Trade and Intellectual Property Rights in the Agricultural Seed Sector

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Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

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26 June 2009

Abstract

The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has continued to be fiercely debated between North and South, particularly with respect to its provisions for the agricultural sector. Article 27.3(b) of the TRIPS Agreement requires WTO member countries to offer some form of intellectual property protection for new plant varieties, either in the form of patents (common in the U.S.) or plant breeder's rights (PBR). This paper analyses the effects of the introduction of PBRs in almost 70 importing countries on the value of exports of agricultural seeds and planting material from 10 exporting EU countries, including all principal traditional exporters of seeds, as well as the US. A fixed effects quantile regression model, based on the general specification for the gravity model for international trade, is estimated using panel data covering 19 years (1989-2007) of export flows in order to assess the effect of International Convention on the Protection of New Varieties of Plants (UPOV) membership on seed imports. Basing inference on the panel bootstrap, we find no significant effect from UPOV membership on seed imports.

1 Introduction

This paper analyses the effect of intellectual property rights (IPRs) on trade in goods. IPRs enterred the trade agenda with the negotiation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) as part of the Uruguay Round leading to the creation of the World Trade Organization (WTO).

Northern countries, led by the US and the EU, have argued that developing countries and economies in transition will benefit from introducing IPR systems, such as patents, trademarks and copyright, from a stimulating effect on trade, investment and technology transfer. On the other side, Southern countries have voiced concerns about the potential negative effects for domestic industries and the exercise of monopoly power by Western-based multinational companies.

From a theoretical point of view, the extent to which the introduction and/or strengthening of IPRs encourages trade remains ambiguous (e.g. Grossman and Helpman, 1990, Grossman and Lai, 2004). On the one hand, stronger IPRs could encourage trade as exporters of products vulnerable to being copied enjoy a market expansion effect. On the other hand, it has been suggested that stronger IPRs might improve the ability of exporters to exercise monopoly power in smaller and less competitive markets, resulting in higher prices and lower quantities. A second reason for a decline in trade is that stronger IPRs will encourage exporting companies to change their mode of serving the foreign market from exports to some form of foreign direct investment (FDI) or licensing of protected products. Given this theoretical ambiguity, the question is ultimately an empirical one.

Quantitative empirical studies of the effect of IPRs on trade have typically been undertaken at a fairly aggregated level involving trade in all goods and services, possibly disaggregated according to broad industry levels. Such studies have generally suggested that stronger IPRs may stimulate international trade in some specific sectors, while not in others (see for example the various studies in Fink and Braga, 2005). Smith (1999) found that US exports were positively correlated with stronger IPRs in importing countries that pose an imitation threat but negatively correlated in other countries. In a subsequent analysis at a more specific sectoral level, Smith (2002) produced similar results for US pharmaceutical exports.

One sector of particular interest in terms of WTO TRIPS negotiations concerns the agricultural plant breeding and seed sector. Agricultural plants are essentially self-reproducing, posing a potential appropriability problem for breeders considering typical investment periods of 10-15 years. Private sector investments in agricultural plant breeding have largely been confined to hybrid varieties, which do not produce seed with the exact same characteristics as the crossing of the two parent varieties. Breeders and seed companies attempt to keep the parental lines secret. For other open-pollinated plants (e.g. wheat, lettuce) or those that reproduce vegetatively (e.g. potatoes) IPR protection is more important. And for hybrids, IPRs can add additional protection, above the in-built physical/biological security that is still vulnerable to being obtained and copied, or even reverse engineered using the tools of modern biotechnology (such as molecular markers).

Article 27.3(b) of the TRIPS Agreement requires WTO member countries to offer some form of intellectual property protection for new plant varieties, either in the form of patents (common in the U.S.) or plant breeder's rights (PBR) which were first developed in Europe. PBRs[1] are a *sui generis* form of IPR that can be seen as combining elements of both patents and copyright protection and which were perceived as better addressing some of the peculiar aspects of protecting biologically-reproducible material, such as plants, in a better manner than patents. PBRs have existed in many European countries for more than 40 years and the general requirements for such protection are enshrined in the International Convention on the Protection of New Varieties of Plants (UPOV Convention).

This paper assesses the effect of UPOV membership, as an indicator of the scope and strength of IPRs affecting the plant breeding sector, on exports of agricultural crop seeds from 10 European countries as well as the US to almost 70 countries around the world. The UPOV Convention has been revised on numerous occasions, and our analysis distinguishes between the two most recent versions, 1978 and 1991, which are relevant today. The 1991 version offers the holder of a PBR more exclusive rights than the 1978 version, primarily by restricting the saving of seed by farmers, even for own use, unless an explicit exemption is legislated. Although countries may no longer join UPOV with adhesion to the 1978 Treaty, there is no binding requirement that members who had previously done so 'upgrade' to the 1991 version.[2]

The effects of stronger IPRs on seed trade has recently been analysed by Yang and Woo (2006), who examined US seed exports to 60 importing countries over the period 1990-2000. US seed exports generally increased over this period and in a static linear panel formulation of the gravity model, Yang and Woo observed a positive significant effect for importing country membership in UPOV. This effect however essentially disappeared in a dynamic formulation, leading the authors to argue that American seed exports exhibit a certain degree of state dependence, and that there was no significant correlation with IPRs.

The current paper builds on the analysis of Yang and Woo in both space and time. First, in addition to US exports, which account for about one-fifth of exports in the world, we also compile data on exports from 10 European countries, comprising the largest seed producers and exporters in that region. Thus, the two major seed exporting economies in the world are included in the analysis. This is partly motivated by the observation that PBR systems in Europe are generally stronger

[1] This form of protection is also referred to as plant variety protection (PVP).

[2] WTO members may actually elect to implement PBR conformant to UPOV 1978, without becoming a UPOV member, and still be meeting their TRIPS obligations.

than in the US, a difference that might be reflected more in considerations taken by European based seed companies. Furthermore, European exports tend to be for different crops and the pattern of importers is also different compared to the US. The list of additional 79 importing countries is also somewhat larger than the 60 used by Yang and Woo. Second, the dataset covers a longer period (1989-2007) for many importers. One benefit of this larger and longer dataset is that it also includes a number of countries that did not import seeds at all, or only in some periods, and possibly only from some exporters. This permits an analysis of whether IPRs contribute to an initiation of trade, as well as controlling more thoroughly for the effects of other factors. Finally, the current analysis also extends that of Yang and Woo by differentiating between the 1978 and 1991 versions of the UPOV Treaty.

Our results do not find any evidence that adoption of UPOV-approved system of PBR positively influences the seed imports, confirming the results of Yang and Woo. This seems fairly clear in the raw data but we apply recently-developed quantile regression techniques to panel data to investigate the issue more systematically. Quantile regression offers the advantage of being robust to outlying observations, as well as capturing possibly different effects of regressors throughout the distribution of the dependent variable, in this case seed imports.

The paper proceeds below as follows. The second section presents data on seed imports compiled for this study. The third section reviews modeling considerations for econometric modeling of this data and proposes the use of the fixed effects quantile regression. The fourth section discusses the additional data employed and the fifth section presents results of the estimation procedure. The final section concludes and offers some direction for further empirical research.

2 Imports of agricultural seed

The dataset compiled for this study consists of imports of seeds by 79 countries over the period 1989-2007 from the US and 10 principal European exporters: Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, the UK.[3] These exporters are also included as importing countries, which is comprised of a wide range of countries of various regions of the world: EU (16), other European (4), North Africa (4), Middle East (4), Sub-Saharan Africa (18), Asia (13), Oceania (2), South and Central America (16) and North America (3). The composition of this list is determined by the availability of the trade statistics, as well as some other variables that are included in the modeling in the next section. In general, EU

[3]Japan is one possible country with considerable exports for which we do not have data.

exports considerably outweigh US exports; for example EU exports totalled more than US$ 1,978 million in 2007 against US exports of US$ 765 million (both figures in constant 2000 dollars). A considerable portion of the exports from European countries are destined for each other's markets (almost two-thirds in 1997). EU exports to other countries are US$ 681 million in 2007, which is quite comparable to those of the US to the same countries, at US$ 621 million (constant 2000 dollars). There are however geographic and crop differences which will be discussed below further. EU exports to other EU exporting countries are still considered here as international trade flows in the current study, primarily because of the difference points in time at which PBR systems were introduced or revised in Europe. (And we also differentiate among US exports to each of these 10 EU exporters.)

