The Role of Intellectual Property Rights in Seed Technology Transfer through Trade – Evidence from U.S. Field Crop Seed Exports

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Abstract

To investigate whether intellectual property rights (IPRs) promote or hinder seed technology diffusion through trade, we use panel data for 134 countries over the period 1985-2010 to evaluate the impact of a country's IPRs on its seed imports from the U.S. by estimating a gravity equation using both linear and nonlinear (Poisson) fixed effects methods. In both the static and dynamic models, the variable for WTO member countries that have implemented the TRIPs (Trade-Related Aspects of Intellectual Property Rights) agreement consistently shows a significantly positive effect on seed imports. We improve on previous studies by focusing on one type of planting seeds - field crop seeds, also accounting for status of growing genetically modified crops, and utilizing an estimation technique (Poisson) that is more viable in the handling of zero trade observations.

Keywords: Intellectual property rights, seed trade, gravity equation

JEL Codes: F14, O34, Q17

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1. Introduction

Rising food prices driven up by food shortages in recent years have triggered social and political unrest in some parts of the world (FAO, 2012). The importance of food security is therefore, being brought back into the public policy spotlight. With a growing world population but limited land and water resources, the world is increasingly reliant on agricultural technology to raise food production. Seed is the basis of crop-based agriculture. Together with other contributing factors such as fertilizers, pesticides, herbicides and irrigation, improved seed varieties have been responsible for much of global yield increases (UPOV, 2009).[1] From conventional to hybrid to genetically modified (GM) seeds, the plant breeding and seed industry has been contributing to agricultural innovation.

The time-consuming nature and high costs associated with plant breeding puts small companies in a disadvantaged position to take on large scale research and development (R&D) efforts. According to the International Seed Federation's statistics, plant breeding companies typically reinvest 12-15% of their sales in R&D with the top 20 companies spending $4 billion every year on R&D. Moreover, the development cycle for a new variety usually takes 10-15 years. As a result, seed technologies are concentrated in a relatively small number of large firms, most of them based in the U.S. or Europe. The Big Six firms identified in a global seed industry study by Howard (2009) are split equally between the U.S. and Europe. The self-producing nature of (non-hybrid) seeds makes plant breeding innovations embodied in seeds particularly susceptible to being imitated or reproduced with minimal difficulty or at a low cost. Non-existent or insufficient intellectual property (IP) protection will jeopardize breeders' interests and reduce private incentives for further innovation efforts. To recover costs and receive proper

[1] UPOV is the acronym for *Union internationale pour la protection des obtentions végétales*, the French name of the International Union for the Protection of New Varieties of Plants.

returns on its R&D investment, the seed industry lobbies hard for stronger legal protection of its innovations. Over the years, intellectual property rights (IPRs) such as patents (more common in the U.S.) and plant breeder's rights (more common in Europe) have been established to regulate the seed market and confer exclusive rights, i.e., market power, for a limited period of time, thus giving the incentive and means to finance R&D activities. With the advent of GM crops, the relevance and significance of IPRs have been intensified as more proprietary seed technologies are involved.

Trade is an important channel through which technology gets transferred across borders (Grossman and Helpman, 1995).[2] Decisions by firms to export to a particular market are influenced by the effectiveness of local IPRs. However, national laws vary. To harmonize IPRs for cross-border trade, the World Trade Organization (WTO) agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs) went into effect on January 1, 1995. It makes protection of IPRs an integral part of the multilateral trading system. TRIPs has made a set of minimum IP standards a requirement for all its 159 members, and is to date the most comprehensive multilateral agreement on intellectual property. Furthermore, Article 27.3(b) of TRIPs also extends IPRs to new plant varieties by stipulating that member states must provide for the protection of seeds and plant varieties either by patents, or an effective *sui generis* system, i.e., a system created especially for this purpose, such as the plant breeder's rights provided in the conventions of the International Union for the Protection of New Varieties of Plants (UPOV), or by any combination of the two. The first UPOV Convention went into force in 1968. Its two most recent revisions are referred to as the "1978 Act" and "1991 Act", of which most of its 70 members are signatories (not including the EU). As a consequence, a country might provide UPOV-like protection without joining UPOV as a result of being a signatory of TRIPs.

[2] Additional technology transfer mechanisms include licensing and foreign direct investment (FDI).

If a country does not have legislation that is either compliant with international IPR standards or is lax in its enforcement of IRPs, seed companies may not want to sell to growers in that country in order to retain control over proprietary information.[3] But if IPRs become too stringent, especially by developing countries standards, they may in fact restrict market access. In either case, IPRs can act as a barrier to trade.

Another source of potential trade distortion is the acceptance or approval status of GM crops in different countries.[4] GM crops have been grown commercially since 1996, initially in 6 countries on 1.7 million hectares to 29 countries with 160 million hectares under cultivation by 2011 (James, 2011). Biotechnology innovations embodied in seeds lower input and production costs as well as enhance crop quality and productivity. However, not all countries have embraced GM crops due to concerns over potential harmful effects on human health and the environment (Singh *et al*., 2006). For instance, an EU moratorium on approval of GM crops (1999-2004) caused trade disputes with the U.S., Canada and Argentina that also affected seed trade. The approval status of GM crops therefore affects a country's import decision with respect to transgenic seeds.

In order to contribute to the understanding of whether IPRs encourage or impede seed technology transfer through trade, the objective of this paper is to assess the impact of a country's intellectual property rights (IPRs) on its seed imports from the U.S., and also to evaluate, if and how growing GM crops affects this relationship. For two reasons, the focus is on one type of seeds – field crop seeds. First, growth in the U.S. seed market has been particularly rapid for major field crops (Fernandez-Cornejo, 2004). Secondly, the four major GM crops are all field crops - soybeans, maize, cotton and canola (James, 2011).

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[3] Monsanto stopped selling soybean seeds in Argentina in the early 2000s when it could not enforce its property rights (Kesan and Gallo, 2007).

[4] Another possible non-tariff barrier is sanitary and phyto-sanitary standards (Jayasinghe et al., 2009)

In this paper both linear and nonlinear fixed effects estimators are used to fit a gravity model with data covering 137 countries over the period 1985-2010. The remainder of the paper is organized as follows: in section 2, a selected number of key previous studies on IPRs and trade are presented; in section 3, the model framework and data are outlined while in section 4 the estimation results and appropriate robustness checks are discussed; finally section 5 contains a summary of the paper and concluding remarks.

2. IPRs and Trade

With regard to how differing levels of IP protection across national borders influence trade flows, theoretical work does not provide an unambiguous answer (Grossman and Helpman, 1990; Grossman and Lai, 2004). Theoretical studies focus on two main counteracting effects of IPRs on market access: market expansion and market power. The market expansion effect increases trade flows toward countries with stronger IPRs because of increased demand and lower marginal exporting costs as a result of reduced threat of imitation. In contrast, trade flows may decrease through the market power effect, as IPRs provide monopolistic control of innovations and the holder of the IPR may exercises their monopoly power by raising prices and restricting export volumes. IPR's net effect on trade depends on the relative magnitude of these two effects. It is further complicated by firms' decisions to engage in licensing or FDI rather than exporting. Therefore, it is essentially an empirical question.

