Determinants of World Demand for U.S. Corn Seeds:

The Role of Trade Costs

Sampath Jayasinghe
Ph.D. Student, Department of Economics, Iowa State University

John Beghin
Professor, Department of Economics, Iowa State University and Visiting Professor at the University of Sydney, Australia.

GianCarlo Moschini
Professor and the Pioneer Hi-Bred Chair in Science and Technology Policy, Department of Economics, Iowa State University.

This preliminary draft: April 30, 2008
Selected paper of the 2008 AAEA Meetings

Abstract

The United States is a large net exporter of corn seeds. Seed trade, including corn, has been expanding but its determinants are not well understood. This paper econometrically investigates the determinants of world demand for U.S. corn seeds with a detailed analysis of trade costs impeding exports flows to various markets. Trade costs include costs associated with distance, tariffs, and sanitary-phytosanitary (SPS) regulations imposed by foreign countries on U.S. corn seed exports. SPS policy information comes from the Excerpt data base of USDA-APHIS. The analysis relies on a gravity-like model based on an explicit specification of derived demand for seed by foreign corn producers. A SPS count variable is incorporated as a shifter in the unit cost of seeds faced by foreign users. We use data from 48 countries and for the years 1989 to 2004. We find that all trade costs matter and have had a negative impact on U.S. corn seed exports. Tariffs matter most; followed by SPS measures and distance. An extensive econometric investigation reveals that qualitative results are robust to specification changes, but that sample selection bias is present in log-linear specifications based on seed export levels and approximating zero trade data with a small positive number.

Keywords: Seeds, corn, SPS, phytosanitary, exports, trade cost, technical barriers, tariffs,

TBT.

1. Introduction

The U.S. commercial seed market is the world's largest with an estimated annual value exceeding $6 billion per year in late 1990s, followed by China and Japan. Over the past decade, the U.S. seed market has been growing in quantity and value, particularly for major field crops such as corn, soybeans, cotton and wheat, which constitute two third of the commercial seed market in the United States (Fernandez-Cornejo and Caswell, 2006). Seed trade has been an integral part of this market expansion. The United States is a net and large exporter of corn seed for planting. The U.S. corn seed export value grew from approximately US$ 68.5 million in 1989 to 174 million in 2004. Italy, Mexico, Canada, France, and Spain are the largest importers of U.S. corn seed. Together, these countries accounted for approximately 60 percent of total U.S. corn seed exports in 2004[1]. However, seed trade is underdeveloped with much potential to expand especially in developing countries (McGee, 1998). Only 10 percent of total U.S. commercial seed goes to developing countries such as India and China. Both these countries represent large potential seed markets along with Brazil and Argentina (Fernandez-Cornejo, 2004).

There has been a rising use of standards and technical regulations as instruments of commercial policy in world agri-food trade, as tariff and quota barriers continue to decline and as consumers demand safer agri-food products (Beghin, 2008a; Henson and Wilson, 2005). Among non-tariff measures, sanitary and phytosanitary (SPS) regulations and technical barriers to trade (TBTs) are of increasing importance as impediments to, and sometimes facilitator of, agri-food trade (Disdier, Fontagné, and Mimouni, 2008; and Moenius, 2006).

[1] On regional basis, North America (36 percent), Western Europe (32 percent), Asia (11 percent), other European countries (6 percent), and South America (4 percent) accounted for 89 percent of the total quantity of U.S. exports in 2004 (FAS USDA, 2007).

Much less is known about seed trade and seed trade policies, which to date has not attracted much attention from economists, although seed scientists have raised concerns (Rohrbach, Minde and Howard, 2003; McGee, 1998). The U.S. seed industry faces significant problems satisfying SPS regulations because of increasing concerns about seed safety, stricter SPS requirements in trade, and competitiveness in export markets, and occasionally protectionism.

There is a large literature on the analysis of TBTs and SPS measures. Notable earlier contributions and reviews include Anderson, et al. (2001); Bureau and Beghin (2001); Deardorff and Stern (1998); Maskus and Wilson (2001); and others (Henson and Wilson (2005) provide a comprehensive discussion of earlier contributions). Beghin (2008b) reviews the more recent developments on this topic. Conspicuously absent in this SPS literature are formal analyses of seed trade determinants and the impact of associated SPS regulations. This void is surprising because seeds are well-known vectors of invasive pests and species propagation. Accordingly, SPS measures have been extensively used in world seed trade in order to mitigate the introduction of exotic species, pests, and diseases, and to limit risks to human and animal health. Examples include quarantine, inspections, tests, certificates, fumigation, and outright bans.

