An Empirical Analysis of the Effects of Plant Variety Protection Legislation on Innovation and Transferability

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Abstract: Under the TRIPs Agreement, all member-countries of the World Trade Organization are required to provide an "effective" system of plant variety protection within a specific time frame. In many developing countries this has led to a divisive debate about the fundamental desirability of extending intellectual property rights to agriculture. But empirical studies on the economic impacts of PVP, especially its ability to generate large private sector investments in plant breeding and facilitate the transfer of technology, have been very limited. This paper examines two aspects of the international experience of PVP legislation thus far (i) The relationship between legislation, R&D expenditures and PVP grants, *i.e.*, the innovation effect, and (ii) The role of PVP in facilitating the flow of varieties across countries, *i.e.,* the transferability effect.

Keywords: Plant variety protection, biotechnology, technology transfer.

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Introduction

Under the TRIPs Agreement[1], all member-countries of the World Trade Organization (WTO) are required to provide an "effective" system of plant variety protection (PVP) within a specific time frame. In many developing countries this has led to a divisive debate about the fundamental desirability of extending intellectual property rights (IPRs) to agriculture. But empirical studies on the economic impacts of PVP, especially its ability to generate large private sector investments in plant breeding and facilitate the transfer of technology, have been very limited. This paper examines two aspects of the international experience of PVP legislation thus far (i) The relationship between R&D expenditures and PVP grants and (ii) The role of PVP in facilitating the flow of varieties across countries. This analysis can generate useful insights for policy makers in developing countries on the design of PVP systems and the allocation of research responsibilities between the public and private sectors.

Plant variety protection is a form of IPRs for new varieties of plants, which is akin to patents but with some important differences[2]. The argument from the perspective of developed countries for the inclusion of IPRs in the Uruguay Round was that the absence of IPRs in developing countries meant the loss of substantial markets for their companies. But two important economic arguments were advanced to developing countries for the extension of IPRs to plant varieties. The first argument was that IPRs were necessary to encourage private investment in plant breeding and create incentives for innovations in plant breeding. Given the self-reproducing nature of seed and the difficulty in appropriating returns from a new variety faced by plant breeders, private investment would not be forthcoming in the absence of IPRs. The second was that in the absence of IPRs, superior varieties bred in the developed world (increasingly proprietary or protected varieties developed in the private sector) would not be offered to them at all, given the fear that any competitor could freely replicate and sell these varieties. A related argument pertains to the incentives created by PVP for foreign participation in domestic plant breeding research. The transfer of "finished" plant varieties, advanced breeding lines, germplasm and breeding technologies can come about as a consequence of foreign direct investment (FDI) in the seeds sector or through technical collaboration agreements between domestic and foreign firms. In the absence of an IPR regime that allows sufficient appropriability of returns from new varieties, foreign participation in domestic plant breeding may be discouraged.

An important empirical question in this context is how the strength of IPR protection and R&D expenditures influence 'innovations' i.e. the development of new plant varieties. We will explore the nature of this relationship using data from developed OECD countries. There have been no previous empirical studies of the transfer of protected varieties across countries although there have been some studies of the transferability of agriculture related inventions (see Evenson: 1990). In this paper we will examine data for thirty UPOV member-countries to assess the extent to which protected plant varieties have moved across countries with PVP legislation and the relative importance of different mechanisms of transfer. We will examine the

[1] Agreement on the Trade-Related Aspects of Intellectual Property Rights, which formed part of the Agreement constituting the WTO.

[2] Two important differences between plant variety protection and patents are that PVP generally allows for farmers' exemption and researchers' exemption, which are not allowed under patents. The former allows farmers to use to seeds of a protected variety saved from the harvest for replanting his land in subsequent seasons without payment of royalty to the breeder and the latter allows researchers to use a protected variety as an "initial source of variation" in the development of other new varieties.

participation of foreigners in the acquisition of PVP certificates in different countries and the factors that determine foreigners' share.

***Innovation*: Variables and Data**

The patents-R&D relationship has been studied at the firm level by several authors (e.g. Hausman et. al :1984); Montalvo :1997; Cincera :1997; Blundell, et. al. :1995; Foltz et al: 2000). Plant variety certificates as outputs of research processes are more homogeneous than patents from across a wide variety of industries and this is an advantage for the analysis of the PVP certificate-R&D relationship. However, data on a key variable in explaining PVP certificates, *agricultural* R&D expenditures, are not available at the firm level. Thus, while total R&D expenditure of firms is obtainable from international databases, the proportions that are spent on activities related to new plant variety generation is unknown. This problem is significant because many giant "life-science" companies that play a major role in the development of new varieties also invest heavily in R&D in related areas such as agro-chemicals, agricultural biotechnology and pharmaceuticals. Therefore, our analysis is performed at the country level, with a cross-section of 13 countries observed over time periods varying from 6 to 9 years over the 1990s. This does bring up the issue of multi-country protection. A country-level panel regards individual countries as separate elements in the cross-section. But this specification becomes hard to justify if firms engage in significant multi-country PVP activity for a given set of varieties. However, at risk of giving the plot away, the later part of the paper actually finds that the transferability of varieties is markedly low. This enables us to be more comfortable with our representation than we otherwise might have been**.** The 13 countries in the database were Australia, Belgium, Canada, Finland, France, Germany, Ireland, Japan, Netherlands, Norway, Spain, Sweden and UK.

Count Data Methods

In modelling the effects of market size, R&D spending and PVP legislation upon PVP grants, it is important to recognize that data on the dependent variable are different from data in typical regression models in three ways: non-negativity, the prevalence of a higher proportion of zeros, and the integer nature of the data. Thus basic assumptions of OLS and linear panel data models, such as normality of the residuals are no longer satisfied, and appropriate 'count' data methods have to be used. The number of PVP grants made in any country in a given year is a typical example of count data. The Poisson regression model has been widely used to study such data. In principle, such data can be analysed using conventional multiple linear regression. But Poisson models can improve upon least squares and linear models by explicitly taking into account the discrete nature of the dependent variable and the large number of zeroes that often characterise these data. For instance, in any year it is possible that owing to administrative reasons, or the time lag involved in testing, no grants are made, while in another year the grants may be "bunched".