The empirical literature so far has been focused on manufactured goods, and studies in this area generally find IPRs to have a significantly positive impact on either OECD or U.S. exports in patent-sensitive sectors. Maskus and Penubarti (1995) present the first systematic evidence on whether differential patent laws influence international trade. Their analysis relies on trade data for a single year, 1984. Their results indicate that stronger patent protection has a positive effect on manufacturing imports into both small and large developing economies. Their finding also supports the view that trade reduction through the exercise of enhanced market power is more important in patent-sensitive sectors than in patent-insensitive sectors.

Using export data for 1992, Smith (1999) assesses the sensitivity of U.S. exports to national differences in patent rights. He finds that in countries that pose a strong threat-of-imitation, weak patent rights are a barrier to US exports, whereas in countries that pose a weak threat-of-imitation, increasing patent rights reinforces monopoly power and lowers U.S. exports to these markets.

Ivus (2010) evaluates the link between patent rights in developing countries and exports from the developed world over the period 1962-2000. She finds strengthening of IPR protection in response to TRIPs raised the value of patent-sensitive exports to developing countries.

A few researchers have studied the relationship between IPRs and seed trade in recent years. Yang and Woo (2006) is the first systematic study on IPRs and seed trade, followed by Eaton (2009). Both papers utilize aggregate seed data and fail to detect a significant effect of their IPR variables on trade in seeds. Using data on 60 countries over 1990-2000, Yang and Woo (2006) show that imports of planting seeds from the US are not discernibly affected by a country’s adherence to international IPR agreements, implying that agricultural trade does not seem sensitive to strengthening of IPRs. With data spanning 19 years (1989-2007), Eaton (2009) also finds no significant effect from UPOV membership on seed imports from 10 EU countries and the U.S. in 70 importing countries and suggests future research to narrow it to a single exporting country and a specific category of seeds. This paper builds on these two studies by utilizing a larger dataset and focusing on a subcategory of agricultural seeds – field crop seeds that include seeds particularly susceptible to IPR infringement.

3. Model Framework and Data

Pioneered by Tinbergen (1962), the gravity model has been an empirical success in explaining bilateral trade flows by exploring the impact of economic size and trade barriers between countries. The model can be derived from a range of trade theories.[5] The modularity of gravity also allows for disaggregation by goods or regions at any scale, which facilitates "analysis of frictions that are likely to differ markedly by product or regional characteristics" (Anderson, 2011). A typical gravity equation resembles the following form:

$$X_{ij} = \beta_0 \frac{Y_i^{\beta_1} Y_j^{\beta_2}}{T_{ij}^{\beta_3}} \tag{1}$$

X denotes trade volume; β_0 is a constant; Y denotes economic size; T represents trade resistance or frictions such as distance-related transport costs between countries i and j. The popularity of the gravity equation also lies in its flexibility. It can be augmented to include a wide range of variables to capture country attributes and various measures of trade barriers and enhancers such as tariffs, currency unions and preferential trade agreements. Since the focus of the paper is on unilateral trade from the U.S. perspective, only the variables of the destination country are included in the analysis. This is also the approach adopted by Yang and Woo (2006) and Eaton (2009).

The dataset comprises a panel covering 134 countries spanning 26 years (1985-2010). The 134 countries consist of any existing sovereign state that has imported field crop seeds from the U.S. at least once during the sample period and contains no missing values in all the regression variables. 1985 was chosen as the sample starting point based on the fact that it was the year when the global seed trade began growing rapidly (International Seed Federation

[5] See Anderson (1979), Bergstrand (1989), Deardorff (1998), Evenett and Keller (2002), Anderson and van Wincoop (2003), Feenstra (2004).

statistics). A description of data sources is included in Table 1, while summary statistics are provided in Table 2 and a correlation matrix is given in Table 3. The dependent variable is the value of annual national field crop seed imports from the U.S (*seedIMP*).[6] The explanatory variables can be grouped into two categories: (1) country economic size (2) potential trade distortions (including both trade enhancers and barriers). The traditional gravity equation also includes geographic distance between trading nations, but since only fixed effects models will be used for analysis, this time-invariant factor will not be identified, hence distance is not included in the models. Fixed effects (FE) models are chosen over random effects (RE) models on the basis that the RE's strong assumption of zero correlation between the unobserved individual effects and explanatory variables is hard to justify for practical reasons.

In variable category (1) the relevant economic size variables are represented by country GDP (*logGDP*) and crop production (*logCropProd*). GDP measures a nation's economic size, with higher national incomes implying more means to purchase. It is therefore expected to have a positive effect on seed imports from the U.S. Gravity equations usually also include the exporting country's GDP, but since in this case there is only one exporting country, its coefficient is absorbed into the time fixed effects. Crop production refers to a country's combined production quantity of cereals, coarse grain, and oilseed crops. This variable measures the size of a country's crop production sector, giving a sense of demand for field crop seeds. Crop production is also highly correlated with arable land and population, two factors commonly seen in gravity models to indicate a country's market size.

In variable category (2) a dummy variable for Free Trade Agreements (*FTA*) with the U.S. is included. FTAs generally open up foreign markets to US exporters by reducing barriers such as tariffs. According to calculations by the Office of the U.S. Trade Representative, for 16 of the

[6] U.S. planting seed export data are not detailed at the GM and non-GM level.

20 countries that the U.S. has FTAs in force with, U.S. exporters will face zero tariffs on 98% or more of agricultural goods once the agreements are fully implemented. The top two field crop seed importers during the sample period are Mexico followed by Canada, both are parties to NAFTA.

Also included in variable category (2) are dummies for UPOV and TRIPs membership as well as planting status of GM crops (*growGM*). Almost all 70 UPOV member states are signatories of either of the two latest revisions, the 1978 Act (*UPOV78*) and the 1991 Act (*UOV91*).[7] The two acts are differentiated because the 1991 Act is more-strict in terms of coverage, period, scope and exemptions. The U.S. has been a UPOV member since 1981 and currently adheres to the 1991 Act. It is reasonable to assume that U.S. seed companies will have more IPR concerns when they decide to export to a country that is not a UPOV member or only conforms to the 1978 Act. Eaton (2009) also differentiated between the 1978 Act and the 1991 Act. His coding of these two variables is based on the assumption that if a country is a signatory of the 1991 Act, then it also conforms to the 1978 Act since the 1991 Act is a stronger version of the 1978 Act. Building on this, another variable called *UPOV78_91* is added to indicate a country that upgrades to the 1991 Act from the 1978 Act. The idea is that there will be an additional effect for these countries compared to those who signed up to the 1991 Act without experiencing the 1978 Act. Even though new members can no longer sign up to the 1978 Act, existing members who still stick with the 1978 Act are not obligated to upgrade. As of 2010, among the 134 countries considered for this paper, 64 are UPOV members, 22 adhere to the 1978 Act, and 41 are signatories of the 1991 Act (of which 14 countries upgraded from 78 Act to the 91 Act).

[7] Belgium is the only country that is still on the 1968/1972 Act.