This paper fills this gap and addresses the following question: what does actually determine seed trade among a list of presumed relevant factors (relative seed price, corn output, tariff, transportation cost, and SPS policies) and what is their relative importance? This is a pertinent research question, which leads to a formal elucidation of seed trade and its policy determinants. To estimate the factors determining world demand for U.S. seed corn exports, we first develop a parsimonious seed export demand model that we later use for an econometric investigation of world demand for US corn seeds using a newly constructed data set covering major corn and silage producing countries and their trade policies (tariffs, SPS measures) faced by US seed exporters, over time. The frequency measure of SPS policies is based on the EXCERPT regulation database collected for USDA-APHIS by Purdue University.

Our investigation relies on a gravity-equation-type model. An original feature of our setup is that the model is grounded in intermediate demand, rather than final demand as all other gravity models. Many agricultural products are indeed intermediate demand of other industries; our specification is likely to be appropriate for other agricultural trade applications. The applied trade literature has neglected this simple but important point on the differentiation of intermediate and final demands (see also Ghazalian et al. (2007) for a related intermediate demand approach). We find that trade costs are important determinants of seed export demand: tariffs, SPS regulations and distance negatively affect U.S. corn seed export demand.

2. A Gravity Equation for Imported Seed Demand

As in the gravity equation, we use the simple constant elasticity of substitution (CES) model structure to incorporate the intermediate demand for corn seed in corn production and eventually to calculate the tariff equivalent estimate of SPS regulations. The significant departure is that the CES applies to production rather than final consumer preferences. In dual form, the cost function for corn production derived from a CES production function can be written as follows:

(1) $$C_j = Q_j \left(\sum_{i=1}^{n} \theta_i W_{ij}^{1-\sigma} + \sum_{k=1}^{m} \phi_{jk} R_{jk}^{1-\sigma} \right)^{\frac{1}{1-\sigma}},$$

where Q_j is corn production for country *j*; W_{ij} is the price paid by corn producers of country *j* for their seed corn sourced in country *i*; R_{jk} is the price of the *k*th non-seed input used in country *j;* σ is a parameter which determines the degree of substitutability of the inputs; and θ_i and ϕ_{jk} are technology productivity parameters associated with the various inputs used. Note that we assume that the productivity parameters of the seed input are the same in all countries, although seeds sourced in different countries can have different productivity. With that we try to capture, somewhat roughly, the fact that origin-differentiated seeds may differ in quality and may be imperfect substitutes. On the other hand, the ϕ_{jk} parameters associated with non-seed inputs are allowed to differ across countries, and thus we do allow for some heterogeneity in the technology for final corn production.

The output-constant factor demands for corn seeds, by Shephard's lemma, are

$$(2)\qquad X_{ij} = \frac{\theta_i}{W_{ij}^{\sigma}} Q_j \left(\sum_{i=1}^{n} \theta_i W_{ij}^{1-\sigma} + \sum_{k=1}^{m} \phi_{jk} R_{jk}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}.$$

We write seed input prices at destination *j* as

$$(3)\qquad W_{ij} = W_i T_{ij},$$

where W_i is the export unit price (FOB) of seed corn sourced in country *i* and $T_{ij} \geq 1$ is the trade cost factor (also known as trade resistance) that reflects the impacts of tariffs, distance and SPS regulations affecting the price of seed corn from country *i* and landed in country *j*. The export unit cost multiplied by the trade cost factor is equal to the price paid by seed corn users in country *j*, W_{ij}. By using equation (3), the seed import demand in each country can be expressed as

$$(4)\qquad X_{ij} = \theta_i Q_j c_j^{\sigma} W_i^{-\sigma} T_{ij}^{-\sigma},$$

where c_j is the unit cost function for corn production defined as

(5) $$c_j = \left(\sum_{i=1}^{n} \theta_i W_{ij}^{1-\sigma} + \sum_{k=1}^{m} \phi_{jk} R_{jk}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}.$$

Demand equations for non-seed inputs could similarly be derived from (1). But in our application we will not have data on them, and so we derive a specialized formulation that allows us to ignore their explicit impacts. Specifically, to proceed we will assume a competitive structure in final corn production, which justifies the constant return to scale (CRTS) assumption implicit in out CES specification. In a competitive equilibrium, therefore, the unit production cost c_j will equal the expected output price, i.e., the expected corn price in country *j*. Furthermore, we do not have data on seed imports from all destinations, but we do have detailed data on export of U.S. corn seeds. So, in what follows we focus on trade in corn seed coming from a single source (the United States).