Data on seed exports from the 10 European countries was extracted from the Eurostat trade database and for the United States, from the US Agricultural Trade Database of the USDA's Foreign Agricultural Service.[4] The latter includes a grouping for agricultural seeds, but in Eurostat there is no single product classification grouping for seed and planting material; instead there are extended HS8 codes (8 digit Harmonized System codes for traded products) under each product grouping, such as maize or vegetables. In total, there were 64 separate seed product codes at HS8 level. The value of seed exports was converted to constant US dollars with base year 2000.

The value of seed imports for each of the countries from both the US and the EU is presented in Figures 1 to 6, which are grouped roughly according to region, but with some exceptions to try to include countries with imports of roughly comparable size of imports. The figures also indicate the year that the importing country became a signatory to either the 1978 Act or the 1991 Act of the UPOV treaty.[5] In cases, such as Belgium, where a country acceded to the 1978 Act prior to 1988 and "upgraded" to the 1991 Act, this is indicated in the figure with an asterix (*) as "UPOV91*". And in cases, such as Switzerland or New Zealand where the country, as signatory to the 1978 Act, did not upgrade, "UPOV78" is presented horizontally (that is, without a specific year) in the figure panel.

The data varies considerably by country, both in terms of size of imports and their development over time. It appears that seed imports fluctuate considerably

[4]http://www.fas.usda.gov/ustrade/USTHome.asp?QI=

[5]The data is taken from the UPOV website (www.upov.org) and various official meeting documents available there. Note also that a number of EU countries are indicated as acceding to the 1991 Act of UPOV in 1995, when in fact the accession process may have taken longer. Such countries were however members of the EC's Community Plant Variety Organization (CPVO) which in 1995 implemented a membership-wide PBR that was conform to the 1991 Act.

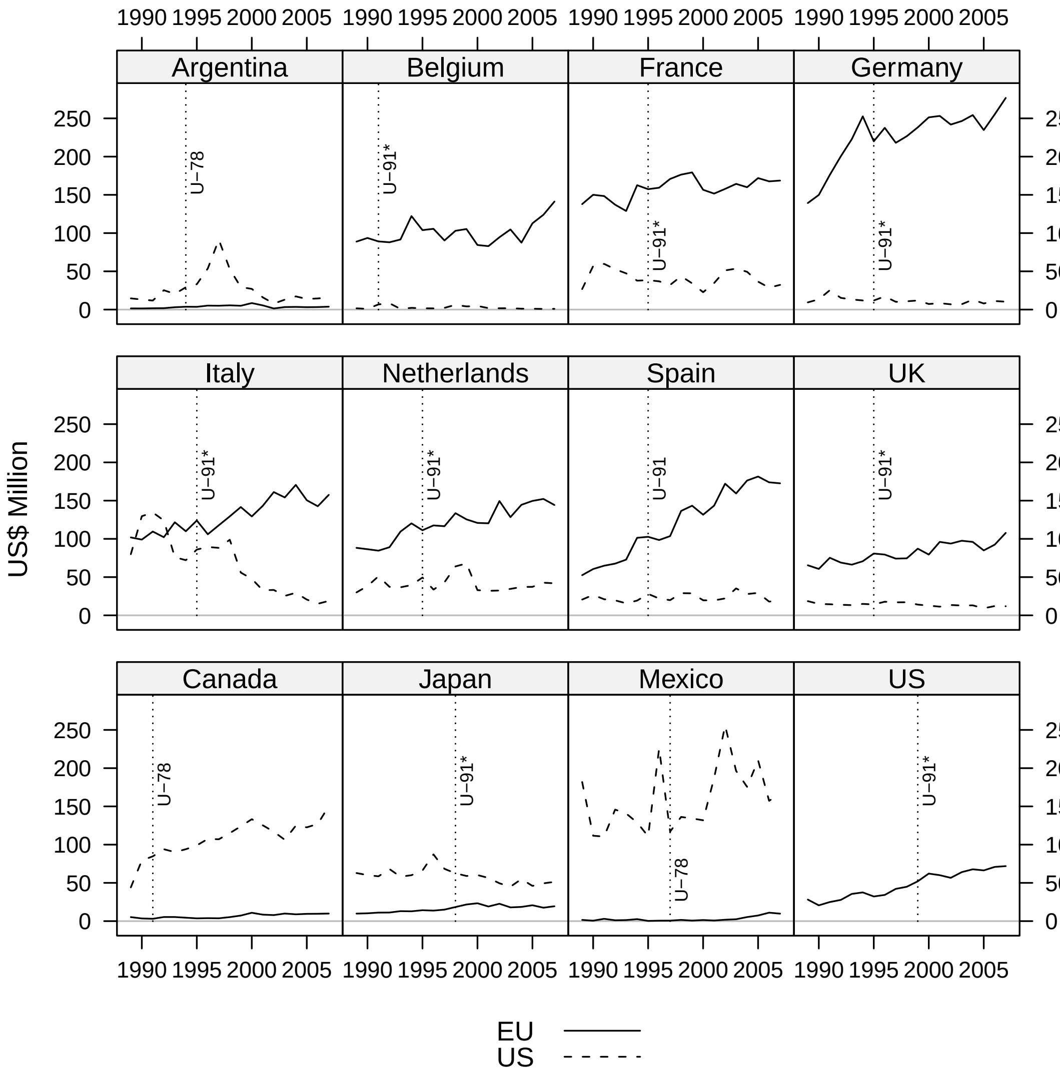

Figure 1: Seed imports (constant US$ 2000) from the EU and the US for selected countries (1989-2007) - Group 1 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

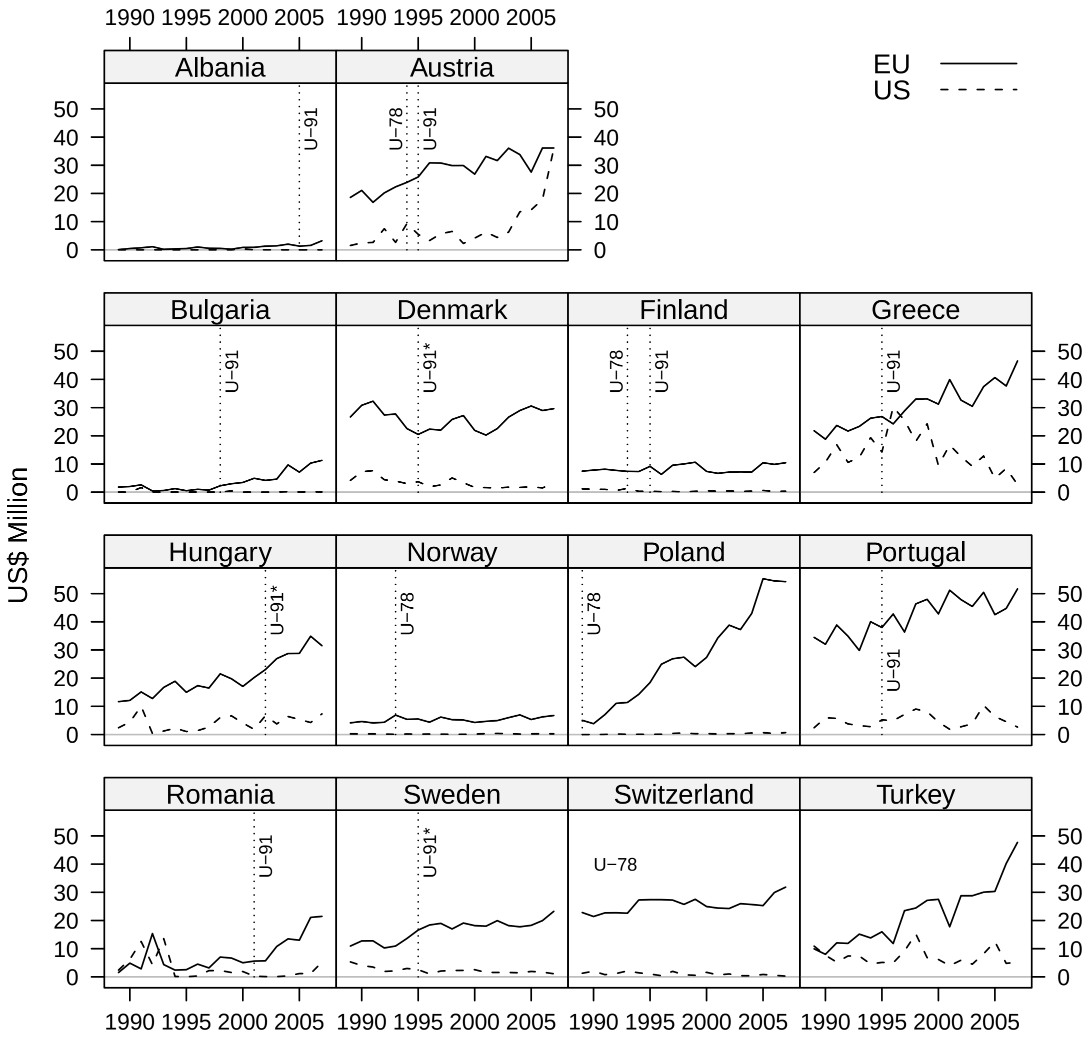

Figure 2: Seed imports (constant US$ 2000) from the EU and the US for selected countries (1989-2007) - Group 2 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