To capture the effect of TRIPs, a transition period is considered. Supposedly TRIPs applies once a country joins the WTO. However, different transition periods of time to delay implementing/applying its provisions are allowed for members based on levels of economic development. Specifically, developed countries among the original members (countries that joined the WTO on January 1, 1995) were granted one year (until January 1, 1996) to ensure that their laws and practices conform with the TRIPs agreement. Developing countries and (under certain conditions) transition economies were given a further period of four years to apply the TRIPs Agreement's provisions by January 1, 2000. 63 countries in our sample fall into this category. Least developed countries (those recognized by the United Nations) were initially allowed until January 1, 2006 to apply the provisions, now extended to July 1, 2013 with the possibility of further extension, and until January 1, 2016 for pharmaceutical patents. 24 countries in our sample belong to this group. Thus, two indicator variables are employed. *WTO_TRIPs* refers to WTO member countries that have implemented the TRIPs agreement, while *WTO_trans* represents WTO member countries that have been granted a TRIPs transition period. Note that many of these members put into effect national legislation to implement much of the TRIPs Agreement before the allowed transitional period expired. Instead of trying to disentangle the separate effects of TRIPs and WTO on trade, the difference in the magnitude of these two variables (both contain the effect of WTO on trade) may provide guidance on the effect of TRIPs, as some countries are using the TRIPs transition period while others are not.

Unlike membership of UPOV or TRIPs, GM crop planting status is not invariant once started. In some European countries such as France, planting of GM crops was discontinued during the early 2000s as France and five other EU countries banned GM crops around the time that the EU moratorium on GM crop approval was in effect (James, 2011). If a country grows

GM crops, it is reasonable to expect that it will have a higher demand for biotech seeds, for which the U.S. is a large producer.

Using dummy variables to capture membership of IPR agreements has drawbacks. Here the assumption is that being a member, regardless of how long the membership has been, the effect is the same. One would think that a long-standing member will be more effective in providing IPR protection than a new member. As discussed in Yang and Woo (2006), binary IPR variables are not ideal in capturing the implementation and enforcement of IP laws. Even though the TRIPs council reviews the legislation of members after their transition periods have expired, the actual implementation is still largely unknown. An alternative measure is a patent rights index originally constructed by Ginarte and Park (1997), and subsequently revised by Park (2008) which also accounts for membership in UPOV and TRIPs. However, due to this index only being available every five years, the value (ranging from 0 for 5) being assumed to be constant for up to five years, it is also not ideal for the analysis in this paper.

Since the data run for 26 years, stationarity of the data is tested for, as running regressions on non-stationary data can produce spurious or misleading results. The Fisher-type panel unit-root based on an augmented Dickey-Fuller (ADF) test is used to perform the ADF test on each panel individually and then combine the p-values from these tests to produce an overall test. This unit root test is run on *seedIMP* and *logGDP*. The null hypothesis is rejected in most cases, the conclusion being that not all panels contain unit roots. The test results are presented in Tables 4 and 5.

4. Estimation

As explained earlier, the empirical analysis is based on the gravity model. To estimate the gravity model of trade, the conventional approach is to first make the model linear by taking logs and then estimate it through the ordinary least squares (OLS) method. Although simple to implement, this approach becomes problematic when there are many zero trade observations in the data.[8] A common practice is to discard the zeros and run a regression on the truncated and strictly positive data. Another approach is to add a small positive value such as 1 to all the observations. If zeros either occur randomly or the occurrence of zeros is small, then exclusion of these values should not significantly affect the results. However, as Anderson (2011) points out, "the prevalence of zeros arises with disaggregation, so that in finely grained data a large majority of bilateral flows appear to be inactive." Helpman, Melitz, and Rubinstein (2008) were confronted with the problem of zeros (about half of the observations) in their analysis of country-level trade flows. They admit the problem of zeros is even more severe at the industry level. That is, in data sets of sectoral trade flows the fraction of zeros is much larger. If the observations with zeros are dropped, that reduces the number of observations used in actual estimation significantly and may lead to biased results. Consequently, an estimation method is required that allows prediction of both zero and nonzero trade values.

In this dataset, zeros constitute approximately 49 percent of the recorded import observations. There is not a single missing value. A closer look reveals that zeros are recorded for countries even before they came into existence. For instance, the Czech Republic became an independent state in 1993 (after Czechoslovakia dissolved into two constituent parts), so from 1985-1992 it should not have any observations, but in the USDA export database they show up as zero trade flows. Of the 134 countries, 20 gained independence after 1985. Such recording naturally leads to questioning of the validity of all zero values. Some of these zeros might be true zeros, but others might represent missing values. If the zeros are treated as missing values,

[8] Another problem is least squares estimator may be both biased and inefficient in the presence of heterogeneity (Westerlund and Wilhelmsson, 2011).

then the gravity equation can be log-linearized for estimation without rendering any observations invalid. Alternatively, if the zeros are treated as true zeros, then they can be dealt with using techniques such as Poisson regression model.

Linear Fixed-Effects Model

This model is specified as:

$$y_{i,t} = \boldsymbol{x}'_{\boldsymbol{i,t}}\beta + \alpha_i + \varepsilon_{i,t} \qquad t = 1, \dots, 26 \tag{2}$$

where y_{it} denotes field crop seed imports by country *i* during year *t*, α_i is an unobserved country fixed effect, ε_{it} is an error term, $\boldsymbol{x_{it}}$ is a vector that contains the exogenous explanatory variables. More specifically, the following equation is estimated,

$$logseedIMP_{it} = \beta_1 logGDP_{it} + \beta_2 logCropProd_{it} + \beta_3 FTA_{it} + \beta_4 growGM_{it} + \beta_5 UPOV_{it}$$
$$+\beta_6 WTO\_TRIPs_{it} + \beta_7 WTO\_trans_{it} + \alpha_i + \varepsilon_{it} \tag{3}$$

The model is kept rather parsimonious since the main interest is in the IPR variables. Regression results are reported in the columns (1) - (4) in Table 6. The only two significant variables are *logGDP* and *WTO_TRIPs*, both at the 5 percent level. The coefficient for *logGDP* is the elasticity of seed imports with respect to GDP (the income elasticity of demand for seeds), implying that each additional 1 percent increase in GDP is estimated to raise seed imports by about 1.2 percent, given the other predictor variables in the model are held constant. Crop seed imports are also positively affected by *WTO_TRIPs*. For a WTO country that has implemented TRIPs, seed imports are expected to be 2.46 times (=exp(0.9)) that of a country that has not implemented the agreement. All the statistically insignificant variables are positive except for *UPOV*.

