hence, the endogeneity problems due to omitted variables can be controlled. The second challenge is the presence of heteroskedasticity with zero-valued trade and the log-linearized gravity equation. Santos-Silva and Tenreyro (2006 and 2009) have demonstrated that the Poisson Pseudo-Maximum Likelihood (PPML) model is a very suitable estimator for the large number of zero trade flows under such situations. This study contributes to the literature when an extremely large number of zero observations are used in the gravity model with the PPML estimator. Further, an extremely large number of zeros may lead to the variance exceeding the mean (called overdispersion). The consequences of overdispersion are a violation of the assumption of homoscedasticity and misleading inferences. This study also applies a negative binomial (NB) estimator, which has more advantages in dealing with overdispersion, to contrast the results with the PPML estimator. Therefore, the fourth objective is to apply the PPML estimator with fixed effects and the NB estimator to further distinguish the impacts of FMD and RTA on international pork trade.

Several other factors may also affect pork exports, such as common official language, past colonial connections, and religious beliefs. Countries with a common language and past colonial connections are more likely to trade with each other due to similar culture. Muslims and Jews are prohibited to consume pork, so countries with larger groups of Muslims and Jews are not likely to import pork. The last objective is to identify the influence of these factors on pork trade. This study contributes to basic understanding of the impacts of FMD outbreaks in international pork trade, the role of RTAs, and other important factors, while analyzing their difference influences in FMD-infected and FMD-free countries.

Literature Review

Numerous studies have found that FMD outbreaks can dramatically influence consumption behavior, market prices, production in all stages, and meat products' trade. Yeboah and Maynard (2004) discovered that consumers responded negatively to FMD outbreaks and decreased their consumption level in the short-run. Roh, Lim, and Adam (2006) estimated the negative effects of FMD outbreaks on cattle, beef, hog, and pork prices in Korea during 2000 and 2002. Costa, Bessler, and Rosson (2011) found that beef, pork, and chicken export prices in Russia declined after its FMD outbreak due to the imposition of an import ban. These prices reverted to normal after the import ban was overturned. Paarlberg, et al., (2008) identified the impacts of FMD outbreaks, which caused pork and hog prices to decline. All prices ended up recovering after three to five quarters based on standard- and high-outbreak scenarios. Jarvis, Cancino, and Bervejillo (2005) concluded that FMD outbreaks still impede agricultural trade among many countries. Past FMD research demonstrates that FMD outbreaks can create dramatic impacts on supply and demand in the short-run.

The Gravity Model

The gravity model is widely used to examine bilateral trade flows (Anderson, 2008). Numerous studies reveal how to measure the impacts of regulations, policies, and standards on food trade using this model (Swann, et al., 1996; van Beers and van den Bergh, 1997; Peridy, et al., 2000; Wilson and Otsuki, 2004; Anderson and van Wincoop, 2004; and Anders and Caswell, 2009). Recent research has recognized possible endogeneity problems due to omitted variables (Anderson and van Wincoop, 2003) and the presence of heteroskedasticity when using log-linearized specifications of the gravity model (Santos-Silva and Tenreyro, 2006) or when excluding zero observations (Hurd, 1979).

The first formal theoretical foundation of the gravity equation was provided by Anderson (1979). Due to the omitted bias concern (prices) in the gravity equation, Anderson and van Wincoop (2003) point out that a proper gravity equation must recognize endogenous multilateral prices terms for bilateral trade countries. Anderson and van Wincoop (2003) and Feenstra (2004) suggest using country-specific fixed effects as an alternative method in specifying multilateral price terms for computational ease.

Baier and Bergstrand (2007) confirm that country-specific fixed effects are not able to eliminate the endogeneity bias if an FTA coefficient is included, so they used country-and-time fixed effects under a panel setting to explain time-varying multilateral resistance terms, such as RTAs. Grant and Lambert (2008) also demonstrate the gravity model with a series of fixed effects showing RTA impacts on member trade. These studies show that properly applied fixed effects can avoid endogeneity problems due to omitted variables.

It is common to use log-linearized specifications in a gravity model equation. Santos-Silva and Tenreyro (2006) point out that heteroskedasticity can be quantitatively important in a gravity equation because Jensen's inequality, i.e., $E(\ln y) \neq \ln E(y)$, is neglected. When observations of the dependent variable include zeros, the problem of heteroskedasticity leads to biased estimation, even if the gravity equation is controlled by fixed effects. Hurd (1979) indicates the problem of heteroskedasticity can be enlarged if zeros are excluded. Santos-Silva and Tenreyro (2006) propose an augmented gravity equation in levels using a Pseudo-Maximum-Likelihood (PML) estimator, which can handle zero-valued trade, so the problem of heteroskedasticity can be avoided.

