Choosing the best model in the presence of zero trade: a fish product analysis

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CHOOSING THE BEST MODEL IN THE PRESENCE OF ZERO TRADE: A FISH PRODUCT ANALYSIS

Running head: Gravity Model Selection in Seafood Trade

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Abstract

The purpose of the paper is to test the hypothesis that food safety (chemical) standards act as barriers to international seafood imports. We use zero-accounting gravity models to test the hypothesis that food safety (chemical) standards act as barriers to international seafood imports. The chemical standards on which we focus include chloramphenicol required performance limit, oxytetracycline maximum residue limit, fluoro-quinolones maximum residue limit, and dichlorodiphenyltrichloroethane (DDT) pesticide residue limit. The study focuses on the three most important seafood markets: the European Union's 15 members, Japan, and North America. Our empirical results confirm the hypothesis and are robust to the OLS as well as alternative zero-accounting gravity models such as the Heckman estimation and the Poisson family regressions. For the choice of the best model specification to account for zero trade and heteroskedastic issues, it is inconclusive to base on formal statistical tests; however the Heckman sample selection and zero-inflated negative binomial (ZINB) models provide the most reliable parameter estimates based on the statistical tests, magnitude of coefficients, economic implications, and the literature findings. Our findings suggest that continually tightening of seafood safety standards has had a negative impact on exporting countries. Increasing the stringency of regulations by reducing analytical limits or maximum residue limits in seafood in developed countries has negative impacts on their bilateral seafood imports. The paper furthers the literature on food safety standards on international trade. We show competing gravity model specifications and provide additional evidence that no one gravity model is superior.

Key words: seafood trade, food safety (chemical) standards, zero-accounting gravity model,

Heckman selection model, Poisson family regression

JEL Codes: F13, Q17, Q18

CHOOSING THE BEST MODEL IN THE PRESENCE OF ZERO TRADE: A FISH PRODUCT ANALYSIS

Introduction

The impact of food safety standards on bilateral trade is commonly evaluated using the gravity econometric model. This model is popular in bilateral trade analysis because it is supported by both empirically successful studies as well as strong theoretical foundations based on the constant elasticity of substitution (CES) system (Anderson, 1979), the monopolistic competition model (Bergstrand, 1985, 1989), the classical Heckscher-Ohlin model (Deardorff, 1998), and recently the general equilibrium model (Anderson & Wincoop, 2003; Feenstra, 2004).

The gravity model is traditionally estimated by the ordinary least squares (OLS) method in the form of the log-linear transformation (Burger et al., 2009). This OLS specification recently has been criticized since it truncates all zero trade values, resulting in biased estimates because dropped zero trade observations are rarely identically and randomly distributed. In addition, Santos Silva and Tenreyro (2006) argue that the log-linear transformation of the gravity model can bias estimated results in the presence of heteroskedasticity because Jensen's inequality implies that $E(\ln y) \neq \ln E(y)$ and the consistency of estimates is violated.

Recent applied economic research has explored alternative specifications to address the problems encountered by the conventional OLS estimation of the gravity model. Arbitrarily adding a small positive number to all trade flows is traditionally the most common approach to make the logarithmic transformation of zero trade observations be definable (Burger et al., 2009). This approach is problematic since it does not rely on any theoretical and empirical justification (Linders & de Groot, 2006). The second alternative for addressing the zero trade issue is to use a sample selection model, such as the Heckman model. Martin and Pham (2008)

note that the Heckman maximum likelihood model performs well if one can find true excluded variables. However, Liu (2009) argues that since the Heckman gravity model adopts the log-linear specification as the conventional OLS estimation, it is still subject to heteroskedasticity due to the Jensen's inequality problem raised by Santos Silva and Tenreyro (2006).

The third alternative approach treats bilateral trade data like count data and relies on the Poisson family regressions for estimating the gravity equation multiplicatively without taking the log linear transformation. For example, Santos Silva and Tenreyro (2006) propose to use the Poisson pseudo maximum likelihood (PPML) estimation. Burger et al. (2009) further extend the PPML estimation of Santos Silva and Tenreyro (2006) by considering the negative binomial, zero-inflated Poisson, and zero-inflated negative binomial models. The Poisson regressions can solve the zero-omitted problem faced by the conventional log-normal OLS specification of the gravity equation and are robust to heteroskedasticity. However, according to Burger et al. (2009) the standard Poisson model is sensitive to problems of overdispersion and excess zero trade flows. To date the choice and accuracy of alternative econometric specifications for accounting zero trade flows in bilateral trade analysis are mixed and there is not a commonly accepted solution (Burger et al., 2009). However, Xiong and Beghin (2011) suggest a method to determine the best model, which we follow. With their groundnut trade data the ZINB is a better model, though our findings are not as conclusive.

In this paper we use zero-accounting gravity models to evaluate the impact of food safety (chemical) standards on developed country seafood imports. The chemical standards on imported seafood established by developed countries on which we focus on include chloramphenicol (minimum) required performance limit ($Chloramphenicol$), oxytetracycline maximum residue limit ($Oxytetracycline$), (fluoro)-quinolones maximum residue limit ($Quinolones$), and

dichlorodiphenyltrichloroethane (DDT) pesticide residue limit (DDT). The study focuses on the three most important seafood markets namely the European Union's 15 ($EU15$) members, Japan, and North America (including Canada and the United States). We support the view that standards act as barriers to international trade and hypothesize that increasing stringency (reducing required performance limit or maximum residue limits) of chemical standard regulations in developed countries has negative impacts on their bilateral seafood imports.

With improvements in analytical technologies and scientific understanding on food safety hazards, developed countries are able to impose more stringent food safety standards. The stringent transformation of food safety regulations has pushed agri-food exporting countries in general and developing countries in particular to face the dilemma of losing important export markets or improving food safety monitoring and management systems to make sure that their export products meet market requirements (Donovan et al., 2001; Jaffee & Henson, 2004).