2.1. A model for U.S. corn seed exports

Because we consider seed sourced in the Unites States only, in what follows we simplify the notation and drop the subscript i that denotes the source. To make this foregoing model operational, we also need to be specific on the formulation of the trade resistance factor. We write this factor as:

(6) $$T_j = \left(1+\tau_j\right)\left(1+S_j\right)^{\beta}\left(1+D_j\right)^{\gamma},$$

where T_j is the trade resistance factor, towards seed imports from the United States, in country *j*; τ_j is the (ad valorem) trade tax on seed corn levied by country *j* ; S_j is a variable capturing the effects of SPS regulation in country *j* (we will represent that as the count of SPS measures that apply to U.S. corn seed exports to country *j*); D_j is the distance from the United States to country j; and β and γ are coefficients that parameterize the effects of SPS variables and distance into tariff factor equivalent effects.

With the foregoing parameterization, the import of corn seed in country j is written as

$$(7) \qquad X_j = \theta\, Q_j c_j^{\sigma} W^{-\sigma} \left[\left(1+\tau_j\right)\left(1+S_j\right)^{\beta} \left(1+D_j\right)^{\gamma} \right]^{-\sigma},$$

where, again, we have dropped the origin subscript so that, for example, W represents the U.S. corn seed export price. This equation represents the basis of our estimating model in the empirical application.

The seed trade equations that arise from our CES structure can be expressed in share form which, although structurally equivalent, will allow a different stochastic specification at the estimation stage. Specifically, summing over all destinations, total U.S. seed production X^s satisfies $X^s = \sum_{j=1}^{n} X_j$, so that the share of U.S. corn seed export accounted for by country j, is written as:

$$(8) \qquad \frac{X_j}{X^s} = \frac{Q_j c_j^{\sigma} T_j^{-\sigma}}{\left(\sum_{l=1}^{n} Q_l c_l^{\sigma} T_l^{-\sigma} \right)},$$

where the trade resistance factor is given by equation (6). Further defining total (world) final corn output as $Q^w \equiv \sum_{j=1}^{n} Q_j$, these share equations can also be written as

$$(9) \qquad \frac{X_j}{X^s} = \frac{Q_j}{Q^w} \frac{c_j^{\sigma} T_j^{-\sigma}}{\left(\sum_{l=1}^{n} \frac{Q_j}{Q^w} c_l^{\sigma} T_l^{-\sigma} \right)},$$

or, upon log transformation,

$$(10) \qquad \ln\left(\frac{X_j}{X^s}\right) = \ln\left(\frac{Q_j}{Q^w}\right) + \sigma \ln c_j - \sigma \ln T_j - \ln\left(\sum_{l=1}^{n} \frac{Q_l}{Q^w} c_l^{\sigma} T_l^{-\sigma} \right).$$

This representation of the share equation is the single-industry derived-demand equivalent to the gravity equation: X^s and Q_j correspond to aggregate output in the exporting and importing countries; T_j is the trade cost factor between the exporting and importing countries, and $\left(\sum_{l=1}^{n}\left(Q_l / Q^w\right) c_l^{\sigma} T_l^{-\sigma}\right)^{-1}$ represents output-weighted world average trade openness often called the multilateral trade resistance.

3. Empirical Formulations

The model that we have developed is estimated with a sample of M observations of US corn seed exports going to n countries. The first empirical model that we formulate is the log transformation of equation (7), leading to the following model:

$$(11) \qquad \ln\left(\frac{X_{jt}}{Q_{jt}}\right) = \alpha_0 + \sigma \ln\left(\frac{c_{jt}}{(1+\tau_{jt})W_t}\right) - \sigma\beta \ln\left(1+S_{jt}\right) - \sigma\gamma \ln\left(1+D_{jt}\right) + u_{jt},$$

where $t = 1,2,...,M$ and $j = 1,2,...,n$, the intercept satisfies $\alpha_0 = \ln(\theta)$, and u_{ij} is an error term that is assumed to be independently and identically distributed, so that observations over all destinations can be pooled.

