Determinants of World Demand for U.S. Corn Seeds: The Role of Trade Costs

Sampath Jayasinghe, John C. Beghin, and GianCarlo Moschini

Working Paper 09-WP 484
January 2009

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Sampath Jayasinghe is a research assistant in the Department of Economics at Iowa State University. John C. Beghin is the Martin Cole Professor of International Agricultural Economics, and GianCarlo Moschini is the Pioneer Chair in Science and Technology Policy, both in the Department of Economics at Iowa State University.

Questions or comments about the contents of this paper should be directed to John Beghin, 275, Heady Hall, Department of Economics, Iowa State University, Ames, IA 50011; Ph: (515) 294-5811; Fax: (515) 294-0221; E-mail: jbeghin@iastate.edu.

Abstract

The United States is a large net exporter of corn seeds. Seed trade, including that of 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 export flows to various markets, including costs associated with distance, tariffs, and sanitary and phytosanitary (SPS) regulations. The analysis relies on a gravity-like model based on an explicit specification of derived demand for seed by foreign corn producers, estimated based on data from 48 countries and for the years 1989 to 2004. An SPS count variable is incorporated as a shifter in the unit cost of seeds faced by foreign users. A sample selection framework is used to account for the determination of which trade flows are positive. All trade costs matter and have had a negative impact on U.S. corn seed exports. Tariffs matter most, followed by distance and SPS measures.

Keywords: corn, distance, phytosanitary, seeds, SPS, tariff, technical barriers, trade cost.

1. Introduction

The U.S. commercial seed market is the world's largest, with an estimated annual value exceeding $6 billion per year in the late 1990s, followed by those of 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-thirds 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 arguably 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. These two countries represent large potential seed markets, along with Brazil and Argentina (Fernandez-Cornejo, 2004).

The use of standards and technical regulations as instruments of commercial policy in world agri-food trade has been rising, 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 facilitators of, agri-food trade (Disdier, Fontagné, and Mimouni, 2008; and Moenius, 2006).

[1] On a 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).

Despite the substantial body of work analyzing the impact of standards and technical regulations on agricultural and food trade, little is known about seed trade determinants. Seed trade policies have not attracted much attention from economists, although seed scientists have raised concerns about SPS policies (Rohrbach, Minde, and Howard, 2003; and 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, competitiveness in export markets, and, occasionally, protectionism.

There is a large literature on the analysis of TBTs and SPS measures. Notable contributions include Anderson, McRae, and Wilson (2001); Beghin and Bureau (2001); Deardorff and Stern (1998); and Maskus and Wilson (2001). Henson and Wilson (2005) provide a comprehensive discussion of these and other earlier contributions. Beghin (2008b) reviews the more recent developments on this topic. Recent analyses include Calvin, Krissoff, and Foster (2008); Peterson and Orden (2008); Yue, Beghin, and Jensen (2006); and Yue and Beghin (forthcoming). Conspicuously absent in this SPS literature are explicit 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 quarantines, inspections, tests, certificates, fumigation, and outright bans.

This paper fills this gap and addresses the following questions: 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? These are pertinent research questions, which lead 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 develop a parsimonious seed export demand model and use it for an econometric investigation of world demand for U.S. corn seeds. The empirical analysis relies on a newly constructed data set covering major corn and silage producing countries and their trade policies (tariffs and SPS measures), which are faced by U.S. seed exporters. The frequency measure of SPS policies is based on the EXCERPT (Export Certification Project Demonstration) regulation database collected for the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), by Purdue University.

Our investigation relies on a sectoral gravity-equation-type model. An original feature of our setup is that the model is grounded in intermediate demand rather than final demand as are most other gravity models. Many agricultural products are indeed intermediate inputs used in other industries, and thus our specification is likely to be of interest 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 to final consumer preferences. Taking a dual approach to the specification of this technology, 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 that 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 conditional factor demands for corn seeds, by Shephard's lemma, are

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

Seed input prices at destination *j* can be written as

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

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*.