The Poisson regression model specifies that each y_i (e.g. the number of grants made in country i) is drawn from a Poisson distribution with parameter λ_i which is related to the regressors $\mathbf{x_i}$. The primary equation of the model is:

$$\Pr(Y_i = y_i) = \frac{e^{\lambda_i} \lambda_i^{\,y_i}}{y_i!}$$

The most common formulation for λ_i is the log-linear model:

$\mathrm{Ln}\ \lambda_i = \boldsymbol{\beta}'\mathbf{x_i}$

Where $\mathbf{x_i}$ are explanatory variables and $\boldsymbol{\beta}'$ is a vector of coefficients. It can be shown that the expected number of events (e.g. PVP grants per period) is:

$E(y_i \mid \mathbf{x_i})$ =Variance $(y_i \mid \mathbf{x_i}) = \lambda_i = e^{\beta'\mathbf{x}}$

The Poisson model can be estimated using maximum likelihood techniques. The log-likelihood function is:

$LnL = \sum_{i=1}^{n}(-\lambda_i + y_i\beta'\mathbf{x_i} - \ln y_i!)$

The likelihood equations are:

$$\frac{\partial LnL}{\partial \beta} = \sum_{i=1}^{n}(y_i - \lambda_{ii})\mathbf{x_i} = \mathbf{0}$$

β is generally estimated by software programmes using the Newton-Raphson iterative algorithm (Greene: 1995).

Poisson models can be extended to panel data (Hausman, Hall and Griliches: 1984). The approaches to accommodating heterogeneity of individual units in panel data are the fixed effects specification and the random effects specification. In the fixed effects specification, the individual (country) specific effects are treated as being correlated with the included exogenous variables. In the random effects specification, the individual specific effects are assumed to be uncorrelated with the exogenous variables and to be randomly distributed among individual units. A random effects specification was adopted as the country specific effects influencing grants – namely coverage of genera/species in PVP legislation, agro-climatic conditions affecting the development of new varieties and the potential for spillover of varieties from abroad- were unlikely to be correlated with the explanatory variables included in the equation. The formulation adopted for λ_i was:

$$\text{Ln } \lambda_{it} = \text{Constant} + b_1 \text{ Ln (MARKET)}_{it} + b_2 \text{ Ln (PATENT)}_{it} + b_3 \text{ Ln (RD)}_{i,t-1} + b_4 \text{ Ln (RD)}_{i,t-2} + b_5 \text{ Ln (RD)}_{i,t-3} + b_6 \text{ Ln(RD)}_{i,t-4} + b_7 \text{ Ln (SPILLSTK)}$$

where i indexes countries and t indexes time periods, the dependent variable is the observed number of grants PVP grants (GRANTS) and

MARKET = Size of the market for agricultural inputs.

PATENT = Index of strength of IPR system.

RD = Lagged values of agriculture research expenditure by public and private sector institutions in a country.

SPILLSTK = Cumulative stock of PVP certificates in other countries.

A larger size of the market for seeds can be expected to lead to a larger number of grants. A key hypothesis was that stronger IPR regimes lead to the development and protection of more varieties. R&D expenditures can be expected to a have a positive effect on the number of grants. We have noted earlier that once PVP is introduced, it tends to become the norm for breeders (in both the public and private sectors) to protect their varieties. Therefore, if more R&D expenditures lead to the development of more new varieties, then the coefficients of the lagged values of R&D expenditures should be positive. However, if the potential for innovation is getting exhausted, then it is possible that the coefficients may be negative reflecting the diminution of opportunities for innovation. The number of lags of R&D expenditures used in the estimation was dictated by the availability of data. Given the time lags in the breeding process, the most recent expenditures were not expected to have the highest impact on grants.

The spill-in variable, represented by the cumulative stock of PVP certificates in other countries, was also expected to have a positive impact on grants. The harmonisation of PVP legislation in different countries through the UPOV Convention is intended to enable breeders to seek protection for their varieties in several countries. All the countries included in the sample are members of the UPOV Convention and allow "national treatment" to nationals of other UPOV member-countries. This is likely to increase the possibilities of spill-ins. As PVP regimes become more mature, the benefits from protection might be more easily perceived and the number of grants may tend to increase with time. However, a trend variable was not included in the equation because it was found to be highly collinear with the spill-in variable.

Results

The results of the count data regressions are presented in Table 1 below. The table presents results from two alternative models. The overall Poisson model does not account for the heterogeneity of individual units, essentially treating the entire sample as a single cross section. It is mainly presented in order to provide comparison with the specification of choice, the random effects Poisson model.

Table 1: Determinants of PVP Grants – Count Data Regression Results

Dependent variable: Grants Mean =307.54 Std. Deviation=345.54 No. of observations= 104				
	Overall Poisson		**Random Effects Poisson**	
	Co-efficient	**Std. Error**	**Co-efficient**	**Std. Error**
Constant	-2.71**	0.27	-2.71	2.18
Ln MARKET	0.37**	.0.008	0.26**	0.012
Ln PATENT	5.68**	.074	5.69**	0.17
Ln $RD_{i,t-1}$	0.18**	.05	0.21**	0.032
Ln $RD_{i,t-2}$	0.37**	0.065	0.42**	0.047
Ln $RD_{i,t-3}$	0.48**	0.061	0.58**	0.034
Ln $RD_{i,t-4}$	-0.99**	0.046	-0.80**	0.031
Sum of Ln $(RD)^{\#}$	0.04	-	0.41	-
Ln SPILLSTK	-0.26**	0.022	0.035**	0.008
Alpha	-	-	0.43*	0.27
** Significant at 1% level of significance * Significant at 10% level of significance # This is the sum of the coefficients of Ln $RD_{i,t-1}$, Ln $RD_{i,t-2}$, Ln $RD_{i,t-3}$ and Ln $RD_{i,t-4}$ and not a variable included in the equation			$R^2_{PEARSON}$ = 0.60 $R^2_{DEVIANCE}$ = 0.57	
Log-likelihood of Poisson regression with no group effects =-8438.625 Restricted log-likelihood of Poisson regression with no group effects (all βs =0) =-19586.96 Log-likelihood of Poisson effects with group effects (random effects specification) =-2999.067				