Poisson Fixed-Effects Model

Helpman, Melitz, and Rubinstein (2008) develop a two-stage estimation procedure that models the probability of bilateral trade (Probit) in the first stage and predicts trade flows (logged Gravity Equation) in the second stage. Silva and Tenreyro (2009) point out that the largest drawback of this approach is the strong distributional assumption: all random components of the model are homoskedastic, which is too strong to make it practical. Although their focus is mainly on the issue of heteroskedasticity, in an earlier paper Silva and Tenreyro (2006) proposed using a Poisson pseudo-maximum likelihood (PPML) estimation technique as a way of including zero observations of the dependent variable in the estimation. They use the method to estimate the gravity equation on a cross section of 136 countries in 1990. In comparison, they found biases present in both the traditional specification of the gravity equation and in the Anderson-van Wincoop (2003) specification (which includes country-specific fixed effects). Westerlund and Wilhelmsson (2011) explore and extend upon an idea first pointed out by Wooldridge (2002), namely that the fixed effects panel Poisson Maximum Likelihood (ML) estimator can also be applied to continuous variables.[9] They applied this technique with a panel structure and suggest using the Poisson fixed effects estimator which performs well in small samples in comparison to linear estimates. Their Poisson fixed effects approach is also adopted in this paper, the following equation being estimated in levels:

$$y_{it} = \alpha_i \exp(\beta x_{it}) + \varepsilon_{it} \tag{4}$$

The notation here is the same as in the linear model. More specifically, the following equation is estimated:

[9] This is also confirmed by Cameron and Trivedi (2010) that the Poisson FE estimator can be applied to any model of multiplicative effects and an exponential conditional mean, essentially whenever the dependent variable has a positive conditional mean.

$$y_{it} = \alpha_i \exp(\beta_1 logGDP_{it} + \beta_2 logCropProd_{it} + \beta_3 FTA_{it} + \beta_4 growGM_{it} + \beta_5 UPOV_{it}$$
$$+\beta_6 WTO\_TRIPs_{it} + \beta_7 WTO\_trans_{it}) + \varepsilon_{it} \quad (5)$$

The fixed-effects Poisson regression results are reported in Table 6 columns (5) - (8). As with the linear model, only *logGDP* and *WTO_TRIPs* are significant (at the 1 percent and 5 percent levels respectively). While the number of countries stays the same, the number of observations almost doubles. Using the results for specification (8) by way of illustration, a 1 percent GDP increase leads to about a 2 percent increase in seed imports. U.S. seed exports to a WTO member country that has implemented TRIPs is about 3.25 (=exp(1.18)) times that of a country that has not implemented TRIPs. All the statistically insignificant variables are positive except for *FTA*. Compared to the linear model results, the magnitude of the two significant variables are larger in the Poisson fixed effects models – for *logGDP* it is 1.2 percent vs. 2 percent, and for *WTO_TRIPs* it is 2.46 times vs. 3.25 times.

Robustness checks

As discussed earlier in the data description, the models are refitted when *UPOV* is replaced with *UPOV78*, *UPOV91* and *UPOV78_91* (the results being reported in Table 7). In the linear models, the coefficient for *UPOV91* is significantly negative, meaning this stringent act probably reduces seed trade through the market power effect. The coefficient for *UPOV78_91*, however, is significantly positive, implying that when the 1991 act is taken into consideration in relation to the 1978 act, that is, for countries that upgraded to the 1991 act from the 1978 act, the combined effect is positive, which more than cancels out the negative effect of *UPOV91*. But this result does not carry over to the Poisson model. Other than that, *logGDP* and *WTO_TRIPs* are still the only two statistically significant variables, maintaining the same signs and similar magnitudes.

The estimation method is then applied to a smaller set of countries: when countries that have imported less than 10 times from the U.S. during the 26-year period are discarded, with this filter 64 countries remain in the dataset. Because no country traded 10 times, this serves as a natural gap. The numbers of observations are much closer between the two models (1383 vs. 1582) once this criterion is applied. Even then, a comparison shows the regression results, reported in Table 8, are very similar to those of the full 134-country sample. This would seem to suggest that results of the model do not depend on frequency of trading. The magnitudes of the two significant variables are slightly larger. By reducing the sample size, there is potential for selection bias to be introduced, as countries that import less may be excluded because they have weak IPRs. Nonetheless, the hope is to reduce irregularity or idiosyncrasy by focusing on countries on which there are more observations. Statistically speaking, the underlying regression relationship can be better identified with data points of more regular occurrences.

Linear Dynamic Panel Data Models

In panel data *y* is observed over time, opening up the possibility that *y* is dependent in part on its values in preceding periods. Dynamic panel models include one or more lags of the dependent variable as regressors. For a fixed effects (or random effects) model, consistent estimators can be obtained by instrumental variable (IV) estimation in the first difference model, using appropriate lags of regressors as the instruments (Cameron and Trivedi, 2009). Consider an autoregressive model of order 1 (AR(1)) for $y_{i,t}$ (*lgseedIMP*) with 26 years of data (1985-2010):

$$y_{i,t} = \gamma y_{i,t-1} + x_{i,t}^{'}\beta + \alpha_i + \varepsilon_{i,t} \qquad t = 2, \ldots, 26 \tag{6}$$

The notation here is the same as in the models previously introduced. Use first difference to remove the fixed effect,

$$\Delta y_{i,t} = \gamma \Delta y_{i,t-1} + \Delta x_{i,t}^{'}\beta + \Delta\varepsilon_{i,t} \qquad t = 3, \ldots, 26 \tag{7}$$

The first two years of data are lost in order to construct $\Delta y_{i,t-1}$. Also, $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$ is correlated with $\Delta \varepsilon_{i,t} = \varepsilon_{i,t} - \varepsilon_{i,t-1}$ because $y_{i,t-1}$ depends on $\varepsilon_{i,t-1}$.

Arellano and Bond (1991) developed a consistent generalized method of moments (GMM) estimator that uses moment conditions in which lags of the dependent variable and first differences of the exogenous variables are instruments for the first-differenced equation. Specifically, $\Delta y_{i,t-1}$ is instrumented using one or more subsequent lags, i.e. $y_{i,t-2}$ and back, because they are uncorrelated with $\Delta \varepsilon_{i,t}$. Differences of the exogenous variables serve as their own instruments.

The lagged levels can be rather poor instruments for first differenced variables, especially if the variables are close to a random walk. A system estimator named after Arellano and Bover (1995) and Blundell and Bond (1998) uses additional moment conditions in which lagged first differences of the dependent variable are instruments for the level equation. This estimator provides more precision, but the cost of the system GMM estimator involves a set of additional restrictions on the initial conditions of the process generating *y*.

Both estimators are built on a crucial assumption that the idiosyncratic errors are serially uncorrelated, otherwise the moment conditions of these GMM estimators will be invalid. This assumption is testable by the Arellano-Bond test. This autocorrelation test is a test of whether $\Delta \varepsilon_{i,t}$ is correlated with $\Delta \varepsilon_{i,t-k}$ for $k \geq 2$, based on the correlation of the fitted residuals. If $\varepsilon_{i,t}$ are serially uncorrelated, it is expected to be rejected at order 1 but not at higher orders because at order 1 the first differences are necessarily autocorrelated.

These two estimators are applied to the first differenced AR (1) model (6). The regression results are reported in Tables 9-12. All regressions include the first lag of *y* ($y_{i,t-1}$) as a regressor. Unless otherwise noted, only the first available subsequently lagged y are used as an instrument (so that just $y_{i,t-2}$ is the instrument in period t).