Since the early 2000s, chemical standards including veterinary drug and other chemical residues have become the most serious challenges in the international seafood trade (Ababouch et al., 2005). These challenges are because of improvements in available analytical technologies and increasing awareness and concern of consumers and regulators on food safety and quality in developed countries. The paper makes a contribution to the ongoing discussion on whether food safety standards (non-tariff measures) act as catalysts or barriers to trade. The hypothesis of standards as barriers is tested via the conventional OLS gravity model as well as the alternative zero-accounting specifications of the gravity model. In addition, the paper brings in further discussions on applications of alternative gravity model specifications to address problems encountered by the conventional gravity model specification such as zero trade flows and heteroskedasticity.

The paper is organized as follows: after this introduction, the second section provides a review of the theoretically-based gravity model suggested by Anderson and van Wincoop (2003) and common zero-accounting alternative specifications of the gravity equation. The third section specifies empirical estimation models and data sources. Estimated results and conclusions are presented in the fourth and fifth sections.

Conventional OLS and Zero-Accounting Models of the Gravity Equation

Anderson and van Wincoop's gravity model:

Tinbergen (1962) was the first to apply the Newtonian law of universal gravitation in physics to generate the gravity econometric model for studying bilateral trade flows. This model links bilateral trade flows between countries i and j to their GDPs, bilateral distance, and other factors affecting trade barriers (Anderson & Wincoop, 2003). In its simplest form, the stochastic gravity econometric model states (Santos Silva & Tenreyro, 2006) that:

$$T_{ijt} = K_0 \frac{M_{it}^{\beta_1} M_{jt}^{\beta_2}}{D_{ij}^{\beta_3}} \varepsilon_{ijt} \qquad (1)$$

where T_{ijt} is bilateral trade flow between countries i and j in period t, M_{it} and M_{jt} are the GDPs of country i and country j in period t, respectively; D_{ij} is the bilateral distance between country i and j; K_0 is a unknown constant; β_1, β_2, and β_3 are unknown parameters; and ε_{ijt} is a random error term. From this basic equation, other characteristics affecting bilateral trade such as common language, common border, colonial tie, regional trade agreements, tariffs, and food safety standards can be included as control variables. Eq. (1) is traditionally converted into the linear form by taking logarithms of both sides and estimated by the ordinary least square (OLS) method:

$$lnT_{ijt} = \alpha_0 + \beta_1 lnM_{it} + \beta_2 lnM_{jt} - \beta_3 lnD_{ij} + \epsilon_{ijt} \quad (2)$$

$$where \ \alpha_0 = lnK_0 \ and \ \epsilon_{ijt} = ln\varepsilon_{ijt}$$

The gravity Eqs. (1) and (2) are not based on economic theory. However, since 1979 theoretical foundations of the gravity model have been developed by economists such as Anderson (1979), Bergstrand (1985), and Deardorff (1998). More recently, Anderson and van Wincoop (2003) argue that previous specifications of the gravity equations ignored *multilateral resistance terms* (MRTs) which can result in biasing estimated results. Based on the constant elasticity of substitution (CES) expenditure system, Anderson and van Wincoop (2003) suggest that unitary income elasticity with the theoretically grounded gravity model[1] be estimated as:

$$\ln\left(\frac{T_{ijt}}{M_{it}M_{jt}}\right) = \alpha_0 - \beta_3 lnD_{ij} + lnP_i^{1-\sigma} + lnP_j^{1-\sigma} + \epsilon_{ijt} \quad (3)$$

$$P_i^{1-\sigma} = \sum_j P_j^{\sigma-1}\theta_j\exp(-\beta_3 lnD_{ij})$$

$$P_j^{1-\sigma} = \sum_i P_i^{\sigma-1}\theta_i\exp(-\beta_3 lnD_{ij})$$

where $P_i^{1-\sigma}$ and $P_j^{1-\sigma}$ are multilateral resistance terms (*MRTs*); $\theta_{i(j)}$ is the nominal income share of countries i (j) in world nominal income; and σ is the elasticity of substitution between all goods.

The gravity Eq. (3) can be estimated by nonlinear or linear OLS with fixed effects suggested by Anderson and van Wincoop (2003). The relevance of including GDPs in the gravity equation has been questioned because it is not relevant to the micro-founded gravity

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[1] Eq. (3) can be written in the level form as: $T_{ijt} = K_0 \frac{M_{it}^{\beta 1} M_{jt}^{\beta 2}}{D_{ij}^{\beta 3}} P_i^{1-\sigma} P_j^{1-\sigma} \epsilon_{ijt}$

model (Disdier & Marette, 2010; Feenstra, 2004). Hence, a common trend of recent bilateral

trade studies applying the gravity regression is to exclude GDPs and estimate the gravity model

(3) by the OLS method with time and country fixed effects (e.g., Burger et al., 2009; Disdier &

Marette, 2010):

$$lnT_{ijt} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 lnD_{ij} + \epsilon_{ijt} \qquad (4)$$

where α_t, α_i, and α_j are time fixed effects and fixed effects representing *MRTs* of trading

partner i and j's, respectively.

Santos Silva and Tenreyro (2006) criticize that the OLS estimation of the log linear

gravity in Eqs. (2) - (4) faces two important econometric problems: (i) In the presence of

heteroscedastic errors, elasticity estimates are biased because of Jensen's inequality and (ii) the

log linear transformation of zero trade observations is infeasible. As a matter of fact, much of

bilateral trade data contain a large number of zero trade observations. Researchers either have to

drop zero trade observations or systematically add a small positive number to all trade

observations for the log linear transformation being defined. Since zero trade flows are rarely

randomly distributed, truncating these observations can lead to biased results. Similarly adding a

small positive value to trade flows has no theoretical justification and can distort estimated

results (Flowerdew & Aitkin, 1982). Because of these problems, the conventional OLS

regression of the gravity equation will not yield consistent parameter estimates.