Santos-Silva and Tenreyro (2006) use Monte Carlo simulation to show that the Poisson PML (PPML) estimator is relatively robust and adequately behaved among different estimators including ordinary least square (OLS), Tobit, non-linear least square (NLS), and PPML. Their simulations show that the PPML estimator is still well behaved among different estimators when the dependent variable is non-negative (Santos-Silva and Tenreyro, 2006; 2009). Westerlund and Wilhelmsson (2009) also examine the effects of zero trade with the gravity model using a Monte Carlo simulation under a panel data structure. They had up to 83% of the values equaling zero for the dependent variable in their simulations. They also suggest using the Poisson fixed effects estimator. Hence, this study contributes to the literature on the extremely large number of zero observations in the gravity model and the PPML estimator.

Sun and Reed (2010) were the first to use the PPML estimator with fixed effects in the gravity model to deal with FTA variables on agricultural trade. The potential endogeneity problems with the FTA variable involve reverse causality between higher trade volumes and trade agreements (Sun and Reed, 2010). Their application of fixed effects shows that the endogeneity problem from omitted variables can be controlled. The endogeneity problem involves bias and underestimates the parameters (Lee and Swagel, 1997). Finding instrumental variables (IV) is an alternative traditional solution for endogeneity problems, but Baier and Bergstrand (2007) conclude that IV estimation is not a reliable approach for dealing with the endogeneity bias. They propose a gravity model with country-and-time fixed effects under a panel data structure to account for the endogeneity problem. Hence, this study will apply a PPML estimator in a gravity model with country-and-time fixed effects under a panel data structure.

Data and Empirical Models

Data

Bilateral trade data (X_{ijt}) in U.S. dollars from 1996 to 2007 for pork exports are derived from the United Nations Commodity Trade Statistics Database (http://comtrade.un.org).

The sample period of the data is three-year intervals (from 1996 to 2005 plus 2007, the last year of data) in order to reduce computational time and eliminate possible autocorrelation. There are 172,050 observations $(186 \times 185 \times 5)$ that include 165,675 zeros (over 96% of the sample). Pork exports are Harmonized System (HS) coding 0203, i.e., meat of swine, fresh, chilled, and frozen. The records of FMD outbreaks and control policies from 1996 to 2007 come from the OIE (http://www.oie.int/hs2/report.asp?lang=en). Real gross domestic product (RGDP) in U.S. dollars is obtained from the FAS/USDA (http://www.ers.usda.gov/Data/Macroeconomics). Distance, colonial relations, and common official language are collected from the Centre d'Etudes Prospectives et d'Informations Internationales (http://www.cepii.fr/anglaisgraph/bdd/distances.htm). The RTA variable shows if the exporting country has a RTA relationship with the importing country and is collected from the WTO website.

The definition and statistical summary of variables are shown in table 1. Annual total value of pork exports among 186 importing countries (shown in Appendix II) averaged $0.4 million (U.S. dollars). The average real GDP for these countries is $224 billion (U.S. dollars) annually. The average distance between the largest urban areas for the countries is 7,936 kilometers. Almost 16% of the observations represent that countries use the same official language. Only 0.7% of the observations reveal that countries have past colonial connections. From 1996 to 2007 over 58 countries had FMD outbreaks (about 12 percent of the observations). Over six percent of the observations have trading countries with an RTA connection.

Empirical Framework

This study employs a gravity model with the PPML estimator by controlling several different fixed effects for comparisons. Each result of the PPML estimator will contrast with the results of a NB estimator. We specify the empirical models for the first objective as:

(A) Only time fixed effects

$$(1)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2(RGDP_{jt}) + \alpha_3(Dist_{ij}) + \alpha_4(Lang_{ij}) +$$

$$\alpha_5(Col45_{ij}) + \alpha_6(\text{Muslim}_{\text{j}}) + \alpha_7(FMD_{it}) + \alpha_8(FMD_{jt}) + \alpha_9(RTA_{ijt}) + \varepsilon_{ijt}$$

(B) Time and bilateral country pair fixed effects

$$(2)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_{ij}^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2(RGDP_{jt}) + \alpha_7(FMD_{it}) + \alpha_8(FMD_{jt}) +$$

$$\alpha_9(RTA_{ijt}) + \varepsilon_{ijt}$$

(C) Bilateral country pair and country-and-time fixed effects

$$(3)\ \ln\left[\frac{X_{ijt}}{(RGDP_{it})(RGDP_{jt})}\right] = \alpha_0 + \alpha_{ij}^{\theta} + \alpha_{it}^{\theta} + \alpha_{jt}^{\theta} + \alpha_9(RTA_{ijt}) + \varepsilon_{ijt}$$