The overall fit of the model as revealed by the $R^2_{PEARSON}$ and $R^2_{DEVIANCE}$ is good and a reasonable degree of stability is observed between the two models. All the coefficients (except the constant and α) are significant at the 1% level of significance. There is a considerable increase in the log-likelihood for the random effects specification when compared to the overall Poisson specifications. The coefficient of the value of agricultural output is positive and significant, which implies that more varieties are developed and offered for protection when the market size is larger. This is also consistent with the results from the previous section, which showed that, for specific crops, the "saturation" level is a function of the volume of output. A key result from Table-1 is that an increase in the strength of IPR protection leads to an increase in grants. A stronger PVP legislation will, therefore, encourage a larger number of varieties to be offered for protection. For countries with relatively weak IPR regimes in our sample like Canada, Finland and Ireland, this implies that moving up closer to the OECD average for regime strength could mean a significant improvement in varietal development and protection. It should be noted that as the specification for λ_{it} is of the form Ln $\lambda_{it} = \boldsymbol{\beta}'\mathbf{x}_{it}$ and the $\mathbf{x}_{it}$ are all in log form, the coefficients are also the elasticities. A 10% increase in the value of the index results in a 56.9% increase in the number of varieties offered for protection.

The coefficient on the spill-in variable is positive and significant but small in absolute terms. What this implies is that an exogenous increase in the stock of PVP certificates in other countries results in a statistically significant but small increase in varietal protection in the home country. A 10% increase in the world stock of PVP certificates results in only a 0.3% increase in PVP certificates in the home country. This implies that the transferability of varieties across countries with PVP is very limited. This conclusion is reinforced later in the paper, where we find that the incidence of multi-country protection of varieties is extremely limited. This may be either because varieties bred in one country are not suitable for use in other countries or because PVP by itself does little to facilitate the transfer of varieties between countries. It is possible that the use of the cumulative stock of PVP certificates in other countries is a less than perfect representation of spillover possibilities. In practice, it may be only the cumulative stock of valid PVP certificates that may reflect the potential for spillovers. If the PVP certificate for a variety has been surrendered in one country owing to lack of commercial potential, it is unlikely to be offered for protection in another country. However, the estimation could not be attempted using the stock of valid certificates as the spill-in variable, as the relevant data were not available for some countries in the sample.

The overall Poisson specification and the random effects specification produce similar coefficients for the R&D expenditure variables. The coefficients of the first three lags are positive and significant while the fourth lag is negative and larger than the first three in absolute value. It is conventional in the patents-R&D literature to look at the sum of lagged R&D coefficients in addition to the individual ones. The sum from the random effects specification indicates that the effect of R&D expenditures on PVP grants is positive and quite strong. A 10% increase in R&D spending over four years results in a 4.1% increase in PVP grants. The development of a new variety may require several generations of breeding and crossing. The coefficients of 0.21, 0.42 and 0.58 for the first three lags of the R&D expenditures reflect the nature of the plant breeding process[3]. A 10% increase in the previous year's R&D expenditure is seen to increase the number of varieties offered for protection only by 2.1%, while a similar increase in periods (t-2) and (t-3) generates an increase in grants of 4.2% and 5.8% respectively. From the point of view of development of finished varieties, the R&D expenditures in (t-2) and (t-3) have the maximum impact. A negative and significant coefficient for the fourth lag is counter-intuitive but this has been a common enough feature in the patent-R&D literature. In fact many of these studies report a U-shaped lag structure (Hausman et al.: 1984; Cincera 1997). Pakes and Griliches (1980) speculate that the later lags in these models might be influenced by

[3] It must be noted that the explanatory variables are the lagged values of agricultural R&D expenditures and not the value of plant breeding R&D expenditures (for which no data are available). The elasticity of grants with respect to plant breeding expenditures could be higher.

lag truncation effects, i.e., the uncaptured effects of R&D expenditures from before the sample period[4].

Transferability

The indicator that we will use to assess the impact of PVP on the transferability of varieties is the incidence of multi-country protection of plant varieties. Plant variety rights obtained under PVP legislation are national in scope, i.e. rights granted in one country are independent of rights granted in any other country (UPOV: 1994). Protection in each country has to be applied for and obtained separately; though a breeder who gets his variety protected in one UPOV member-state enjoys a 'rights of priority' (discussed later) for getting it protected in other member-states. When a breeder in country i decides to protect his variety by getting a PVP certificate in country i, he/she has also the option of obtaining (for a cost) a PVP certificate in country j. Decisions regarding the exercise of this option are informative regarding direct international spillovers between country i and j. The breeder in country i (having already determined that the variety is worth protecting in country i) will assess the likely market for the variety in country j. Protection is likely to be sought in country j only if the returns from marketing the variety in country j are likely to exceed the transaction costs of obtaining protection (Evenson: 2000). The incidence of multi-country protection is, therefore, an indicator of the transferability of varieties across countries. It is an indicator of the extent to which varieties protected in one country command a market in other countries. It is this indicator that we will use in our analysis. We shall refer to the spread (spillover) of plant varieties through the acquisition of IPRs in different countries as the flow or movement of varieties. If PVP does facilitate the transfer of plant varieties between countries, then we would expect to see significant flows of varieties across countries with PVP systems.