The baseline results using the Arellano-Bond estimator are presented in Table 9. Columns (1) - (4) are based on the full sample covering 86 countries. Only two variables, the lagged *L.lgseedIMP* and *logCropProd*, are consistently significant (both at the 1 percent level). Their positive coefficients indicate that the more a country imports seeds from the U.S. in previous year, the more it will import during the current year; the higher the crop production capacity, the more the seed import. Columns (5) - (8) are based on the reduced sample of countries that have imported seeds from the US more than 18 times during the 26-year sample period. The number of countries dropped to 48 (from 86), but the number of observations decreases only by about 200. *L.lgseedIMP* and *logCropProd* remain consistently significant and positive, with larger magnitudes. In addition, the two WTO variables have gained statistical significance (also at the 1 percent level). The coefficient of *WTO_TRIPs* is slightly higher than that of *WTO_trans*, suggesting that WTO member countries that have implemented TRIPS have an advantage in seed imports from the U.S. as compared to those member countries that are still in the TRIPs transition period. By removing countries that trade less frequently, data discontinuity decreases, and the instruments are more reliable.

Two post-estimation tests are performed, one being the Arellano-Bond test for autocorrelation of order 3 in the first-differenced residuals, the other the Sargan test of the validity of over-identifying restrictions (to determine if the instruments are suitable) since more instruments are used than the parameters being estimated. The test results (pass or fail) are reported in the tables. All the model specifications pass both tests, confirming that there is no serial correlation in the errors and the over-identifying restrictions are valid.[10]

In Table 10, results are presented for a similar estimator with the only difference being inclusion of all the other regressors also lagged once. In the case of the lagged exogenous variables, only *L.logCropProd* and *L.FTA* are consistently significant, with negative and positive coefficients respectively. This seems to suggest that the more crop a country produce last year, the less seeds it will import this year. *L.FTA* shows a positive lagged effect, which is understandable as agreements take time to be effective. Other than that, the pattern of results is the same as the baseline model, and this model also passes both specification tests. However, the baseline Arellano-Bover/Blundell-Bond system estimator fails the Sargan test, but for completeness the results are included in Table 11.

Table 12 displays results using the Arellano-Bover/Blundell-Bond system estimator with all the regressors lagged once. All specifications pass the Arellano-Bond test, but the first four specifications do not pass the Sargan test at any level. For (5)-(6), the null hypothesis cannot be rejected at the 0.01 or the 0.05 levels. The results pattern is very similar to that in the Arellano-Bond estimation with all the regressors lagged once. There seems to be little efficiency gain in this estimation as the standard errors only decrease for some coefficients.[11]

[10]The model is also refitted with up to 2 lagged *y* as instruments. Very similar results are obtained, but this model does not pass the Sargan test for over-identifying restrictions, hence the results are not reported.
[11] All the above linear dynamic estimators are one-step (instrumental variables estimation) estimators. The more efficient two-step estimators are also applied, but the results became very unstable, hence the results are not reported here.

In summary, the results from the linear dynamic panel models indicate that seed imports depend moderately on past imports and are positively affected by the implementation of the TRIPs agreement.[12]

5. Summary and Conclusions

In the trade arena, IP standards are a contentious issue between the North and the South, especially when it comes to trade in goods that embody new technologies (Eaton, 2009). The North argues that the South should adopt higher standards as stronger IPRs have a stimulating effect on trade, investment and technology transfer; whereas the South is concerned with tighter IPRs negatively affecting domestic industries and consumers. As the embodiment of plant breeding technology that has huge implications for producer and consumer welfare especially in the developing countries, seed is ideal for a study of IPRs' effect on trade to understand the issues surrounding this debate better.

This paper sheds light on an issue highly relevant to agricultural trade - whether and how trade in agricultural seeds is sensitive to a country's level of intellectual property rights (IPRs) protection. In other words, do IPRs stimulate or impede seed trade? Access to improved seed varieties is essential for growers around the world to feed an increasing global population in a sustainable fashion.

Like many other goods that embody technological innovations, an important channel for seed technology to be transferred across borders is through trade. Depending on the technology component, an exporter's decision to serve and how to serve a particular market is more or less influenced by the extent of IPR protection in that market. This is particularly true for the seed

[12] It should be noted that estimating Poisson dynamic panel models would be complicated by the initial conditions problem. Proposers of solutions to this problem warn however that they may only work reasonably well in datasets with high signal-to-noise rations (Wooldridge, 2005; Blundell *et al*., 2002). This technique will be explored in future work.

industry as plant breeding involves costly and lengthy investment, and the final product – seeds either reproduce on their own or can be imitated at low costs. Weak IPRs are likely to deter exporters from entering foreign markets or selling newest technology to those markets.

As a leader in seed technology, seeds produced by U.S. seed companies are sought after by growers in other countries. In this paper, USDA's seed export data to 134 countries are analyzed over the 1985-20010 period. Attention is limited to field crop seeds only as this is a fast growing sector of seed trade. Moreover, the major genetically modified (GM) crops are all field crops, i.e., corn, soybeans and cotton.

To further investigate the role of IPRs in seed technology transfer through trade, this paper builds on the research effort of Yang and Woo (2006) and Eaton (2009) by including a larger and longer dataset in terms of both the number of countries and years included, and focusing on a subcategory of agricultural planting seeds – the field crop seeds that include seeds particularly susceptible to IPR infringement. A modified gravity model was fitted to a country panel. The analysis is performed using a standard gravity trade model framework. Relevant economic size variables are represented by country GDP and quantity of crop production. The IPR variables are included as a form of trade distortion, as are regional free trade agreements between the U.S. and other countries, and a country's status in growing GM crops is also included.

In this paper, the two most relevant international agreements on IPRs are considered, both as membership dummies. The first is the International Convention for the Protection of New Varieties of Plants (UPOV). The second is the World Trade Organization's (WTO) agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs).

Due to the substantial presence of zeros in the trade data and the suspicion that some of these zeros might actually be missing values, the fixed effects Poisson estimator suggested by Westerlund and Wilhelmsson (2011) which can predict both zero and positive trade values, is compared with the traditional linear fixed effects estimator. *WTO_TRIPs* is found to have a significantly positive impact on seed exports in both types of models, with its magnitude larger in the Poisson models. Given the time-series dimension of the data set, subsequently a linear dynamic model using the Arellano-Bond estimator and an extension of this estimator is applied to the data. When the sample is restricted to countries that have imported seeds from the U.S. on a more continuous basis (trade frequency>18), both *WTO_TRIPs* and *WTO_trans* show up in the results as statistically positive, with the former's magnitude slightly larger than that of the latter, suggesting that seed trade is positively affected by the implementation of TRIPs agreement. Quite different results have been found compared to the previous studies on IPRs and seed trade by Yang and Woo (2006) and Eaton (2009), i.e., importing country membership in international IPR agreements can have a significant positive effect on seed exports. The results presented in this paper will generate discussion as they contribute to what is already a contentious debate between developed and developing countries, i.e., trade in goods and new technologies.