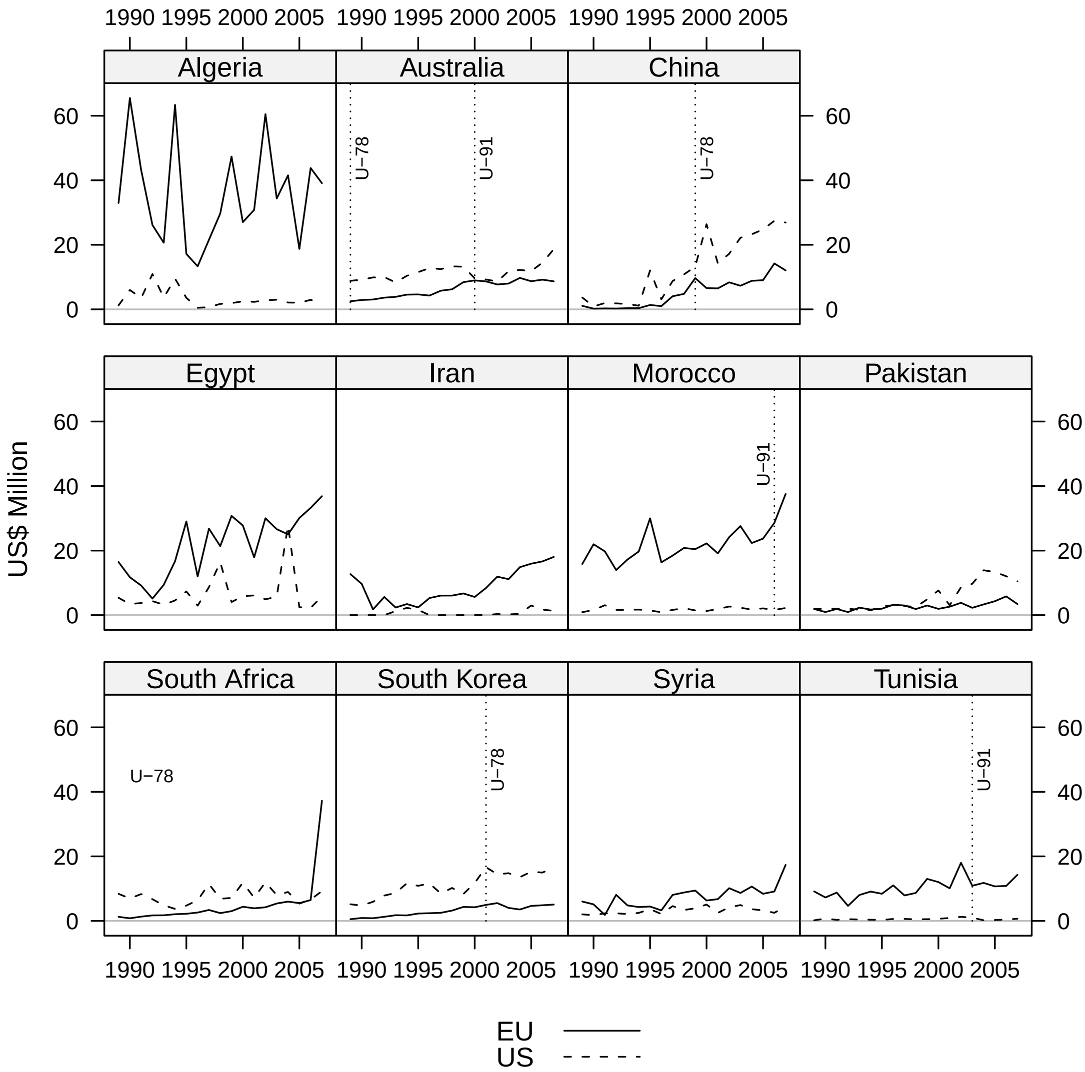

Figure 3: Seed imports (constant US$ 2000) from the EU and the US for selected countries (1989-2007) - Group 3 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

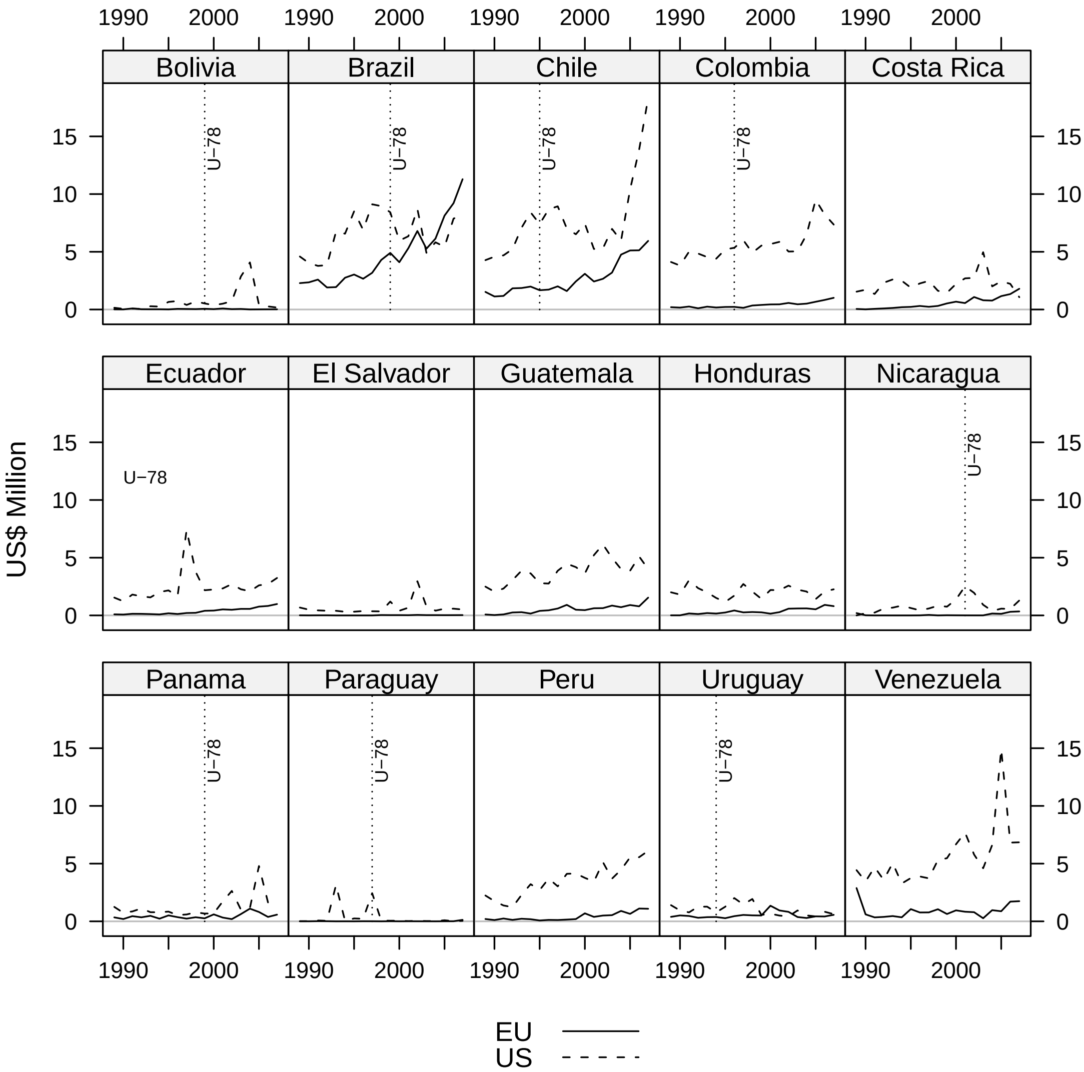

Figure 4: Seed imports (constant US$ 2000) from the EU and the US for selected Latin American countries (1989-2007) - Group 4 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