In equations (1) to (3), *t* denotes time, *i* denotes exporting country and *j* denotes importing country; $\ln X_{ijt}$ is the log of pork export value from exporting country *i* to importing country *j* in time *t*; α_t^{θ} are time fixed effects; α_{ij}^{θ} denote bilateral country pair fixed effects; α_{it}^{θ} and α_{jt}^{θ} denote country-and-time fixed effects to account explicitly for the time-varying multilateral price terms. Both $RGDP_{it}$ and $RGDP_{jt}$ are real gross domestic product of the exporting and importing countries, respectively, as a proxy for economic size. $Dist_{ij}$ is the distance between exporting country *i* and importing country *j* used as a proxy for transportation costs. Other geographic and preference similarities, such as sharing a common language $(Lang_{ij})$, past colonial connections since 1945 $(Col45_{ij})$, and religion in importing country *j* $(\text{Muslim}_{\text{j}})$, are commonly used in gravity equations. RTA_{ijt} is a dummy variable indicating the existence of a regional trade agreement between the exporting country *i* and importing country *j*. The variable FMD_{it} (FMD_{jt}) denotes a dummy variable indicating the exporting country *i* (importing country *j*) with FMD. The ε_{ijt} is assumed to be a log-normally distributed error term.

Equation (1) presents a basic gravity model with time fixed effects, and further identifies whether the coefficients of variables, i.e., $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and Muslim_{j}, have the expected signs. Equation (2) has time and bilateral country pair fixed effects which account for all time-invariant bilateral barriers, so $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and Muslim_{j}, are excluded and explained by fixed effects. Equation (3) not only has bilateral country pair fixed effects but also country-and-time fixed effects which account for multilateral resistance (price) terms. The variables FMD_{it} (FMD_{jt}) are excluded and explained by the fixed effects. The income coefficients are restricted to unity in equation (3), which is consistent with the theoretical gravity model in Anderson and van Wincoop (2003).

(D) Policy effects with time fixed effects

(4) $\ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2 (RGDP_{jt}) + \alpha_3 (Dist_{ij}) + \alpha_4 (Lang_{ij}) +$

$$\alpha_5(Col45_{ij}) + \alpha_6(\text{Muslim}_j) + \alpha_7(FV_{it}) + \alpha_8(FV_{jt}) + \alpha_9(FS_{it}) + \alpha_{10}(FS_{jt}) +$$

$$\alpha_{11}(RTA_{ijt}) + \varepsilon_{ijt}$$

(E) Policy effects with time and bilateral country pair fixed effects

(5) $$\ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_{ij}^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2(RGDP_{jt}) + \alpha_7(FV_{it}) + \alpha_8(FV_{jt}) +$$

$$\alpha_9(FS_{it}) + \alpha_{10}(FS_{jt}) + \alpha_{11}(RTA_{ijt}) + \varepsilon_{ijt}$$

The empirical models for the second objective are expressed in equations (4) and (5). The variables $FV_{it}(FV_{jt})$ denote an interaction dummy variable indicating when the exporting country *i* (importing country *j*) with FMD adopts a vaccination policy; the variables $FS_{it}(FS_{jt})$ denote an interaction dummy variable indicating when the exporting country *i* (importing country *j*) with FMD adopts a slaughter policy. The other variables are defined previously. Equations (4) and (5) identify the parameters of vaccination and slaughter policies for FMD-infected countries. The specifications of equation (4) and (5) are the same as equations (1) and (2), respectively, except for the parameters related to FMD. The model specifications controlling for both country-and-time and bilateral country pair fixed effects in identifying vaccination and slaughter policies are the same as in equation (3).

Empirical Results

The empirical results contain several comparisons, such as the PPML estimator versus NB estimator, models with different fixed effects, FMD impacts on exporters versus importers that vary between slaughter and vaccination policies, and treatment of zero-valued trade. The empirical results of the NB estimator are only for comparing the coefficient signs and significant levels to the results of the PPML estimator, since the NB estimator varies with the scale of the dependent variable. The NB estimator has a well-known advantage in dealing with overdispersion, and it is important to make sure that the PPML estimator generates similar signs and significance levels when there is an extremely large number of zero observations.