The limitations of this research have a lot to do with the data. The accuracy of *growGM* status may also be contaminated by measurement errors as field trials are suspected to be misinterpreted as commercial release. The results are also complicated by firm's FDI and licensing efforts, as exports are not the only way to sell products and technology. For example, Ferrantino (1993) was able to investigate the effects of membership in intellectual property treaties in the context of U.S. exports, foreign affiliate sales, and flows of royalties and license fees. He found the impact of national membership in IPR treaties on arm's length exports is minimal.

For future research, variables should be developed that better control for an importing country's need for imported field crop seeds, particularly, need for seeds from the U.S. Several factors affect the demand for seeds: demand for a commodity (price of crops), government interventions such as quality standards, and the cost of other inputs like fertilizers. Another area to consider is if and how IPRs influence the mode of serving foreign markets.

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Table 1: Data sources

Variable	Definition	Data source
seedIMP, *logseedIMP*	Field crop seed imports from U.S. (US$)*	USDA's GATS (Global Agricultural Trade System)
logGDP	GDP (constant 2000 US$)	World Bank's World Development Indicators
logCropProd	Combined production quantity of cereals, coarse grain and oil crops (tons)	FAOSTAT
FTA	Free Trade Agreement	Office of the United States Trade Representative web site
growGM	GM crops planting status	James, Clive. *Global Status of Commercialized Biotech/GM Crops*, 1996-2010.
UPOV	UPOV member country	UPOV web site
UPOV78	Signatory of UPOV 1978 Act	UPOV web site
UPOV91	Signatory of UPOV 1991 Act	UPOV web site
UPOV78_91	Signatory of both Acts	UPOV web site
WTO_TRIPs	WTO member countries that have implemented TRIPs	WTO web site
WTO_trans	WTO member countries that are given transition time	WTO web site

*Adjusted to 2000 price using U.S. Bureau of Labor Statistics' export price index for agricultural commodities.

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
seedIMP	3214	1760211	7441764	0	1.25e+08
logseedIMP	1643	12.57749	2.441212	7.039608	18.64305
logGDP	3214	23.63359	2.184026	19.16246	29.2831
logCropProd	3214	14.5309	2.666419	4.584968	20.36659
FTA	3214	.0364032	.1873205	0	1
growGM	3214	.0746733	.2629044	0	1
UPOV	3214	.2812694	.4496886	0	1
UPOV78	3214	.2710019	.4445462	0	1
UPOV91	3214	.0952085	.2935483	0	1
UPOV78_91	3214	.0472931	.2122981	0	1
WTO_TRIPs	3214	.3571873	.4792452	0	1
WTO_trans	3214	.183883	.387449	0	1

Table 3: Correlation matrix

	logseedIMP	*logGDP*	*logCropProd*	*FTA*	*growGM*	*UPOV*	*UPOV78*	*UPOV91*	*UPOV78_91*	*WTO_TRIPs*	*WTO_trans*
logseedIMP	1.0000										
logGDP	0.5102	1.0000									
logCropProd	0.4412	0.7215	1.0000								
FTA	0.1505	0.1063	0.0286	1.0000							
growGM	0.2199	0.2949	0.3075	0.2571	1.0000						
UPOV	0.2460	0.5052	0.2967	0.1957	0.3059	1.0000					
UPOV78	0.2156	0.4683	0.2758	0.2081	0.2901	0.9596	1.0000				
UPOV91	0.0057	0.2451	0.1237	0.1481	0.0247	0.4290	0.4471	1.0000			
UPOV78_91	0.0547	0.2894	0.1100	0.0983	0.0532	0.3240	0.3377	0.7552	1.0000		
WTO_TRIPs	0.0898	0.2339	0.0556	0.1768	0.3377	0.4143	0.4003	0.3386	0.2895	1.0000	
WTO_trans	-0.0731	-0.2008	-0.0983	-0.0423	-0.0865	-0.1930	-0.1803	-0.1486	-0.1071	-0.3954	1.0000

Table 4: Fisher-type unit-root test statistics for *seedIMP*

Inverse chi-squared	P	672.4488	1240.7127	338.8849	893.7540
Inverse normal	Z	-13.9949	-26.4938	-5.2897	-21.0128
Inverse logit t	L*	-16.2480	-32.4117	-5.3738	-23.0988
Modified inv. chi-squared	Pm	22.1600	49.9587	6.0365	33.1089
Time trend		Y		Y	
Drift term			Y		Y
ADF regressions		1 lag	1 lag	2 lags	2 lags

Notes: Ho: All panels contain unit roots; Ha: At least one panel is stationary.
AR(1) is assumed; AR parameter: Panel-specific; Panel means included.
All statistics are significant at the one percent level.

Table 5: Fisher-type unit-root test statistics for *logGDP*

Inverse chi-squared	P	227.8202*	428.6124	270.3295	420.3116
Inverse normal	Z	1.2556*	-7.3215	0.8938*	-6.4942
Inverse logit t	L*	1.0405*	-7.6689	0.4147*	-6.8507
Modified inv. chi-squared	Pm	0.6680*	10.3737	2.7228	9.9724
Time trend		Y		Y	
Drift term			Y		Y
ADF regressions		1 lag	2 lags	3 lags	2 lags

Notes: Ho: All panels contain unit roots; Ha: At least one panel is stationary.
AR(1) is assumed; AR parameter: Panel-specific; Panel means included.
* indicates no statistical significance. All other statistics are significant at the one percent level.

Table 6: Linear Fixed Effects models vs. Poisson Fixed Effects models (full sample)

	Linear Fixed Effects				Poisson Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*seedIMP*	*seedIMP*	*seedIMP*	*seedIMP*
logGDP	1.231**	1.240**	1.170**	1.188**	2.259***	2.223***	2.058***	2.013***
	(0.548)	(0.553)	(0.549)	(0.556)	(0.690)	(0.690)	(0.749)	(0.741)
logCropProd	0.316	0.314	0.310	0.307	0.365	0.376	0.197	0.205
	(0.291)	(0.291)	(0.284)	(0.283)	(0.597)	(0.595)	(0.491)	(0.484)
FTA	0.196	0.211	0.168	0.202	-0.150	-0.233	-0.118	-0.220
	(0.329)	(0.325)	(0.335)	(0.327)	(0.253)	(0.218)	(0.250)	(0.221)
growGM	0.174	0.183	0.125	0.143	0.473	0.447	0.446	0.412
	(0.260)	(0.262)	(0.258)	(0.260)	(0.320)	(0.315)	(0.310)	(0.305)
WTO_TRIPs			0.881**	0.911**			1.152**	1.183**
			(0.401)	(0.409)			(0.530)	(0.515)
WTO_trans			0.433	0.456			0.863	0.906
			(0.404)	(0.405)			(0.589)	(0.590)
UPOV		-0.0593		-0.134		0.160		0.196
		(0.184)		(0.187)		(0.251)		(0.276)
Observations	1,643	1,643	1,643	1,643	3,214	3,214	3,214	3,214
Countries	134	134	134	134	134	134	134	134

Notes: Time fixed effects (year dummies) are included for all specifications but not reported here.
Cluster-robust standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Linear Fixed Effects models vs. Poisson Fixed Effects models (full sample, *UPOV8*, *UPOV91*, *UPOV78_91*)