The Heckman specification:

The Heckman solution to the gravity econometric model retains the log linear

transformation of the model and treats zero trade values as censored observations. The sample

gravity model now contains both censored and uncensored observations, and is presented in a

two equation context, including the selection Eq. (5) and the outcome Eq. (6):

$$Y_{ijt}^* = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \delta_3 lnD_{ij} + u_{ijt} \qquad (5)$$

$$lnT_{ijt}^* = \alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 lnD_{ij}\epsilon_{ijt} \qquad (6)$$

where Y_{ijt}^* defines a latent variable deciding whether or not bilateral trade between two countries

i and j in the sample is observed and lnT_{ijt}^* determines the logarithm of the volume of bilateral

trade; u_{ij} is the error term associated with the selection process. We do not observe Y_{ijt}^* in the

selection equation and the logarithm of the volume of trade lnT_{ijt}^* in the outcome equation.

Instead we observe: $Y_{ijt} = 1 \; if \; Y_{ijt}^* > 0; \; Y_{ijt} = 0 \; if \; Y_{ijt}^* \leq 0;$ and $lnT_{ijt} = lnT_{ijt}^* \; if \; Y_{ijt}^* > 0$

and lnT_{ijt} is not observed $if \; Y_{ijt}^* \leq 0.$

The Heckman model requires that error terms u_{ijt} in Eq. (5) and ϵ_{ijt} in the Eq. (6) follow

a bivariate normal distribution with zero means, standard deviation σ_u and σ_ε and correlation ρ

(Hoffmann & Kassouf, 2005):

$$\begin{bmatrix} u_{ijt} \\ \epsilon_{ijt} \end{bmatrix} \sim N \left\{ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho\sigma_u\sigma_\epsilon \\ \rho\sigma_\epsilon\sigma_u & \sigma_\epsilon^2 \end{bmatrix} \right\} \qquad (7)$$

The model can be estimated by the two-step procedure suggested by Heckman (1979) or

the one-step maximum likelihood estimation. The one-step approach estimates the selection and

outcome equation simultaneously. Whereas, the two-step procedure first estimates the bivariate

selection equation using a probit model and generates the inverse of the Mills ratio:

$$\lambda(\alpha_u) = \frac{\phi(\frac{\alpha_0 + \alpha_t + \alpha_i + \alpha_j - \delta_3 lnD_{ij}}{\sigma_u})}{\Phi\left(\frac{\alpha_0 + \alpha_t + \alpha_i + \alpha_j - \delta_3 lnD_{ij}}{\sigma_u}\right)} \qquad (8)$$

where ϕ and Φ are the standard normal density function and the cumulative distribution function, respectively. The variable $\lambda(\alpha_u)$ is then included as an additional regressor, allowing the parameters β of the outcome equation to be consistently estimated by the OLS method.

The advantage of the Heckman model is that it can deal effectively with the zero trade observations and also allows researchers to distinguish the impact of bilateral barriers on the extensive as well as the intensive margins of trade (Cipollina et al., 2010). An extensive review of the literature on the Heckman model carried out by Puhani (2000) shows that the one-step maximum estimation empirically gives better results than the two-step Heckman estimator. Based on Monte Carlo simulations, Martin and Pham (2008) also show that the one-step maximum likelihood estimation performs well if one can find true restricted variables. However with large datasets, the full maximum likelihood approach is computationally burdensome, and in that case, the Heckman two-step estimation might be considered as the best procedure (Helpman et al., 2008; Wooldridge, 2002). A small number of bilateral trade studies using both the two-step Heckman estimation approaches have been carried out by economic researchers recently (e.g., Disdier & Marette, 2010; Helpman et al., 2008; Jayasinghe et al., 2010; Linders & de Groot, 2006).

The Heckman estimation approach faces two essential problems. First, model identification is a critical issue. Since the selection function is nonlinear, the model is technically identified. However Cameron and Trivedi (2010) state that if the nonlinearity implied by the probit selection model is slight, then the identification is fragile and researchers need to look for exclusion restrictions. An excluded variable is the one that influences the selection process but does not affect the outcome equation. Second, the Heckman selection estimation does not address Jensen's inequality problem raised by Santos Silva and Tenreyro (2006) and is

apparently sensitive to violations of the homoscedasticity and normality assumptions of error

terms. If these assumptions fail to hold, estimated results of the gravity model using the

Heckman procedure are biased and inconsistent. Monte Carlo simulations with a number of

estimators conducted by Martin and Pham (2008) show that heteroskedasticity is an important

source of bias. Under such a situation, the Poisson family regressions are competitive approaches

to the Heckman selection model since these models can also deal with zero trade issues

efficiently and are less susceptible to the heteroskedasticity problem.

Poisson family regressions:

The application of Poisson family regressions to bilateral trade analysis is pioneered by

Santos Silva and Tenreyro (2006). In the prevalence of zero bilateral trade flows and

heteroskedastic error terms resulting from Jensen's inequality, Santos Silva and Tenreyro (2006)

argue that the gravity model should be estimated multiplicatively using the Poisson Pseudo

Maximum Likelihood (PPML) estimation. Following Burger et al. (2009), we assume that

$T_{ijt,}$ the bilateral trade flow between countries i and j in period t, has a Poisson distribution with a

conditional mean μ which is a function of a matrix of bilateral and multilateral trade barriers, and

the probability mass function

$$Pr[T_{ijt}] = \frac{\exp(-\mu)\mu^{T_{ijt}}}{T_{ijt}!}, (T_{ijt} = 0, 1, 2, \dots) \qquad (9)$$

where

$$\mu = \exp(\alpha_0 + \alpha_t + \alpha_i + \alpha_j - \beta_3 ln D_{ij}) \qquad (10)$$

The Poisson model requires the equidispersion property, meaning that the conditional

variance must be equal to the conditional mean (Cameron & Trivedi, 2010). However, this

equidispersion property is commonly violated because the dependent variable of bilateral trade

flows is often overdispersed, implying that the conditional variance exceeds the conditional

mean. The presence of overdispersion might result in inefficient estimation of the Poisson model.