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

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

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 work with a specialized formulation that allows us to sidestep the modeling of 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 our 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 the foregoing model operational, we also need to be specific on the formulation of the trade resistance factor. We write this factor as

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

where T_j is the trade resistance factor, in country *j*, toward seed imports from the United States; 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* (which we will represent 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 U.S. corn seed in country j can be 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). Alternatively, 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) $$\frac{X_j}{X^s} = \frac{Q_j}{Q^w} \frac{c_j^{\sigma} T_j^{-\sigma}}{\left(\sum_{l=1}^{n} \frac{Q_j}{Q^w} c_l^{\sigma} T_l^{-\sigma} \right)},$$

or, upon log transformation,

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

This representation of the share equation is the single-industry derived-demand equivalent to the standard 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 U.S.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) $$\ln\left(\frac{X_{jt}}{Q_{jt}}\right) = \alpha_0 + \sigma \ln\left(\frac{c_{jt}}{(1+\tau_{jt})W_t} \right) - \sigma\beta \ln\left(1 + S_{jt}\right) - \sigma\gamma \ln\left(1 + D_{jt}\right) + u_{jt},$$

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 model follows this approach and, from equation (9), 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 U.S.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.

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[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) can be dropped from the estimating sample.

A distinct problem is that of the LHS variable taking on zero values for a sizeable portion of our data set (about 30 percent 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, although pooling the observations neglects that, to put it in a concise form, 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 applications, 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.

A different approach recognizes that zero observations of trade, and the intensity of trade given positive observation, are somewhat distinct phenomena to be explained; concentrating on the latter objective, this approach 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 no 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 have bivariate normal distribution. 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 USDA, which reports both value and volume. 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 the Economic Research Service, USDA. Annual seed corn production in the United States is calculated by adding total exports of U.S. seeds to the estimated total domestic (U.S.) use of seeds.[3] Annual U.S. domestic use of seed is assumed to be equal to corn planted acres times

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

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 the Agricultural 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 the calendar year. We concentrate on 1989 to 2004 because of 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 tons (mmt) per year, including seed corn and forage, during the time period of the study. Australia was added to the sample because 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.[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 the FAOSTAT data. Notably, we found that Japan, the United Kingdom, and the Netherlands have sizeable imports of corn seeds but no significant seed maize production in the 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

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[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.

bushels of grain maize per one ton of silage to get units in green maize physical equivalent. Corn production data are by calendar year. Our original country sample consisted of 54 countries. We deleted Belarus, Moldova, Kazakhstan, and the 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.

As noted earlier, in our framework the expected producer price of corn is assumed to approximate the (unobserved) unit cost of corn seed production under the assumption of perfect competition in corn production and CRTS. We obtain 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. The current producer price is by calendar year and based on the FAOSTAT.

Tariffs applied to U.S.-sourced corn seeds are based on World Bank's World Integrated Trade Solution (WITS) database (see Table 7 in the 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 backtrack to 1989 assuming the same value for missing information. Tariff data are by calendar year.

Direct air distance between the U.S. and the major financial capital of each country is based on the World Distance Tables from the Inter-University Consortium for Political and Social Research (ICPSR) database. 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. The SPS regulations for each country are updated in 2006 by the EXCERPT. However, older regulations starting from 1996 are reported in the EXCERPT archives. We look at phytosanitary certificates, import permit, and field inspection as well as some other demanding regulatory requirements, including 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 has imported a small amount of seeds in recent years. Some seed lines have to be imported by China to initiate local production. Hence, the Chinese trade ban has not been 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 an 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 Eastern European countries, which are now members of the European Union (EU). Notably, in the last 10 years, Hungary started with an 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 better seeds.

5. Econometric Results

Table 1 provides ordinary least square (OLS) estimation 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. We hypothesize a negative response of the dependent variable to all trade cost components. All parameter 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. Nonlinear least squares are used to estimate the share specification (12). 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 percent 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 holds 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 reports the results for maximum likelihood (ML) estimation of a sample selection model for the log-linear gravity equation (11). Notice that both the selection and the trade equations depend on the trade cost components (tariff, distance, and SPS) and a time trend as appears in the selection model but not in the trade equation. The selection equation has all parameters significant with the expected sign. The negative signs on the estimated parameters of the trade cost components in the selection model indicate that the likelihood to trade diminishes as the trade cost factors increase. Also, the positive sign on the estimated parameter of the time trend in the selection model indicates that the likelihood to trade has increased over time, consistent with trade integration.