The empirical results are reported in Tables 2 and 3; each coefficient has its expected sign and is significantly different from zero. Coefficients for $RGDP_{it}$ and $RGDP_{jt}$, are close to unity which allows us to restrict to them when we apply the bilateral country pair and country-and-time fixed effects in Table 2. The coefficients $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and $Muslim_j$ have the expected signs and are significant at the 1% level in Table 2 and 3 when time fixed effects are controlled. Comparing to the results of the NB estimators, the estimated parameters for these variable are significant at the 1% level and have expected signs. The larger distance between countries means higher transportation costs, so the negative sign is expected. Among international pork traders, if countries have a common official language and colonial connections, then they are more likely to have pork trade with each other. Religious beliefs, i.e., Muslims and Jews, have an important role and negatively impact international pork trade.

In Table 2, the estimated parameters for FMD_{it} have the expected negative sign and are significantly different from zero for all of the estimation techniques, indicating FMD has negative impacts on pork exporters. This result confirms that FMD-infected exporters reduce shipments when they were confirmed as an FMD-infected region.

Estimated parameters for FMD_{jt} have the expected signs and are significantly different from zero when time fixed effects are used; further, the estimated parameters are similar between the PPML and NB estimators. When bilateral country pair and time fixed effects are used these coefficients are positive, but not significantly different from zero. The NB estimation shows result very similar to the PPML model. FMD-infected importers may not increase pork imports with an outbreak. However, these results do not distinguish between slaughter and vaccination policies.

In Table 3, the estimated parameters for FV_{it} have the expected signs and are significant at the 1% level for all of the estimation techniques. The estimated parameters for FS_{it} have the expected signs and are significant at the 1% level for all of the estimation techniques, except for the NB estimator with time fixed effects. Any pork exporter with FMD faces lower pork exports no matter which policy, slaughter or vaccination, is adopted. However, an FMD-infected exporter with a vaccination policy encounters a larger negative impact than an FMD-infected exporter with a slaughter policy; no matter which fixed effects are controlled. This implies that a slaughter policy can result in smaller negative impacts than a vaccination policy for exporting countries.

Pork importers with FMD may not necessarily import more pork depending which policy is adopted. Except for the result of the NB estimator with time and bilateral country pair fixed effects, the estimated parameters for FS_{jt} have the expected signs and are significant at the 1% level for all estimation techniques. FMD-infected importers increase pork imports when they adopt a slaughter policy, as reflected in figure 2a. Due to the supply shortage, FMD-infected importers with a slaughter policy would need to increase their imports. The estimated parameters for FV_{jt} are not significantly different than zero and have different expected signs, except for the result of the PPML estimator with time fixed effects. This implies that FMD-infected importers with a vaccination policy may not significantly increase pork imports. This result confirms the second hypothesis that FMD-infected importers will not specifically import more if they adopt a vaccination policy, as reflected in figure 2b.

As mentioned before, exporters with a vaccination policy have larger negative impacts on pork trade than those with a slaughter policy. A country could import and export pork (e.g., the U.S.). Thus, an FMD outbreak would impact exports and imports. If one compares the aggregated impacts (adding export and import effects) of a vaccination policy versus a slaughter policy in a country, the slaughter policy would have smaller negative impacts on international trade than with the vaccination policy. Hence, a slaughter policy not only strengthens the efficacy in controlling FMD outbreaks, but also eases the impacts of FMD outbreaks. FMD outbreaks can impair the global food chain and international pork trade. In order to retain a position as a top pork exporter, a slaughter policy seems a better choice than a vaccination policy.

The estimated parameters for the RTA_{ijt} variables also have the expected positive sign and are significant at the 1% level in Tables 2 and 3 for all estimation techniques. These empirical results contribute to the literature of RTA factors in agricultural trade (Grant and Lambert, 2008; Sun and Reed, 2010). When the RTA is included in the model, it is important to avoid endogeneity problems due to omitted variables. In table 2, we include country-and-time fixed effects under a panel setting to control time-varying multilateral price terms. These fixed effects will cover those related variables with bilateral and countries-by-time factors, so the estimated parameters for the RTA will be identical and only present in the table 2. Note that the estimated parameters of variable RTA_{ijt} are all very similar in magnitude among the PPML estimators, and have identical results with the NB estimator. This implies that the variable RTA_{ijt} may present less of an endogeneity problem for these PPML and NB estimators by controlling different fixed effects. The endogeneity concern seems less pronounced even when the primary results are only controlled with time and bilateral country pair fixed effects in table 2 and 3.