A negative binomial (NB) model is frequently employed to correct for overdispersion (Burger et

al., 2009). The probability mass function of the negative binomial distribution (NB) is defined as

$$Pr[T_{ijt}] = \frac{\Gamma(\alpha^{-1}+T_{ijt})}{T_{ijt}!\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}} \left(\frac{\mu}{\mu+\alpha^{-1}}\right)^{T_{ijt}} \qquad (11)$$

where Γ is the gamma function and α is the variance parameter of the gamma distribution. A

likelihood ratio test of α can be used to test whether the negative binomial distribution is

preferred over the Poisson distribution. According to Cameron and Trivedi (2010), the NB model

is more general than the Poisson because it allows overdispersion and will reduce to the Poisson

model as α approaches zero.

Numerically, the PPML and NB models can both handle zero trade flows. However,

these models are no longer suitable when the number of observed zero values exceeds the

number of zeros predicted by the estimated model (Burger et al., 2009). Under such a situation,

extensions of the PPML and NB models, Zero Inflated Poisson (ZIP) and Zero Inflated Negative

Binomial (ZINB) models can be used to overcome the encountered problems. The zero inflated

Poisson regression consists of two parts. The first part contains a logit (probit) equation

modeling the probability of zero bilateral trade flows (no trade at all). The second part takes

bilateral trade flows including zero trade values as count data and estimates a Poisson model.

The probability mass functions of the first part and second part of the zero inflated Poisson model are as Eqs. (9) and (10), respectively:

$$Pr[T_{ijt}] = \psi_{ij} + (1 - \psi_{ij}) \exp(-\mu) \quad if \; T_{ijt} = 0 \qquad (12)$$

and

$$Pr[T_{ijt}] = (1 - \psi_{ij}) \frac{\exp(-\mu)\mu^{T_{ijt}}}{T_{ijt!}} \quad if \; T_{ijt} > 0 \qquad (13)$$

where ψ_{ij} is the proportion of zero trade observations in the study sample ($0 \le \psi_{ij} \le 1$). It appears from Eqs. (9) and (10) that, when ψ_{ij} *is* 0 the ZIP model reduces to the Poisson model. In the presence of both overdispersion and zero inflated problems in the study sample, a zero-inflated negative binomial (ZINB) model can be defined in a similar fashion to the ZIP model:

$$Pr[T_{ijt}] = \psi_{ij} + (1 - \psi_{ij}) \left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}} \quad if \; T_{ijt} = 0 \qquad (14)$$

and

$$Pr[T_{ijt}] = (1 - \psi_{ij}) \frac{\Gamma(\alpha^{-1}+T_{ij})}{T_{ijt!}\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}} \left(\frac{\mu}{\mu+\alpha^{-1}}\right)^{T_{ijt}} \quad if \; T_{ijt} > 0 \quad (15)$$

Similar to the Heckman selection model, the ZIP and ZINB models allow researchers to examine the impact of trade barriers on both the intensive (the probability of trade being observed) and extensive (the volume of trade being observed) margins of bilateral trade. In addition, the ZIP and ZINB models are robust and less sensitive to the heteroskedasticity and normality assumptions of the error terms. These models might be more appropriate to model bilateral trade flows with excess zero trade observations. However the choice of the econometric model specification should be based on standard statistical tests because "having many zeros in

the dataset does not automatically mean that a zero inflated model is necessary" (Cameron & Trivedi, 2010, p. 605).

According to Burger et al. (2009), the likelihood ratio test of overdispersion can be used to test whether the PPML model is favored over the NB model. Similarly the Vuong statistic (Vuong, 1989) can be employed to discriminate between the ZIP/ZINB model and its counterparts. The Vuong statistic follows a standard normal distribution with large positive values favoring the ZIP/ZINB model and large negative values favoring the PPML/NB model (Cameron & Trivedi, 2010). For the choice of the model specification, researchers might apply additional goodness of fit statistics to evaluate the performance of different alternative models. For example, in addition to formal statistical tests, Burger et al. (2009) also compare the predicted and observed values of the dependent variable to examine how well competing models perform. Unfortunately in their study, as in our study, they find that different goodness of fit statistics do not lead to the same conclusion.

Empirical Model Specification and Data Sources

In order to test the hypothesis that chemical standards act as barriers to international seafood trade, we first estimate the OLS gravity model suggested by Anderson and van Wincoop (2003) and the Heckman model in the log linear form of the dependent variable, bilateral trade. We then estimate the gravity model in the level form using the Poisson family regressions: the PPML, NB, ZIP, and ZINB models.

The OLS gravity model specification is as follows:

$$lnT_{ijt} = \alpha_0 + \alpha_t + \alpha_i + \alpha_j + \beta_1 ln(Distance_{ij}) + \beta_2 Chloramphenicol_{jt}$$

$$+ \beta_3 Oxytetracycline_{jt} + \beta_4 Quinolone_{jt} + \beta_5 DDT_{jt} + \beta_6 Contiguos_{ij}$$

$$+ \beta_7 Colony_{ij} + \beta_8 Common\_Lang_{ij} + \beta_9 EU15_{ij} + \beta_{10} NAFTA_{ij}$$

$$+ \varepsilon_{ijt} \qquad (16)$$

where T_{ijt} is bilateral seafood imports of Canada, the EU15 members, Japan , and the United

States in period t; $ln(Distance_{ij})$ stands for the natural logarithm of the bilateral distance

between countries i and j; $\alpha_t, \alpha_i, and\ \alpha_j$ are time, exporter and importer fixed effects.

Four variables represent chemical food safety standards of interest: $Chloramphenicol_{jt}$

is minimum required performance limit in parts per billion (ppb) imposed by importing country j

in period t; and $Oxytetracycline_{jt}, Quinolone_{jt},\ and\ DDT_{jt}$ are respectively maximum

residue limits (MRLs) of oxytetracycline, quinolones (fluoro), and DDT pesticide in part per

billion (ppb) in seafood regulated by importing country j in period t. The remaining variables are

dummies: $Contiguous_{ij}$, $Colony_{ij}$, and $Common\_Lang_{ij}$ respectively equal to 1 if two trading

partners share a common border, having colonial tie, and having common official language, and

equal to 0 otherwise; $EU15_{ij}$ and $NAFTA_{ij}$ are regional trade agreement dummies, respectively

equal to 1 if both trading countries i and j are in the EU-15 members or belong to North

American Free Trade Agreement, and equal to 0, otherwise.