The PVP legislation of most countries provides for 'national treatment' of foreigners, which is a requirement under both the UPOV Convention and the TRIPs Agreement. This implies that foreigners (both natural and legal persons) have the same right to protect their varieties as nationals. Foreigners may acquire PVP certificates when protected varieties are directly transferred from one country to another (as discussed previously). However, another important method of acquisition of IPRs by foreigners may be acquisition of PVP certificates by entities in which they have a controlling interest. Such entities, which could be 100%, owned subsidiaries, joint ventures or companies with majority foreign shareholding could seek protection for varieties developed through their research programmes. The plant breeding programme of these entities may attempt to incorporate traits from improved varieties or lines developed elsewhere into locally adapted varieties, thus creating new varieties for the domestic market. In such cases, transfer of proprietary varieties or breeding lines and germplasm may be an adjunct to the investment and collaboration activities of foreigners. When PVP grants are made to foreigners for varieties not protected elsewhere, it is likely that the new varieties are the outcome of such activities.

The share of PVP certificates accruing to foreigners also provides a measure of the "transfer-effect" of PVP – either through acquisition of IPRs for varieties already developed in other countries or through exchanges that accompany investment and collaboration operations. If the latter mechanism is dominant, then the share of PVP certificates owned also foreigners create an

[4] A large positive and significant coefficient of the last lag can be explained as the result of the influence of R&D expenditures prior to the sample period, which may be dying out slowly. However, what we have in our case is a large negative and significant coefficient on the last lag which is more problematic to explain. One plausible explanation in the context of plant breeding is that the negative coefficient on the lag (t-4) reflects the previous exploitation of the innovation pool. That is, if varieties developed from R&D expenditures in the period (t-4) and earlier have already been protected, then its impact in the current year may be to reduce the number of varieties that can be developed and offered for protection from a given innovation pool.

indicator of the incentives by the PVP legislation for foreigners to produce 'innovations' for the domestic market.

Transfer of Protected Varieties by Crop

The analysis of the transfer of protected varieties across 30 UPOV member-countries has been attempted using the database of protected varieties referred to earlier. This analysis is made possible by two features of the UPOV Convention that make it possible to identify varieties that have been protected in more than one country. These are (a) provisions regarding denomination of varieties and (b) provision regarding "right of priority". The identification of varieties protected in more than one country was done for the following crops (1) wheat (2) maize (3) soybean (4) potato (5) perennial ryegrass and (6) oilseed rape. The data on varieties protected in more than one UPOV member-country for these six crops is summarised in Table-2.

Table-2: Transfer of Protected Varieties Across UPOV Member-Countries

Crop	**Wheat**	**Maize**	**Soybean**	**Potato**	**P.Ryegrass**	**Oilseed Rape**
No. of varieties for which PVP grants made	2450	4761	1474	1408	973	978
Varieties protected in:						
2 countries	331 *(13.5%)*	561 *(11.7%)*	59 *(4.00%)*	287 *(20.38%)*	202 *(20.7%)*	155 *(15.84%)*
3 countries	74 *(3.02)*	70 *(1.47%)*	1 *(0.06%)*	136 *(9.65%)*	86 *(8.83%)*	50 *(5.11%)*
4 countries	26 *(1.06%)*	18 *(0.37%)*	-	61 *(4.33%)*	32 *(3.2%)*	22 *(2.24%)*
5 countries	11 *(0.44%)*	2 *(0.04%)*	-	60 *(4.26%)*	10 *(1.02%)*	15 *(1.53%)*
6 countries	3 *(0.12%)*	2 *(0.04%)*	-	34 *(2.41%)*	2 *(0.20%)*	5 *(0.51%)*
7 countries	2 *(0.08%)*	1 *(0.02%)*	-	20 *(1.42%)*	-	1 *(0.10%)*
8 countries	1 *(0.04%)*	1 *(0.02%)*	-	20 *(1.42%)*	-	1 *(0.10%)*
9 countries	1 *(0.04%)*	-	-	14 *(0.99%)*	-	1 *(0.10%)*
10 countries	-	-	-	6 *(0.42%)*	-	-
11 countries	2 *(0.08%)*	-	-	3 *(0.21%)*	-	-
12 countries	-	-	-	3 *(0.21%)*	-	-
13countries	-	-	-	2 *(0.14%)*	-	-
14 countries	-	-	-	2 *(0.14%)*	-	-
15countries	-	-	-	3 *(0.21%)*	-	-
16 countries	-	-	-	1 *(0.07%)*	-	-
Varieties protected in more than one country	451 *(18.40%)*	655 *(13.7%)*	60 *(4.06%)*	652 *(46.30%)*	332 *(34.12%)*	250 *(25.56%)*
Varieties protected in more than 2 countries	120 *(4.89%)*	94 *(1.97%)*	1 *(0.06%)*	365 *(25.92%)*	130 *(13.36%)*	95 *(9.71%)*

Table-2 lists for each of the six crops the total number of varieties for which PVP grants have been made in 30 UPOV member-countries and the number of varieties that have been protected in two or more countries. 18.4% of wheat varieties, 13.7% of maize varieties, 4% of soybean varieties, 46.3% of potato varieties, 34.12% of ryegrass varieties and 25.56% of oilseed rape varieties have been protected in two or more countries. The movement of varieties appears to be very significant in the case of potato as more than 25% of the varieties are protected in three or more countries. It is the only crop where there is a variety protected in as many as 16 countries.

The largest contribution to the inter-country movement of varieties is made by the category "varieties protected in two countries". If this category mainly reflects the movement of varieties between neighbouring countries having similar agro-climatic conditions (or special arrangements for marketing each others' varieties) then the figures in Table-2 may be overestimating the extent to which PVP facilitates the international movement of varieties. The movement of protected varieties across *regions* may provide a better indicator of the role played by PVP in facilitating transfer. In order to assess the inter-regional flows of protected varieties the 30 UPOV member-countries included in Table-2 were divided into the following regional groups: (1) Asia (2) Australia and Africa[5] (3) Europe (4) North America (5) South America.

A matrix of inter-regional flows of protected varieties is presented in Appendix-1. Each cell in the matrix is formed by the intersection of the "row" region and a "column" region. For example, the cell formed by the intersection of the row "Asia" with the column "Australia" is used to represent the flow of protected varieties between these two regions. Similarly the cell formed by the intersection of the row "Europe" and the column "Europe" is used to represent the flows of protected varieties between countries in European region. The percentage figure for each crop in each cell is calculated as:

($\Sigma V_{i,j}$ /Total number of varieties protected in two countries)

where $V_{i,j}$ is the number of varieties protected in country i and country j, and i indexes countries in the row region and j indexes countries in the column region. As the matrix is a symmetric one, data are only entered in cells above the diagonal.