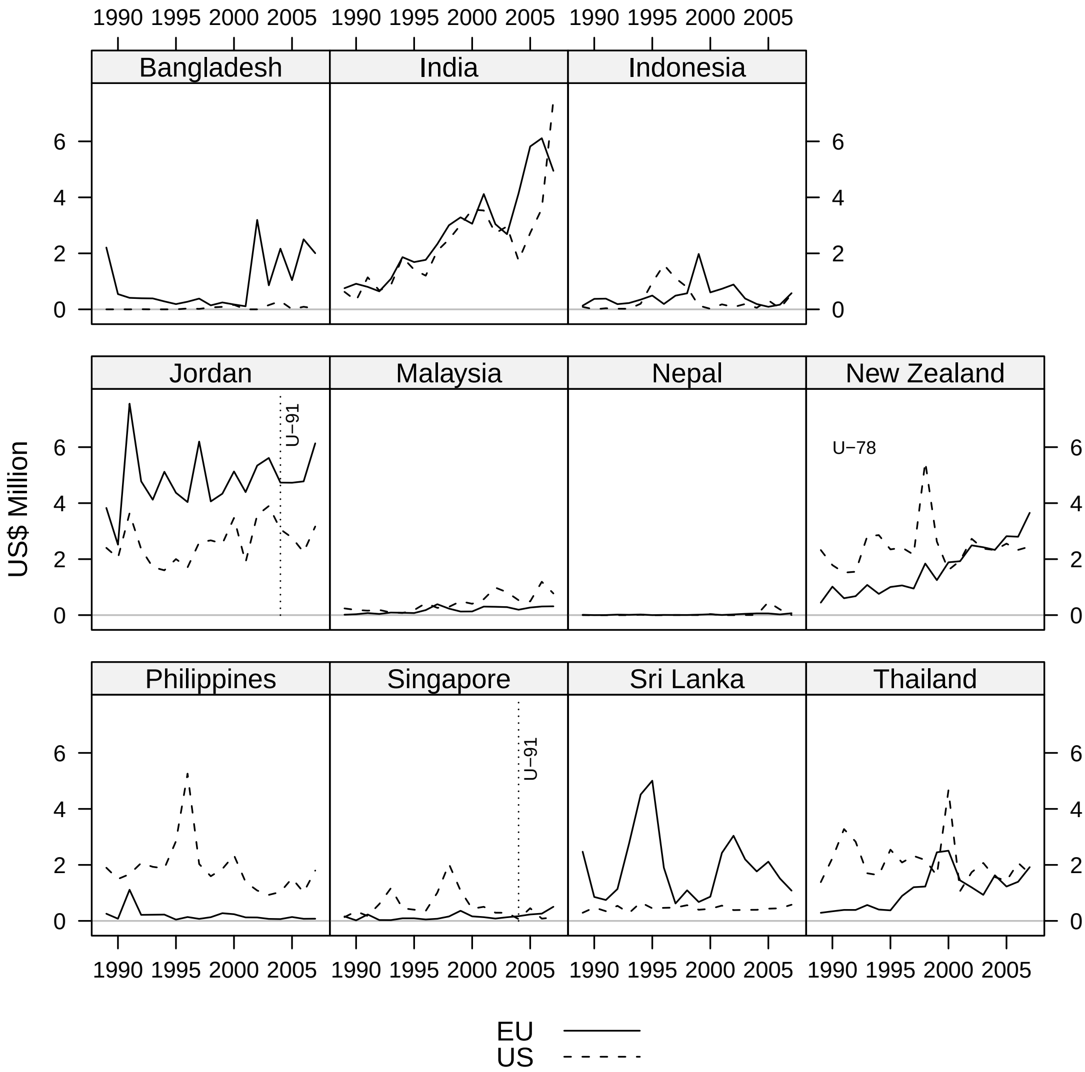

Figure 5: Seed imports (constant US$ 2000) from the EU and the US for selected countries (1989-2007) - Group 5 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

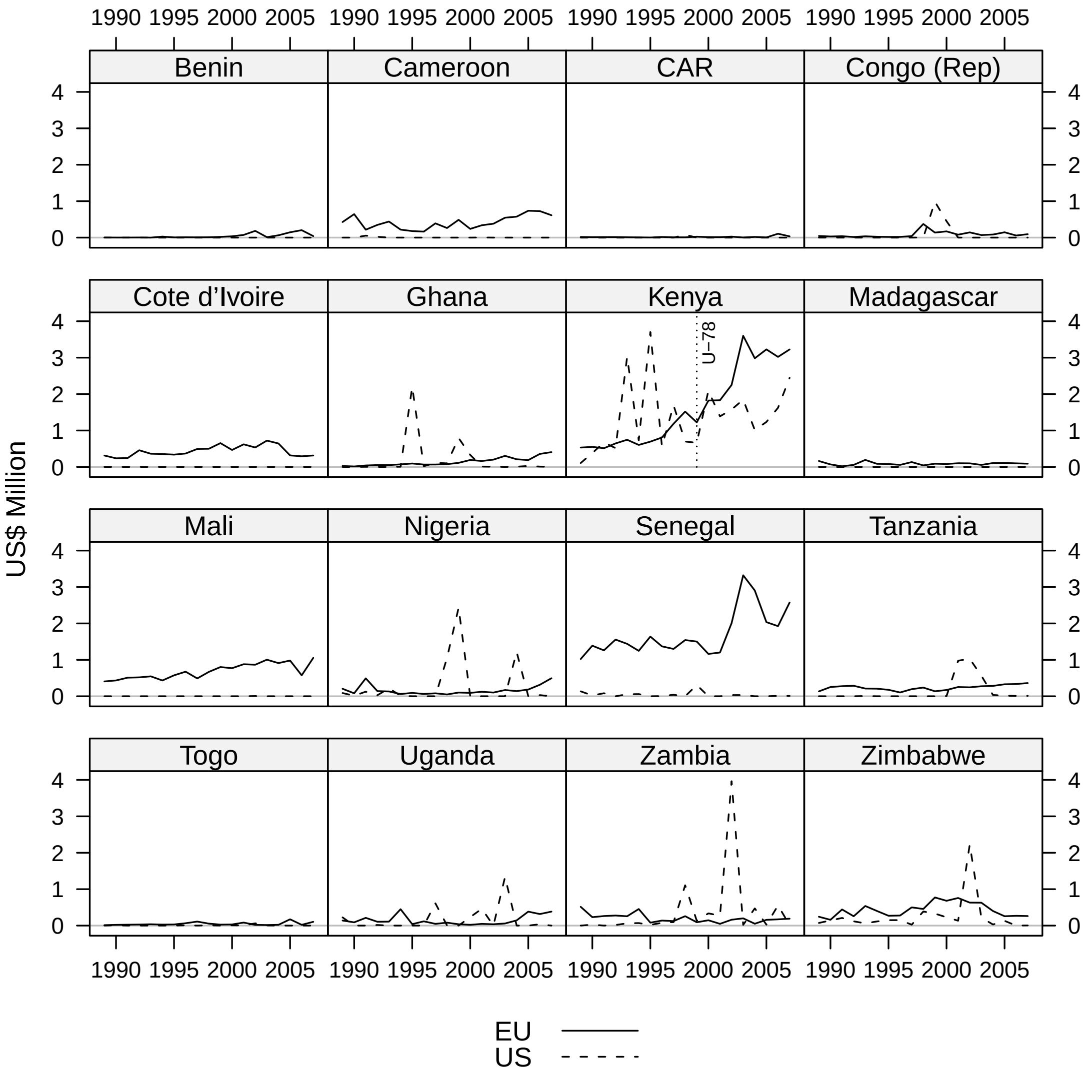

Figure 6: Seed imports (constant US$ 2000) from the EU and the US for selected African countries (1989-2007)- Group 6 (Date of accession to UPOV 1978 or 1991 Acts is also indicated; see text for explanation)

from year to year. Some show a general increasing trend, while others might be casually described as mean-reverting. There are also clear differences between EU and US exports. While EU countries import seeds primarily from other EU countries, Canada and Mexico import primarily from the United States, reflecting both similarities in cropping systems, and the general economic integration of the North American Free Trade Association (Figure 1). It can also be seen though that Latin American countries in general import considerably more seeds from the US than the EU (Figure 4, with Argentina in Figure 1), with the exception of Brazil where imports from the two sources are of comparable value.