The log of shares as in equation (10) could similarly be formulated as an estimating equation by using the parameterizations in (6) and by adding an error term. Alternatively, we can consider the actual share equation itself. Our second estimating equation follows this approach and it is written as

$$(12) \qquad \frac{X_{jt}}{X_t^s} = \frac{Q_{jt}}{Q_t^w} \frac{c_{jt}^{\sigma}\left[\left(1+\tau_{jt}\right)\left(1+S_{jt}\right)^{\beta}\left(1+D_{jt}\right)^{\gamma}\right]^{-\sigma}}{\left(\sum_{l=1}^{n} \frac{Q_{jt}}{Q_t^w} c_{lt}^{\sigma}\left[\left(1+\tau_{lt}\right)\left(1+S_{lt}\right)^{\beta}\left(1+D_{lt}\right)^{\gamma}\right]^{-\sigma}\right)} + u_{jt}$$

where u_{ij} is, again, an error term that is assumed to be independently and identically distributed.[2] The parameter θ, which is the same for all destinations, does not appear in this share equation. Note that the denominator of this share equation includes a production-weighted "multilateral trade resistance" measuring the world average trade openness (for US seed corn). The latter empirical equation is the closest in spirit to recent gravity equation investigations (e.g., Disdier, Fontagné, and Mimouni, 2008).

3.1. The "zeros" problem

Two econometric issues that have been recognized to affect gravity model estimations are those of heteroskedasticity and zero values for the left-hand-side (LHS) variable. Correcting for possible heteroskedasticity is a challenging issue. The two estimating equations that we have derived attack this problem in a different way. In equation (11) the possibility of (a special type of) heteroskedasticity is accommodated by the standard log transformation of the LHS variable. In equation (12), it is the transformation into shares that attempts to achieve that. Both are crude methods, but a more ambitious approach is beyond the scope of the current paper.

A distinct problem is that of the LHS variable taking on zero values for a sizeable portion of or data set (about 30% of the observations). Several methods have been used in previous applications; Martin and Pham (2008) provide a taxonomy and a brief review of the relevant literature. One approach is to pool zero and non-zero observations. The logic of that is that zero trade is in need of an explanation as much as the quantity of positive trade,

---

[2] Note that, by construction, the error terms in equation (12) satisfy $\sum_{j=1}^{n} u_{jt} = 0, \forall t$. This reflects the well known singularity property of share equation systems. At the estimation stage, therefore, observations pertaining to one of the destinations (the United States, in our application) need to be dropped from the estimating sample.

although pooling the observations neglects that not all zeros are born equal. An additional problem with the strategy of pooling zero and non-zero observations arises with the log-linear version of the model in (11) because the log of zero is undefined. In the results reported below we handle that problem in the *ad hoc* way found in other application, by replacing observed seed trade X_{jt} by $X_{jt} + \varepsilon$, where ε is a 'small" number. The share model in equation (12), on the other hand, is obviously not in need of such an adjustment.

Recognizing that zero observations of trade, and the intensity of trade given positive observation, are somewhat distinct phenomena to be explained, a different approach concentrates on the latter objectives, drops all observations with a zero value of the LHS variable, and estimates the gravity model with the resulting "truncated" sample. We provide estimation results from this approach as well, for both the log-linear model and the share model. A more satisfactory approach, however, consists of addressing both the issues of zero trade and of the intensity of trade in a sample selection framework (Amemiya, 1984). We apply this estimation procedure to the log-linear model of equation (11). To briefly review, let y_t denote the vector of the LHS variables at time t corresponding to the trade equation (11), and let z_t be the corresponding trade indicator variable that takes on value one if positive trade is observed, and value zero if zero trade is observed. These observable variables are related to two latent variables that satisfy the following linear processes:

$$(13) \qquad \begin{bmatrix} y_t^0 \\ z_t^0 \end{bmatrix} = \begin{bmatrix} H_t\pi \\ L_t\psi \end{bmatrix} + \begin{bmatrix} u_t \\ v_t \end{bmatrix},$$

where H_t and L_t are vectors of conditioning variables, π and ψ are vectors on unknown parameters, and the error terms are identically and independently distributed. We further assume that they are normally distributed, so that maximum likelihood estimation is possible. Specifically:

$$(14) \qquad \begin{bmatrix} u_t \\ v_t \end{bmatrix} \sim NID\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \omega^2 & \rho\omega \\ \rho\omega & 1 \end{bmatrix} \right).$$

Finally, the observables of the model are related to these latent variables as follows: $y_t = y_t^0$ if $z_t^0 > 0$ and $y_t = 0$ otherwise; and, $z_t = 1$ if $z_t^0 > 0$, $z_t = 0$ otherwise.