Appendix-1 provides a strikingly different picture of the movement of protected varieties across countries. An extraordinarily high proportion of the movement of protected varieties is actually just the movement between European countries. The intra-European movement of protected varieties represents more than 90% of the "sharing" of varieties between countries in the case of wheat, potato, perennial ryegrass and oilseed rape and 85% in the case of maize. For maize, the movement of varieties between North America and Europe is significant (13%). Soybean is an exception where the intra-Europe flows represent only 33.3% of the total flows. Flows between North America and Australia (13%), North America and Europe (5.9%) and North America and South America (33%) are the other significant flows in the case of soybean.

Even within Europe, a limited number of pairs of EU countries account for much of the intra-Europe movement of varieties. This can be seen in Appendix-2, which lists the contribution of important pairs of EU countries to the intra-Europe flow. Appendix-2 also shows that a large part of the intra-Europe movement of varieties is the result of the varieties protected under national PVP systems switching to EU wide protection under the Community Plant Variety Office[6].

[5] Africa was clubbed with Australia, as there was only one country in Africa with PVP - South Africa.

[6] The Community Plant Variety Office (CPVO) of the EU issues PVP certificates that provide protection in the whole of the EU based on a single application. However, EU-wide PVP rights granted by the CPVO cannot be held concurrently with national rights in EU countries. For the purposes of Table-2, the CPVO has been treated as a separate entity (i.e. as if it were another country). If a variety was first protected in the UK and then in the CPVO, it means that UK protection was surrendered to obtain EU-wide rights. Therefore, a switch from national rights to EU-wide rights in respect of a protected variety gets reflected as "flow" from UK to CPVO.

The important country pairs that account for a large proportion of the inter-country flows in Europe are (1) Germany-France (2) Germany-Netherlands (3) France-Spain (4) UK- Denmark and (5) UK-Ireland. In the case of maize, 42.3% of all flows of protected varieties worldwide are accounted for by the exchanges between Germany and France. Similarly Germany and the Netherlands account for 31.7% of all exchanges in ryegrass. It is clear from the data presented in Appendices 1 and 2 that multi-country protection of plant varieties is almost entirely a European phenomenon confined largely to a few Western European countries. It is useful to examine the reasons for the large intra-European flows as it can provide insights into factors that influence the movement of varieties.

The large intra-European flows can be partly attributed to the similarities and complementarities of agro-climatic conditions (McMullen: 1987). However, we do not observe large flows between countries of other regions where such similarities of agro-climatic conditions exist. Intra-European flows appear to be mainly attributable to a set of measures that considerably enhance a breeder's ability to appropriate returns from a new variety.

a) Berland and Lewontin (1986) argue that the "catalogue" and "seed certification" that are the two pillars of the European seed regulatory system provide de facto appropriability for breeders even in the absence of formal PVP systems. In the presence of PVP systems they act as enforcement mechanisms.
b) Most non-European legislation (including that of the United States) allows farmers to save seeds of protected varieties for planting subsequent crops. European legislation has, however, moved toward stringent restrictions on the use of farm-saved seed of protected varieties. Under arrangements worked out between farmers and breeders in EU countries, all farmers[7] have to pay royalty to breeders even when they use farm-saved seed of protected varieties (the royalty payable on farm-saved seed are lower than those applicable to commercial seed). This restriction greatly increases the revenue that a breeder can derive from marketing a new protected variety.
c) The EU has also established a common EU-wide PVP legislation administered by the Community Plant Variety Office (CPVO) based in France. The CPVO grants EU-wide protection certificates. This makes it possible for a breeder to obtain protection for his variety in all EU countries with a single application. The transaction costs for obtaining protection in several markets is greatly reduced.

The matrix in Appendix-1 shows that with the exception of intra-European flows (that can be attributed to the special factors discussed above) intra and inter-regional flows of protected plant varieties have been virtually nil or have been minuscule in relation to the number of varieties offered for protection. There is, therefore, very little evidence to support the view that PVP is an instrument facilitating the direct transfer of varieties across countries. PVP may be a necessary condition for the transfer of self/open-pollinated varieties crops bred in the private sector, but it is not a sufficient one. The need for plant varieties to be adapted to specific agro-climatic conditions inherently limits their transferability. But the experience of Europe shows that even if adaptability constraints do not operate, significant flows of protected plant varieties take place only when PVP is supplemented with measures that provide access to large markets, support enforcement of breeders' rights, enhance appropriability of returns and reduce transaction costs for obtaining protection.

The foregoing is not intended to suggest that transfers of all plant genetic resources (which include not only finished varieties but also "primitive cultivars, landraces, wild and weedy relatives" (Sedjo:1998) and breeding lines and germplasm accessions in genebanks) between countries are limited. It only suggests that the movement of finished plant varieties, *which are*

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[7] Small farmers are exempted.

the only elements of plant genetic resources currently subject to IPRs, is limited. Extensive transfers of germplasm, breeding lines and even landraces take place between public sector institutions in different countries (Evenson: 2000).

Foreigners' Share of PVP Certificates

In this section we will attempt an econometric estimation of the determinants of (1) the number of grants made to foreigners and (2) the share of PVP grants accruing to foreigners. It was postulated that both these variables would be a function of (a) the size of the commercial market for seed (b) the size of the domestic research system (c) the strength of IPR protection (d) the openness of the economy (e) the age of PVP legislation. While the determinants of the share of foreigners were estimated using a conventional linear panel data model, the determinants of grants to foreigners were estimated using a count data regression model. Both the estimations were done with data for the following 20 countries Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. The period covered for each country was either 1981-1998 or from the inception of PVP legislation to 1998. The number of observation for each country was not the same (the panel was unbalanced) because many countries introduced PVP after 1981.