In terms of PBRs, there is also a wide range of situations. EU countries were among the first to move to UPOV 1991 from the 1978 version. Other industrialized countries, such as the US or Japan took longer (respectively 1999 and 1998), while neither Canada nor New Zealand had notably not signed the 1991 Act as of 2004. Seed imports in Australia and New Zealand are considerably lower than many other industrialized countries. One might be tempted to infer that Australia's adoption of UPOV 1978 Act in 1989 preceded a steady increase in seed imports through the 1990s, but this trend did not change with the adoption of the 1991 Act in 2000. Such inferences however are weakened by the lack of data for before 1989, as well as more recently. New Zealand's imports of seed are relatively minimal, reflecting partly the lesser importance of crop production in its agricultural sector, and despite the adoption of the 1978 Act earlier in the 1980s.

Looking at a variety of European countries, including new EU members (Figure 2), essentially all are members of UPOV. But whereas some Central and Eastern European countries such as Bulgaria, Romania and Hungary have now acceded to the 1991 Act, other fairly high-income countries such as Norway and Switzerland have remained with the 1978 Act.[6] It might be inferred from the graph that Bulgaria's joining UPOV 1991 led to an increase in seed imports in subsequent years. Such a hypothesis might also hold for Romania but the earlier fluctuations in seed imports to this country suggest the importance of some other factors.

Considering the experiences of Latin American countries (Figure 4), it is clear that none of these had adopted the 1991 Act (as of 2004). Indeed, there are almost no examples of developing countries joining UPOV 1991 within (or before) the sample period (exceptions include Jordan, Tunisia and Singapore). For countries such as Argentina (actually shown in Figure 1), Brazil, Colombia and Chile, it seems that UPOV 1978 membership came after an earlier surge in seed imports. Perhaps for

[6]These countries are not members of the European Community Plant Variety Protection Office (CPVO) which would require them to respect the terms of the 1991 Act.

Argentina, this was followed by a further acceleration in seed imports, which then perhaps for reasons related to the economic crisis beginning in the late 1990s, decreased markedly. Other countries, such as Costa Rica, Guatemala, and Peru have had a general rising trend in seed imports without any PBR protection.

Many Asian countries had also not yet adopted UPOV PBRs, including Bangladesh, India, Indonesia, Iran, Malaysia, Nepal, Pakistan, the Philippines, Sri Lanka and Thailand (Figures 4 and 5).[7] Some of these countries, such as Bangladesh, Malaysia and Nepal have marginal seed imports, but others, such as India, Iran and Pakistan, have experienced steadily increasing seed imports. Among Asian UPOV-member countries, China and South Korea show patterns somewhat similar to Chile and Colombia: rising seed imports throughout the 1990s prior to the adoption of the 1978 Act, without no apparent increase in seed imports in the short period immediately thereafter.

For almost all of Sub-Saharan Africa, seed imports really are minimal in size (Figure 6).[8] Kenya and South Africa (the latter shown in Figure 3) are the principal exceptions, with the East African country importing considerable seed and planting material for its growing horticultural sector. Kenya's imports were increasing prior to the adoption of the UPOV 1978 Act in 1999, which followed by further steady growth. Although less volatile in the subsequent five years, it is difficult to infer on the basis of such visual analysis alone whether this constituted some sort of structural break. In comparison to other countries in the region and the rest of the continent, Kenya's experience does not suggest though that UPOV membership has 'kick-started' seed imports, and other factors have likely played a more important role. The comparison with Uganda is relevant given the growth in the horticultural sector experienced there since the mid-to-late 1990s. While the low seed imports for this country could be interpreted as reflecting the proposition that seed imports will remain low without IPR protection, it seems more plausible that other factors play a more important role in making Uganda less attractive an export destination than Kenya, and these factors were already at play before Kenya joined UPOV. South Africa, is of course, not really comparable in economic terms to the rest of Sub-Saharan Africa. The country's seed imports are considerably higher, showing also an

[7] India stands out as having not chosen the UPOV PBR model legislation; instead, after considerable debate, the country crafted its own version of PBR protection that also includes provision for the protection of farmers varieties. This system was though not yet implemented as of 2004.

[8] The sixteen countries of the African Intellectual Property Organization (AIPO, but often referred to by its French acronym, OAPI, as its membership consists primarily of francophone countries of West and Central Africa; see `http://www.oapi.wipo.net/en/OAPI/historique.htm`) agreed to implement UPOV 1991 as part of the revised Bangui Agreement with the EC of 1999. The legislation establishing PBRs only took effect on 1 January 2006, and the extent of implementation is still not clear.

upwards trend. As the country adopted the UPOV 1978 Act earlier, the comparison with surrounding countries of Southern Africa may support an interpretation that PBRs are one of the relevant differences supporting a more productive agricultural sector in South Africa (but other factors again need to be accounted for, as will be attempted in the subsequent sections).[9]

In general then, the figures do not suggest very strong evidence for a positive incentive effect from PBRs on the export of seeds to adopting countries. While the compilation and graphical presentation of this data might be seen as sufficient, given the earlier work of Yang and Woo, the subsequent sections attempt to examine this data more systematically using modern panel data methods, controlling not only for other factors, but also for unobserved heterogeneity among importing countries.

3 Empirical modeling of seed imports

The econometric model developed here builds on the work of Yang and Woo (2006) in two respects. First, we take a dynamic fixed effects model inspired by the gravity model of international trade as the starting point. Second, we apply quantile regression techniques to permit a more thorough analysis of the data, which is discussed further below after elaborating in some detail on the first point. The analysis of Yang and Woo clearly rejected pooling of the data, or even a random effects formulation. After the presentation of the full dataset above, the level of heterogeneity among countries suggests a fixed effects model as by far the most plausible assumption.[10] In addition, our primary interest is in the effect of time-varying variables, in this case UPOV membership. Yang and Woo also found strong evidence for the inclusion of lagged seed imports in the model, which again is strongly supported the graphical inspection of the data. In their analysis, exclusion of lagged imports resulted in serious omitted-variables bias that could even support erroneous inferences on the significance of UPOV membership.

Our model, like that of Yang and Woo, is partly based on the gravity model, which was developed to explain the pattern of aggregate bilateral trade flows in a general equilibrium setting (for example, Anderson and van Wincoop, 2003). Here

[9]Note that peaks in imports in Zambia (1998, 2003) and Zimbabwe (2003) are accounted for primarily by imports of maize seed in the form of food aid.

[10]To assume that individual effects are uncorrelated with the error term has little interpretation in a situation, such as with the gravity model, where one cannot substantiate such an assumption in terms of sampling from a larger population. With this type of cross-country analysis, which incorporates essentially the entire population of interest, the individual effects are more than likely to be correlated with unobserved variables, for example, and such reasoning can be motivated by appealing to arguments of heterogeneity among countries and even historical path dependence.

we are concerned however with modeling trade in one particular sector. Other recent applications to the food and agriculture sector include papers by Amponsah and Ofori Boadu (2007), Jayasinghe and Sarker (2008), and De Frahan and Vancauteren (2006), who analysed the effect of harmonised food safety regulations on intra-EU trade in 10 different food products, each of which was estimated as a separate equation.[11] While the use of the gravity model for the analysis of specific disaggregated products still leaves much to be desired (and hopefully improved in further research), its use is perhaps better justified when interest centres on the effect of a specific policy measure, such as in the current paper. We are less concerned about properly explaining trade in seed and planting material but wish to see how this trade has been affected by the introduction of PBRs in various countries in recent years.[12]

Furthermore, we choose to aggregate imports from various exporter countries, given that bilateral flows are subject to even more volatility than is observed above in the aggregate imports, and this volatility is not accounted for by typical explanatory variables in the gravity model (presented below). Again, given the present interest in assessing effects of UPOV systems, it seems logical to begin first at a higher level of aggregation, and to proceed to finer levels if the preliminary results warrant such steps. This choice in the specification means that only importer-specific explanatory variables are included. We do though take heed of the findings of Baltagi et al. (2003) who demonstrate the potential bias from omitting any fixed effect terms (including time effects), as well as their interaction terms, in the specification of the gravity model.