Over 96% of our sample data consist of zero-valued trade. This study uses a Heckman model as a final test to identify the effects of including zero observations in the sample. The indication of the Mills ratio in the Heckman model can confirm that the absence of control for zero observations may generate biased results (Disdier and Marette, 2010). The FMD_{jt} and FV_{jt} variables are excluded for the Heckman model to reduce collinearity concerns for the PPML regressions in Table 2 and 3, respectively (Puhani, 2000). The results of the inverse Mills ratios in Table 2 and 3 reveal that there is indeed a selection bias, and the empirical results are significantly different when zero observations are excluded. If we exclude these zero observations, our empirical results may be biased. In other words, these zero observations do possess important information for international pork trade, so they should be included in the model.

Conclusion

Our research findings confirm that FMD-infected exporters suffer from reduced pork exports, but FMD-infected importers may not increase their pork imports, depending on which policies importers adopt. FMD-infected countries can adopt either a slaughter or vaccination policy. Among pork exporters, countries with a slaughter or vaccination policy suffer reduced pork exports; countries with a slaughter policy have smaller reductions than those with a vaccination policy.

Among pork importers, countries with a slaughter policy tend to increase pork imports due to the shortage of domestic supply. However, importing countries with a vaccination policy do not significantly increase pork imports. The aggregate impacts for a country with a slaughter policy are smaller than those with a vaccination policy. This implies that a slaughter policy not only controls but also eases the impacts of FMD outbreaks. In order to retain a position as a top pork exporter, a slaughter policy seems a better choice than a vaccination policy. Better understanding of importer countries' reactions to FMD helps bilateral trade negotiation strategies that reduce the loss from FMD outbreaks, and also helps agribusinesses with their strategic response to the animal health scare.

The existence of an RTA also influences pork exports and imports. About 157 exporting countries had an RTA relation with other countries in the sample during 1996 to 2007. Our empirical findings on the RTA correspond and contribute findings on the FTA and RTA effects. The results indicate that some FMD-infected importers do not import more pork, but those following a slaughter policy and those with an RTA connection do.

The concerns of endogeneity and heteroskedasticity have often been raised with gravity models. The endogeneity problem is controlled here with bilateral country pair and country-and-time fixed effects, and the empirical results are consistent among the different ways for controlling fixed effects. The heteroskedasticity problem exists in our trade data whether zero observations are included or not. Over 96% of the observations in the pork trade data base consist of zero observations. Hence, it is important to examine whether sample selection bias exists. The results of the Heckman model indicate that zero observations should not be eliminated. Hence, this study contributes to the application of the PPML estimator using an extremely large number of zero observations. The PPML estimator shows its application successfully when including this extreme number of zeros.

References

Anders, S.M. and J.A. Caswell. 2009. "Standard as Barriers versus Standards as Catalysts: Assessing the Impact of HACCP Implementation on U.S. Seafood Imports." *American Journal of Agricultural Economics* 91(2):310-21.

Anderson, J.E. 1979. "A Theoretical Foundation for the Gravity Equation." *American Economic Review* 69(1):106–16.

Anderson, J.E. "International Trade Theory." *The New Palgrave Dictionary of Economics,* Second Edition, Eds. Steven N. Durlauf and Lawrence E. Blume. Palgrave Macmillan, 2008.

Anderson, J., and E. van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review* 93:170–92.

Anderson, J. and E. van Wincoop. 2004. "Trade Costs." *Journal of Economic Literature,* 42:691-751.

APHIS, 2007. Foot-and-Mouth Disease. Factsheet, Veterinary Services, USDA, February 2007.

Baier, S.L., and J.H. Bergstrand. 2007. "Do Free Trade Agreements Actually Increase Members' International Trade?" *Journal of International Economics* 71:72-95.

Costa, R., D.A. Bessler, and C.P. Rosson. 2011. "The Impacts of Foot and Mouth Disease Outbreaks on the Brazilian Meat Market." Paper presented at the annual meeting of AAEA, Pittsburgh, PA 24–26 July.

Disdier, A.-C., and S. Marette. 2010. “The Combination of Gravity and Welfare Approaches for Evaluating Nontariff Measures.” *American Journal of Agricultural Economics* 92(3):713–26.

Eichengreen, B., and D.A. Irwin. 1998. The Role of History in Bilateral Trade Flows. NBER Chapters. In: *The Regionalization of the World Economy*, ed. Jeffrey Frankel, 33-57. Chicago: University of Chicago Press.

Feenstra, R.C. *Advanced International Trade: Theory and Evidence.* New Jersey:Princeton University Press, 2004.