Determinants of number of grants to foreigners

The number of grants accruing to foreigners in each country was estimated using a panel Poisson model. A random effects specification was adopted as the country specific effects influencing grants – namely coverage of genera/species in PVP legislation, agro-climatic conditions affecting the transferability of varieties and the distance of the country from major plant breeding countries- were unlikely to be correlated with the explanatory variables included in the equation. The formulation adopted for λ_{it} was:

$$\text{Ln } \lambda_{it} = \text{Constant} + b_1 \text{ Ln (MARKET)}_{it} + b_2 \text{ Ln (PATENT)}_{it} + b_3 \text{ INTERACTION}_{it} + b_4 \text{Ln (GBRDPP)}_{it} + b_5 \text{PVPAGE}_{it} + b_6 \text{EFI}_{it}$$

where i indexes countries and t indexes time periods, the dependent variable is the observed number of grants to foreigners (NRGRANT) and

MARKET	=	Size of the market for agricultural inputs
PATENT	=	Index of strength of IPR system
INTERACTION	=	Ln (MARKET) *Ln (PATENT)
GBRDPP	=	Variable reflecting the size of the domestic research system
PVPAGE	=	Age of PVP legislation
EFI	=	Economic Freedom Index reflecting the openness of the economy

Stronger IPRs can be expected to encourage foreigners to seek more PVP grants. The potential for commercial sales of protected varieties is also likely to vary with the size of the market. Foreigners may seek more grants in larger markets. But from the point of view of the foreign breeder what matters is the appropriability of returns and this may be influenced by the strength of IPRs. The interaction term is the product of Ln (MARKET) and Ln (PATENT). The Ln (PATENT) in the interaction term may be seen as affecting appropriability by increasing or decreasing the effective size of the market. For instance, if PVP legislation places restrictions on the use of farm saved seed, then it would have the effect of enlarging the market for commercial sales of protected varieties.

The size of a country's research system could affect grants to foreigners in several ways. A larger domestic research system may mean that foreigners face greater competition from domestic breeders and this could reduce the grants accruing to them. However, as we have noted, foreign participation may come about through investment and collaboration activities as well. For such activities a larger domestic research system may be advantageous to foreigners as it may offer (1) access to a large pool of germplasm and breeding lines developed by the public sector (2) access to a pool of trained manpower (plant breeders). A larger research system may also offer greater opportunities for collaborations with domestic companies. Therefore, the coefficient for the size of the domestic research system could be positive or negative.

The number of grants to foreigners can generally be expected to increase with the age of PVP legislation. In the initial phases of PVP, grants to foreigners may be limited as foreigners take time to get familiarised with the system and see how effective enforcement of rights is going to be. Once the legislation is seen to be effective, foreign participation may increase. But it is also possible that the early phases of PVP may see a surge in grants to foreigners as they seek protection for (transferable) varieties that can be introduced in the domestic market. After the initial surge and with growing competition from domestic breeders, grants to foreigners may decline. The coefficient for PVPAGE could be positive or negative.

Greater openness of the economy may also induce a larger number of grants to foreigners. This is likely to be the case when the development of new varieties by foreigners is a result of their local investment in the seed industry and/or research. The coefficient for EFI can be expected to be positive. The results of the count data regression model based on the Poisson random effects specification are presented in Table-5.

Table-5: Determinants of PVP Grants to Foreigners – Count Data Regression Results

Poisson model with random group effects					
Dependent Variable: NRGRANT Number of observations: 236		Mean =104.250		Standard Deviation =92.07	
Independent Variables:					
Variable	**Co-efficient**	**Standard Error**	**b/Std. Error**	**P-value**	**Mean of X**
Constant	-12.6703	0.8098	-15.644	0.0000	
Ln (MARKET)	0.9511	0.0436	21.794	0.0000	15.965
LN (PATENT)	10.9678	0.6879	15.943	0.0000	1.323
INTERACTION	0.6489	0.0373	-17.370	0.0000	21.23
Ln (GBRDPP)	0.4161	0.0108	3.837	0.0001	4.96
EFI	0.1850	0.0065	2.836	0.0046	7.998
PVPAGE	0.2880	0.0006	42.336	0.0000	15.283
Alpha	0.1043	0.0372	2.789	0.0051	
				$R^2_{PEARSON}$	= 0.7747
				$R^2_{DEVIANCE}$	= 0.7340
Log-likelihood of Poisson regression with no group effects					=-2996.340
Restricted log-likelihood of Poisson regression with no group effects (all βs =0)					=-9308.841
Log-likelihood of Poisson effects with group effects (random effects specification)					=-658.6119

There is no universal definition of R^2 in non-linear models. The commonly used "pseudo-R^2 statistics for Poisson models are the $R^2_{PEARSON}$ and the $R^2_{DEVIANCE}$. The high values of these two statistics (0.77 and 0.73 respectively) suggest that the overall fit of the model is good. All the coefficients are significant at the 5% level of significance and have the expected signs. The log likelihood of the Poisson model with random group effects represents a considerable improvement over the log likelihood of the model without any group effects. This shows that taking account of the unobserved heterogeneity of individual countries improves the fit of the model. The elasticities of the dependent variable with respect to the explanatory variable are given in Table-6. The values have been calculated at the overall mean of the explanatory variables.