The implied structural parameter estimates are reported in the lower part of Table 3. These implied parameter estimates are significant and similar in magnitude to the results reported in Table 2 for the truncated specification of (11). The estimated correlation coefficient $\hat{\rho}$ is negative and statistically significant, indicating a sample selection bias in the data. A comparison of OLS parameter estimates from the specification (11) in Table 1 with those of ML estimates in Table 3 indicates the selectivity bias in this analysis when using the OLS method. In particular, consider the change in the estimates for distance and SPS from OLS to the ML estimates. The coefficient for distance decreases from 0.4157 in OLS to 0.2312 in ML. The coefficient for tariffs decreases from 2.1365 in OLS to 1.4885 in ML. On the other hand, the coefficient for SPS increases from 0.3459 in OLS to 0.4769 in ML. In summary, the impact of distance and tariffs is overestimated and the impact of SPS is underestimated when failing to correct for the selectivity bias in the data.

Although the sample selection approach is popular in empirical analysis, marginal effects are often misinterpreted when a regressor enters into both selection and trade equations. In this case, when $\hat{\rho} \neq 0$, it is incorrect to interpret the estimated parameters of the trade equation shown in Table 3 as the marginal effect. Even if one were interested only in the conditional impact of a regressor (that is, conditional on trade taking place), in addition to the direct impact as per the estimated coefficients one still needs to account for the indirect effect (essentially, through the inverse Mills ratio; see, e.g., Greene, 2001). Furthermore, when a regressor affects both the intensity of trade and the probability that trade takes place, the total unconditional impact is arguably the effect of interest. To compute such unconditional marginal effects we follow Hoffmann and Kassouf (2005). The conditional and unconditional marginal effects are reported in columns 2 and 3 of Table 4. We evaluate the values of the conditional and unconditional marginal effects at the sample mean of the observations used to fit the model. The conditional marginal effects represent the elasticities of trade given that trade takes place (intensive margin). The unconditional marginal effects represent the elasticities of trade for all countries, trading and not trading (both intensive and extensive margins). The estimated unconditional marginal effects for the trade cost components are larger in absolute value than the conditional effects, because the former takes into account both extensive and intensive margins, whereas the latter only measures the intensive margin.

The tariff factor has the largest marginal effect, followed by distance and SPS factors. The striking result is the importance of the distance factor on both trade margins. The estimated parameters in the first column of Table 4 provide a poor gauge of the total marginal effect of the respective explanatory variables on trade.

Distance has the strongest effect on the extensive margin (likelihood to trade) as measured by the difference between the unconditional and conditional marginal effects. This suggests that transportation cost (as proxied by distance) is the major trade cost inhibitor of the emergence of new trade followed by tariffs and SPS measures. However, at the intensive margin, tariffs matter the most followed by distance and SPS measures.

In summary, the results show that trade costs do matter considerably in corn seed trade. Tariff factors have the largest effect, followed by the cost factor reflecting geographical distance, and last, the factor for SPS regulations, provided that sample selection bias is properly addressed. Gauging the effects of trade costs based on the estimation of equation (11) and/or equation (12) alone would be quite misleading. When properly computed using marginal effects derived from the sample selection model, the magnitude and ranking of the impacts of these trade costs on seed trade differ from the estimated regression coefficients on which they are based. The marginal effects are much larger in absolute value than the associated coefficients and reveal the relative importance of cost associated with distance.

We also note that our responses to distance are within the range of estimates reviewed by Disdier and Head (2008). Average tariffs on the U.S. seed trade have been moderate (10 percent in our sample) over the last two decades. Yet, the high response of corn seed exports to tariffs suggests that tariffs remain an important barrier that could be reduced. Also, SPS regulations pose a significant barrier to U.S. seed exports.

6. Concluding Remarks

The U.S. seed market is the largest in the world and is expanding. Seed trade has been an important part of this expansion. Despite these facts, seed trade and its determinants remain a somewhat 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 a sound conceptual foundation based on derived demand in production, accounting for major trade costs including transportation, tariff factors, and the cost of SPS measures affecting seed trade flows. We use a count of SPS regulations affecting U.S. corn seeds embedded in a cost factor and posit that the 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 a 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. We also address the large number of zero-trade observations in the data using both a sample truncation and a sample selection model.