The selection equation in the Heckman selection model contains all variables included

in the OLS gravity model Eq. (15), while in the outcome equation the common language variable

is excluded for robustness of model identification. The choice of common language as the

excluded variable in the Heckman model is adopted from Martin and Pham (2008), and Disdier

and Marette (2010). Disdier and Marette (2010) explain that trade of seafood products seems less influenced by cultural links as common language because these products are usually homogeneous goods. With regards to Poisson family regressions, all left hand side variables in the OLS gravity model Eq. (15) are also included in the PPML, NB models as well as the ZIP and ZINB models. The likelihood ratio test of overdispersion is deployed to discriminate the PPML and NB models, whereas the Vuong statistic is used to test whether the ZIP/ZINB model is favored over its counterpart.

Data for the empirical model estimation are drawn from various sources. Bilateral seafood import data come from the UNCOMTRADE database (the1996 Harmonized System, product code 03). Control variables using in the empirical modeling, such as distance, geographical continuity (common border), colonial relationship, and common language are from CEPII'S distance database (Centre d'Etudes Prospectives et d'Informations Internationales, 2009). Dummy variables representing regional trade agreements, $EU15$ and $NAFTA$ are created based on information taken from online data. Our four main variables of interest representing chemical food safety standards, chloramphenicol standard comes from Disdier and Marette (2010) and Debaere (2005). Oxytetracycline standards are from Chen, Wang, and Findlay (2008). Quinolones standards are collected online from several sources such as Seafood Network Information Center (Bacler, 2008; Huet et al., 2006; Tom, 2010). DDT standards are from a technical report compiled by Southeast Asian Fisheries Development Centre (SEAFDEC) in 2008 (Tan & Saw, 2008). Information on interested chemical standards are also cross-checked with legal documents promulgated by competent authorities in importing countries (e.g., the European Commission Decision 2002/657, the violation records posted on websites of food safety inspection authorities). The data set include data from 2001 to 2008.

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Estimated Results and Discussions

Table 1 shows the empirical results of the OLS and Heckman maximum likelihood models estimated in the log linear specification form. All zero observations have been omitted in the OLS model whereas all zero values are retained in the Heckman model. Fixed effects representing time period, reporters (importers) and partners (exporters) are included in both models. To control for heteroskedasticity and possible correlations of the same country pair across years, we use the country pair clustering option with White's (1980) standard error method. The double log linear OLS model means that the coefficients can be directly interpreted as the marginal change in the dependent variable induced by a change in independent variables, *ceteris paribus*. Whereas, the Heckman ML estimation is nonlinear, its coefficients are just linear indexes and cannot be directly interpreted as marginal changes in the dependent variable caused by a change in independent variables. Therefore, average marginal effects of the Heckman model are computed by the STATA 11.0 software and presented in Column 4, 5, and 6 of Table 1.

The choice of average marginal effects is preferred over marginal effects at means of the independent variables because the Heckman model is the nonlinear regression method with marginal effects change from observation to observation. Average marginal effects are computed by averaging marginal effects of individual data values, whereas marginal effects at the means only computes effect of one data point of independent variables (Cameron & Trivedi, 2010). The conditional marginal effect, and not the coefficient of the Heckman model, is comparable with the coefficient of the OLS model (Hoffmann & Kassouf, 2005).

As shown in column 1 and column 4 of Table 1, results of the OLS and Heckman models are similar with regards to significance level, magnitude and sign of considered independent variables. These results might come from the fact that the selection bias is statistically significant

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however not a serious problem, because the coefficient ρ is small (0.087). For example, the coefficient of the bilateral distance in both the OLS and Heckman models is as commonly found in the gravity estimation literature. One percent increase in the bilateral distance results in a decrease of 1.32% in bilateral seafood imports as predicted by the OLS model and of 1.28% as predicted by the Heckman model.

In both the OLS and Heckman models, four variables representing chemical food safety standards ($Chloramphenicol, Oxytetracycline, Quinolones$ and DDT)[2] are positive and statistically significant which is the hypothesized sign. Stricter chemical standard regulations (lowering analytical limit or maximum residue limits in traded products) in developed countries have negative impacts on their seafood imports. With regards to the intensive margin (volume) of trade, conditioned on positive trade being observed, one unit reduction in chloramphenicol analytical limit (1 ppb) reduces bilateral seafood import 0.86% predicted by the OLS model and 0.84%predicted by the Heckman model.[3]

Among the three chemicals with an established Maximum Residue Limits (MRL), the oxytetracycline standard has a less-severe negative impact on seafood import compared to that of quinolones and DDT. If the oxytetracycline MRL drops 0.01 ppm (10 ppb), seafood imports in the EU-15, Japan and North America would decrease 1.3%as predicted by both the OLS and Heckman model. Whereas, dropping the quinolones residue limit by 1 ppb would result in a decrease of nine percent in bilateral seafood import in Canada, EU-15 members, Japan, and the United States. The DDT regulation also has a significant influence on reducing bilateral seafood

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[2] For simplicity from now we drop all subscripts of the study variables.
[3] Semi-elasticity is computed by using the formula suggested by Hoffman and Kassouf (2005): percentage change in the dependent variable in the log form by one unit change in an independent variable is $[\exp(\beta) - 1] * 100)$

import. Decreasing DDT maximum limit in seafood 0.01 ppm (10 ppb) would reduce bilateral seafood imports by 2.9%.