Table-6: Elasticities of PVP Grants to Foreigners

Dependent Variable: PVP Grants to Foreigners		
Elasticity of dependent variable w.r.t.		
Strength of IPRs	(ε_{IPR})	0.6
Size of market	(ε_{MARKET})	0.09
Size of domestic research system	(ε_{GBRDPP})	0.041
Openness of the economy	(ε_{EFI})	0.14
Age of PVP legislation	(ε_{PVPAGE})	0.048

The elasticity of grants with respect to the strength of IPR variable is positive. This suggests that a stronger IPR regime will induce greater participation by foreigners in the acquisition of PVP grants. However, it should be noted that ε_{IPR} is the sum of two terms:

$$\varepsilon_{IPR} = \frac{\delta \text{ Ln (NRGRANT)}}{\delta \text{ Ln (PATENT)}} = b_2 - b_3 \text{ Ln (MARKET)} = 10.967 - 0.6489*15.965 = 0.6$$

While the coefficient of Ln (PATENT) i.e. b_2 is positive, the term b_3*Ln (MARKET) is negative and reduces the elasticity. The negative coefficient of the interaction term can be seen as the "competition effect". While stronger IPRs may encourage foreigners to seek more grants, the same IPR regime also creates incentives for domestic breeders to seek grants. The competition from domestic breeders tends to reduce the value of $\varepsilon_{IPR.}$ Similarly, the elasticity of grants to foreigners with respect to the size of the market is also positive. A larger market size induces a larger number of grants to foreigners. But once again, ε_{MARKET} is composed of two terms:

$$\varepsilon_{MARKET} = \frac{\delta \text{ Ln (NRGRANT)}}{\delta \text{ Ln (MARKET)}} = b_1 - b_3 \text{ Ln (PATENT)} = 0.9511 - 0.6489*1.323 = 0.09$$

While the coefficient of Ln (MARKET) is positive, the term b_3*Ln (PATENT) is negative and reduces the elasticity. Following the argument in the previous paragraph, the negative interaction term could be seen as the result of competition from domestic breeders.

The positive elasticity of grants to foreigners with respect to the size of the domestic research system suggests that a larger domestic research system may offer certain advantages to foreigners. As already noted, these advantages could lie in the availability of domestic collaborators, access to local trained manpower or access to germplasm collections etc. As expected, greater openness of the economy to trade and investment induces greater participation by foreigners in the acquisition of PVP grants. The positive elasticity with respect to the age of PVP legislation suggests that foreigners may seek more grants once they are familiar with the domestic PVP system (and see it as being effective).

Determinants of Foreigners' Share of PVP Grants

For determining the share of foreigners in PVP grants the equation used was:

$$CUMSHAREit = Constant + b_1 \text{ Ln (MARKET)}_{it} + b_2 \text{ Ln (PATENT)}_{it} + b_3 \text{ INTERACTION}_{it} + b_4 \text{Ln (GBRDPP)}_{it} + b_5 \text{PVPAGE}_{it} + b_6 \text{EFI}_{it}$$

where i indexes countries and t indexes time periods.
$CUMSHARE_{it}$ = Cumulative share of foreigners in PVP grants and the other variables are as defined previously. $CUMSHARE_{it}$ was derived from the WIPO data set, which contained data on the total PVP grants made to residents and non-residents.

The random effects specification was chosen for the panel data estimation, as the country specific effects were not expected to be correlated with the explanatory variables. The results of the estimation are presented in Table-7.

Table-7: Determinants of Share of foreigners in PVP Grants- Panel Regression Results

Random effects model for panel data					
Dependent variable: $CUMSHARE_{it}$ (Cumulative share of foreigners in PVP grants) Number of observations=255	Mean = 0.2544		Standard deviation =0.08609		
Independent variables:					
Variable	**Coefficient**	**Standard Error**	**b/Std. Error**	**P-value**	**Mean of X**
Constant	0.0174	0.0276	0.632	0.5272	
Ln (MARKET)	0.0748	0.0111	6.720	0.0000	7.175
LN (PATENT)	0.0410	0.1673	2.455	0.0141	0.5943
INTERACTION	0.0742	0.0118	-6.285	0.0000	9.533
Ln (GBRDPP)	0.0199	0.0155	-1.284	0.1991	2.220
EFI	0.0526	0.0141	3.717	0.0002	3.609
PVPAGE	0.0017	0.0017	1.027	0.3044	7.055
R^2=0.502 Autocorrelation of residuals 0.16 Hausman test statistic for fixed effects versus random effects =2.90 (6 df, probability value =0.8218					

The overall fit of the model is reasonable with an R^2 of 0.502 and all the coefficients have plausible signs. The coefficients for the variables denoting size of the market, strength of IPRs, interaction of IPRs with market size and the openness of the economy are highly significant, while the coefficients for the size of the domestic research system and the age of PVP legislation are not significant. The elasticities of the cumulative share of foreigners with respect to the explanatory variables are given in Table-8. The elasticities were calculated at the overall mean of the (untransformed) variables. For comparison purposes the elasticities of the share of residents in PVP grants with respect to the independent variables is also given along side.

Table-8: Elasticities of Share of Foreigners in PVP Grants

Dependent Variable:	Share of foreigners in PVP grants	Share of residents in PVP grants
Elasticity of dependent variable w.r.t.		
Strength of IPRs (ε_{IPR})	-1.39	+1.757
Size of market (ε_{MARKET})	-0.036	+0.046
Size of domestic research system (ε_{GBRDPP})	-0.035	+0.045
Openness of the economy (ε_{EFI})	+0.753	-0.95
Age of PVP legislation (ε_{PVPAGE})	+0.048	-0.06

The elasticity of foreigners' share with respect to the strength of the IPR variable is negative. It is given by:
$\varepsilon_{IPR} = [b_2 + b_3 * \text{Ln (MARKET)}]*(1/\text{CUMSHARE}) = -1.39$

Though the coefficient of Ln (PATENT), i.e. b_2, is positive, the elasticity is negative because the term (b_3* Ln (MARKET)) is negative. We have already seen that the strength of the IPR variable has a positive impact on the *number* of grants to foreigners. Therefore, the negative elasticity of foreigners' *share* implies that stronger IPRs provide greater incentives for innovation to domestic breeders than they do to foreign breeders. Our sample is confined to developing countries and such an effect may arise only when domestic research capability exists and can respond to PVP incentives. But such an effect may well obtain in developing countries that have a large National Agricultural Research System.

The elasticity of foreigners' share with respect to market size is also negative. It is given by:
$\varepsilon_{MARKET} = [b_1 + b_3 * \text{Ln (PATENT)}]*(1/\text{CUMSHARE}) = -0.036$
Here again, though the coefficient of Ln (MARKET), i.e. b_1, is positive, the elasticity is negative because the term (b_3* Ln (PATENT)) is negative. We have seen that a larger market size induces a larger *number* grants to foreigners. The negative elasticity of foreigners' *share* with respect to market size may, therefore, be due to the fact that a given increase in market size induces a still larger increase in grants to residents.