Grant, J.H., and D.M. Lambert. 2008. “Do Agricultural Trade Agreements Increase members Agricultural Trade.” *American Journal of Agricultural Economics* 90(3):765–82.

Hurd, M. 1979. “Estimation in Truncated Samples When there is Heteroscedasticity.” *Journal of Econometrics* 11(2-3): 247-58.

Jarvis, L.S., J.P. Cancino, and J.E. Bervejillo. 2005. “The Effect of Foot and Mouth Disease on Trade and Prices in International Beef Markets.” Presented at Agricultural & Applied Economics Association Annual Conference, 2005.

Lambert, D.M., and S. McKoy. 2009. “Trade Creation and Diversion Effects of Preferential Trade Associations on Agricultural and Food Trade.” *Journal of Agricultural Economics* 60(1):17–39.

Lee, J.-W., and P. Swagel. 1997. “Trade Barriers and Trade Flows across Countries and Industries.” *Review of Economics and Statistics* 79:372–82.

Paarlberg, P.L., A.H. Seitzinger, J.G. Lee, and K.H. Mathews. 2008. *Economic Impacts of Foreign Animal Disease*. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service. ERR-57, May.

Peridy, N., P. Guillotreau, and P. Bernard. 2000. "The Impact of Prices on Seafood Trade: A Panel Data Analysis of the French Seafood Market." *Marine Resource Economics* 15(1): 45-66.

Puhani, P.A. 2000. "The Heckman Correction for Sample selection and its Critique." *Journal of Economic Surveys* 14(1):53–68.

Roh, J.S., S.S. Lim, and B.D. Adam. 2006. "The Impacts of Foot-and-Mouth Disease (FMD) on Hog, Pork, and Beef Prices: The Experience in Korea." Presented at NCR–134 Conference, 2006.

Santos-Silva, J.M.C., and S. Tenreyro. 2006. "The Log of Gravity." *The Review of Economics and Statistics* 88:641–58.

Santos-Silva, J.M.C., and S. Tenreyro. 2009. "Further Simulation Evidence on the Performance of the Poisson Pseudo-Maximum Likelihood Estimator." *CEP Discussion Paper* No. 933 Centre for Economic Performance, London, UK.

Sun, L., and M.R. Reed. 2010. "Impacts of Free Trade Agreement on Agricultural Trade Creation and Trade Diversion." *American Journal of Agricultural Economics* 92(5):1351–63.

Swann, P., P. Temple, and M. Shurmer. 1996. "Standards and Trade Performance: the UK Experience." *Economic Journal* 106:1297-1313.

van Beers, C. and C.J.M. van den Bergh. 1997. "An Empirical Multi-Country Analysis of the Impact of Environmental Regulations on Foreign Trade Flows." *Kyklos* 50(1):29-46.

Westerlund, J., and F. Wilhelmsson. 2009. "Estimating the Gravity Model without Gravity using Panel Data." *Applied Economics* 41:1466–4283.

Wilson, J.S. and T. Otsuki. 2004. "To Spray or Not to Spray: Pesticides, Banana Exports, and Food Safety." *Food Policy* 29(2):131-46.

Yeboah, G., and L.J. Maynard. 2004 "The Impact of BSE, FMD, and U.S. Export Promotion Expenditures on Japanese Meat Demand." Paper presented at the annual meeting of AAEA, Denver CO, 1–4 August.

Table 1. Descriptive Statistics of Variables (N = 172,050)

Variables	Description of variable	Mean	Std. Dev.	Min.	Max.
Exports (X_{ijt})	Annual total value of countries' pork exports (U.S. $ in thousands)	411	11,900	0	1,540,000
RGDP ($RGDP_{it}$)	Annual real GDP for exporting countries (2005 U.S. $ in billions)	224	960	0.052	13,050
RGDP ($RGDP_{jt}$)	Annual real GDP for importing countries (2005 U.S. $ in billions)	224	960	0.052	13,050
Distance ($Dist_{ij}$)	The shortest distance from the largest population regions to the U.S. (km)	7,936	4,492	35	19,780
Language ($Lang_{ij}$)	Discrete variable=1 if importing countries use same official language with exporting countries	0.156	0.363	0	1
Col45 ($Col45_{ij}$)	Discrete variable=1 if importing countries had colonial relations with exporting countries since 1945	0.007	0.082	0	1
Muslim ($Muslim_j$)	Discrete variable=1 if over 50% of Muslim population in importing countries	0.237	0.425	0	1
RTA (RTA_{ijt})	Discrete variable=1 if importing countries had RTA relations with exporting countries	0.062	0.241	0	1
eFMD (FMD_{it})	Discrete variable=1 if exporting countries had FMD outbreaks in time t	0.113	0.316	0	1
iFMD (FMD_{jt})	Discrete variable=1 if importing countries had FMD outbreaks in time t	0.113	0.316	0	1
eFMD*V (FV_{it})	Discrete variable=1 if exporting countries had FMD outbreaks and applied a vaccination policy	0.073	0.260	0	1
eFMD*S (FS_{it})	Discrete variable=1 if exporting countries had FMD outbreaks and applied a slaughter policy	0.073	0.260	0	1
iFMD*V (FV_{jt})	Discrete variable=1 if importing countries had FMD outbreaks and applied a vaccination policy	0.040	0.195	0	1
iFMD*S (FS_{jt})	Discrete variable=1 if importing countries had FMD outbreaks and applied a slaughter policy	0.040	0.195	0	1