Dummy variables representing common border ($Contiguous$), colonial tie ($Colony$) and EU-15 membership are statistically significant and have the expected sign in both the OLS and Heckman model. Bilateral seafood imports between country pairs sharing a common border are predicted to be 110.11 % (the Heckman model) and 134.44 % (the OLS model) higher than those between other country pairs. Countries having historical colonial ties also bilaterally trade more than other country pairs, between 183.42 % (the Heckman model) and 210.16% (the OLS model) higher. Similarly EU-15 members import a lot of seafood from each other (ranging from 327.33 % in the Heckman model to 359.49 % higher as predicted by the OLS model). In contrast, NAFTA membership does not help strengthen the bilateral seafood trade among its members. This is in line with findings in the trade literature that seafood trade among NAFTA shows a decreasing trend compared to that between a NAFTA member and other countries.

In addition to the conditional marginal effect, the Heckman model also provides information on the unconditional marginal effect (another dimension of the intensive margin of trade) and the marginal effect on the probability for bilateral trade taking place (the extensive margin of trade). In this paper, unconditional marginal effects are computed by the STATA software under the assumption that the dependent variable (log of bilateral seafood import) is equal to zero when it is not observed. As reported in Column 5 of Table 1, unconditional marginal effects are smaller than their counterpart conditional marginal effects. For instance, the magnitude of the average marginal effect of $Chloramphenicol$ on the dependent variable (log of bilateral import) changes from 0.008 (conditional) to 0.005 (unconditional). As Hoffmann and Kassouf (2005) suggest, the unconditional marginal effect equals to the conditional marginal

effect plus the effect associated to a change in the probability of being selected (e.g., into bilateral trade). Since the conditional marginal effects on small bilateral trade values (e.g., zero and small positive observations) are small, the resulting unconditional marginal effects are smaller.

With regards to the extensive margin, chemical food safety standards under examination only have negligible impacts on the probability of bilateral imports. As reported in Column 6 of Table 1, coefficients of *Chloramphenicol* and *Oxytetracycline* are not statistically significant, whereas coefficients of *Quinolones* and *DDT* are significant but small in magnitude. Reducing *Quinolones* one unit (1 ppb) would bring a reduction of 0.3%to the probability of positive trade being observed. The bilateral distance variable has a negative relationship with the probability of positive trade being observed. One percent increase in the bilateral distance results in a drop of 0.121 percentage points of the probability of bilateral import. Compared to other pairs, countries having a colonial relationship have a higher probability (an additional 0.051) to conduct bilateral seafood imports. The common language variable also has a similar effect on increasing the probability of trade (with an additional amount of 0.065). Surprisingly, the dummy variable representing NAFTA membership does not affect the intensive margins of trade but has a large effect on the extensive margin. This incidental finding might result from the unusual pattern of bilateral seafood trade between NAFTA member countries.

As suggested by the literature, the OLS and Heckman models could have problems of misspecification and heteroskedasticity. Therefore, the Ramsey Reset specification test was used to evaluate the outcome (trade) equation of the Heckman and OLS models. Following Santos Silva and Tenreyro (2009; 2006) and Xiong and Beghin (2011), we added the square of fitted values into the auxiliary regression for the test. The significance of this additional regressor

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confirms that the model is misspecified. To address the heteroskedasticity concern specifically of the Heckman model a homoskedasticity test was used on the first stage probit estimation. Following Santos Silva and Tenreyro (2009), the square and cubic of the linear index (xb) predicted by the first stage probit model were included in the auxiliary probit regression. The joint significance of these additional regressors confirms that heteroskedasticity exists. Because of these results, we consider the Poisson family of regressions.

Results of the Poisson family regressions are reported in Table 3. Estimates of the PPML and NB models are shown in Column 1 and 2, respectively. The ZIP and ZINB[4] models' coefficients are included in Columns 3 to 6 of Table 2. The ZIP and ZINB model each consist of two equations. The logit equation models the probability of the zero- trade group, and the Poisson or Negative Binomial equation predicts the probability of bilateral trade (including zero trade observations as an additional count) as count data. Since the dependent variable in Poisson family equations is linked to the exponential conditional mean, the coefficients can be interpreted as semi-elasticities (Cameron & Trivedi, 2010).[5]

As shown in Table 3 with the exception of the NB model, the parameter estimate of the bilateral distance tends to be lower in the Poisson family regressions compared to those from the OLS and Heckman model. For example, one percent increase in the bilateral distance would be associated with a decrease of 0.67%, 0.65%, and 0.36% of bilateral seafood imports as respectively predicted by the PPML, ZIP, and ZINB models. The direction and magnitude of coefficients of variables representing chemical food safety standards (*Chloramphenicol,*

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[4] Due to problems with convergence of the ZINB model, the model presented has only exporter and time fixed effects.

[5] Percentage change in the dependent variable in the log form by one unit change in an independent variable is $[\exp(\beta) - 1] * 100)$. This formula is correct for independent variables in level form either continuous or dummy variables. For a continuous variable, semi-elasticity is approximately equal to ($\beta * 100$).

$Oxytetracycline, Quinolones, and DDT$) remain similar to those found in the OLS and Heckman equations. Quinolone standards continue to have the strongest negative impact on bilateral imports. Decreasing 1ppb in quinolone standards (increasing the stringency of regulation) results in a reduction of 6.7%, 11.5 %, and 7.2% of imports, predicted by the PPML, NB, and ZINB models.

The impact of $NAFTA$ and common language variables on seafood imports predicted by the Poisson family regressions do not show a consistent direction. The parameter estimate of the NAFTA variable changes from negative and statistically significant in the PPML and ZIP models to positive and statistically significant in the ZINB model. The sign of dummy variables representing common border ($Contiguous$), colonial tie ($Colony$), and bilateral pairs of EU-15 membership ($EU15$) in all Poisson family regressions appear as expected. However the magnitude of coefficient estimates of these variables is generally larger than those predicted by the OLS and Heckman models. For instance, bilateral seafood imports between countries sharing common border increases from 86.26%, 191.54%, 195.65%, and up to 1,219.71% as predicted by the PPML, NB, ZIP, and ZINB models. Similarly, the increase in imports between countries both in EU-15 members ranges from 197.73% to 689.32%, 702.85%, and 1,011.17% as predicted by the ZINB, ZIP, PPML, and NB models.