One benefit of aggregating the imports is that we can avoid the difficulties posed by observations of zero trade flows, which have been highlighted recently by Santos Silva and Tenreyro (2006). They demonstrated the potential inconsistency of gravity modeling using a logarithmic transformation of the structural equation, and instead suggest using Poisson quasi-maximum likelihood estimation (QMLE).[13] With aggregated seed imports, there are effectively no zero observations, permitting more easily

[11] Earlier applications to food and agriculture include papers by Koo et al. (1994) and Dascal et al. (2002).

[12] From a theoretical perspective, an alternative would be to specify a structural partial equilibrium model for the good concerned, including all relevant bilateral trade flows. This approach is faced though with almost insurmountable data requirements and estimation difficulties. It is really only possible when the number of trading countries is fairly limited. In the end, a modified gravity equation can also be viewed as a fairly crude reduced-form of the underlying partial equilibrium model.

[13] The advantages of QMLE were recently verified and extended by Henderson and Millimet (2008). Another approach is the use of two-part or hurdle models, as implemented by Helpman *et al.* (2008),Koop *et al.*(2007, pp. 240-2)and Ranjan and Tobias(2007).

the use of logarithms of both dependent and (continuous) explanatory variables. In addition, the choice of the quantile regression framework means that the problem of Jensen's Inequality in taking logarithms of expectations, as explained by Santos Silva and Tenreyro, is avoided. To further substantiate our approach, we find that the distribution of the logarithm of seed imports in our sample follows a roughly symmetric single-peaked shape. It is also worthwhile noting that application of the QMLE methodology to a dynamic fixed effects model would be complicated by the initial conditions problem; potential solutions to this include an extended formulation including lagged (possibly meaned) explanatory variables as well as initial values of the dependent variable (see Wooldridge, 2005).[14] An alternative is the GMM approach developed by Blundell *et al.* (2002). Proposers of both of these solutions warn however that they may only work reasonably well in datasets with high signal-to-noise ratios, whereas the noisiness of the seed import data implies benefits for robuster techniques.[15] For their dynamic model, Yang and Woo applied the generalized least squares (GLS) estimator of the random effects dynamic panel data (see Hsiao, 2003). Although this implies accepting the assumption that the country effects are uncorrelated with the error term, which they had rejected in the case of the static model, the finding of insignificant coefficients on their IPR variables is likely to be robust to this possible misspecification.[16] In their situation, as with ours, the research question concerns in the first instance the potential effects of IPRs on seed trade, and only the development of a robust explanatory model as a second possible objective.

3.1 The fixed effects quantile regression

For all the reasons explained above, we choose to model seed imports using the fixed effects quantile regression framework. Developed by Koenker (2004, 2005) and recently applied by Lamarche (2008) to educational attainments, the basic dynamic

[14]In exploratory work, we attempted to specify and estimate some disaggregated models with specific effects for both exporters and importers as a conditional random effects Poisson model (and also as dynamic linear model using GMM). We failed however to reach a satisfactory and robust specification, although in general the results do not contradict our findings presented below with respect to UPOV membership. We also estimated a dynamic Probit model for the presence of bilateral seed exports between country-pairs, with similar conclusions.

[15]Both Wooldridge's (2005) random effects approach and the GMM approach of Blundell *et al.* (2002) involve augmenting the model with potentially many lags of explanatory variables. Attempts at such approaches with the current dataset quickly encountered collinearity problems, as the authors acknowledge is possible. Blundell *et al.* demonstrate that their GMM estimator is likely to be severely biased, particularly in small samples and with 'persistent' regressors that change little over time.

[16]Three of five of the statistically significant coefficients in Yang and Woo's results are for time-invariant variables (see their Table 5).

model is

$$Q_{y_{it}}\left(\tau|x_{it},\,\alpha_i\right) = x_{it}'\beta\left(\tau\right) + y_{i,t-1}\gamma\left(\tau\right) + \alpha_i \;\; i = 1,...,N \; t = 1,...,T_i \tag{1}$$

where y_{it} is observation on the dependent variable (here seed imports) for cross-sectional group i (importing country) at time t, and $Q\left(\tau|\;\right)$is the conditional quantile function for quantile τ $(0 < \tau < 1)$.[17] The observations on the explanatory variables are the vector x_{it} and the (importing country) fixed effects are α_i, which corresponds to a specific intercept (location shift) for each importing country, as in the conventional fixed effects conditional mean model. This dynamic formulation includes a lagged observation on seed imports, $y_{i,t-1}$. The quantile regression model specifies the coefficients β, γ as possibly varying per quantile and these are therefore a function of τ.

The parameters β, γ and α are estimated by

$$\underset{\beta,\alpha}{\operatorname{argmin}} \sum_{k=1}^{K}\sum_{t=1}^{T}\sum_{i=1}^{N} w_k \rho_{\tau_k}\left(y_{it} - x_{it}'\beta\left(\tau_k\right) - y_{i,t-1}\gamma\left(\tau\right) - \alpha_i\right) \tag{2}$$

where w_k refers to weights attached to each quantile. Koenker has developed an algorithm to solve this optimization problem, making use of sparse linear algebra and interior point methods and available for implementation in `R`.[18] Following the example of Lamarche (2008)[19], we use the panel bootstrap (see, for example Cameron and Trivedi, 2005) to estimate confidence bounds for the estimator, sampling with replacement over the 80 importing countries (indexed by i in 2). We report results for 500 bootstrap replications, but these were essentially unchanged with 1000 replications.

The dynamic formulation of the model raises some additional issues. The inclusion of the lagged dependent variable in the fixed effects model should permit us to differentiate between stationarity and unobserved heterogeneity in the data generating process. Figures 1 to 5 suggest that in the case of many countries the series

[17] The conditional quantile function is defined as $Q_Y\left(\tau|X\right) = \inf\left\{y \;:\; F_{Y|X}\left(y\right) \geq \tau\right\}$ where $F_{Y|X}$ is the conditional distribution function of Y given X, and τ is conventionally used to designate the quantiles over the interval $(0, 1)$.

[18] The program code is available at `http://www.econ.uiuc.edu/~roger/research/panel/rq.fit.panel.R` and requires the `quantreg` package (Koenker, 2008) for `R` (R Core Development Team, 2009). Koenker (2004, 2005) considers estimators of 2 that also include a penalty function $\lambda \sum_{i=1}^{N} |\alpha_i|$ as an additional term, which is intended to improve the performance of the estimator. The penalty function can be specified to reflect different assumptions on α. For present purposes we use the simple additive formulation and report results below with $\lambda = 1$; sensitivity analysis indicates that our estimates of $\beta\left(\tau\right)$ are not strongly influenced by a wide range of values of this shrinkage parameter, which Koenker describes as a subject of ongoing research.

[19] And as recommended by Koenker (`http://www.econ.uiuc.edu/~roger/research/panel/rq.fit.panel.R`).

may be nonstationary, although certainly not in all. Indeed, in their analysis, Yang and Woo (2006) apply the panel unit root test of Im *et al.* (2003) and reject the null hypothesis that all series are nonstationary, though this still admits the possibility that one or more of the series is characterized by a unit root. Their estimated coefficient on lagged imports in the dynamic model is 0.64, which indicates a certain amount of state dependence in seed imports. We base our strategy on their results and simply estimate dynamic formulations of the model, which is clearly suggested by the raw data. We estimate various static versions as well but do not report the results here. In general, the static versions yield much different parameter estimates, but as found by Yang and Woo, the omission of the lagged variable is not plausible and rejected by simple significance tests.

Our medium-length panel (maximum $T_i = 17$) also suggests the possibility of applying recently-developed panel vector autoregressive (VAR) and error correction models to the data.[20] Further improvements have also been made in unit root testing in panels that allow for possible cross-sectional dependence, and the testing of more sophisticated hypotheses (for an overview, see Breitung and Pesaran (2008)). One limitation though for present purposes of panel VAR concerns the analysis of the effect of UPOV membership, which is a dummy variable. Thus, the strategy would have to be one of first testing for unit roots and structural breaks in the panel, as has been demonstrated by Carrion-i-Silvestre *et al.* (2005). That approach would entail testing for structural breaks, using the testing framework of Bai and Perron (1998, 2003), in each of the series separately as a first step. These tests will have relatively limited power though with maximum series length of 17 and such a low signal-to-noise ratio. We therefore leave such an approach for future work when more additional data allows the analysis of a longer panel.