4. Data Description

The U.S. seed corn export data are based on Foreign Agricultural Trade of the United States (FATUS) from the United State Department of Agriculture (USDA) which reports both value and volume (Table 1 in the Data Appendix available from the authors) . Under FATUS, volume is derived from value divided by the unit value of the largest seed category. We found some irregularities in the volume data reported in FATUS. Hence, we transformed the seed export value (US $) into quantities (metric tons) using the U.S. seed corn price in respective years as the average export unit value. This step provides quantity data that are consistent with the value data and that are quality adjusted as the export volume is expressed in the same volume unit for every country. The U.S. seed corn quantities and prices are from Economic Research Service, USDA (Tables 2 and 3 in Data Appendix). Annual seed corn production in the United States is calculated by adding total exports of US seeds to the estimated total domestic (US) use of seeds (Table 2 in Data Appendix).[3] Annual U.S. domestic use of seed is assumed to be equal to corn planted acres times the seed rate as assumed by USDA. Corn planted area for all purposes is taken from the National Agricultural Statistics Service (NASS), Agricultural Statistics Board, USDA. Average seeding rate per acre for corn is based on data from Cropping Practices Surveys and Agricultural

[3] When estimating trade share by country, we compute shares based on total seed use for countries included in the sample, and hence shares sum up to one.

Resource Management Survey (ARMS), Economic Research Service, USDA. The U.S. corn seed use data are by calendar year.

The seed export data are based on calendar year. We concentrate on 1989 to 2004 due to the limited export data availability in FATUS. Our final country sample consists of 48 countries based on the following criteria. This sample was selected based on an average minimum corn production of 1 million metric ton (mmt) per year including seed corn and forage, during the time period of the study. Australia was added to the sample as it has very restrictive corn seed regulations, although its corn production is smaller than 1 mmt. Total world corn production and each country's corn production are based on the Food and Agriculture Organization of the United Nations FAOSTAT (Table 4 in Data Appendix).[4] The FAOSTAT provides production data on Seed Maize (HS code: 1005) as well as Maize for Forage and Silage (HS code: 1214.90). Growers buy hybrid corn seed to produce silage just as they would to produce corn for other purposes. We found inconsistencies between large seed net imports and small corn outputs reported under HS 1005 in some countries in FAOSTAT data. Notably, we found that Japan, U.K., and the Netherland have sizeable imports of corn seeds but no significant seed maize production in FAOSTAT data. Most of these countries use corn for silage instead of maize. Given these facts, we account for the corn production for silage as being relevant for the overall demand for seed corn. To aggregate these two types meaningfully, we use 8 bushels of grain maize per one ton of silage to get units in green maize physical equivalent (based on the information found in Ontario Ministry of Agriculture, Food, and Rural Affairs' Field Crop News Letters). Corn production data is by calendar year. Our original country sample consisted of 54 countries. We deleted

[4] World corn output here is the sum of corn production in countries included in the sample so as to be consistent with the definition of trade shares.

Belarus, Moldova, Kazakhstan, and Russian federation for which we found some irregularities (wide unexplainable swings) in corn production data that could not be reconciled using other data sources. We also deleted Malawi and Nigeria, for which data were incomplete.

The expected producer price of corn is assumed to approximate the unit cost of corn seed production under the assumption of perfect competition in corn production and constant return to scale (Table 6 of Data Appendix). We formulate the expected price by regressing the corn price of each country on the lagged U.S. corn price including time trend and then getting the predicted values (see Data Appendix, part 2 for detailed econometric results). Current producer price is by calendar year and based on the FAOSTAT.

Tariffs applied to US-sourced corn seeds are based on World Bank's World Integrated Trade Solution (WITS) database (see Table 7 in Data Appendix). Tariff data are currently limited to 1996-2004 in WITS. Hence, we found some pre-1996 data from the Trade Analysis and Information System (TRAINS) database and Agricultural Market Access Database (AMAD). We use whatever data are available for 1989-1995 in TRAINS or AMAD and back track to 1989 assuming the same value for missing information. Tariff data are by calendar year.

Direct air distance between U.S. and the major financial capital of each country is based on the World Distance Tables from Inter-University Consortium for Political and Social Research (ICPSR) database (see Table 8 in Data Appendix). We use the log of air distance between the two major cities of the respective countries as the proximity measure. The cities are usually the capitals of the two countries. But we substitute the capital for a major city in a few cases, as the major city seems to be the country's economic center. For example, we use Shanghai for China rather than Beijing. Distance is set equal to zero for the

United States.