Results based on the log-linear specification are sensitive to how the zero-trade data are approached. Truncation and the sample selection approaches yield close estimates with similar qualitative results. Estimated coefficients based on the trade share equation are not sensitive to truncation and do not suggest any presence of a selection bias. However, they do not provide enough information to compute full trade effects because they omit changes in the extensive margin and indirect effects occurring through the sample selection correction. Based on marginal effects computed from the sample selection model, the decreasing order of importance for trade costs is first tariffs, followed by distance, and then SPS regulations.

This study contributes to the existing literature in several ways. The research question addressed here, namely, the determinants of seed export demand, appears to have been ignored to date in the economic literature. Further, we derive a gravity-like approach to export demand based on derived demand in production unlike in other applications of the gravity model to agricultural trade based on final demand. Lastly, the dataset collected for the investigation is also novel in its SPS component and the development of the SPS count variable.

Our analysis has relevant policy implications. Tariffs on agricultural goods remain important, although they have moderately decreased with the Uruguay round of the World Trade Organization and with regional trade agreements. Tariffs on seed trade have been moderate (an average of 10 percent in our sample). Nevertheless, the high response of corn seed exports to tariffs suggests that tariffs remain an important barrier that could be further 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, but cost associated with distance could be reduced, which could lead to new trade.

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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)	9.7756* (1.0208)	11.1816* (1.3173)	12.5876* (1.6409)	13.9935* (1.9784)
Distance (γ)	0.3905* (0.0558)	0.4157* (0.0666)	0.4361* (0.0770)	0.4529* (0.0867)
SPS (β)	0.3506* (0.0708)	0.3459* (0.0814)	0.3421* (0.0914)	0.3389* (0.1004)
Elasticity of substitution (σ)	1.9111* (0.2070)	2.1365* (0.2672)	2.3618* (0.3328)	2.5872* (0.4012)
R^2	0.2425	0.2015	0.1715	0.1502
Observations	709	709	709	709

Note: standard errors are in parentheses.
* denotes significance 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)	0.4157* (0.0666)	0.2552* (0.0433)	0.1569* (0.0152)	0.1629* (0.0188)
SPS (β)	0.3459* (0.0814)	0.4731* (0.0809)	0.4101* (0.0279)	0.3845* (0.0330)
Elasticity of substitution (σ)	2.1365* (0.2672)	1.5794* (0.1642)	1.8613* (0.0644)	1.7227* (0.0739)
R^2	0.2015	0.2976		
Observations[a]	709	494	693	478

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 significance at the 1% level.

[a] The difference in the number of observations between the log-linear model (494) and the share model (478) of truncated samples is due to the deletion of the U.S. observations in estimating the share equation (equation (12)).

Table 3. Maximum likelihood (ML) 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	16.4842*	1.7996	6.7485*	0.8297
Time	0.0596*	0.0134		
$\ln\left(1+D_j\right)$	-1.6129*	0.1915	-0.3442*	0.0657
$\ln\left(1+S_j\right)$	-0.1702*	0.0559	-0.7098*	0.1025
$\ln\left(c_j/\left((1+\tau_j)W\right)\right)$	0.4747*	0.1236	1.4885*	0.1703
Recovered parameters				
Distance (γ)			0.2312	0.0465
SPS (β)			0.4769	0.0871
Elasticity of substitution (σ)			1.4885	0.1703
$\hat{\rho}$			-0.3645*	
$\hat{\omega}$			2.1508	
Observations	709		494	

Note: Maximized log-likelihood value = -1430.75, and * denotes significance at the 1% level.

Table 4: Conditional and unconditional marginal effects of trade costs

Variable	ML estimated coefficient of trade equation[a]	Conditional marginal effect[a]	Unconditional marginal effect[a]
$\ln\left(1+D_j\right)$	-0.3442	-0.9921	-1.8091
$\ln\left(1+S_j\right)$	-0.7098	-0.7782	-0.8644
$\ln\left(c_j/\left((1+\tau_j)W\right)\right)$	1.4885	1.6792	1.9194

[a] Because we use log specifications, the effects correspond to elasticities.