4 Additional data

The principal continuous explanatory variables for importing countries in a sector-specific gravity model are measures of expenditure (see, for example de Frahan and Vancauteren, 2006), in this case on seeds. Data on commercial seed sales is not available for most countries, and any estimates are certainly not available on a longitudinal basis. We therefore include a range of proxies (all taken from the World Bank's World Development Indicators database[21]):

[20] See the special issue edited by Baltagi and Pesaran (2007); relevant estimation strategies also include those of Binder et al. (2005).

[21] `http://www.worldbank.org/wdi`.

- Agricultural GDP at time t (logarithm, US$ constant 2000): LAGAI
- Agricultural GDP per hectare arable land at time t (logarithm, US$ constant 2000): LGHI
- Agricultural GDP per agricultural worker at time t (logarithm, US$ constant 2000): LGPW
- GDP at time t (logarithm, US$ constant 2000): LGDP
- GDP per capita at time t (logarithm, US$ constant 2000): LGDPC

In addition, we add an index of overall trade restrictiveness (TR), ranging between 1 and 10, compiled by the Fraser Institute as part of its Economic Freedom of the World database, and revised annually.[22] The following IPR variables are included among explanatory variables:

- Dummy variable = 1 if country was a signatory of the UPOV 1978 Convention at time t and 0 otherwise: UPOV78
- Dummy variable = 1 if country was a signatory of the UPOV 1991 Convention at time t and 0 otherwise: UPOV91
- An index for the strength of property rights protection, ranging between 1 and 10: PR (also compiled in the Economic Freedom of the World database.

We also include one-year lags for both UPOV variables, as it is quite plausible that there is some delay between a country signing the UPOV agreement, passing necessary legislation, and subsequently implementing a PBR system, which requires the establishment of an agency to administer these legal instruments. The property rights protection index is includes a wide range of indicators, such as time to enforce contracts in court and time required to register a property deed. It is included to provide some measure of the effectiveness of PBR protection, since UPOV member countries can differ considerably in how well their PBR systems work. Differences, which are similar to those between patent systems, include the time required to process applications, the time required to litigate against a suspected infringer, and in general, the confidence plant breeders have in the security of their submitted plant material during the application and testing stages.

Our choice of explanatory variables differs somewhat from those used by Yang and Woo (2006). Concerning IPR variables, they did not differentiate between 1978

[22] Available at `http://www.fraserinstitute.org/researchandpublications/publications/6194.aspx`

and 1991 membership in UPOV, whereas the current analysis treats membership in the later, broader, version, as potentially stronger than the earlier, and more common 1978 version.[23] Nor did they include lagged observations of UPOV membership. For strength of PBR protection, those authors considered using years of UPOV membership but argued that this is too rough a proxy of strength of protection. They did include dummy variables for membership of the Paris Convention and the TRIPS agreement as indicators of IPR protection in general. The latter does not arguably contribute much additional information though since TRIPS membership follows automatically from WTO membership; in Yang and Woo's dataset, 54 out of 60 countries joined WTO/TRIPS in 1995. Additional information contained in membership of the Paris Convention is probably more than adequately reflected in the Economic Freedom of the World property rights index used here, which also has the advantage of offering a continuous, as opposed to a discrete, regressor. Other explanatory variables used by those authors include per capita GDP (as in our analysis), population, area of arable land, and distance between the US and the importing country. We motivate our choice of agricultural GDP, including on a per hectare and per worker basis, as additional proxies for expenditure on seeds as we found more variation among these variables than in area of arable land. Furthermore, annual changes in the area of arable land cannot be expected to reflect changes in the size of expenditures on seeds as much as changes in the value added in the sector. Finally distance from the US reflects the common use of a distance variable in the gravity equation. This is not possible given our aggregation of seed exports from 11 source countries. Furthermore, our choice for a fixed effects model means that all time-invariant variables are not identified, but captured in our importer fixed effect (α).

Summary descriptive statistics are provided in Table 1. Annual imports of seeds range from US$ 1,000 to US$ 311 million. The mean is US$ 29 million while the median is only about US$ 5 million, indicating a left-skewed distribution, whose logarithmic transformation is almost centred. The database contains a reasonable amount of variation in terms of whether the importing country is a signatory of the UPOV 1978 treaty in each period (35% of observations), with only about one-third of those cases comprising the broader 1991 version.

[23]Thus, if a country became a UPOV member with accession to the 1991 Act (that is, was not previously a signatory of the 1978 Act), then UPOV78, as well as UPOV91, equals one.

Table 1: Summary statistics

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
Seed imports ('000 US$)	29,200	4,955	56,792	1	311,600
Log imports	15.2	15.42	2.45	6.908	19.56
LAGAI	22.13	22.05	1.48	18.44	26.05
LGHI	6.97	6.82	1.16	4.14	12.17
LGPW	7.77	7.63	1.63	4.80	10.97
LGDP	24.62	24.70	2.01	20.44	30.00
LGDPC	7.81	7.53	1.58	5.11	10.58
TR	6.41	6.55	1.44	1.79	9.60
PR	5.60	5.43	1.97	1.43	9.62
UPOV78	0.35	0	0.48	0	1
UPOV91	0.13	0	0.34	0	1

5 Results

Results for the dynamic fixed effects quantile regression are presented in Figure 7 in graphical format for ease of interpretation.[24] Each panel in the figure shows the estimates of $\beta(\tau)$ for one explanatory variable (and $\gamma(\tau)$ for lagged imports). These were estimated for each decile ($\tau = 0.1, 0.2, ..., 0.9$, indicated on the horizontal axis) and are represented by the dots. The grey areas represent the 90% confidence intervals, calculated as the 5% to 95% quantiles of the parameter estimates from the 500 panel bootstrap replications. To assist in inferring whether the coefficients differ significantly from zero, the zero line is also drawn in each panel.

The most obvious aspect of the results is the apparent imprecision of the estimated coefficients, with the moderate exception of the UPOV variables. In the case of all explanatory variables, with the sole exception of lagged imports, the estimated coefficients of the conditional quantile function do not differ significantly from zero. This relative imprecision reflects the considerable diversity in the data seen above (Section 2), as well as the fact that we have few explanatory variables that can account for the general fluctuating pattern observed for many countries.

In particular, the proxies for the gravity-model variable on expenditure are insignificant. This result need not necessarily be all that surprising. The gravity model was essentially developed as a static model to explain the overall pattern of trade, not its evolution. Furthermore, as we noted above, the expenditure variables

[24] We present the results only in graphical format, not only for ease of interpretation, but also in the interests of brevity. This is also justified by the nature of the results, as explained in the main text, which does not incite interest in the precise numerical estimates of conditional quantile coefficients and their confidence bounds.

are relatively persistent, showing little variation over time. They therefore offers little explanatory power beyond the individual country fixed effects (not shown), particularly for the annual fluctuations in seed imports.

Lagged imports is the only variable whose coefficient is significantly different from zero with estimated values ranging from 0.29 in the first decile to 0.15 in the ninth. These estimates, as well as the lower confidence bound decline with deciles of current imports, which indicates that explanatory power of this variable also declines with the size of imports in general. Casual inspection of Figures 1 to 5 suggests that the annual variability in imports seems to increase for countries with higher volumes, at least in relative terms, which may explain this result. The upper confidence bound is however constant, suggesting that this pattern need not be so robust. This upper bound (0.63) is quite close to the value (0.64) found by Yang and Woo using a generalized least squares approach, and so the point estimates in our analysis are considerably lower.

The most important result for our purposes is the lack of significant effect of UPOV membership on seed imports. Neither the variable for adhesion to the 1978 Treaty, nor that for the 1991 Treaty are significantly different from zero, and the same applies for their corresponding one-period lags. The point estimates for the coefficients on UPOV 1978 are fairly close to zero, which may offer some support for the view that this earlier version does not offer much significant appropriation for breeders and seed companies, compared to the 1991 version, at least where the latter is implemented in a manner that does curtail or remove the farmers' privilege (as is the case in the EU, for example). But on the other hand, the estimates for the UPOV 1991 variable, aside from also not being significantly different from zero, are not really greater overall in absolute terms (note that the scales of the respective panels in Figure 7 are different).