The number of SPS regulations imposed by the importing country is based on data from the Export Certification Project Demonstration (EXCERPT) database maintained at Purdue University on behalf of USDA APHIS (see Table 9 for the policy count and Table 10 for the years reported in EXCERPT in the Data Appendix). The SPS regulations for each country are updated in 2006 by the EXCERPT. However, older regulations starting from 1996 are reported the EXCERPT archives. We look at the following regulatory requirements: phytosanitary certificates, import permit, and field inspection as well as some demanding regulatory requirements: seed testing, post-entry testing, and quarantine. Virtually all countries require a phytosanitary certificate, except Canada. Australia and China have a seed import ban, although China imports some small amount of seeds in recent years. Some seed lines have to be imported in China to initiate local production. Hence, the Chinese trade ban is not as tight in recent years, although seed imports remain very small relative to the size of the Chinese corn sector. We use a large number for the SPS count (prohibitive SPS compliance cost) for China and Australia to mimic a SPS count equivalent to the bans.

Over time, most countries have streamlined their SPS regulations. Argentina and Chile have a low SPS count. The most radical simplifications have occurred in some East European countries which have now become the members of European Union (EU). Notably, in the last 10 years, Hungary started with a SPS count of 68, streamlined it to 30 in 2003, and eventually adopted EU regulations (SPS count of 3) with EU accession in 2004. South Africa, India, and Indonesia also simplified their regulations by removing all SPS requirements. Egypt, Zimbabwe, and surprisingly Brazil, have very high SPS counts. The Brazilian case is puzzling as the country is a large corn producer that would benefit from accessing to better choices of seeds.

5. Econometric Results

Table 1 provides results for the log-linear specification (equation (11)), with the approximation of trade flows ($X_{jt} \approx X_{jt} + \varepsilon$) for $\varepsilon = 1,\ 0.1,\ 0.01,$ and 0.001. All parameters estimates are statistically significant and have the expected sign. The three sources of trade cost impede trade. As ε becomes smaller, parameter estimates of γ and σ become larger, whereas the estimated response to the SPS cost becomes smaller, suggesting that the estimates are sensitive to treatment of zero-trade flows. For all four runs reported in Table 1, The tariff factor response matters most (-σ), followed by the factor for the cost of distance (-$\gamma\sigma$) and the SPS factor (-$\beta\sigma$).

Table 2 reports results for both the log-linear trade gravity equation (as in Table 1) and share specification (12), and for full and truncated samples. As previously suspected, the estimation of equation (11) based on the truncated sample shows that a sample selection issue is present. With data truncation, estimated parameters for distance and substitution decrease noticeably, and the SPS response β increases by 50% and becomes larger than the response to distance γ. The ranking of effects in the truncated estimation of equation (11) is, by decreasing order, tariff, SPS, and distance. A similar ranking hold for the share model (12). By contrast, the estimates obtained with the share model do not seem sensitive to the presence or exclusion of zero shares. Magnitudes of trade cost estimates and their ranking are similar across the two share specifications (full and truncated samples) and are close to the results obtained for equation (11) using the truncated sample. For these three specifications, the implied elasticities of the dependent variable to the trade cost factors are roughly -0.3 for distance, -0.7 for SPS policies, and -1.7 for tariffs.

Table 3 shows the results for maximum likelihood estimation of a sample selection model for the log-linear gravity equation (11). The selection equation depends on the trade costs components (tariff, distance, and SPS), and the trade intensity equation is specified as in Table 1. The implied structural parameter estimates are shown in the lower part of the table. These implied parameters estimates are significant and within the vicinity of the results reported in Table 2 for the truncated specification of (11). They are also close to those obtained with the share specification. The selection equation has all parameters significant with the expected sign, with the caveat that the tariff factor shows a positive response, a result at odd with our expectations.

In sum, results show that trade costs do matter considerably in corn seed trade. With the zero-trade data appropriately dealt with, tariffs factors have the largest effect, followed by the factor for SPS regulations, and last, the cost factor reflecting geographical distance. Our distance response estimates are well within the range reported by Disdier and Head (2008). Addressing zero trade flows seems to matter most for the log-linear specification based on trade levels. Results exhibit bias in absence of truncation or sample selection procedure. The trade share results appear much more robust to sample truncation and do not show evidence of sample selection bias in the estimates.