	Linear Fixed Effects				Poisson Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*seedIMP*	*seedIMP*	*seedIMP*	*seedIMP*
logGDP	1.231**	1.387**	1.170**	1.316**	2.259***	2.513***	2.058***	2.324***
	(0.548)	(0.538)	(0.549)	(0.539)	(0.690)	(0.662)	(0.749)	(0.748)
logCropProd	0.316	0.280	0.310	0.271	0.365	0.340	0.197	0.180
	(0.291)	(0.290)	(0.284)	(0.280)	(0.597)	(0.588)	(0.491)	(0.484)
FTA	0.196	0.280	0.168	0.270	-0.150	-0.253	-0.118	-0.221
	(0.329)	(0.300)	(0.335)	(0.303)	(0.253)	(0.200)	(0.250)	(0.202)
growGM	0.174	0.0916	0.125	0.0484	0.473	0.483	0.446	0.452
	(0.260)	(0.265)	(0.258)	(0.261)	(0.320)	(0.310)	(0.310)	(0.302)
UPOV78		0.244		0.173		0.275		0.278
		(0.233)		(0.234)		(0.287)		(0.306)
UPOV91		-0.907***		-0.932***		-0.485		-0.380
		(0.319)		(0.320)		(0.454)		(0.524)
UPOV78_91		1.032**		0.999**		1.156*		0.992
		(0.482)		(0.484)		(0.609)		(0.679)
WTO_TRIPs			0.881**	0.924**			1.152**	1.046*
			(0.401)	(0.425)			(0.530)	(0.552)
WTO_trans			0.433	0.470			0.863	0.741
			(0.404)	(0.412)			(0.589)	(0.607)
Observations	1,643	1,643	1,643	1,643	3,214	3,214	3,214	3,214
Countries	134	134	134	134	134	134	134	134

Notes: Time fixed effects (year dummies) are included for all specifications but not reported here.
Cluster-robust standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Linear Fixed Effects models vs. Poisson Fixed Effects models (64-country sample)

	Linear Fixed Effects				Poisson Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*seedIMP*	*seedIMP*	*seedIMP*	*seedIMP*
logGDP	1.245**	1.241**	1.187**	1.194**	2.418***	2.370***	2.202***	2.142***
	(0.563)	(0.565)	(0.560)	(0.565)	(0.727)	(0.726)	(0.794)	(0.782)
logCropProd	0.366	0.367	0.349	0.348	0.538	0.552	0.321	0.330
	(0.324)	(0.325)	(0.316)	(0.316)	(0.621)	(0.618)	(0.513)	(0.505)
FTA	0.112	0.107	0.0731	0.0828	-0.168	-0.267	-0.123	-0.243
	(0.334)	(0.332)	(0.337)	(0.333)	(0.248)	(0.211)	(0.244)	(0.217)
growGM	0.208	0.205	0.154	0.159	0.469	0.438	0.452	0.413
	(0.268)	(0.270)	(0.265)	(0.267)	(0.324)	(0.318)	(0.314)	(0.309)
WTO_TRIPs			0.946**	0.953**			1.170**	1.212**
			(0.459)	(0.463)			(0.563)	(0.543)
WTO_trans			0.312	0.318			0.824	0.878
			(0.457)	(0.458)			(0.621)	(0.616)
UPOV		0.0171		-0.0380		0.188		0.228
		(0.194)		(0.194)		(0.266)		(0.295)
Observations	1,383	1,383	1,383	1,383	1,582	1,582	1,582	1,582
Countries	64	64	64	64	64	64	64	64

Notes: Time fixed effects (year dummies) are included for all specifications but not reported here.
Cluster-robust standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Arellano-Bond estimator

	Full Sample				Trade Frequency > 18			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*
L.logseedIMP	0.192***	0.194***	0.191***	0.193***	0.304***	0.304***	0.299***	0.299***
	(0.0710)	(0.0706)	(0.0694)	(0.0689)	(0.0875)	(0.0869)	(0.0850)	(0.0845)
logGDP	1.858*	1.858	1.797	1.792	0.718	0.710	0.693	0.683
	(1.127)	(1.142)	(1.141)	(1.153)	(1.139)	(1.135)	(1.137)	(1.133)
logCropProd	0.697***	0.698***	0.694***	0.694***	0.862***	0.861***	0.851***	0.849***
	(0.184)	(0.182)	(0.185)	(0.183)	(0.225)	(0.225)	(0.232)	(0.232)
FTA	-0.747	-0.794	-0.743	-0.794	-0.842	-0.856	-0.843	-0.858
	(0.538)	(0.549)	(0.536)	(0.548)	(0.548)	(0.564)	(0.545)	(0.562)
growGM	-0.0962	-0.107	-0.0924	-0.103	-0.178	-0.181	-0.175	-0.178
	(0.242)	(0.248)	(0.241)	(0.247)	(0.165)	(0.167)	(0.166)	(0.168)
WTO_TRIPs			0.346	0.368			1.129***	1.139***
			(0.533)	(0.538)			(0.356)	(0.359)
WTO_trans			0.352	0.376			0.984***	0.994***
			(0.539)	(0.539)			(0.227)	(0.231)
UPOV		0.198		0.217		0.0605		0.0637
		(0.330)		(0.337)		(0.406)		(0.407)
Arellano-Bond test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Sargan test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Observations	1,193	1,193	1,193	1,193	999	999	999	999
Countries	86	86	86	86	48	48	48	48

Table 10: Arellano-Bond estimator (all regressors lagged once)