Various explanations can be offered for the lack of significant effect of UPOV membership on seed imports. The first and most obvious is that in general the initiation of PBRs has little effect on the decisions of seed companies to export to specific markets. Indeed, it is known that companies employ a variety of strategies to protect their new varieties from being reproduced by others, whether farmers or competing sellers. Perhaps the most important of these is biological protection through the use of hybridization, where possible. Another strategy is the use of contracts and carefully-chosen partnerships with growers. In general, these possibilities as well as a range of other factors, including market prospects and country-specific factors, captured in the fixed effects analysis, may be more important in exporters'

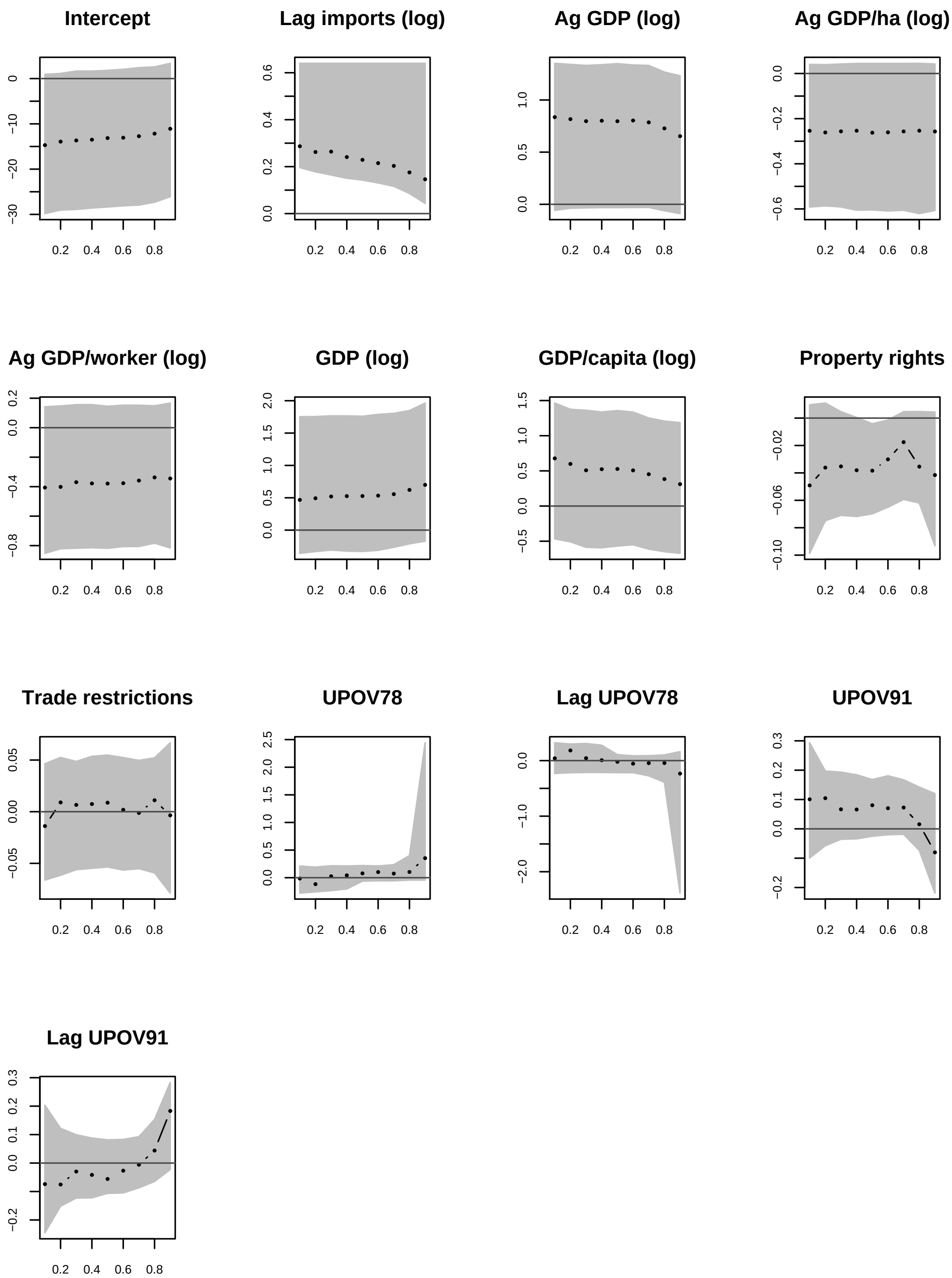

Figure 7: Fixed effects quantile regression estimates

decision-making than PBRs, or UPOV. This does not necessarily mean that PBRs have few consequences for appropriability. Rather, the analysis and the dataset (for which many countries have only recently joined UPOV), assesses the effect of initiating PBRs with UPOV membership on seed imports. So while we have effectively no general evidence of an incentive effect at this stage, we cannot on the basis of our analysis rule out the possibility that a system of PBRs will strengthen trade further in the future.

An alternative explanation is that UPOV membership, by itself, might not be a very good indicator of how effective the PBR system is, and that this effectiveness is more important for the decisions of exporters. Indeed, signing the UPOV Treaty can take place before the system is actually implemented, and for that reason we also included lagged values, though these were also not significant. Partly for this reason, we included the property rights protection variable. Although this is also not significant, it is still possible that this is not well correlated with the effectiveness of the PBR system. Some of the important aspects that determine the effectiveness of PBRs, such as the reliability and efficiency of the legal system, are included in the index employed in our analyis. But some other aspects, such as the security of the variety testing procedures, are specific to PBRs and might play a role, particularly in countries with weaker institutional structures. These are not directly reflected in the property rights variable. Nonetheless, this variable does exhibit considerable variation across countries and also within countries over time. On the other hand, this explanation suggests that many countries have joined UPOV but not yet achieved very effective PBR systems, which raises questions for further research to which we return in the next section.

6 Conclusions

Our analysis has further contributed to the efforts of Yang and Woo (2006) to assess the effects of IPRs on seed trade by adding all major European exporters to US exports, and also by adding additional years of data. We also fail to find any significant effect of UPOV membership on US or EU seed exports to an importing country. Aside from the additional data, which further generalizes Yang and Woo's results, we have differentiated between the two versions of the UPOV Treaty still in effect and the corresponding scope of protection. Ongoing work will concentrate on estimating equations for specific crop sectors (and for specific exporters: US vs EU) as the effects of PBRs might be apparent for crops that are more susceptible to being reproduced for sale, such as vegetatively-propagated species (e.g. potatoes) or open-pollinated species (e.g. wheat).

From a methodological point of view, we chose to apply the quantile regression approach, originally out of interest for possible differential effects among countries according to the level of seed trade. Developments in this area in recent years, in particular the fixed effects quantile regression proposed by Koenker (2004, 2005), make this possible. This parallels the growing interest in incorporating heterogeneity in econometric modelling, which includes other conditional mean approaches such as random coefficients, random parameters, and semi-parametric models.

While we conclude that our methodology is reasonably robust with respect to the question we posed, and probably more robust than conventional conditional mean approaches, it is clear that the dynamic gravity model fails to explain seed trade in an adequate manner. In a static version, it may perform sufficiently well in explaining the overall pattern of trade for a specific product found among countries as this is related to factors such as GDP, population and distance between exporters and importers. But when interest focuses on the effects of a specific policy variable, or aspect of the institutional environment - in our case IPRs - then the dynamic considerations need to be taken into account, and the neglect of fixed effects seems hard to justify. We expect that the new developments in panel VAR models, including the analysis of stationarity and structural breaks (as mentioned above), may offer a more appropriate framework for empirical analysis of these types of issues. A simple glance at our data in Figures 1 to 5 suggests the need to go beyond first-order dynamics as well as apparent heterogeneity in the data generation processes. Such approaches do however require somewhat longer panels in order for hypothesis-testing to have useful power. But these are increasingly becoming available. In the case of our data, we hope to pursue such an approach within the next few years.[25]

Aside from IPRs, our analysis suggests that other factors may play a more important role in influencing the international trade in agricultural seeds, and these could be further investigated. It also seems relevant to conduct more research on the relative effectiveness of PBR systems. If it is the case that this form of IPR protection exists more on paper than in practice, than it becomes relevant from a policy perspective to understand the reasons for this. Debates in Geneva around TRIPS and WIPO often portray ineffective IPR systems in emerging economies or economies in transition as a matter of political will concerning enforcement. We conclude by proposing that future research also admit the possibility that expectations concerning institutional capacity in many countries, in terms of the rule of law,

[25]It may also be relevant to examine specific sub-groups of crops, such as grains and oilseeds, seed potatoes, fruit and vegetables, ornamentals, as both protection measures and incentives might vary.

enforcement of contracts and property rights, and accountability of public officials, might be unrealistic in this area. To the extent that this is the case, then the debate between North and South about TRIPS, or at least parts of this, might be missing the mark.

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