6. Concluding Remarks

The U.S. seed market is the largest in the world and rapidly expanding. Seed trade has been an important part of this expansion of the seed market. Despite these facts, seed trade and its determinants remain a neglected topic in agricultural trade research. We fill this gap with an analysis of trade costs associated with U.S. corn seed trade. We develop a parsimonious seed export demand model with sound conceptual foundation based on derived demand in production accounting for major trade costs including transportation, tariff factor and the cost of SPS measures affecting seed trade flows. We use a count of SPS regulations affecting U.S. corn seeds imbedded in a cost factor and posit that cost factor increases in the SPS count.

We estimate the export demand equation using two sets of empirical specifications directly based on our model, one for seed trade levels based on log-linear equation, and another based on trade shares. The major empirical findings of the study are that all the trade costs have a statistically significant and negative impact on U.S. corn seed exports. The decreasing order of importance is for the tariff factor, then the factor for SPS regulations, followed by the cost factor associated with distance, provided that sample selection bias is properly addressed.

We also addressed the large number of zero-trade observations in the data using in turn a sample truncation and then a sample selection model to first rationalize the trading decision, then its level. Results based on the log-linear specification are sensitive to how the zero-trade data are approached. Truncation and the sample selection approaches yield very close estimates with similar qualitative results. Estimation based on the trade share equation are not sensitive to truncation and do not suggest any presence of a selection bias.

This study contributes the existing literature in several ways. The research question addressed here –the determinants of seed export demand, to the best of our knowledge, is original in the economic literature. We derive a gravity-like approach to export demand based on derived demand in production unlike in other application of the gravity model to agricultural trade based on final demand. The dataset collected for the investigation is also novel in its SPS component and the development of the SPS count variable.

Our analysis has important policy implications. Tariff on agricultural goods remain important although they have somewhat decreased with the Uruguay round of the WTO and with regional trade agreements. Tariff on seed trade have been moderate (10% in our sample). Nevertheless, the high response of corn seed exports to tariffs suggests that tariffs remain an important barrier which could be reduced. The importance of trade costs induced by SPS regulations raises the issue of sorting which of these regulations are legitimate, that is, science based, and which are not and could be eliminated. Distance is irreducible of course. Our finding that distance matters the least among the three sources of trade cost is somewhat heartening.

Future work will further investigate sample selection bias with alternative specifications of the selection equation, and will derive marginal effects of trade costs including both extensive and intensive margins. Finally, we will also explore the sensitivity of results to the inclusion of geographical and regional fixed effects.

References

Anderson, K., McRae, C., Wilson, D., eds. (2001). *The Economics of Quarantine and the SPS Agreement*. Centre for International Economic Studies and the Department of Agriculture, Fisheries and Forestry - Australia/Biosecurity Australia, Adelaide.

Beghin, J. 2008a. "Nontariff Barriers," in *The New Palgrave Dictionary of Economics*, 2nd Edition, S. Darlauf and L. Blume, eds., Palgrave Macmillan LTD: 126-129.

Beghin, J. (2008b). "Recent Advances in the Economic Analysis of TBT and SPS Regulations." Invited paper at the 2008 AARES Conference, Canberra, Australia, February 7, 2008.

Beghin J., and J.C. Bureau. (2001). "Quantitative Policy Analysis of Sanitary, Phytosanitary and Technical barriers to Trade," *Economie Internationale* 87: 107-130.

Deardorff, Alan V., and Robert M. Stern. 1998. *Measurement of Nontariff Barriers: Studies in International Economics*. Ann Arbor MI: University of Michigan Press.

Disdier, A.C., L. Fontagné, and M. Mimouni. (2008). "The Impact of Regulations on Agricultural Trade: Evidence from SPS and TBT Agreements," *American Journal of Agricultural of Economics* 90(2): 336-350.

Disdier, A.C., and K. Head. (2008). "The Puzzling Persistence of the Distance Effect on Bilateral Trade," *Review of Economics and Statistics* 90 (1): 37-48.

Fernandez-Cornejo, J. (2004). "The Seed Industry in U.S. Agriculture. An Exploration of Data and Information on Crop Seed Markets, Regulation, Industry Structure, and Research and Development," USDA ERS Agricultural Information Bulletin No. 786, Washington DC.

Fernandez-Cornejo, J., and M. Caswell. (2006). "The First Decade of Genetically Engineered Crops in the US," Economic Information Bulletin 11, USDA.