The elasticity of foreigners' share with respect to the size of the domestic research system is negative. But the coefficient of Ln (GBRDPP) is not significant even at the 10% level of significance. The negative sign of the coefficient is consistent with the observation that a larger domestic research system may offer greater competition to foreigners and thus reduce their share. The elasticity of foreigners' share with respect to the openness of the economy is strongly positive and coefficient of EFI is highly significant. This shows that the participation of foreigners in the acquisition of PVP grants depends not only on the legislation that is put in place but also on other factors determining the openness of the economy to trade, investment and foreign participation in economic activity.

The insignificant coefficient of PVPAGE suggests that the age of PVP legislation is not a significant determinant of foreigners' share. However, we must note that our sample comprises 20 developed countries where high levels of enforcement can be expected. The situation may well be different in developing countries newly introducing PVP legislation where foreigners may choose to wait and assess the effectiveness of legislation and the enforcement of rights before they seek protection for their varieties.

Taken together, the results of panel data model on the determinants of the share of foreigners in PVP grants and the count data model on the determinants of the number of grants to foreigners allow us to draw the following conclusions in the context of developed countries:

a) Stronger IPRs and a larger market size tend to increase the number of grants to foreigners but reduce the share of foreigners in total grants – which may be the result of competition from domestic breeders or PVP providing greater incentives for innovation to domestic breeders.
b) A larger domestic research system tends to increase the number of grants to foreigners but reduce the share of foreigners in PVP grants (though the latter effect is not significant).
c) Greater openness of the economy increases both the number of grants to foreigners as well as the share of foreigners in PVP grants.
d) Increasing age of PVP legislation increases the number of grants to foreigners and also the share of foreigners (though the latter effect is not significant).

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Appendix 1: Inter-Regional Flows of Protected Varieties

Region → ↓	Asia	Australia and Africa	Europe	North America	South America
Asia	Wheat 0% Maize 0% Soybean 0% Potato 0% Ryegrass 0% Rape 0%	Wheat 0% Maize 0% Soybean 0% Potato 0% Ryegrass 0% Rape 0%	Wheat **0.6%** Maize 0% Soybean 0% Potato **1.05%** Ryegrass 0% Rape 0%	Wheat 0% Maize 0% Soybean **2.0%** Potato 0% Ryegrass 0% Rape 0%	Wheat 0% Maize 0% Soybean 0% Potato 0% Ryegrass 0% Rape 0%
Australia and Africa		Wheat 0% Maize 0% Soybean 0% Potato **1.39%** Ryegrass **1.0%** Rape **3.9%**	Wheat **1.5%** Maize 0% Soybean 0% Potato **3.48%** Ryegrass 0% Rape **0.65%**	Wheat **0.3%** Maize 0% Soybean **13.7%** Potato 0% Ryegrass 0% Rape **0.65%**	Wheat 0% Maize 0% Soybean **1.96%** Potato **0.35%** Ryegrass **1.49%** Rape 0%
Europe			Wheat **91.4%** Maize **85.5%** Soybean **33.3%** Potato **90.9%** Ryegrass **90.1%** Rape **90.3%**	Wheat **2.8%** Maize **13.2%** Soybean **5.9%** Potato **1.05%** Ryegrass **7.43%** Rape **0.65%**	Wheat **0.3%** Maize **0.72%** Soybean **1.96%** Potato **0.70%** Ryegrass 0% Rape **1.95%**
North America				Wheat **0.6%** Maize **0.4%** Soybean **1.96%** Potato **1.05%** Ryegrass 0% Rape 0%	Wheat 0% Maize **0.72%** Soybean **33.3%** Potato 0% Ryegrass 0% Rape **1.95%**
South America					Wheat **2.5%** Maize 0% Soybean **5.88%** Potato 0% Ryegrass 0% Rape 0%

Appendix 2: Major Inter-Country Flows of Protected Varieties in European Countries

Crop →	**Wheat**	**Maize**	**Soybean**	**Potato**	**Perennial Ryegrass**	**Oilseed Rape**
Share of intra-Europe flows in total inter-county flows of protected varieties **(from Table-2)**	**91.4%**	**85.5%**	**33.3%**	**90.9%**	**90.1%**	**90.3%**
Contribution of key pairs of European countries.	EU-CPVO* 25% Czech Rep-Slovakia** 7.1% Germany-France 3.1% Denmark-UK 3.1% Denmark-Sweden 4.6% Spain-France 12.6% France-UK 8% UK-Ireland 4.3%	EU-CPVO* 21.8% Germany-France 42.3% Germany-Netherlands 2.2 France-Hungary 7.6%	EU-CPVO* 5.9% Germany-Austria 7.8% Germany-France 9.8% France-Austria 2% France-Spain 2% France-Hungary 2%	EU-CPVO* 35.54% Czech Rep-Slovakia 7.1% Germany-Denmark 2.4% Germany-France 7.0% Germany-Netherlands 4.9% France-Denmark 3.1% France-Spain 3.1% France-Netherlands 7%	EU-CPVO* 6.44 Germany-UK 7.4% Germany-Netherlands 31.7% Netherlands-Ireland 3% UK-Denmark 5.9% UK-Ireland 4.5% UK-Netherlands 21.3%	EU-CPVO* 29.87% Germany-Denmark 7.1% Germany-France 3.9% Germany-UK 12.3% Germany-Netherlands 6.5% France-UK 6.5% UK-Denmark 7.1% UK-Sweden 3.9%
Total	**68.6%**	**73.9%**	**29.5%**	**70.14%**	**80.2%**	**77.17**

*As explained in the text, EU-CPVO refers to varieties initially protected in a EU country and subsequently offered for protection on a EU-wide basis through the CPVO.
** The large share of Czech Republic- Slovakia "flow" of varieties only reflects the fact that varieties protected in Czechoslovakia continued to enjoy protection in both the Czech Republic and Slovakia after the separation of the two countries.