Table 2. The Impacts of FMD in the Comparisons of Different Estimators and Fixed Effects

Dep. Variable:	PPML		Neg. Binomial		PPML		Neg. Binomial		PPML		Neg. Binomial	
X_{ijt}	(α_t^θ)		(α_t^θ)		$(\alpha_t^\theta, \alpha_{ij}^\theta)$		$(\alpha_t^\theta, \alpha_{ij}^\theta)$		$(\alpha_{ij}^\theta, \alpha_{it}^\theta, \alpha_{jt}^\theta)$		$(\alpha_{ij}^\theta, \alpha_{it}^\theta, \alpha_{jt}^\theta)$	
$RGDP_{it}$	0.625	***	0.809	***	0.713	***	0.676	***	1.000		1.000	
	(0.005)		(0.009)		(0.015)		(0.010)		–		–	
$RGDP_{jt}$	0.204	***	0.224	***	0.215	***	0.256	***	1.000		1.000	
	(0.005)		(0.008)		(0.013)		(0.008)		–		–	
$Dist_{ij}$	–0.733	***	–1.046	***	.		.		.		.	
	(0.015)		(0.024)									
$Lang_{ij}$	0.129	***	0.259	***	.		.		.		.	
	(0.036)		(0.056)									
$Col45_{ij}$	0.683	***	1.236	***	.		.		.		.	
	(0.079)		(0.187)									
$Muslim_j$	–0.782	***	–0.740	***	.		.		.		.	
	(0.037)		(0.047)									
FMD_{it}	–0.582	***	–0.676	***	–0.133	***	–0.659	***	.		.	
	(0.043)		(0.059)		(0.019)		(0.050)					
FMD_{jt}	0.139	***	0.100	*	0.026		0.009		.		.	
	(0.036)		(0.058)		(0.018)		(0.042)					
RTA_{ijt}	0.293	***	0.847	***	0.330	***	1.510	***	0.293	***	1.852	***
	(0.035)		(0.075)		(0.016)		(0.039)		(0.025)		(0.039)	
N	172,050		172,050		172,050		172,050		172,050		172,050	
Log–likelihood	–135940		–47242		–56990		–40746		–50417		–37885	
AIC	271908		94514		114003		81518		102871		77811	
BIC	272049		94665		114114		81638		113118		88067	
Mills Ratio					0.089	**						

Note: *10% significance, ** 5% significance, and *** 1% significance; parentheses represent standard error.

Table 3. The Impacts of FMD in Different Policies (Slaughter versus Vaccination)

Dep. Variable: X_{ijt}	PPML (α_t^θ)		Neg. Binomial (α_t^θ)		PPML $(\alpha_t^\theta, \alpha_{ij}^\theta)$		Neg. Binomial $(\alpha_t^\theta, \alpha_{ij}^\theta)$	
$RGDP_{it}$	0.622	***	0.813	***	0.722	***	0.680	***
	(0.002)		(0.009)		(0.015)		(0.010)	
$RGDP_{jt}$	0.204	***	0.230	***	0.217	***	0.260	***
	(0.002)		(0.008)		(0.013)		(0.008)	
$Dist_{ij}$	–0.732	***	–1.038	***	.		.	
	(0.004)		(0.024)					
$Lang_{ij}$	0.130	***	0.276	***	.		.	
	(0.010)		(0.056)					
$Col45_{ij}$	0.665	***	1.194	***	.		.	
	(0.019)		(0.186)					
$Muslim_j$	–0.779	***	–0.722	***	.		.	
	(0.012)		(0.047)					
FV_{it}	–1.056	***	–1.274	***	–0.368	***	–1.274	***
	(0.021)		(0.072)		(0.034)		(0.080)	
FV_{jt}	0.200	***	0.087		–0.011		–0.041	
	(0.013)		(0.069)		(0.023)		(0.053)	
FS_{it}	–0.074	***	0.119		–0.071	***	–0.243	***
	(0.017)		(0.095)		(0.020)		(0.054)	
FS_{jt}	0.039	**	0.174	*	0.059	***	0.078	
	(0.019)		(0.094)		(0.021)		(0.057)	
RTA_{ijt}	0.284	***	0.861	***	0.334	***	1.516	***
	(0.010)		(0.074)		(0.016)		(0.039)	
N	172,050		172,050		172,050		172,050	
Log–likelihood	–135225		–47165		–56951		–40681	
AIC	270483		94365		113928		81390	
BIC	270644		94536		114059		81530	
Mills Ratio					0.088	**		