Similar to the Heckman selection model, the ZIP and ZINB models also provide an explanation to zero trade values. However the difference between the two approaches is that the Heckman selection equation reports factors affecting the probability of positive trade. In contrast, the logit equation in the ZIP and ZINB models show factors affecting the probability of having zero trade values. Consequently, the sign of independent variables reported in the two probability predicting equations are opposite to each other if the estimation is consistent. As reported in

Column 3 and Column 5 of Table 3, distance has a positive effect on the probability of zero bilateral trade. Increasing bilateral distance associated with increasing the likelihood of zero trade being presented. Chemical standards (e.g., *Quinolones*) have negative effects, meaning that stricter food safety regulations (decreasing the ppb) would increase the probability of having zero trade values. This prediction is consistent with what we find in the Heckman model estimation presented in Table 1.

The Poisson family regressions became an alternative solution to modeling the gravity equation after Santos Silva and Tenreyro (2006). The standard Poisson estimator (PPML) suggested by Santos Silva and Tenreyro (2006) addressed the unobserved heteroskedasticity, however the PPML model might bias the parameter estimates in the presence of excess zero values and overdispersion problem. Modified Poisson regressions such as the NB, ZIP, and ZINB models can be considered as potential alternatives to overcome these problems. However the choice of specific Poisson model specification should be based on formal statistical test as well as economic implications of the parameter estimates.

As presented in Table 3, four standard statistical tests, namely the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), the likelihood ratio test of overdispersion, and the Vuong statistic, are computed for determining the best Poisson model choice. Unfortunately all four statistical tests do not point to the same conclusion. By the AIC as well as BIC criteria the NB model is favored over the other competing models presented in Table 3. The likelihood ratio test of overdispersion also indicates that the NB model is favored over the PPML model. The Vuong test suggests that the ZINB model is more appropriate than the NB, ZIP, and PPML models. This finding is similar to what Burger et al. (2009) found in their

empirical estimation that the model selection basing on formal statistics are indecisive. Nevertheless, the PPML specifications appear dominated by the NB specifications.

Because of the ambiguity of results, Table 4 presents the extensive and intensive marginal effects of the four chemical standards for the Heckman and the ZINB models. As an additional step, we ran the J-test on the Heckman and ZINB models to determine the best model (Davidson & MacKinnon, 1981). The results were inconclusive. These models represent the commonly used models and ones that the statistical analysis suggests are better by certain criteria. The marginal effects are the same sign, same statistical significance, and similar magnitude.[6] The Heckman model does have values that are lower by half for each value. The marginal effects from the two models suggest upper and lower boundaries of the estimates. These marginal effects all suggest that these standards lower the intensive trade and only quinolones and DDT lower the extensive margin.

Conclusions

The main objective of this investigation was to test if food safety (chemical) standards act as barriers to international seafood trade. Our empirical estimation results confirm this hypothesis and are robust to the OLS as well as alternative zero-accounting gravity models such as the Heckman ML procedure and the Poisson family regressions. Increasing the stringency of regulations by reducing analytical limits or maximum residue limits in seafood in developed countries has negative impacts on their bilateral seafood imports. Quinolones standard shows strong negative impacts on seafood trade aggregated at two-digit level. Chloramphenicol

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[6] Care needs to be taken in evaluating the results: The positive sign suggests that a tightening (lower value of ppb) of the regulation has a negative effect on trade. Likewise for the ZINB, the extensive marginal effect is of the probability of zero trade as compared to Heckman which reflects the probability of positive trade. The differences in signs indicate that both marginal effects are similar.

standards (*Chloramphenicol*) have less negative impact on seafood import aggregated at the two digit level (product code 03 in the HS 1996 system).

For the choice of the best model specification to account for zero trade and heteroskedastic issues, the paper shows that it is inconclusive to base on formal statistical tests. This finding is similar to the findings of Martin and Pham (2008) and Burger et al. (2009). Similar to Xiong and Beghin (2011), we find heteroskadiscity in the Heckman model; however, the J-test does not provide conclusive evidence of a best model. Based on the magnitude of coefficients, their economic implication, and previous findings in the literature, the Heckman ML and ZINB estimations provide ranges for plausible estimates. Since the correlation coefficient (ρ) in the Heckman between the selection equation and outcome equation is small, dropping zero trade values does not result in serious bias. Nevertheless, the Heckman estimation is superior to the OLS method since it offers two other dimensions, the statistical inference to the full population (including trading and not trading pairs) and the extensive margin of trade (the probability for positive trade being observed). The Vuong test suggests that the ZINB model is more appropriate than the other Poisson models. Therefore we consider both models.

While compliance with these stringent food safety standards is increasingly difficult for developing countries, it also opens opportunities for successful firms and exporting countries to sharpen their competitive advantage (Henson & Jaffee, 2008). These dynamic impacts of food safety standards should be further investigated, using the alternative zero accounting specifications of the gravity model discussed above. We did not investigate welfare implications of the impact of these non-tariff measures in importing countries. Future work could assess these welfare implications accounting for the health effects of food safety as in Disdier and Marette (2010).