	Full Sample				Trade Frequency > 18			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*
L.logseedIMP	0.188***	0.189***	0.189***	0.190***	0.302***	0.302***	0.306***	0.306***
	(0.0701)	(0.0699)	(0.0674)	(0.0670)	(0.0830)	(0.0829)	(0.0796)	(0.0794)
logGDP	2.145	2.128	2.100	2.080	1.211	1.211	1.137	1.130
	(1.365)	(1.369)	(1.368)	(1.372)	(1.576)	(1.583)	(1.565)	(1.577)
L.logGDP	-0.0725	-0.0561	-0.130	-0.106	-0.947	-0.961	-0.937	-0.953
	(1.220)	(1.223)	(1.275)	(1.279)	(1.580)	(1.574)	(1.576)	(1.563)
logCropProd	0.579***	0.574***	0.581***	0.577***	0.608***	0.611***	0.619***	0.622***
	(0.150)	(0.152)	(0.156)	(0.160)	(0.170)	(0.172)	(0.180)	(0.183)
L.logCropProd	-0.321*	-0.321*	-0.310*	-0.309*	-0.556**	-0.552**	-0.519**	-0.514**
	(0.187)	(0.186)	(0.183)	(0.183)	(0.221)	(0.219)	(0.223)	(0.221)
FTA	-0.799	-0.839	-0.787	-0.833	-0.882	-0.896	-0.857*	-0.879*
	(0.533)	(0.545)	(0.503)	(0.520)	(0.558)	(0.573)	(0.498)	(0.523)
L.FTA	0.831***	0.865***	0.826***	0.861***	0.897***	0.887***	0.879***	0.873**
	(0.288)	(0.308)	(0.289)	(0.309)	(0.320)	(0.338)	(0.322)	(0.339)
growGM	-0.0913	-0.104	-0.0853	-0.0994	-0.180	-0.185	-0.158	-0.166
	(0.226)	(0.234)	(0.224)	(0.232)	(0.157)	(0.157)	(0.163)	(0.161)
L.growGM	-0.163	-0.158	-0.160	-0.156	-0.0116	-0.0165	0.000935	-0.00443
	(0.190)	(0.198)	(0.190)	(0.198)	(0.226)	(0.230)	(0.222)	(0.226)
WTO_TRIPs			0.364	0.384			1.106***	1.110***
			(0.558)	(0.567)			(0.386)	(0.394)
L.WTO_TRIPs			-0.206	-0.251			-0.586	-0.594
			(0.683)	(0.665)			(1.238)	(1.224)
WTO_trans			0.371	0.388			0.917***	0.921***
			(0.559)	(0.554)			(0.277)	(0.276)
L.WTO_trans			-0.151	-0.199			-0.423	-0.435
			(0.643)	(0.627)			(1.205)	(1.191)
UPOV		0.188		0.225		0.0576		0.0998
		(0.321)		(0.336)		(0.393)		(0.410)
L.UPOV		-0.122		-0.129		0.0567		0.0429
		(0.389)		(0.391)		(0.355)		(0.369)
Arellano-Bond test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Sargan test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Observations	1,191	1,191	1,191	1,191	998	998	998	998
Number of id	86	86	86	86	48	48	48	48

Table 11: Arellano- Bover/Blundell- Bond estimator

	Full Sample				Trade Frequency > 18			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*	*logseedIMP*
L.logseedIMP	0.269***	0.271***	0.270***	0.272***	0.315***	0.318***	0.314***	0.316***
	(0.0577)	(0.0575)	(0.0563)	(0.0562)	(0.0732)	(0.0724)	(0.0710)	(0.0701)
logGDP	0.0435	-0.0434	0.00173	-0.0811	0.184	0.0926	0.148	0.0644
	(0.374)	(0.391)	(0.375)	(0.391)	(0.388)	(0.366)	(0.387)	(0.369)
logCropProd	0.180	0.204	0.212	0.233	0.142	0.180	0.157	0.192
	(0.196)	(0.196)	(0.189)	(0.189)	(0.235)	(0.203)	(0.233)	(0.203)
FTA	-0.840	-0.939	-0.849	-0.948	-0.840	-0.943	-0.846	-0.942
	(0.606)	(0.607)	(0.604)	(0.604)	(0.642)	(0.649)	(0.643)	(0.651)
growGM	0.0426	-0.00658	0.0494	0.000771	-0.188	-0.238	-0.183	-0.230
	(0.256)	(0.262)	(0.262)	(0.268)	(0.211)	(0.210)	(0.213)	(0.211)
WTO_TRIPs			0.329	0.289			1.341**	1.280**
			(0.520)	(0.504)			(0.559)	(0.505)
WTO_trans			0.553	0.522			1.291**	1.237***
			(0.540)	(0.536)			(0.506)	(0.466)
UPOV		0.395		0.395		0.415		0.386
		(0.388)		(0.385)		(0.513)		(0.506)
Arellano-Bond test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Sargan test	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail
Observations	1,348	1,348	1,348	1,348	1,066	1,066	1,066	1,066
Number of id	102	102	102	102	48	48	48	48

Table 12: Arellano- Bover/Blundell- Bond estimator (all regressors lagged once)

	Full Sample				Trade Frequency >18			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	logseedIMP	logseedIMP	logseedIMP	logseedIMP	logseedIMP	logseedIMP	logseedIMP	logseedIMP
L.logseedIMP	0.276***	0.277***	0.278***	0.280***	0.328***	0.329***	0.329***	0.330***
	(0.0541)	(0.0542)	(0.0519)	(0.0520)	(0.0683)	(0.0682)	(0.0672)	(0.0670)
logGDP	1.225	1.179	1.213	1.154	1.032	1.064	0.975	0.999
	(1.313)	(1.307)	(1.308)	(1.301)	(1.562)	(1.543)	(1.551)	(1.533)
L.logGDP	-0.903	-0.907	-0.912	-0.901	-0.633	-0.744	-0.605	-0.707
	(1.260)	(1.262)	(1.255)	(1.252)	(1.508)	(1.484)	(1.513)	(1.481)
logCropProd	0.509***	0.516***	0.514***	0.519***	0.642***	0.657***	0.639***	0.654***
	(0.168)	(0.169)	(0.160)	(0.160)	(0.192)	(0.184)	(0.193)	(0.186)
L.logCropProd	-0.553***	-0.543***	-0.543***	-0.534***	-0.713***	-0.692***	-0.693***	-0.672***
	(0.173)	(0.171)	(0.179)	(0.177)	(0.215)	(0.201)	(0.210)	(0.195)
FTA	-1.031*	-1.100*	-1.033*	-1.108*	-1.146*	-1.189*	-1.125*	-1.171*
	(0.591)	(0.602)	(0.570)	(0.581)	(0.644)	(0.659)	(0.588)	(0.609)
L.FTA	0.998***	1.024***	0.987***	1.014***	1.029***	0.973**	1.013***	0.962**
	(0.358)	(0.372)	(0.361)	(0.374)	(0.394)	(0.402)	(0.389)	(0.396)
growGM	0.0249	-0.00166	0.0360	0.00743	-0.160	-0.184	-0.137	-0.162
	(0.235)	(0.239)	(0.237)	(0.242)	(0.186)	(0.186)	(0.191)	(0.189)
L.growGM	-0.0659	-0.0815	-0.0786	-0.0947	0.0348	0.00240	0.0393	0.00703
	(0.249)	(0.247)	(0.249)	(0.247)	(0.250)	(0.242)	(0.248)	(0.240)
WTO_TRIPs			0.238	0.244			1.159**	1.122***
			(0.508)	(0.523)			(0.465)	(0.435)
L.WTO_TRIPs			-0.166	-0.239			-0.487	-0.543
			(0.551)	(0.545)			(1.141)	(1.137)
WTO_trans			0.477	0.481			1.057***	1.027***
			(0.516)	(0.523)			(0.393)	(0.373)
L.WTO_trans			-0.191	-0.264			-0.356	-0.409
			(0.525)	(0.515)			(1.118)	(1.106)
UPOV		0.309		0.343		0.174		0.199
		(0.346)		(0.357)		(0.415)		(0.433)
L.UPOV		-0.102		-0.108		0.174		0.154
		(0.414)		(0.419)		(0.399)		(0.409)
Arellano-Bond test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Sargan test	Fail	Fail	Fail	Fail	Pass*	Pass*	Pass*	Pass*
Observations	1,345	1,345	1,345	1,345	1,064	1,064	1,064	1,064
Number of id	102	102	102	102	48	48	48	48

Pass*- reject at the 10 percent level