Note: *10% significance, ** 5% significance, and *** 1% significance; parentheses represent standard error.

Appendix I – Trading Groups

AFTA – ASEAN Free Trade Area
CAN – Andean Community of Nations
APTA – Asia-Pacific Trade Agreement
CACM – the Central American Common Market
CAFTA-DR – the Dominican Republic-Central America-United States Free Trade Agreement
CARICOM – Caribbean Community and Common Market
CEFTA – Central European Free Trade Agreement
CEZ – Common Economic Zone
CIS – Commonwealth of Independent States
COMESA – the Common Market for Eastern and Southern Africa
EAC – the East African Community
EAEC – Eurasian Economic Community
EFTA – European Free Trade Association
EU[27]
MERCOSUR – Southern Common Market
NAFTA – the North American Free Trade Agreement
PAFTA – Pan-Arab Free Trade Agreement
PICTA – Pacific Island Countries Trade Agreement
SAARC – the South Asian Association for Regional Cooperation
SACU – Southern African Custom Union)
SADC – Southern African Development Community
SAFTA – South Asian FTA
SAPTA – South Asian Preferential Trade Agreement
SPARTECA – South Pacific Regional Trade and Economic Co-operation Agreement
TPP – the Trans-Pacific Partnership

Appendix II – Countries List

Afghanistan	Chad	Haiti	Micronesia	Solomon Islands
Albania	Chile	Honduras	Rep. of Moldova	South Africa
Algeria	China	Hong Kong	Mongolia	Sri Lanka
Andorra	Colombia	Iceland	Morocco	Sudan
Angola	Comoros	India	Mozambique	Suriname
Antigua and Barbuda	Congo	Indonesia	Namibia	Swaziland
Argentina	Costa Rica	Iran	Nepal	Switzerland
Armenia	Côte d'Ivoire	Iraq	New Caledonia	Syrian Arab Rep.
Australia	Croatia	Israel	New Zealand	Taiwan
Azerbaijan	Cuba	Jamaica	Nicaragua	Tajikistan
Bahamas	Dem. Rep. of the Congo	Japan	Niger	United Rep. of Tanzania
Bahrain	Djibouti	Jordan	Nigeria	Thailand
Bangladesh	Dominica	Kazakhstan	Norway	Togo
Barbados	Dominican Rep.	Kenya	Oman	Tonga
Belarus	Ecuador	Kiribati	Pakistan	Trinidad and Tobago
Belize	Egypt	Korea	Palau	Tunisia
Benin	El Salvador	Kuwait	Panama	Turkey
Bermuda	Equatorial Guinea	Kyrgyzstan	Papua New Guinea	Turkmenistan
Bhutan	Eritrea	Laos	Paraguay	Uganda
Bolivia	Ethiopia	Lebanon	Peru	Ukraine
Bosnia and Herzegovina	EU-27	Lesotho	Philippines	United Arab Emirates
Botswana	Fiji	Liberia	Qatar	USA
Brazil	Gabon	Libya	Russian Federation	Uruguay
Brunei Darussalam	Gambia	Macedonia	Rwanda	Uzbekistan
Burkina Faso	Georgia	Madagascar	Saint Kitts and Nevis	Vanuatu
Burma	Ghana	Malawi	Saint Lucia	Venezuela
Burundi	Greenland	Malaysia	Saint Vincent and the Grenadines	Viet Nam
Cambodia	Grenada	Mali	Samoa	Yemen
Cameroon	Guatemala	Marshall Islands	Serbia and Montenegro	Zambia
Canada	Guinea	Mauritania	Seychelles	Zimbabwe
Cape Verde	Guinea-Bissau	Mauritius	Sierra Leone	
Central African Rep.	Guyana	Mexico	Singapore	