Gravity Model Selection in Seafood Trade

Table 1: Empirical results of the OLS and Heckman maximum likelihood estimations

Variables	OLS Model	Heckman MLE Model				
	ln(Import) (1)	ln(Import) (2)	Selection (3)	Conditional Marginal Effect (4)	Unconditional Marginal Effect (5)	Prob. of Selection (6)
ln(Distance)	-1.3234***	-1.3589***	-0.7791***	-1.2820***	-1.0835***	-0.1213***
	(0.0894)	(0.09)	(0.0581)	(0.0891)	(0.0583)	(0.0085)
Chloramphenicol	0.0085***	0.0898***	0.0023	0.0084***	0.0052***	0.0004
	(0.0024)	(0.0023)	(0.0023)	(0.0024)	(0.0014)	(0.0003)
Oxytetracycline	0.0013***	0.0013***	0.0018	0.0013***	0.0006***	1.16e-05
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(9.14e-06)
Quinolones	0.0861***	0.0876***	0.0178***	0.0859***	0.0496***	0.0028***
	(0.0042)	(0.0041)	(0.0025)	(0.0041)	(0.0025)	(0.0004)
DDT	0.0029***	0.0029***	0.0008***	0.0029***	0.00018***	0.0001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(1.07e-05)
Contiguous	0.8519***	0.7780***	0.3754	0.7424***	0.6136*	0.0600
	(0.2653)	(0.2608)	(0.3870)	(0.2540)	(0.3321)	(0.0632)
Colony	1.1319***	1.0724***	0.3201***	1.0418***	0.7139***	0.0510***
	(0.1740)	(0.1569)	(0.1007)	(0.155)	(0.1200)	(0.0163)
EU15	1.5249***	1.5236***	0.7889***	1.4524***	1.3125***	0.1294***
	(0.3216)	(0.3204)	(0.2589)	(0.3142)	(0.3060)	(0.0440)
NAFTA	-0.6798	-0.7072	4.4879***	-0.9261	0.2670	0.5367***
	(0.5734)	(0.6137)	(0.3500)	(0.6172)	(0.5989)	(0.0117)
Common Lang	-0.1599		0.4071***			0.0650***
	(0.1533)		(0.0759)			(0.0130)
R-squared	0.675					
rho		0.087***				
N	13519	30960				
Censored N		17441				

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Uncensored N	13519
Log pseudolikelihood	-36671.8
Wald chi2(245)	

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard errors.

Table 3: Tests on OLS and Heckman ML models

Test indicators	OLS model		Heckman ML model	
Ramsey Reset test[a]	F-statistic	P-value	Z-statistic	P-value
H0: No specification error	119.83	0.000	1.71	0.087
Heteroskedasticity test[b]	$X^2 - statistic$	P-value	Z-statistic	P-value
H0: Homoskedasticity	531.27	0.000	7.24	0.000

Note: [a]Ramsey Reset test for misspecification tested on the outcome (trade) equation of the OLS and Heckman specifications.

[b]Homoskedasticity test was on the first stage probit estimation of the Heckman model and the OLS regression. The joint significance of these additional regressors confirms that heteroskedasticity.

Gravity Model Selection in Seafood Trade

Table 3: Results of Poisson family regressions

Variables	PPML model	NB model	ZIP model Logit	ZIP model Import	ZINB model[7] Logit	ZINB model[7] Import
ln(Distance)	-0.6682***	-1.7315***	1.4121***	-0.6452***	0.3221***	-0.3594***
	(0.0955)	(0.0994)	(0.0541)	(0.0001)	(0.0223)	(0.0276)
Chloramphenicol	0.0071***	0.0098***	-0.0036	0.0069***	-0.0013	0.0091***
	(0.0010)	(0.0027)	(0.0035)	(5.65E-06)	(0.0029)	(0.0035)
Oxytetracycline	0.0012***	0.0010***	-0.0002***	0.0012***	4.75E-05	0.0012***
	(0.0001)	(0.0001)	(0.0001)	(2.04E-07)	(0.0001)	(0.0001)
Quinolones	0.0672***	0.1151***	-0.0317***	0.0669***	-0.0067**	0.0715***
	(0.00672)	(0.0047)	(0.0033)	(1.09E-05)	(0.0026)	(0.0032)
DDT	0.0057***	0.0047***	-0.0014***	0.0022***	-0.0005***	0.0025***
	(0.0022)	(0.0039)	(0.0001)	(4.70E-07)	(0.0001)	(0.0001)
Contiguous	1.0704***	0.6225**	-0.8845***	1.0841***	-3.4024	2.5804***
	(0.2673)	(0.2934)	(0.3283)	(0.0003)	(2.5893)	(0.1420)
Colony	0.6084***	1.0197***	-0.5987***	0.5901***	-0.6098***	1.3060***
	(0.2343)	(0.1965)	(0.1059)	(0.0003)	(0.0949)	(0.1020)
EU15	2.0830***	2.4083***	-1.4181***	2.0658***	-25.3058	1.0911***
	(0.4009)	(0.2816)	(0.2958)	(0.0006)	(10771.040)	(0.0806)
NAFTA	-0.7634*	-1.0613	-27.9923	-0.6961***	-23.4802	1.0499***
	(0.4171)	(0.9559)	(1823547.0000)	(0.0005)	(78357.300)	(0.4504)
Com Lang	0.0179	0.8948***	-0.6881***	-0.0085***	-0.2370***	-1.1179***
	(0.2022)	(0.1573)	(0.0809)	(0.0085)	(0.0672)	(0.0753)
Fixed effects	yes	yes	yes	yes	Yes	Yes
Observations	30960	30960		30960		30960
Log pseudolikelihood	-135800000.0	-133206.7		-127000000.0		-140620.9
AIC	823223.0	266909.4		253000000		281371.7
BIC	823231.3	268977.9		253000000		281913.9
Overdispersion (α)		7.2***				940000000.0***
Vuong statistic				65.28***		52.9***

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard error

[7] Due to convergence problems, the ZINB model is estimated with exporter and time fixed effects.

Table 4. Average Marginal Effects of MRL Standards

	Intensive Margin	Extensive Margin	Intensive Margin	Extensive Margin
	Heckman Sample Selection		Zero-Inflated Negative Binomial	
Chloramphenicol	0.00522***	0.00035	0.00913***	-0.00128
Oxytetracycline	0.00062***	0.00001	0.00116***	0.00005
Quinolones	0.04950***	0.00277***	0.07151***	-0.00669**
DDT	0.00177***	0.00012***	0.00250***	-0.00045***

***, **, and *: significant at 1%, 5%, and 10% respectively; numbers in parentheses are White's standard error. The standards become stricter as the MRL becomes smaller; therefore, a more stringent MRL has a negative effect on trade at the intensive and extensive margin for the Heckman specification and the intensive. Base on a J-test (Davidson & MacKinnon, 1981), we were not able to find support of one model over the other.

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