Frankel, J. (1997). "Regional Trading Blocs in the World Economic System." Institute for International Economics, Washington, DC.

Ghazalian, P, L. Tamini, B. Larue, and J.P. Gervais. 2007.A Gravity approach to evaluate the significance of trade liberalization in vertically-related goods in the presence of non-tariff barriers." MPRA Paper No. 2744.

Henson, S., and J.S. Wilson,(2005). *The WTO and Technical Barriers to Trade*, Edward Elgar Publishing.

Martin, W., and Pham, C., "Estimating the Gravity Model when Zero Trade Flows are Frequent," *World Bank Working Paper*, January 2008.

Maskus, K.E., and J.S. Wilson. (2001). *Quantifying the Impacts of Technical Barriers to Trade, Can it be done?*, The University Michigan Press.

McGee, D.C. (1998). "Initiatives to Improve the International Seed Health System." *Seed Technology* 20: 18-22.

Moenius, J. (2006). "The Good, the Bad, and the Ambiguous: Standards and Trade in Agricultural Products," Paper prepared for the IATRC Summer Symposium, Bonn, Germany, May 28-30.

Rohrbach, D.D., I.J. Minde, and J. Howard. (2003). "Looking Beyond National Boundaries: Regional Harmonization of Seed Policies, Law and Regulations," *Food Policy* 28: 317-333.

Table 1. Log linear gravity equation of U.S. corn seed exports (1989-2004) Full sample with X_{jt} replaced by $X_{jt}+\varepsilon$

Variable	Estimated structural parameters with:			
	$\varepsilon=1$	$\varepsilon=0.1$	$\varepsilon=0.01$	$\varepsilon=0.001$
Intercept (α_0)	10.1037[a] (1.0455)	11.5279[a] (1.3477)	12.9522[a] (1.6783)	14.3764[a] (2.0235)
Distance (γ)	0.3617[a] (0.0512)	0.3837[a] (0.0607)	0.4015[a] (0.0701)	0.4162[a] (0.0786)
SPS (β)	0.3263[a] (0.0683)	0.3194[a] (0.0782)	0.3138[a] (0.0876)	0.3093[a] (0.0960)
Elasticity of substitution (σ)	2.0360[a] (0.2174)	2.2782[a] (0.2802)	2.5204[a] (0.3490)	2.7626[a] (0.4208)
R^2	0.2604	0.2167	0.1843	0.1612
Observations	639	639	639	639

Note: standard errors are in parentheses.
[a] denotes significant at the 1% level;

Table 2. Structural parameters from the Log linear gravity equation model and the share equation model

Variable	Estimated structural parameters with:			
	Log-linear model		Share model	
	Full Sample	Truncated Sample	Full Sample	Truncated Sample
Distance (γ)	0.3837[a] (0.0607)	0.2428[a] (0.0412)	0.1595[a] (0.0159)	0.1655[a] (0.0199)
SPS (β)	0.3194[a] (0.0782)	0.4635[a] (0.0807)	0.3981[a] (0.0289)	0.3767[a] (0.0350)
Elasticity of substitution (σ)	2.2782[a] (0.2802)	1.6520[a] (0.1725)	1.8168[a] (0.0658)	1.7064[a] (0.0782)
R^2	0.2167	0.3161	0.4428	0.4353
Observations	639	450	623	434

Note: In the log linear model with full sample, X_{jt} replaced by $X_{jt}+0.1$; standard errors are in parentheses; and [a] denotes significant at the 1% level.

Table 3. Maximum likelihood estimation of sample selection model
Log linear gravity equation specification

	Selection equation		Log of trade equation	
Variable	Parameter estimate	Standard error	Parameter estimate	Standard error
Intercept	14.2897	2.1429	7.0038	0.8524
$\ln(1+\tau_j)$	1.2057	0.1983		
$\ln\left(c_j/\left((1+\tau_j)W\right)\right)$			1.6777	0.1559
$\ln\left(1+D_j\right)$	-1.4941	0.2312	-0.2534	0.0739
$\ln\left(1+S_j\right)$	-0.1661	0.0554	-0.6097	0.1144
Recovered parameters				
Distance (γ)			0.1510	0.0434
SPS (β)			0.3634	0.0764
Elasticity of substitution (σ)			1.6777	0.1559
Observations	639		450	

Note: Maximized log-likelihood value = -1293.44; $\hat{\omega} = 2.4925$; $\hat{\rho} =$ -0.8717.